National Seminar on

Strategies for Increasing Production and Export of Spices

Proceedings of Seminar

24-26 October 2002 at Calicut, Kerala

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Indian Society for Spices &
Indian Institute of Spices Research
Calicut - 673 012, Kerala

In collaboration with

ICAR, New Delhi

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PREFACE

We have extreme pleasure to present the proceedings of the National Seminar on Strategies for Increasing Production and Export of Spices was the eighth National Seminar organized by the Indian Society for Spices. During its existence in the last twelve years the Society could focus on most of the issues pertaining to the cultivation, production management, diseases and pest management, post harvest and marketing aspects of spices, medicinal and aromatic plants. It is heartening to note that the Seminars organized by the Society has always received the full attention of the various core groups of these sectors.

The above National Seminar was organized at IISR, Calicut during 24-26 October 2002. There were about 87 papers covering Production Strategies for Optimization of Inputs, Biodiveristy and Conservation, Biorational Management of Pest and Disease and Value Addition, Marketing and Export Strategies. There were three invited papers focusing on production of vanilla, cropping systems and global market outlook of pepper.

This publication brings out the full articles under Crop Production (22), Biodiversity (9), Biorational Management (4) and Value Addition and Marketing (8).

The opinions expressed in the papers in this issue are that of the authors and need not represent the views of ISS. Due to paucity of time there may be some short falls in the presentation which may kindly be ignored.

The support given by various agencies, Dr. V A Parthasarathy, Director, IISR, Calicut; Dr. V S Korikanthimath, President, ISS and Staff Members of the Indian Institute of Spices Research, Calicut are acknowledged with gratitude.

The help rendered by Ms. T V Sandhya in typesetting and suggestions by the Editorial Committee is also gratefully acknowledged.

Secretary
Indian Society for Spices
For the Publication Committee

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Production Strategies for Optimization of Inputs

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SPICES IN COCONUT BASED CROPPING SYSTEM

H H Khan and V Krishnakumar

Central Plantation Crops Research Institute, Kasaragod, India.

Introduction

Most appropriately called as "Tree of Abundance" or " Kalpavriksha", Coconut is a plantation crop occupying the land for decades together. This plant provides all of its part to mankind for one use or the other. Coconut palms use the most valuable natural resources for cropping only partly, and thus provide opportunities for the farmer to make their use for cultivating other crops. Coconut based cropping system is an approach where natural resources are most efficiently utilized in a plantation. It serves as a buffer against price fluctuations, enhances return per unit area thus maximising the income of the farmer who judiciously puts to use the available resources at his disposal. This system not only ensures crop diversity, but also yields products that are capable of satisfying varying needs of food items of the farming families. The success of such a system will be determined by the selection of appropriate crops and their cultivation practices.

Coconut and spices are important commercial crops of the humid tropics and their distribution is confined mostly within 22 N° and S. They require, more or less the same climatic conditions for optimum growth and production. The incident light received underneath the palms favours the growth of spices such as black pepper, vanilla, clove, nutmeg, cinnamon and all spice (Pimenta dioeca L.Merr). Herbal spice like long pepper also requires filtered light similar to that of other annual spices like ginger and turmeric.

Cropping/Farming systems

Coconut growers in India are predominantly small and marginal growers where time, land and other resources are underutilised especially if it is grown as a sole crop. In coconut holding size has been found to have a direct relation to the management of the plot and yield. Probably a similar situation exists in spices also. When the holding size is small, adequate income is not generated, leading to neglect of the crop. Neglect of small holding leads to low productivity and high cost of production. Small holding also contributes to crowded population of component crops and poor fertilizer and pest management.

Mono-cropping is instrumental for degradation of the natural resource base. Besides it fails to ensure stable income to these groups of farmers and cause crop loss due to biotic and abiotic stresses. Coconut is perhaps is one of the least labour oriented long living plantation crop with an economic life span of 50 to 60 years, which utilizes only 30 to 40% of resources in coconut garden. Cropping system approach aims to increase the benefits derived from crop production by efficient utilization of both natural (solar radiation, water and soil) and socio-economic (human, credit, power and market demand) resources. Multiple cropping is an age- old concept practiced by many farmers, probably without looking into its scientific aspects, to maximize land productivity per unit area and unit time. This practice is commonly observed in areas of high rainfall in the tropics where temperature and moisture are not limiting factors throughout the year for crop production.

Under intercropping situations, the component crops are grown in such a way that minimum competition for light exists. This can be achieved by proper choice of crops and genotypes, the shorter component being shade tolerant and one of the components being harvested sufficiently early so that the later harvested component is not generally affected.

Advantages of cropping/farming systems

1. More efficient use of sunlight, soil moisture and nutrients is possible from an appropriate intercropping/mixed cropping pattern in coconut garden.
2. Increased crop diversity will lead to more production stability and reduced risk of failure.
3. Improved economic stability will result from diversification of crops, especially inter/mixed/multistoried /high density multi species cropping system.
4. Production of quality produces due to reduced pesticide use because of lower pest and disease incidence and nutrient cycling in diverse systems.
5. More employment generation for the farm family.

The yield advantage of intercropping combination originates either due to higher yield of individual crop or due to higher plant population densities or both. A yield advantage from intercropping situation is achieved also due to efficient use of growth resources. Generally the component crop will have varied requirement of growth resources and when they are cultivated together they are able to compliment each other so as to achieve a better overall use of environmental resources than when grown individually. The component crops with diverse growth habit have been found to be able to absorb plant nutrient or moisture from different layers of soil and to intercept light more effectively under the intercropping situation than under monocropping.

Criteria for selection of inter/mixed crops

The desirable characters of crops to be grown under or in between coconut palms are given below.

- Crops should be selected according to their shade tolerance and amount of solar radiation available in the plantation.
- Should not grow as tall as coconut.
- Should not be more susceptible than the main crop to diseases they have in common.
- Should not require harvesting or other operations that would damage the main crop or induce soil erosion or damage soil structure.
- Should not have an economic life longer than the main crop.
- Their root system should exploit different soil horizons/zones.
- Demand and marketing opportunities of the crop produces.

Farming system in coconut-opportunities

Planting density for coconut: While planting coconut in a new area, it is advisable to plan for a cropping/farming system, which may be adopted in the future. Though the recommended spacing for coconut is 7.5x7.5 m it is always preferable to go in for a wider spacing of 8.0 x 8.0 m or 10.0 x 10.0 m in square system to accommodate inter/mixed crops.

Where wider inter rows are preferred, such as mixed farming system, single or double hedge system of planting may be adopted to keep spacing within the row narrow and between rows wide. Planting in square system will accommodate inter/mixes crops. Wider spacing will provide more land, light and water for other crops as well. A tall variety of coconut will allow more light to fall in the garden and it is to be preferred for undertaking inter/mixed cropping programmes.

Rooting pattern of coconut: Studies have revealed that rooting pattern of coconut is such that only 25% of land area is effectively used. A spacing of 7.5 x 7.5 m in the square system is recommended for coconut for optimum production. Coconut palms, like other monocots, have a typical adventitious root system. Under favourable conditions, as many as 4000 to 7000 roots are found in a middle aged palm. About 74% of the roots produced by a palm under good management do not go beyond 2 m lateral distance and 82% of the roots are confined to 30 to 120 cm depth of soil. Thus, the active root zone of coconut is confined to 25 % of the available land area and the remaining area could be efficiently exploited for raising inter/mixed crops (Kushwah et al, 1973).

Crown structure and light transmission: In an inter/mixed cropping system, light is the major limiting factor for the growth of component crops since light penetration is reduced through interception and absorption by the taller canopy plants. The light interception in a cropping system influences the growth, productivity and biomass production of the component crops. Although the full yield potential cannot be realized in many crops under such a system as much as that obtained under monocropping system, the reduced yield itself is indicative of their adaptability to low light profiles. Age, spacing, soil fertility, varietal characteristics, leaf area and time of the day influence the light penetration through the canopy. As coconut canopy's space utilization is very low, plenty of sunlight infiltrates and falls on the ground unutilized. The venation structure of the coconut crown and the orientation of leaves allow part of the solar radiation to pass through the canopy and fall on the ground. It has been estimated that as much as 56 % of the sun light is transmitted through the canopy during the peak hours (10.00 to 16.00 hrs.) in palms aged around 25 years. The diffused sunlight favours growing a number of shade tolerant crops in the interspaces of coconut.

Based on the growth habit of the palm and the amount of light transmitted through its canopy, the life span of coconut palm could be divided into three distinct phases from the point of view of intercropping (Table 1).

Table 1. Life span of coconut palms, light transmission & suitability for intercropping

Growing condition	Age of palm (years)	Light transmission	Suitability of intercrops
Planting till full development of canopy	Up to 8	Good initially, decreases with age	For growing annuals, biennials, intercrops have minimal competition with coconut plants
Young palms	9 to 25	Maximum ground coverage (80%), Poor light availability	Not ideal for intercropping, if wider spacing is followed, annuals can be grown, suitable for vanilla
Grown up palms	> 25	Gradual increase in light availability	Ideal for annual/ perennial crops

When palms grow up, slant rays of sunshine will add to light coming in between the leaves. When palms grow old, after about 50 years, a gradual reduction in canopy may occur and more light will penetrate (Fig1).

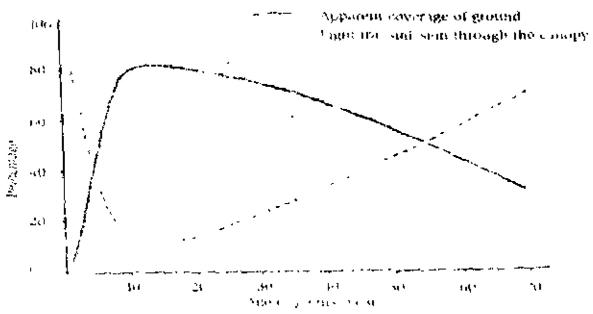

Fig. 1. Apparent ground coverage and light transmission in coconut plantation (Nelliyat, et al, 1974).

Ecological conditions influence palm development substantially; therefore, only local conditions can determine at what age of the palm mixed cropping with trees is possible, or not. A factor that decides the compatibility of crop combinations in a cropping system such as coconut culture is the ability of the associated crops to come up under shade. This ability has been reported to vary widely between species of plants with varying degree of yielding (Bai and Nair, 1982).

As coconut and inter crops will compete for light, water and minerals, spacing between component crops is an important factor. In densely planted coconut plantations, intercropping should be restricted and only shade tolerant crops are to be grown. In very densely planted plantations the palms that do not yield satisfactorily have to be removed.

Spices suitable for growing coconut under plantation, their requirements and cultivation as intercrops

Major spices like black pepper, cardamom, ginger, turmeric, vanilla, nutmeg, clove and cinnamon will grow well under coconut. Spices are generally very sensitive to violent fluctuations of the crop environment. They are very sensitive to continuous water logging even for a day unlike coconut, which can tolerate water logging for a few days ranging from 5 to 10 days. Spices like tamarind, cinnamon and curry leaf, which are hardy and can withstand moisture stress to a certain extent. Perennial spices will show a positive cash flow only after few years of planting. Availability of local labour and management skills are other factors to be considered while selecting the crop combinations in a system.

Black pepper

Black pepper (*Piper nigrum* L) is grown in Kerala, Karnataka, Tamil Nadu and North-eastern states including Sikkim. It is also grown in some areas in Andhra Pradesh, Orissa, West Bengal, Goa, Maharashtra and Gujarat. The total area under this crop in India during 1999-2000 was 1.92 lakh ha. with a production of 58,300 t. It grows successfully between 20° N and S of the equator and from sea level to 1500 m msl. It is a plant of humid tropics requiring 2000 to 3000 mm rainfall, tropical temperature and high humidity with little variation in day length throughout the year. The crop tolerates temperature between 10 and 40° C. The ideal temperature is 23 to 32° C with an average of 28° C. Optimum soil temperature for root growth is 26 to 28° C. The plants grow well in soils ranging from heavy clay to light sandy clays rich in humus with friable nature, well drained, but still with ample water holding capacity. Soils with neutral pH and high organic matter content are found to enhance productivity of the crop.

Among the released high yielding varieties, Sreekara, Subhakara, Panniyur-2 and Panniyur-5 are shade tolerant and are suitable for mixed cropping under coconut. Panniyur-1 may be suitable in widely spaced and old coconut plantations of more than 40 years old, where more light is available. Pepper can be planted in coconut basin using coconut trunk itself as the standard and also in the inter space. Plant 2 to 3 rooted cuttings in pits of 50 x 50x 50 cm size about 1 m away from the base of trunk in the northern side of palms. The vines may be trained along the ground and then on the palms as they grow by tying to the trunk during the first two years. Pepper begins to yield from third year onwards and come to stabilized yield from 5th or 6th year after planting under well managed conditions. Adopt the following agro management practices for growing pepper as inter crop along with coconut.

1. Allow vines to trail on the palm approximately to a height of 5 to 6 metres and thereafter top shoots climbing on coconuts may be cut to facilitate harvesting of coconut and pepper using a bamboo ladder.
2. Avoid growing pepper in areas likely to be water logged. Adequate provision for drainage is to be provided in the plantation.
3. No digging of the plant basin should be done. Application of organic manure and inorganic fertilizers should be carried out in appropriate time. In situ vermicomposting in the basin can supply nutrients needed for growth and yield of both coconut and pepper.
4. Clean the coconut crown regularly and cut dried coconut leaves while harvesting to reduce the damage to pepper vines trailed on palms.
5. Adopt appropriate and timely plant protection measures to reduce disease or pest problem of both the crops.

On an average one kg of dry pepper can be harvested from one vine, but the productivity of vine is found to vary from 1 to 10 kg/vine depending up on the location, age of the vine, height up to which it is maintained and management practices followed.

Potty et al (1979) evaluated performance of six varieties of pepper as intercrop in coconut garden and reported that Karimudna and Panniyur-1 performed better than the others. The average yield of dry pepper recorded was 1.17 to 1.3 kg/standard from a coconut based multistoried cropping system at CPCRI, Kasaragod (Anon, 1984). Sadanandan et al (1993) reported an increase of 53% and 172% in yield, respectively for coconut and pepper in a mixed cropping situation. Results of experiments conducted in Goa conditions indicate that pepper can be grown satisfactorily as a mixed crop in coconut gardens and the plants started flowering and yielding from third year of planting. The average yield recorded was 0.76 and 0.44 t/ha, respectively for Panniyur-1 and Karimunda (Mathew et al, 1993).

It can be noticed that there is an increase in net returns to the tune of Rs.13, 300/ha by mixed cropping pepper in coconut gardens.

Economics of coconut-pepper mixed cropping at CPCRI, Kasarasgod is given in Table 2.

Table 2. Economics of coconut-pepper mixed cropping at CPCRI, Kasarasgod (Rs/ha/year at 2000-2001 prices)

System	Invest. cost	Annuity value	Total annual cost	Yield of pepper (kg/ha)	Unit value of pepper (Rs)	Gross returns	Net returns
Coconut monocrop	60,000	17,000	24,500	-	--	46,800	22,300
Coconut+ pepper	70,000	19,600	28,800	175	100	64,300	35,500

(Source: CPCRI Technical bulletin, No.24)

Ginger

Ginger (*Zingiber officinale* Roscoe) is mainly grown in states of Kerala, North Eastern States including Sikkim, Himachal Pradesh, Orissa, Karnataka, Maharashtra and Tamil Nadu. The area cultivated with ginger during 1999-2000 was 77,000 ha and the total production was 2.63 lakh t. Ginger requires tropical or sub-tropical climate. It performs well up to an altitude of 1500 m msl, the optimum being sea level up to 900 m. The minimum temperature requirement is 13° C and the maximum is 32° C and the optimum range is 19 to 28 ° C. The optimum soil temperature for germination is 25 to 26 °C and for growth is 27.5°C. Ginger is cultivated both under rain fed and irrigated conditions. In areas receiving less rainfall, the crop needs regular irrigation. It is sensitive to water logging, frost, salinity and tolerant to wind and drought. Partial shade is found to increase yield. It has wider adaptability under different soil types, and for higher yield the soil should be loose, friable and offer minimum resistance to the rhizome development. Well drained soil with at least 30 cm depth is essential, but by adopting bedding and surface mulching, shallower soil can be used effectively. The most suitable pH is 6 to 6.5. Ginger can be grown in a variety of soil such as sandy loam, clay loam, black rich clay soils and lateritic soils.

The best time for planting ginger is with the receipt of pre-monsoon showers. If irrigated, it can be planted well in advance during mid February to early March. Planting material for ginger should be collected from genuine sources and free from any diseases. Ginger should not be grown as an intercrop in coconut garden where drainage is a problem.

Turmeric

Turmeric (*Curcuma longa* L.) is mainly grown in Kerala, Andhra Pradesh, Himachal Pradesh, Karnataka, Maharashtra, Orissa and Tamil Nadu. It is also grown in North Eastern states like Sikkim. The area under turmeric cultivation and total production was 1.61 lakh ha and 6.54 lakh t, respectively (1999-2000). A well distributed rainfall of 1200 to 1400 mm in 100 to 120 rainy days is ideal for the crop. The crop can be cultivated from sea level up to an altitude of 1200 m msl. High yield is obtained in high in altitudes ranging form 450 to 900 m msl. Turmeric responds well to irrigation in fertile garden lands. A temperature range of 30 to 35 °C during germination, 25 to 30 °C during tillering, 20 to 25°C during rhizome initiation and 18 to 20°C during bulking stage have been found ideal for growth and production in turmeric. A well drained loamy or alluvial soil with good organic matter status and a pH range of 5.0 to 7.5 is ideal. The crop does not tolerate water logging. Being an exhaustive crop, turmeric requires heavy manuring for higher productivity.

Intercropping with annual rhizome spices like ginger and turmeric in coconut garden is a common practice adopted for increasing income from unit holding. They are planted in raised beds of 1.0-1.2m width, 30 cm height and of suitable length, preferably 3 m. Farm yard manure is to be mixed with soil of the pit after planting. Application of Trichoderma prevents soft rot disease incidence in ginger. Ginger is planted at a spacing of 25 x 25 cm at a depth of 4.5 cm with bud facing upwards. Turmeric rhizomes are planted at a spacing of 15 x 30 cm and covered with dry powdered cattle manure. Covering the seedbed with green leaves is to be done after planting and is to be repeated after 45 and 90 days of planting. The yield of ginger and turmeric as inter crops under good management conditions ranges from 10 to 12 t / ha on wet basis.

The economic feasibility of raising short and long season annual spice crops like turmeric and ginger in middle aged WCT coconut garden was evaluated at CPCRI, Kasaragod. In the experiment, spice crops produced a satisfactory yield. (Table 3).

Table 3. Yield performance of spices as intercrops under coconut plantation

Intercrop	Yield (kg/ha)	Expenditure (Rs/ha)	Gross income (Rs/ha)	Net profit (Rs/ha)	Additional labour requirement (man days)
Turmeric	4441	6285	8882	2597	108
Ginger	2426	6679	7290	611	108

The net profit received was more from turmeric than ginger (CPCRI, Kasaragod).

From a recent study, Sairam et al (1997) worked out the capital requirements, gross return, net return and profit from spices in a coconut based intercropping system, which is given in tables 4 and 5.

Table 4. Capital requirements of coconut based intercropping system (Rs/ha)

Inputs	Coconut mono crop	Coconut+ Turmeric	Coconut+ Ginger
Labour	7800(54.93)	22750(52.12)	22750(38.57)
Seed	--	10000(22.91)	25000(42.39)
Organic manure	2363(16.64)	4725(10.83)	4725(8.01)
Fertilizers	2537(17.87)	3171(7.27)	3506(5.94)
Plant protection	1000(7.04)	2000(4.58)	2000(3.39)
Miscellaneous	500(3.52)	1000(2.29)	1000(1.70)
Total	14200(100)	43646(100)	58981(100)

Figures in parenthesis indicate the per centage

The expenditure on account of labour for intercropping was increased by Rs. 15, 000 indicating the increase in labour requirement under such a system compared to monocropping of coconut.

Table 5. Economics of coconut based intercropping system (Rs/ha)

Particulars	Coconut monocrop	Coconut+ Turmeric	Coconut+ Ginger
Gross returns	31500	81500	100500
Net returns	17300	37900	41500
Cost for intercrops*	--	29500	44800
Returns from intercrops	--	50000	69000
Profit from intercrops**	--	20500	24200

*Out put prices were coconut Rs.3 per nut, turmeric Rs 5 and ginger Rs.8.60 per kg.
** Input and out put prices considered were for the year 1993-1994

The net profit from growing intercrops in coconut garden was Rs. 20,500/ha for turmeric and Rs. 24,200 for ginger, indicating the profitability of the system.

Results of intercropping studies in coconut plantation done in Assam, where coconut is a non-traditional crop reported by Chowdhury and Deka (1997) (Table 6) also indicated that yield of coconut improved due to intercropping.

Table 6. Mean yield of coconut and intercrops (only spices) (1991-1994)

System	Coconut (nuts/palm/year)	Pepper (kg/ha)	Ginger (kg/ha)	Turmeric (kg/ha)
Coconut, pepper, ginger, banana, Assam lemon, pine apple	51.4	74	925.3	--
Coconut, betel vine, banana, Assam lemon, turmeric, colocasia	53.3	--	--	768.5
Coconut alone	29.5	--	--	--

Economics of coconut based intercropping system (Horticultural Research Station, Mondouri, BCKV, West Bengal (Anon, 2001b) (Table 7).

Table 7. Economics of intercropping in coconut garden (only spices are considered here) (Rs/ha).

System	Cost of cultivation	Gross return	Net return	Return from intercrop	Cost for intercrop	Profit from intercrop
Coconut alone	19,000	37,170	18,170	--	--	--
Coconut+ turmeric	47,000	88,620	41,620	51,450	28,000	23,450
Coconut+ ginger	73,950	1,32,370	58,420	95,200	54,950	40,250

Selling price: Coconut: Rs 3.5/nut, Ginger Rs.8.0/kg, Turmeric: Rs.3.5/kg

In West Bengal also ginger was found to be highly remunerative as intercrop in coconut. The profit was Rs.40,250/ha whereas, it was Rs.23,450/ha from turmeric.

Long pepper

Long pepper (*Piper longum* L.) requires a hot, moist climate and an elevation between 100 and 1000m msl for its cultivation. It can be successfully grown in areas that receive heavy rainfall with high relative humidity. The plant is found to grow as an undershrub in its natural habitat. This makes the crop as an ideal one for intercropping in coconut plantations. It can be grown under partial shade with 20 to 25 % light intensity. It performs well in a rich well drained loamy soil. Laterite soil rich in organic matter content with good moisture holding capacity are also suitable. The variety "Viswam" is an ideal one for intercropping in coconut garden under irrigated condition.

The vines start flowering six months after planting and flowers are produced almost throughout the year. The yield of dry spike is about 400 kg/ha in the first year, which increases to 1t/ha during third year and thereafter it declines. Hence the whole plant is to be harvested after three years. The stem is cut close to the ground and roots are dug up. The average yield of dry root is 500 kg/ha.

Clove

Clove (*Syzigium aromaticum* L Merr.Et.Perry) is mainly grown in Tamil Nadu, Kerala and Karnataka. The total area and production of clove for 1999-20002 was 2399 ha and 1750 t, respectively. The plants require a humid climate and grow at 600 to 1000 m msl with a rainfall of 1500 to 2000 mm and a mean temperature of 20 to 30 °C. Deep red loam, sandy soil, black soil and deep gravelly sub soil are suitable. Water logging should be avoided.

Clove can also be grown as a profitable mixed crop in coconut plantations aged around 20 years onwards with fertile, well drained soils with assured irrigation in the west coast as well as in the elevated places like Coorg, Shimoga and Chickmagalur areas of Karnataka. Although the yield potential of clove under the shade of coconut is slightly reduced, a small farmer of coconut can still gain additional income from such a cropping system. One clove seedling can be planted in the center of 4 coconut palms in pits taken with size of 60 x 60 x 60 cm.

Under optimum management, clove plants start bearing from fourth year onwards. The tree will be about 2 to 3 metres in height, and will bear mostly along the sides where afternoon sun strikes. Branches should not be allowed to bend downwards, and harvesters should not climb small trees. A tree attains full bearing stage at 20 years age, and will continue to yield for a further 60 years after which the yield will decline. On an average a full bearing tree can yield around 4 kg of dried cloves.

Nutmeg

Nutmeg (*Myristica fragrans* Houtt) is grown in Kerala, Karnataka and Tamil Nadu. It is grown in area of 7,210 ha and the production for 1999-2000 was 2245t. A humid tropical climate is the best for nutmeg and it grows up to an elevation of 100 m msl. A well distributed rainfall of 1500 to 2000 mm and a mean temperature of 20 to 30 °C are ideal for nutmeg. Well-drained soils rich in humus is the best. Water logged soils as well as soils with moisture stress are to be avoided.

One year old nutmeg grafts are to be planted at the center of 4 palms in pits taken with size of 60 x 60 x 60 cm. Grafts prepared from high yielding female trees are to be used for planting. Trees come to flowering at 3 to 5 years of age and full bearing comes at 10 to 15 years. On an average, 1500 to 2000 fruits yielding 8 to 12 kg nuts and 1.5 to 2.0 kg mace will be obtained /tree year.

Cinnamon

Cinnamon (*Cinnamomum zeylanicum* Blume) is mainly grown in Kerala, Karnataka and Orissa. The area under this crop was 713 ha and the production was 370 t. It is a hardy plant, which tolerates a wide range of climatic conditions. The plant thrives well at altitudes ranging from 300 to 350 m msl though it can be cultivated up to 1000 m msl. It flourishes in places where annual rainfall is 1500 to 2500 mm and with an average temperature of 27° C.A hot and moist climate is highly suited for cinnamon and prolonged spells of dry weather are not conducive for its growth. It grows in a wide range of soils, even in marginal soils with poor soil fertility. Sandy loam soil rich in organic matter is the best. Water logged soil and marshy areas are not ideal as they give an undesirable product.

It can be planted in the double hedge system at spacing of 3 m between plants. The pit size is 60 x 60 x 60 cm. Harvesting can be started from fourth year and continued in alternate years. This is a labour intensive operation and hence mixed cropping with cinnamon will be profitable only in areas where labour is cheaply available or family labour is used.

Nelliat (1979) reported the beneficial effect of growing cocoa, pepper, clove, cinnamon and nutmeg in coconut garden. The yield of cinnamon quills was 30 to 35 g and that of chips 15 to 20 g in 1974, which was increased to 82 and 30 g, respectively in 1978. The yield recorded for cinnamon grown in single hedge was 146.0g quills/pant and that of chips was 43.4g/palnt. However, there was a decline in yield when cinnamon was grown in double hedge. The yields were 44.8 g quills and 37.9 g chips/plant (Anon, 1984).

Vanilla

Vanilla (*Vanilla planifolia* Andrews) is mainly grown in Karnataka, Kerala and Tamil Nadu. Vanilla requires a warm climate with frequent rains. It is adapted to a wide range of soil types rich in humus and having good drainage. Clayey soils and waterlogged soils are not suitable for vanilla cultivation. Temperature ranging from 21 to 32°C is optimum for growth and yield. It thrives well in humid tropical climate with an annual rainfall of 2000 to 3000 mm with two to three drier months prior to flowering. It can be cultivated from sea level to an elevation of about 1500m msl. Vanilla requires 40 to 50% shade depending up on its growth and hence can be successfully cultivated as an inter crop in coconut gardens.

Vanilla has recently attracted attention of a large number of farmers as a profitable mixed crop in arecanut and coconut plantations in Karnataka, Kerala and Tamil Nadu. This orchid spice, being a climber, requires a standard for climbing. Low branching trees with rough bark and small leaves are grown for this purpose. Glyricidia is found to be an ideal standard for vanilla in many growing areas. The growth of the standard is to be adjusted to a height of 1.2 to 1.5 m to facilitate training of vanilla vines around the branching shoots. The standards can be planted in between two rows of coconut palms at a spacing of 2.5 to

3.0 m between rows and 2 m within the row in pits of 30 X30 x 30 cm Use cuttings of around 5 cm diameter and 150 to 200 cm length and plant them with the onset of rains after the summer break, and it should be at least 6 months before planting vanilla in August-September. If longer cuttings (at least 1 m long) are used for planting and with proper management in terms of manuring, irrigation and training of vines, vanilla comes to flowering in the third year. Individual flowers are to be pollinated artificially and a trained person can pollinate around 800 to 1000 flowers a day. Vanilla is a crop where the family labour (including women) can be very efficiently utilized for crop production. Vanilla can yield on an average about 1 to 1.5 kg fresh beans per plant and 70 to 75 beans (around 18 to 20 cm long) makes one kg.

Korikanthimath et al (1999) studied the feasibility of growing vanilla as a mixed crop in coconut garden spaced at 9x9 m in lower elevation (plains) and low rainfall area under assured irrigation. Vanilla was planted at a spacing of 1.5x 1.5 m in 4 rows between two rows of coconut palms accommodating a population of 3825 plants/ha. Cost of cultivation of vanilla in the pre bearing, first year of bearing and of coconut (average 4 years from 94-95 to 97-98), gross and net return of mixed cropping vanilla under coconut is given in table 8 a, b.

Table 8a. Cost of cultivation of vanilla during pre-bearing, bearing and of coconut (Rs./ha) (average 4 years)

Items	Cost of vanilla Pre-bearing stage	Cost of vanilla Bearing stage	Average cost of coconut (94-95 to 97-98)
A. Materials	1,19,495	18,970	9,135
B.Labour inputs	16,634	11,510	659
C. Drip system	25,000	---	--
Total	1,61,129	30,480	9,794

Table 8b. Yield, cost and return of mixed cropping vanilla under coconut (Rs./ha)

Year	Yield		Price		Gross return	Cost of cultivation	Net return
	Coconut (nuts/ha)	Vanilla (kg/ha)	Coconut (Rs./nut)	Vanilla (Rs./kg)			
94-95	8,333	---	3.0	--	24,999	1,32,489	-1,07,490
95-96	12,500	---	3.2	--	40,000	27,538	12,462
96-97	18,750	---	4.5	--	84,375	30,687	53,688
97-98	25,000	85	4.0	1500	2,27,500	41,171	1,86,329
Average					94,219	57,971	36,247

The negative net return during the first year was mainly on account of high cost of planting material for vanilla. The crop comes to bearing only three year after planting. They recorded a gross and net profit of Rs. 94,219 and 36,247/ha, respectively over a period of 4 years. The BC ratio was 1.34 indicating that cultivation of vanilla as a mixed crop in coconut plantation will be highly rewarding. .

Multistoried cropping with spices

Multistoried cropping with spices is another way of improving land use efficiency more than 100 %. In this system of cropping, the aim is to maximize production from unit area of land per unit time wherein economic yields of compatible crops are harvested from different heights in a vertical plane. Coconut palms above 20 years old are suitable for this system and black pepper, the spice component of the system can be trained on the palms and allowed to occupy 2 to 8 m height of the trunk to form as the second floor.

High Density Multispecies Cropping System (HDMSCS)

This involves growing a large number of crops to meet the diverse needs of the farmers. This is most suited for smaller holdings and aims at maximizing production from unit area of land and time simultaneously ensuring sustainability. This system will also supply large quantities of degradable biomass and their effective utilization can bring down the external nutrient requirement considerably.

Under the All India Coordinated Research Project on Palms, coconut based high density cropping systems involving spice crops as applicable to different agroclimatic conditions are being evaluated. The details of centers and crops tested are as follows .

Table 9. Details of centers (under AICRPP) and intercrops evaluated

Name of the center	Crops grown
1. Ambajipet (AP)	Acid lime, guava, pomegranate, pepper, pine apple, banana and coffee
2. Arsikere(Karnataka)	Clove, Nutmeg, Pepper, Pine apple, mango, banana, coffee
3. Kahikuchi(Assam)	Pepper, betel vine, citrus, pine apple, banana
4. Andaman Centre	Coconut, clove, cinnamon, nutmeg and coffee
5. Ratnagiri(Maharashtra)	Coconut, clove, nutmeg, cinnamon, all spice, pepper, banana, pepper trained on glyricidia
6.Veppankulam(Tamil Nadu)	Coconut, banana, citrus, guava, tapioca, betel vine, pulses, nutmeg, clove

Patil et al (1991) at Ratnagiri (Maharashtra) studied the influence of interplanting with tree spices on coconut yield. The palms from nutmeg block produced the highest yield (121nuts/palm) followed by those in cinnamon block (114 nuts/palm) and clove (80 nuts/palm). The yield of coconut was 78 nuts/palm when it was grown as a monocrop. It was also observed that the yield of coconut increased over a period of time after planting spices as intercrops (Anon.1999). The maximum increase was noticed in clove plot (93.93%) followed by all spice (79.08%), nutmeg (75.80%) and cinnamon (74.86%). This is mainly because the palms are benefited from the application of fertilizers and irrigation to the associated crops and the cultural operations given to them, which are generally not available to the pure stand of coconut. The net profit from monocrop of coconut was Rs.30, 475/ha whereas, mixed cropping especially with spices like nutmeg and cinnamon gave a net return of Rs.82, 355 and Rs. 62,475, respectively (Anon, 1998).

The Coconut Based HD MSCS experiments started at Ratnagiri (Maharashtra) by incorporating different spices is being continued. The average yield of coconut in different blocks of spices is given in table 10.

The yield of coconut increased after planting intercrops irrespective of the influence of component crops. The maximum increase in yield was recorded in clove plot (both the years), followed by all spice and cinnamon.

Table 10. Average yield of coconut in different blocks of spices in different years (AICRP on Palms, Ratnagiri centre, Maharashtra)

	Cinnamon	Clove	Nutmeg	Allspice	Garcinia	Black pepper	Control
Av.yield before planting spices	69.25	47.08	70.56	49.15	63.67	82.87	76.70
Av.yield after planting spices	120.14*	91.57	120.12	89.91	94.52	102.44	---
	118.84**	91.07	119.17	95.28	95.28	102.21	---
Per cent increase	73.49*	94.50	70.24	82.93	48.52	23.62	---
	71.61**	93.44	69.66	82.99	49.65	23.10	---

* 2000-2001 ** 2001-2002

Economics of coconut based HD MSCS recorded for 2001-2002 is presented in Table 11.

Table 11. Economics of coconut based high density multispecies cropping system (Rs./ha)

	Nutmeg	Clove	Cinnamon	Pepper	All spice	Garcinia + Cinnamon		Control
Yield								
Coconut	21495	15210	17210	16720	16875	19000	----	13740
Spices	74520 41.05*	33.30	167.3	--	--	980	105	
Cost								
Coconut	58673	58673	58673	58673	58673	58673		58673
Spices	30485	21260	25755	22035	12780	23470		
Total	89158	79933	84428	80708	71453	82143		58673
Total return								
Coconut	128970	91260	103260	100320	101250	11400		82440
Spices	70258	14985	29278	--	--	7840	183	--
Total	199227	106245	132538	100320	101250	140215	75	82440
Net profits								
Coconut	70298	32588	44588	41648	42578	55328		23768
Spices	39773	-6275	3523	-22035	-12780	2745		--
Total	110071	26313	48110	19613	29798	58073		23768

Yield Coconut: No./ha Nutmeg: No./ha,*=Mace-kg/ha, Clove &Cinnamon: kg/ha
Garcinia: No./ha
Source: AICRP on Palms-Ratnagiri center, Maharashtra Annual Report for 2001-2002

The center is recording yield data of coconut under the HDMSCS experiment to work out the influence of mixed spice crops on yield of coconut over the years. The results of 2001-2002 are presented in Table 12. (Source: AICRP on Palms-Ratnagiri center, Maharashtra Annual Report for 2001-2002).

The data presented above indicate that there is decline in yield of coconut mixed crops with different spices except of all spice and garcinia. The percent decrease was more with nut meg and cinnamon followed by clove. This could be due to the root competition of component crops with coconut, which requires detailed studies for confirmation.

Table 12. Yield of coconut in HDMSCS at Ratnagiri, Maharastra (2001-2002)

Treatment	Pre-terat.yield (no./palm/year) 1989-1993	Yield in transit period 1993-1996	Post treat.yield (no./palm/year) 1996-2002	Percent ↑ or ↓ in yield
Cinnamon				
A	125.79	107.78	113.69	-12.10
B	135.09	116.60	101.00	-34.09
Clove				
A	110.73	97.79	96.23	-14.50
B	102.08	89.71	96.62	-5.46
Nutmeg				
A	132.24	109.15	106.86	-25.38
B	127.95	104.15	104.92	-23.03
All spice				
A	93.09	92.52	100.83	+7.74
B	102.84	104.23	102.74	+0.10
Garcinia				
A	107.79	119.00	120.04	+12.25
B	115.24	105.19	114.87	-0.37
Black pepper				
A	113.66	104.99	95.56	-18.10
B	118.14	98.39	95.14	-23.00
Control				
A	108.00	61.71	70.93	+2.93
B	84.52	77.94	73.79	-10.73

A= Full dose of fertilizer B= Half dose of fertilizer

The HDMSCS experiment started at CPCRI, Kasaragod in 1983 is being continued by giving different doses of fertilizers to the coconut and component crops. It was observed that yield of cloves, one of the spices in the system varied with fertilizer levels and the tree did not flower below 1/3 dose in 2000 and below ¼ dose in 2001.The average yield (2000-2001) was the highest at full recommended dose (Table 13).

Table 13. Yield of clove in High Density Multispecies Cropping System under Coconut

Treatment Fertilizer dose	Yield of clove (dry, kg/plant) 2000	2001	Average yield (dry, kg/plant)
Full	1.34	1.18	1.26
2/3	1.35	1.07	1.21
1/3	0.86	0.87	0.87
¼	--	0.49	0.25
1/5	--	--	--
Control	--	--	--

Source: Anon, 2001a

Adoption of coconut based inter/mixed cropping and mixed farming system incorporating spices as components is found to generate employment potential considerably when compared to mono cropping of coconut (Table 14).

Table 14. Assessment of employment potential of coconut based farming system model, CPCRI, Kasaragod (Man days/ha/year) (Das, 1990).

System	Jan-Mar	Apr. - June	Jly.-Sep.	Oct.-Dec	Total	% change over monocrop	
Rainfed							
Coconut	15	15	57	33	120	--	--
" +ginger	239	265	81	35	620	417	--
Irrigated							
Coconut alone	27	19	57	41	144	20	--
MSCS*	82	70	113	70	335	179	133
MF**	232	193	203	222	850	608	490

* Multispecies cropping system involving coconut, cocoa, pepper and pineapple

** Mixed farming involving coconut, pepper, fodder, cattle, rabbits and subsidiary crops

Adoption of the cropping system by the farming community will ultimately be decided by its economic advantage. While the monocropping of coconut generates employment opportunities only for around 150 man days/ha/year and a net income of Rs. 10.400/ha/year, the various cropping systems generate additional employment of 130 to 600 man days /ha/year and income ranging from Rs.36,500 in the case of coconut+ginger to Rs.50, 000 under coconut based mixed farming incorporating pepper on the palms (Table 15).

Table 15. Economics and employment potential of coconut based spices growing condition (Gopalasundaram et al, 1993).

System	Net return (Rs./ha/year)	Additional employment (man days/ha/year)
Cocount mono crop	10,400	--
Coconut+Ginger	36,500	500
Coconut+Clove	38,500	NA
Multistoried cropping system	30,300	210
Coconut based mixed farming	50,000	600

Organic farming of coconut and spices

The demand for organically produced products in the national and international market is ever increasing mainly due to health concerns associated with pesticide residue and other related problems. Organic cultivation of crops without use of any chemical inputs comes handy in this regard.

Organic farming in coconut plantations aims to create an eco-system that can contribute to the sustainability in productivity without depending on artificial external inputs such as chemical fertilizers and pesticides. It also aims to maintain soil fertility through use of organics by way of recycling of organic wastes in the farm itself. Technologies have been developed for utilisation of waste biomass available in coconut plantations estimated to be around 14t/ha/year (Prabhu et al, 2001).

Indian coconut industry is characterized mainly by the higher per centage of small and marginal farmers (>90%) who generally do not apply any chemical fertilizer or very minimal quantity, if at all application is made. This provides ample opportunities for converting these farms into organic ones.

Adoption of organic farming in coconut based farming system helps to maintain crop diversity and enhances ecological balance of coconut cultivation. The complimentarity associated with such a system promotes effective utilisation of available farm resources and contributes to increased productivity per unit of land put under farming. Efficient on farm recycling of biomass can minimize the use of chemicals in cultivation of these crops including spices to a great extent.

Conclusion

In the present context of fragmentation of holdings and shrinking of agricultural land due to large scale urbanization and industrilisation, increasing the unit income per unit time from unit of land area is very much essential. Widely spaced and perennial crop like coconut provides ample opportunities in this regard. In the free world trade of commodities, depending on a single crop is always risky and hence adoption of multicropping/mixed farming system will definitely provide higher income and employment as well as protect the farmer against falling prices of any particular commodity. In the years to come, coconut based farming system will hold a key role to play for sustainability and should receive attention from all concerned. Since spices, which are high value commercial crops compatible with coconut, they can also be efficiently fitted as inter/mixed crops in areas where coconut is cultivated.

Reducing the cost of production with sustainable high yield has the greatest relevance at all times. A system approach offers considerable scope for achieving this objective. However, research efforts in this area have been limited. A clear analysis of the dynamism of the existing system in the area of soil health, maintenance of soil moisture, microbial load, their synergistic/antagonistic effects, fate of applied nutrients, soil erosion, soil radiation profile, allelopathic effects, rooting pattern and foraging behaviour of component crops in a multiple cropping situation etc. need detailed investigations to make the system self sustaining and cost effective.

References

Anonymous 1984 CPCRI Annual report for 1980. p 29.

Anonymous 1998). Annual Report of All India Coordinated Research Project on Palms, Kasaragod.pp: 49-54.

Anonymous, (1999). *Annual Report of All India Coordinated Research Project on Palms*, Kasaragod.

Anonymous, (2000). CPCRI Annual report for 2000.p 37

Anonymous, (2001a). CPCRI Annual report for 2001.p.26

Anonymous, (2001b). Prospects of coconut based cropping system in West Bengal. Coconut Development Board.pp: 1-12.

Bai, E.K and Nair, R.V (1982). Shade response of some common rain fed inter crops. Placrosym V. pp: 394-401.

Chowdhury, D and Deka, K.K (1997). Coconut based inter/mixed cropping under Assam conditions. J.Plantation Crops, 25(1): 106-108.

Das, P.K. (1990). Economics of coconut based farming systems. Proc.XXVII Cocotech Meeting, APCC. S de Silva (Ed.) pp: 539-554.

Gopalasundaram, P, Thomas Varghese, P, Hegde, M.R, Nair, M.G.K and Das, P.K. (1993). Experiences in coconut based farming system in India. In: Advances of Coconut Research and Development, Oxford and IBH, New Delhi. pp: 383-393.

Korikanthimath, V.S, Hiremath, G.M, Venugopal, M.N and Rajendra Hegde. (1999). Feasibility of vanilla cultivation in coconut. J.Medicinal and Aromatic Plant Sciences, 21:1033-1039.

Kushwah, B.L, Nelliyat, E.V, Markose, V.T and Sunny, A.F (1973). Rooting pattern of coconut (*Cocos nucifera* L.). Indian J.Agronomy, 18:71-72.

Mathew, P.A, Nagabhushanan, S and Dhandar, D.G (1993). Multicropping trials in coconut in Goa. In: Advances of Coconut Research and Development, Oxford and IBH, New Delhi. pp: 437-439.

Nelliyat, E.V, Bavappa, K.V.A and Nair,P.K.R (1974).Multistoreyed cropping – New dimensions on multiple cropping in plantation crops. World Crops,26:262-266.

Nelliyat, E.V (1979). Prospects of multiple cropping in coconut and arecanut gardens. CPCRI Technical Bulletin.p: 3-5.

Patil, J.L, Haldankar, P.M, Jamdagni, B, M and Salvi, M.J (1991). Influence of interplanting with tree spices on yield of coconut. Indian Coconut Journal.22 (1): 15-18.

Potty, N.N., Radhakrishnan, T.C, Ashokan, P.K (1979). A note on the early growth and performance of six varieties of pepper in the multistoried cropping programme in coconut garden.Agri.Res. J.Kerala, 17(1): 151-152.

Prabhu, S.R, George V. Thomas, Biddappa, C.C and Radha D. Kale. (2001). Basic and applied aspects of vermicomposting. Vatika. Issue 1:5-16.

Sadanandan, A.K, Jose Abraham, Anandaraj.M and Hamza (1993). Effect of coconut-pepper mixed cropping on soil fertility and crop productivity. In: Advances of Coconut Research and Development, Oxford and IBH, New Delhi. pp: 433-435.

Sairam, C.V, Gopalasundaram, P and Uma Maheswari (1997). Capital requirements for adoption of coconut based intercropping systems in Kerala.Indian Coconut J. 27(10): 2-4.

2

STRATEGIES FOR INCREASING PRODUCTION AND EXPORT OF VANILLA

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Abstract

Vanilla is a tropical orchid grown for its pleasant flavour. It has a prime position among food flavours, vanilla essence is largely used in the preparation of Ice Creams, Chocolates, bakery products, puddings, pharmaceuticals, liquors and perfumes. Vanilla was introduced to India in the eighteenth century, but the cultivation on commercial scale has caught up since 1990's, with the slump in prices for most of the cash crops cultivated in the Western Ghat belt of South India. This situation coupled with historic high prices for vanilla has induced the growers to cultivate this crop in a large scale. Vanilla is completely an export oriented spice crop; the prevailing agro-climatic conditions are congenial for its cultivation. In this paper the world scenario, Indian scenario, bottlenecks for increasing production, strategies for increasing production and export are discussed.

Introduction

Vanilla is obtained primarily from the fully grown but unripe fruits or "beans" of a climbing orchid *Vanilla planifolia* Andrews (*V. fragrans* (Salisb.) that have been subjected to fermentation-curing process to produce the characteristic aroma. It is indigenous to wet low land forests in South-Eastern Mexico, Guatemala and other parts of Central America. The substance chiefly responsible for the unique fragrance and flavour of the vanilla bean is vanillin (C8 H8 O3). Among the food flavours, vanilla has a prime position. Vanilla essence is largely used in the preparation of ice creams, chocolates, bakery products, puddings, pharmaceuticals, liquors and perfumes. Vanilla is the second most expensive spice traded in the world market.

The vanilla flavour industry was based on the processed beans of the vanilla plants. With the advent of chemical technology to produce vanillin/ethyl vanillin, the synthetic substitutes have taken over the use of vanilla beans. However, vanilla bean is still the most preferred food flavour spice.

Apart from *Vanilla planifolia,* two other vanilla species *Vanilla tahitensis* J.W.Moore, the Tahitian vanilla, which is cultivated in the Tahiti Islands and *Vanilla pompona* Scheide. cultivated in some of the South Pacific Islands also yield vanillin, but of inferior quality (Purseglove *et al* 1981).

Vanilla – World Scenario

World production: The total area of vanilla cultivation in the world during the year 2001 was 40,846 ha and production was 5,583 MT. There has been no appreciable increase in area under vanilla cultivation in the traditional vanilla growing countries. Four major types of vanilla beans are distinguished in the world market. The Bourbon vanilla, (produced in

Madagascar, Comoro and Reunion); The Java Vanilla (produced in the island of Java in Indonesia); The Bourbon-like vanilla (mainly produced on the island of Bali in Indonesia); and Mexican vanilla. They differ in flavour profile, organoleptic and analytical properties as a result of different growing conditions, harvesting and curing process. The Bourbon vanilla ranks top in terms of quality. The major vanilla producing countries are Madagascar, Comoro, Indonesia, Mexico and the Reunion. Among these countries, Madagascar holds prominent position having a cultivated area of 25,550 ha under vanilla. Of late, Indonesia has started to produce more with a production of 2,102 MT from 9,700 ha. Area and production of vanilla in different countries during 2001 are given in Table –1.

World trade: Aggregate global demand for vanilla is estimated at about 4,000 to 5,000 MT a year. The world market for vanilla beans is highly concentrated in a few developed countries. Three countries, USA, France and Germany alone account for about 80% of world imports, the US absorbs 50-60%, France and Germany between 10-15% each. These three countries are also major re-exporters of both vanilla beans and processed vanilla products.

Table 1. Area and production of vanilla in the world (2001)

Country	Area (ha)	Production (mt)
Madagascar	25550	1815
Indonesia	9700	2102
Mexico	2280	550
China	1200	600
Comoro	700	180
Reunion	600	30
Tonga	290	130
French poly. **Polynesia**	220	40
Malawi	80	20
Uganda	80	40
Zimbabwe	45	10
Guadeloupe	40	8
Kenya	40	8
Fiji islands	20	Na
Cook islands	1	0
Turkey	Na	50
Total	40846	5583

Source: F.A.O. Rome

Import of vanilla beans by important countries during five years from 1996 are given in Table 2.

Vanilla beans are primarily used as ingredients in the food industry. In USA, over 95% of the vanilla beans are processed in to extracts sold to flavour manufacturers or to the retail trade.

Three types of vanilla extracts and flavours are manufactured. Pure vanilla extracts, vanilla with other material flavours and vanilla flavours, which may contain artificial substances. Only a small proportion of vanilla beans is consumed directly, except in France where the proportion is about 20%. The dairy industry is the largest consumer of vanilla extracts and flavours. The confectionery, baking and beverage industries are the other major industrial users. Vanilla is most subjected to competition from imperfect substitutes (low-cost artificial flavourings). Four types of substitutes exist to date, viz., synthetic vanillin, ethyl vanillin, other natural flavours and Tissue culture products (Blarel & Dolinsky 1995).

Table 2. Import of vanilla beans by important countries during 1996 – 2000 (IN MT)

Country	1996	1997	1998	1999	2000
Usa	1524	2198	1941	1361	1304
France	420	460	490	565	491
Germany	291	332	320	326	312
Canada	95	204	110	119	66
Japan	79	95	69	91	115
Netherlands	222	106	182	102	-
Uk	92	225	290	385	395
Spain	139	292	125	Na	Na
Others	357	648	390	97	141

Source: UN Statistics NA = figures Not Available

Figures of ITC have been used where UN statistics are not available.

Vanilla – Indian Scenario

The history of introduction of vanilla into India appears to be obscure. Reports indicate that vanilla, was introduced by the British for planting at Kurtallam in the spice garden owned by the East India Company more than 200 years ago. However, "The Wealth of India" Raw Materials, volume 10, 1982 (a publication of the Council of Scientific and Industrial Research) mentions that vanilla was experimentally introduced to West Bengal, Bihar, Tamil Nadu, Pondicherry, Karnataka, Kerala and Assam only a 100 years ago. The earliest record, which could be located in regard to cultivation of vanilla by the National Committee on Vanilla, was at Kallar Fruit Research Station in the Nilgiris. According to the reports available in the station, vanilla was under cultivation there since 1945.

Research: Systematic research on vanilla since its introduction has been lacking. However, preliminary work was carried out with regard to cultivation and processing of the produce at the Regional Agricultural Research Station, Ambalawayal in Wynad district of Kerala and Kallar/Burliar Fruit Research Station, in Nilgiris district of Tamil Nadu. Investigations initiated in 1960 at the Research Station, Ambalawayal, with the financial assistance of the Indian Council of Agricultural Research resulted in understanding of the crop.

The Kallar/Burliar Fruit Research Station has also carried out some preliminary investigations on this crop. The work done at this station has been mainly on plant multiplication, hand pollination and curing. This station in 1958 published a handout on vanilla cultivation.

Efforts of the Spices Board: Considering the export potential, Spices Board launched a scheme for vanilla cultivation during 1990-91 for covering an area of 30 ha in five years. Planting under this scheme was started during 1990-91 in an area of 2 ha at Ramamangalam near Muvattupuzha in Ernakulam district of Kerala State. The scheme was later enlarged to cover an area of 75 ha. In the revised scheme, provision has been made to use tissue culture plantlets besides stem cuttings for planting. The growers have used cuttings from the plants planted under the scheme for the expansion the area subsequently. Under the scheme, it was proposed to take up planting in Dakshina Kannada district in Karnataka, Kozikode and Ernakulam districts in Kerala and Kanyakumari district in Tamil Nadu (Koshy John 1999).

Being a new crop, presently there is no stabilized market for vanilla in India. However, a few companies/exporters have been buying the cured as well as raw beans from the growers, whatever little quantity that has been produced.

Spices Board is currently implementing the following schemes for the benefit of the interested growers

a. Vanilla new planting programme
b. Vanilla Certified Nursery scheme
c. Scheme for Setting up of Processing Units
d. Vanilla Award Scheme
e. Scheme for assisting producers for promoting exports of organic Spices (including vanilla)

Karnataka State appears to have a history of vanilla cultivation. It is reported that one Mr. Coleman Higgins cultivated cardamom and vanilla in Heggan Valley, near Sringeri, in Chickmagalur district in the early 1900's. A recent survey shows that Karnataka State is presently having the largest area under vanilla cultivation in India. There are a number of growers now in Dakshina Kannada district who have taken interest in vanilla cultivation findings its profitability. Cultivation has been spreading to the neighbouring districts.

The Department of Horticulture, Government of Karnataka, initiated several schemes for development of vanilla cultivation in Karnataka during 1997-98. According to the Department, 874 demonstration plots of one acre each (600 plants/acre) have been established, in addition to two progeny orchards (Anonymous 2000). Growers have been supplied with drying boxes/trays under the scheme and training programmes have also been organised for the benefit of growers. The Department of Horticulture has been supplying vanilla rooted cuttings to the growers free of cost. During 2001-2002, planting materials worth Rs.88.392 lakhs have been distributed and the scheme is continued.

Thus, efforts to propagate and popularize vanilla cultivation in India have resulted in large number of farmers taking up vanilla cultivation particularly in Karnataka and Kerala. Research and development activities of the Spices Board have given the required impetus to the private and organized efforts of the farmers' organizations. As a result, the area under vanilla cultivation has been steadily increasing in the recent years and it is estimated that area under vanilla cultivation in India is about 1,800 ha and the production was about 6 to 8 tonnes during 1999-2000, 20 MT during 2000-2001 and about 65 MT during 2001-02 season.

Bottlenecks in increasing the production

Being a new crop vanilla poses a number of constraints for development. There are certain specific bottlenecks such as paucity of good quality planting material, the requirement of hand pollination and long and cumbersome on-farm processing of beans. It may be necessary to look into various constraints in vanilla production before drawing up a strategy for development.

Paucity of planting material: Though vanilla produces seeds, they are difficult to germinate under normal conditions. Hence, propagation is done through stem cuttings. Normally, 60 cm long stem cuttings are used for planting, and two node cuttings are used for raising nurseries. Since cultivation had been very limited and neglected, the availability of planting material was confined to only a few locations in Kerala, Karnataka and Tamil Nadu.

Cultivation in non-traditional areas: Some innovative farmers have commenced cultivation of vanilla in non-traditional areas where the rainfall and humidity are very low. There is need to develop suitable technology to support these efforts. As vanilla is a capital-intensive crop, setting up of crop insurance fund to encourage farmers to take up vanilla cultivation would insulate the farmers from vagaries of nature.

Need to update package of practices: Systematic research has been started only recently to develop necessary cultivation practices of vanilla. Most of the practices presently followed are based on the general orchid culture or the technologies developed in other countries. In a majority of vanilla growing countries, vanilla is an island crop grown at sea level. Some of the plantings did near the coast have produced good yields in India also. In India, vanilla is coming up very well in places located at different elevations from sea level to about 1,000 m above MSL. There is need for developing location specific package of practices and update it periodically.

Processing: Vanilla beans do not possess any flavour or aroma at the time of harvest. A long-drawn process involving cessation of vegetative life, sweating, rapid drying, slow drying and conditioning are required to produce quality beans. The whole process may last 2-3 months as per the traditional system. In the international market the quality is determined by the way the vanilla is cured. The stage of harvest and the method of curing, therefore, play a major role in determining the quality of the produce. As vanilla is being cultivated by a large number of small growers with holdings less than one-hectare area, in varied agro-climatic conditions, the quality of the end product varies very much even if they follow common curing process. Hence, it is essential to set up common processing facilities to get uniform good quality produce. The traditional curing process also requires a lot of space for processing. Hence, there is need to mechanise the processing system. This requires research to develop indigenous processing technology.

Storage, handling and packaging of vanilla: Vanilla beans during curing and after curing have to be stored properly. Otherwise the quality will be affected. Growth of moulds during slow drying and conditioning is a major problem faced by the growers. Research on the storage, handling and packaging is lacking. It is relevant to develop appropriate technology for storing vanilla without affecting the quality. Research on packing and storage materials is required to develop suitable materials.

Marketing: Lack of assured market either for the raw beans or for the processed beans is a major deterrent in vanilla development. There is neither a firm price nor a recognized agency for marketing of the beans in our country as the present production of vanilla beans is negligible. There is need to make the growers aware of the international price on a regular basis. It is important for the agencies that buy the beans to build confidence in growers in vanilla cultivation. Hence, developing market information systems to give upto date information is essential. Brand promotion, logo promotion, participating International exhibitions, buyer seller meets and other export promotional activities are required to boost export. Indian vanilla is exported directly in the form of processed whole beans. It is reported that the major importing countries like USA and France are re-exporting vanilla to other European countries after value addition. Thus, there is ample scope for value addition in the country itself. Research on suitable value addition is required to export at least a part of processed beans in the form of value added products. Visits to consuming countries would give us an insight to the requirement of these countries. Product development is another area to be looked into.

Quality: Quality is the key word in the International market. Hence, constant monitoring of quality parameters and quality upgradation is essential. This could be achieved by setting up quality control and upgradation laboratories.

Non-availability of trained manpower: Only a very limited number of personnel who have some knowledge on the culture and processing of vanilla are available in India. The growers and extension staff of the State governments and the developmental agencies have to be trained on methods of cultivation and processing of the beans along with the farmers by these personnel. Organising periodic training programmes on different aspects of cultivation and processing is essential to update the information. Exposure visits to producing countries will give first hand information to the growers on the cultivation practices followed.

Narrow germplasm base: The source of introduction of vanilla into our country is not known. It is likely that only one plant or a few cuttings have been brought here initially from one location, as the variations of the existing plants are quite narrow. In this situation, it is not easy to select superior vines or to improve such material through hybridization programme from the available vines. Hence, introduction, multiplication and supply of improved genetic material from other producing countries will help in enhancing productivity.

Inadequate Research: As discussed elsewhere, very little research work has been done on this crop. This is not adequate considering the potential for development. A possible way to grow vanilla in India appears to be as an inter-crop in coffee plantations and coconut and arecanut gardens. Studies should, therefore, be initiated for developing improved methodology of growing vanilla as an inter-crop. The aspects of cultivation system, nutrient requirements, physiology of flowering and fruit set, plant protection and artificial pollination have to be studied in depth. Simpler methodology has to be developed for processing of the beans ensuring quality.

Promoting organic vanilla cultivation, processing and marketing. Vanilla being an orchid crop responds very well to organic inputs. The pests and diseases identified in vanilla cultivation are very limited and can be easily controlled by botanicals. Most of the areca gardens are under organic cultivation in the State and vanilla cultivated in these gardens will also be organic. There is great potential to cultivate vanilla organically.

Finance: Vanilla being a high-value crop requires high capital investment to deal in procurement of raw beans, processing and export of processed beans. It is essential that financial institutions support these activities with adequate finance.

Potential for increasing production

The world consumption of synthetic vanillin/ ethyl vanillin, which was 12,000, MT in 1988 increased to 16,000 MT during 1992. This is a substantial jump of 7.5% per annum. The consumption of synthetic substitutes is estimated to be 28,000 MT at present. Use of natural colours, flavours and foods are reported to be growing at an annual rate of 2 to 4%. If only 0.1% of synthetic substance, i.e., 28 MT is to be substituted with natural vanilla beans, there would be an additional demand for 1,400 MT of vanilla beans per year. To produce this, an additional area of 4,700 ha has to be brought under vanilla cultivation. It is reported that the area expansion in major producing countries during the past five years has been marginal. It has increased from 40,020 ha in 1998 to only 40,846 ha in 2002. Hence, there is great scope for area expansion, production and export of vanilla in the country.

A major part of the world vanilla requirement is met through synthetic substitutes, vanillin / ethyl vanillin. These artificial products have substituted vanilla beans because of very low price. The competition between synthetics versus natural produce will continue so long vanilla beans are not adequately produced and the price is kept very high.

Because of the attractive price prevailing in the international market, there has been substantial increase in the production of vanilla beans. The annual production of vanilla beans from different countries have gone upto 5,583 tonnes in 2001 as against the production of 2,000 tonnes in 1988.

India should plan to bring at least 3,500 hectares under this crop in the next 3-5 years (George 1999). With the increase in production, it will be possible to bring down the import of synthetic substitutes considerably into our country. The oleoresin industry in India is at present importing 5-10 MT of processed beans per annum. This could be substituted completely by our produce if the quality is assured.

To bring 3,500 ha under vanilla by 2005-7 AD, an action plan should be drawn up covering production of planting materials including tissue culture technology, introduction and breeding of improved plant material, training of extension worker and farmer for production and on-farm processing, arrangements of various inputs for cultivation, marketing facilities and assurance of a reasonable price. Organized procurement of green beans and common curing facilities for uniform quality has to be thought of, along with implementation of developmental programmes. A well conceived research programme should also be initiated to tackle the field problems and also for building up expertise in production, processing and packaging technology.

Approach and strategy for increasing production

1. Setting up of Agriculture Export Zones (AEZ) and canalizing all the inputs and technologies through the AEZ to maximize the benefits.
2. Identification of areas of AEZ depending upon the agroclimatic conditions suitable for vanilla cultivation, the actual geographic areas will have to demarked for the purpose.
3. Identification of farmers/ group of farmers and farming clusters.
4. Raising quality planting material and distribution for expansion of area under vanilla cultivation.
5. Organising training programmes and visits of farmers to vanilla growing areas to motivate and educate them.
6. Area expansion by using quality planting material raised under certified Nurseries. Providing support by way of irrigation facilities to identified plots. Setting up of crop insurance fund to encourage farmers to take up vanilla cultivation.
7. Setting up of procurement centres for procuring green beans and transportation to processing units.
8. Setting of conventional/ modified processing units in identified zones to process the produce from the existing area in a phased manner. Establishment of Grading and Storage facilities.
9. Promotion of export of processed beans after quality certification. Concurrently initiating research and development activities on agronomy, physiology and cultivation practices in vanilla.
10. Import of exotic/ improved genetic material from other producing countries, their multiplication and release for large-scale cultivation.
11. Establishment of demonstration plots in all representative areas and their maintenance.
12. Organising farmers' visits to producing countries.
13. Promoting research on developing packaging and storage material for vanilla.
14. Providing suitable storage material to processing and storage centres.
15. Promoting research on developing suitable indigenous processing technology and upgradation of technology of existing units.
16. Establishment of quality evaluation and upgradation facilities.
17. Promoting research on product development and value added products. Export promotion of value added products.
18. Promoting organic vanilla cultivation, processing and marketing. Developing domestic and export market by way of brand promotion.
19. Setting up of market information centres.

20. Organising visits to consumer countries.
21. Providing financial support by way of seed money for procurement of raw beans and export of processed beans.
22. Development of Domestic market: Even though vanilla is an export oriented crop, it is desirable to develop domestic market concurrently to safeguard the growers against fluctuations in International prices and also glut in production.

Economic Analysis

It is estimated that about 3,500 ha of area will come under full bearing by 2009-10 in India, if the current rate of expansion continues. They will yield on an average about 300 kg/ ha of processed beans. At the prevailing international market price of US$ 200/ kg, the produce will fetch foreign exchange of Rs. 987 crores or US$ 210 million annually. However, to work out realistic returns, average International price for the past 10 years has been taken excluding the historic high and low prices. This comes to US$ 47/ kg and assuming an exchange rate of Rs. 47/ US$, the projected annual export earnings will be US$ 49 million or Rs. 231 crores.

Social benefits

Vanilla has become an alternative/ companion crop in arecanut, coconut and coffee based cropping systems supporting growers in a period of crisis where the market price of most of the crops cultivated in these areas have crashed and there are no prospects of their stabilisation in the near future.

Being a capital and labour intensive crop, the average size of vanilla garden is only 1.50 acres. With the increased area of vanilla to about 3500 ha, about 5,833 families are expected to be benefited directly. In addition, the cultivation of vanilla in 3,500 ha will generate an employment of 8.75 lakh man-days per annum (@ 250 man-days per hectare). To process 1050 MT produce, it is essential to establish about 42 processing units of 25 MT each. Setting up of 42 processing units in the identified zones would further generate employment of 2.63 lakh man-days annually. The area expansion and cultivation of vanilla would, therefore, generate a total employment of 11.38 lakh man-days annually, which will be mainly in the rural area. Further, it is anticipated that there will be about 30% additional generation of employment indirectly through associated activities. This will have a positive impact on the socio economic conditions in the identified rural areas.

Economics of cultivation

Vanilla flowers in the 3rd year after planting. Under proper care and management it will produce about 80 kg processed beans in the 4th year and 150 kg in the 5th year. The yield will increase further and stabilize at 300 kg by the 6th year. The yield is likely to be available for 15 years and thereafter it will decline gradually to uneconomic levels. Replanting is normally carried out at this time.

Unit cost for vanilla cultivation:

The cost of development of vanillery at the recommended density of 1, **600 to 2,000** plants per hectare is given below. The cost will vary with density of planting.

Cost of cultivation for the 1st year		-	Rs. 34,375-00
-Do- for the 2nd year		-	Rs 13,200-00
-Do- plus processing of beans for the 3r year		-	Rs 17,500-00
	Total		Rs. 65,075-00

Sale price: A sale price of Rs. 1504/kg. Of beans has been assumed as a farm gate price taking the average international price for the past 10 years (excluding the extreme high and low) in to account. The international price comes to US$ 47/kg, and farm gate price is kept at US$ 15 less than the international price i.e. US$ 32/ kg. Conversion of Rs.47/US$ is taken for calculations.

Rate of returns

Details/ Year	I	II	III	IV	V	VI to XV
Costs	34375	13200	17500	20000	25000	25000
Benefits				120320	225600	451200
Net benefits	(-34375)	(-13200)	(-17500)	100320	200600	426200

Unit cost for establishment of vanillery in one ha (1,600 vines) works out to Rs.65, 075 for the first three years. The maintenance cost during 4th year will be Rs.20, 000/- and from 5th year onwards 25,000/- ha.

The total investment for a period of 15 years including pre-bearing stage comes to Rs.3, 60,075 per ha. The total yield of processed beans expected during this period is 3,230 kg, which works out to Rs. 48,57,920/- at the rate of Rs. 1504/- per kg.

A small quantity of vanilla beans from India has already entered the international market. The analysis made by a few Indian and foreign firms to assess the quality have found the produce internationally acceptable. There are analytical reports to show that the vanillin content, which is the critical factor for the price determination is more than 2% in fairly well processed Indian beans. Accordingly, it should be possible for Indian vanilla to make a definite entry in the international market and fetch a good price. The price for Indian vanilla, if properly processed and conditioned, will be equal or even more than that of Java vanilla.

On a trial balance the net income from vanilla cultivation during its economic life cycle comes to Rs. 41.28 lakh per ha. The income and expenditure taken are based on current prices without considering any inflationary trends, price variation, and interest on capital, managerial expenses and opportunity cost on land and agricultural occupation. The total investment for a period of 15 years including pre-bearing stage comes to Rs 3.65 lakhs per ha. This gives us a cost benefit ratio of 11.30, which, perhaps is the highest compared to any crop.

Unit cost for vanilla cultivation

Area 1 ha spacing – 3 m x 2 m
Wage rate Rs. 85 per manday Plant population – 1600 nos

Details	Year					
	I		II		III	
	Input	Cost	Input	Cost	Input	Cost
Preparation of land, layout, digging of pits, planting of support trees and vanilla cuttings	65 Man Days	5525	5 Man days	425		
Cost of planting material for support trees	1600 Nos.	**3200**	160 Nos.	**320**		
Cost of planting material for vanilla	1600 Nos.	19200	160 Nos.	1900		
Cost of fertilisers N @ Rs. 7.60/ kg, P_2O_5 @ Rs. 18.75/ kg & K_2O @ Rs. 8.30/ kg	N 24 kg P_2O_5 16 kg K_2O 48 kg	880	48 kg 32 kg 96 kg	1760	72 kg 48 kg 144 kg	**2640**
Cost of bamboo splits, mulch, manures etc.	LS	1000	LS	2000	LS	2500
Cost of plant protection	LS	320	LS	420	LS	460
Intercultural operations including weeding, fertiliser applications, spraying, training etc.	50 Man Days	4250	75 man days	6375	100 Man days	8500
Hand pollination, harvesting, etc					40 Man days	3400
Total		**34375**		**13200**		17500

Unit cost for vanilla cultivation (continued)

Year	Amount (Rs.)
I	34,375
II	13,200
III	17,500
Total (Rs)	65,075

Yield (cured beans)

Year	IV	V	VI to XV
	80kg	150 kg	300kg

As approved by NABARD , Trivandrum, Kerala (Anonymous 1998).

Note: The cost of labour and the price realization of processed vanilla are taken as per prevailing rates.

References

Anonymous, 1992. Report of the National committee on Vanilla. Published by Spices Board, Govt. of India, Cochin.

Anonymous, 2000. Vanilla Status Paper. Published by Spices Board, Cochin.

Anonymous, 1998. Model bankable project on vanilla: National Bank for Agriculture and Rural Development, Thiruvananthapuram.

Benoit Blarel and Diane Dolinsky, 1995. Market imperfections and Government Failures: The Vanilla Sector in Madagascar. In "Marketing Africa's High-value Foods: Comparative Experiences of an emergent Private Sector" pp 255. Edited by Steven Jaffe & John Morton, Kendall/Hunt Publishing Co., IOWA.

George, C.K. 1999. Prospects of vanilla In India: Presented at the Workshop on vanilla organized by the Spices Board at Kochi on 5.7.1999.

Koshy John, 1999. Vanilla Development programmes in India: Presented at the Workshop on vanilla organized by the Spices Board at Kochi on 5.7.1999.

Nambiar, O.T.S. 1999. Vanilla marketing aspects: Presented at the Workshop on vanilla organized by the Spices Board at Kochi on 5.7.1999.

Purseglove, J.W., Brown, E.G., Green, C.L. and Robbins, S.R.J. 1981. Vanilla. In Spices Vol II : 644-735. Longman Scientific & Technical publisher. England.

3

GIS based Land Suitability Classification for Black Pepper in Kerala

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Abstract

The area under black pepper in Kerala is around 1,84370 ha with a production of 56430 Tons. Due to reasons of economical and agro-climatic changes, pepper cultivation is becoming non-remunerative and being neglected for other remunerative crops. Thus, there is a need to check the cost of cultivation and attain a sustainable limit in the application of fertilizers and chemicals. For this, a detailed study into the agro-climatic and geographical characteristics is essential, taking into account the biotic and abiotic parameters. The objective of this study is to develop a rapid field method for recording essential land attributes and for interpreting the data for site productivity and suitability for growing black pepper in Kerala. The evaluation was based on the land suitability classification method as prescribed by Food and Agricultural Organisation. The various parameters considered for this study were pH, Temperature, Humidity, Organic Carbon and Cation Exchange Capacity. The recorded features and the attribute data were then digitally encoded in a GIS database and overlay analysis was conducted by comparing the attribute values with the parameter standards prescribed by the Indian Institute of Spices Research. Accordingly, the data was classified as Most Suitable, Moderately Suitable, Less suitable and Unsuitable. The suitability classes were then checked with the yield of black pepper from these regions and it was found to be related.

Key words: black pepper, GIS, land suitability.

Introduction

Kerala being the leading state in area and production of black pepper has contributed a lot in the spice trade. The area under black pepper in Kerala is around 1,84370 ha with a production of 56430 Tons. Due to various reasons, the present market of black pepper has declined leading to heavy loss and neglect of the crop. Thus, it is mandatory to check the cost of cultivation and attain a sustainable limit in the application of fertilizers and chemicals. For this, a detailed study into the climatic and geographical characteristics is essential, taking into account the biotic and abiotic parameters and, a rapid field method recording essential land attributes should be developed for interpreting the data for site productivity and suitability. Land suitability classification can further help farmers to understand their region and take up sustainable measures to optimize yield potential. Land suitability classes are assessed by carrying out various simple steps in which various soil and site features are recorded and interpreted.

Methodology

Land suitability for pepper cultivation was carried out using the following four steps

1. Data integration
2. Crop suitability Classification
3. Classification of Geological Landforms

4. The classification of the soils in each geological landforms suitable for pepper growing was sorted out taluk wise.

a. Data integration: Data regarding the climate, soil characteristic and geographical characteristics were collected from the National Bureau of soil survey and land use planning. The attributes suitable for Black pepper cultivation was incorporated into
b. Crop suitability classification: The ideal crop conditions were worked out based on published data and was categorized as in Table 1, 2, 3 and 4.
c. Classification of geological landforms: To understand the soils in each region, classification of the geological landforms was done. The soil series belonging to each landform was analysed using GIS and later classified into i) Most suitable ii) Moderately suitable iii) Less suitable and iv) Unsuitable

Data analysis

The chemical and physical aspect were analysed using GIS and were plotted against the critical requirement of black pepper. The climatic requirement of Kerala was suitable and all the soils came within the suitability range. The Nutrient factors varied and the most essential nutrients were taken as the criteria for the selection of the land. The soil reaction factor that was depicted by pH and CEC was also taken into account and the analysis was carried out. The classification of suitability was done by taking into account the most variable biotic and abiotic parameters which were then quantified into various classes based on their recurrence in the suitability. Based on this method the parameters that matched the best for cultivation of black pepper were pooled into groups which were classified as a) Most Suitable b) Moderately Suitable c) Less suitable and d) Not suitable.

Table 1. Climatic classification for cultivating Black pepper

Climate	Most Suitable	Moderately Suitable	Not Suitable
Temperature (°C)	15-32	Upto 36	>40 & <12
Humidity (%)	75-90	60-75	<60
Rainfall (mm)	1100-2500	Upto 3500	<800

Table 2. Soil classification

Soil Characteristics	Most ideal	Tolerable limit	Unfavourable
Soil depth (depth of the	100	100-150	< 100 and
solum((cm)	40	40-60	> 150
A Horizon	80	80-100	< 40
B Horizon			< 80
C Horizon			
Soil texture	Sandy loam	Clayey loam	Sand and Clay
Soil temperature (°C)	25-28	28-30	>30
Electrical conductivity dS m^{-1}	0.1-0.3	1-2	>2
pH	5.5-6.5	7	>7 & < 40
Cation Exchange Capacity (C mol (P+)/Kg)	8.2-14.7	20	> 20

Table 3. Nutreint requirement

Soil Nutrients	Most Ideal	Tolerable limit	Unfavourable
Organic Carbon	2-3	5	<1
Phosphorous (ppm)	12-30	Upto 90	<5
Potassium (ppm)	90-180	280	<90
Magnesium (ppm)	40-100	190	<10
Manganese (ppm)	5-30	50	<55
Calcium (ppm)	60-750	1300	>2000
Iron (ppm)	12-65	90	>100
Zinc (ppm)	2-7	52	<0.5
Copper (ppm)	1-7	40	>100

Table 4. Geographical requirement

Geographical Characteristic	Most Ideal	Tolerable limit	Unfavourable
Latitude	20 ° North - 20° South	25 ° North - 25 ° South	Above 20° North and below 25° South
Altitude MSL	750-1000	1500	> 1500
Slope (%)	2-3	Upto 6	> 6

Data analysis

The chemical and physical aspect were analysed using GIS and were plotted against the critical requirement of black pepper. The climatic requirement of Kerala was suitable and all the soils came within the suitability range. The Nutrient factors varied and the most essential nutrients were taken as the criteria for the selection of the land. The soil reaction factor that was depicted by pH and CEC was also taken into account and the analysis was carried out. The classification of suitability was done by taking into account the most variable biotic and abiotic parameters which were then

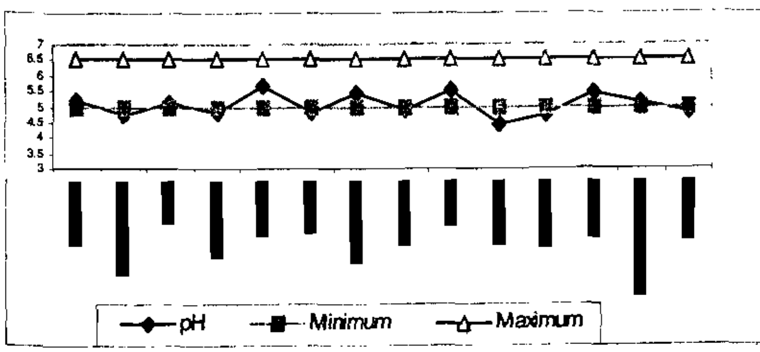


Fig. 1. pH of Khondalite landform

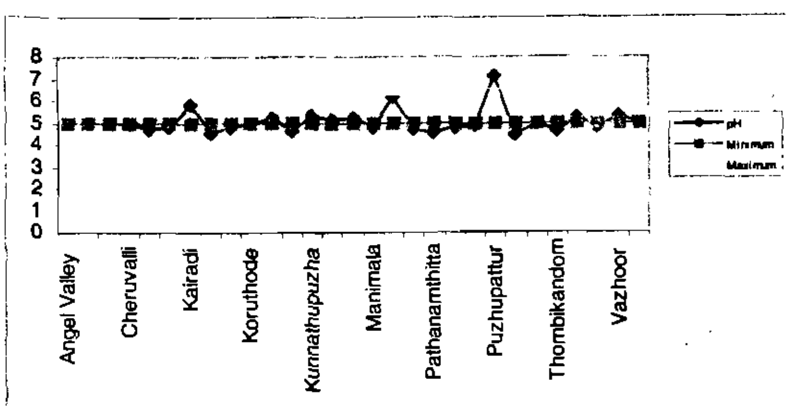


Fig. 2. pH of soils in the charnockite region

quantified into various classes based on their recurrence in the suitability. Based on this method the parameters that matched the best for cultivation of black pepper were pooled into groups which were classified as a) Most Suitable b) Moderately Suitable c) Less suitable and d) Not suitable

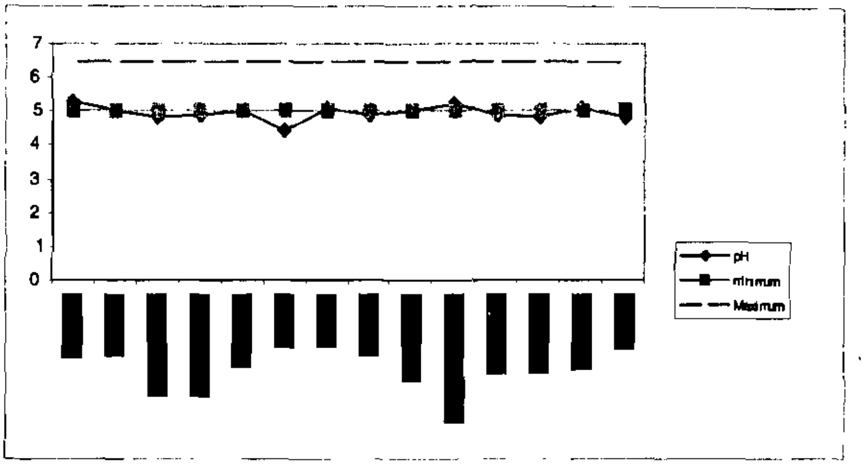


Fig. 3. pH of soils in the Granite – Gneiss Landform

Results and Discussions

Khondalite landform: There are around thirteen soils series identified in this region and five of them are in the most suitable range for cultivation of Black Pepper.

The pH of the Khondalite region (Fig. 1) varies from 4.1 to 5.1 and most of the soil series in this region has pH suitable for black pepper. Five of the soil series have a suitable Cation Exchange Capacity (Fig.5) and they have optimum organic carbon content (Fig. 9). The soil series, Thrikannamangal and Palkulam, which covers a large area in the Khondalite land form is the most suitable soil series for Black pepper.

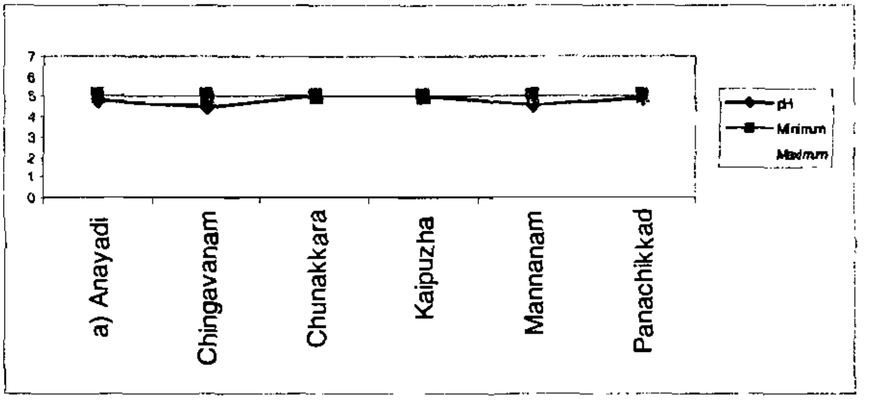


Fig 4. pH of Laterite landform

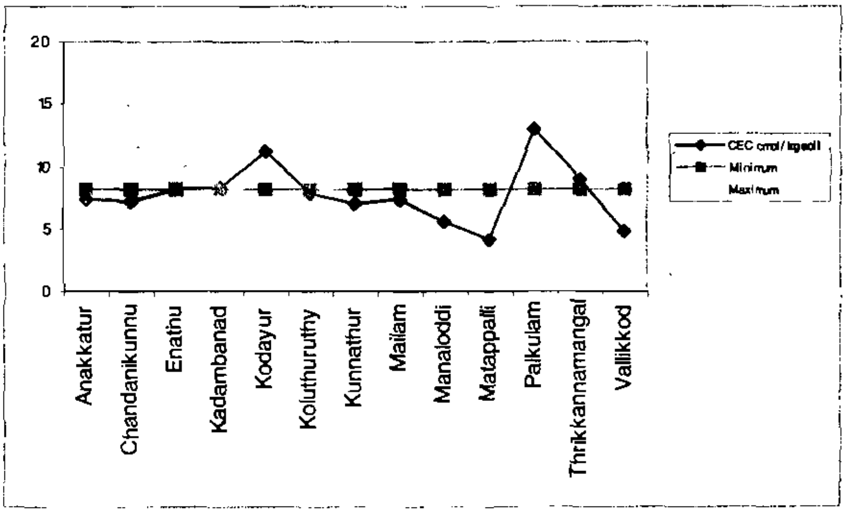


Fig. 5. Cation Exchange Capacity (CEC) of Khondalite landform

Charnockite landform: The Charnockite landform, which extends from Pathanamthitta to Kasargode, accommodates a large area of black pepper growing regions. The pH ranges from 4.3 to 6.2 (Fig.2) with a Cation Exchange Capacity between 5.5 to 20.3 (Fig 6). The organic carbon content is also high ranging from 1.9 to 3.6% (Fig 10). The most suitable soil series for growing black pepper are Puzhupattur, angel valley cheruvally and kottangal soil series.

Granite Gneiss landform: The granite –gneiss landform covers parts of Idikki, Ernakulam, Thrissur, Palakkad, Malapuram, Kozhikode, Waynad and Kannur Districts. pH of the soil ranges from 4.4 to 5.3 (Fig. 3), Cation Exchange Capacity ranges from 4 to 13.3 (Fig.8) Organic Carbon content ranges from 1 to 4.5 (Fig.11) . The most suitable soil series for cultivating black pepper are Ezhallur, Kallurkad and Paiyavoor.

Laterite Landform: Laterite land forms covers parts of Thiruvananthapuram, Kollam, Alapuzha, Kottayam, Ernakulam, Thrisuur, Malapuram, Kannur and Kasaragod. The pH of this land form ranges from 4.4 to 5(Fig. 4) and Cation Exchange Capacity ranging from 4.1 to 10 (Fig. 7). The organic Carbon content % ranges from 0.8 to 2.2 (Fig. 12). The most suitable soils for cultivating Black pepper are Mannanam and Panachikad.

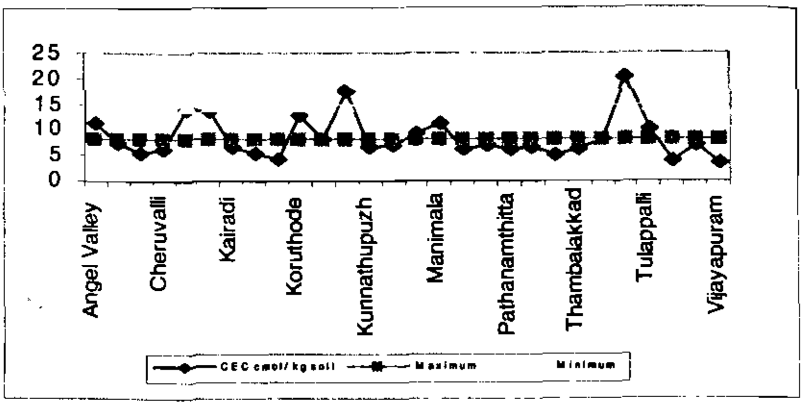


Fig. 6. Cation exchange Capacity of Charnockite land form

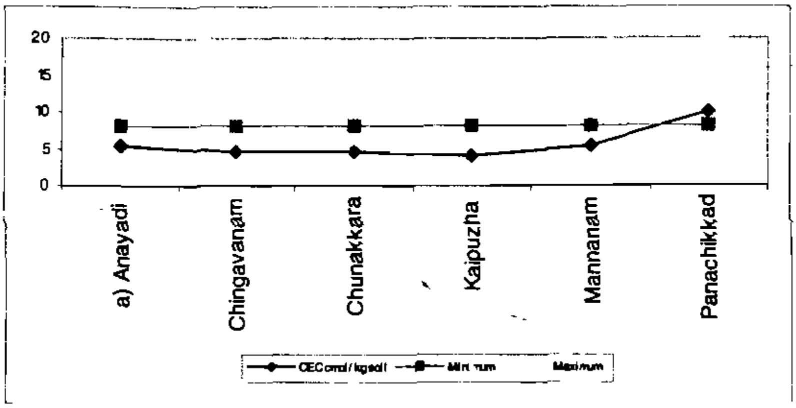


Fig. 7. Cation exchange Capacity of Laterite land form

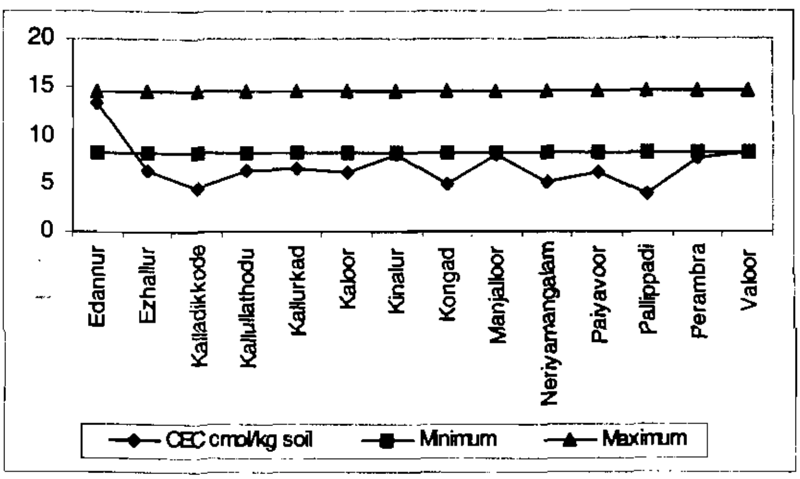


Fig. 8. Cation exchange capacity of Granite Gneiss Landform

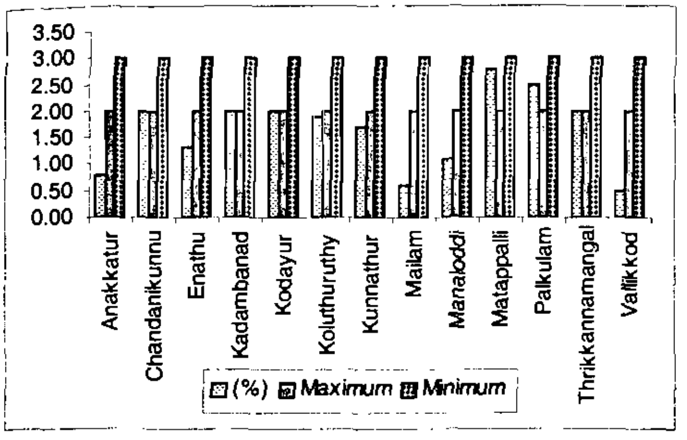


Fig. 9. Organic Carbon Content in Khondalite Landform

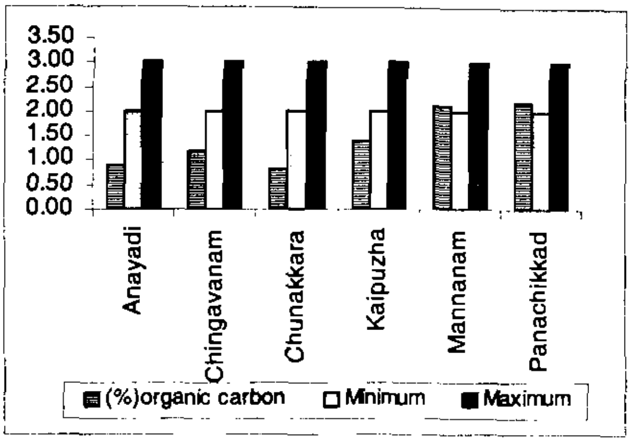


Fig 10. Organic Carbon of Charnockite Landform

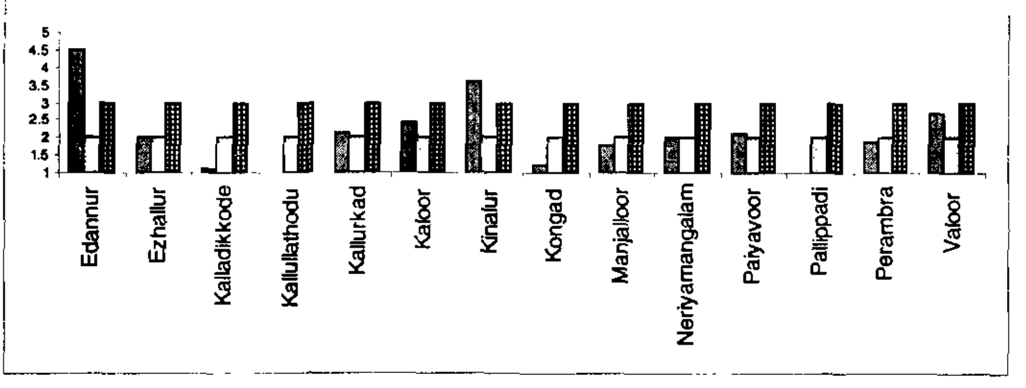


Fig 11. Organic Carbon in Granite Gneiss Landform

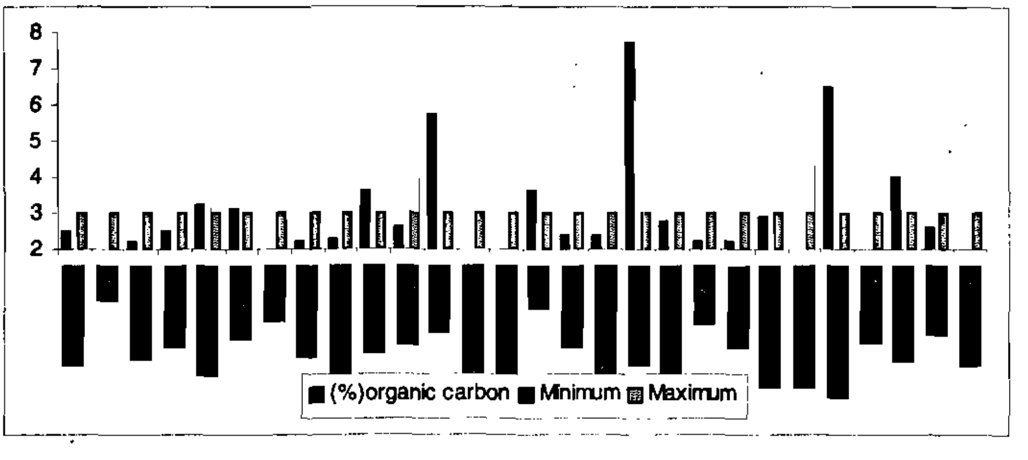


Fig. 12. Organic Carbon in Laterite Landform

state

Climatic Suitability for Black pepper (Distribution of optimum rainfall and ideal temperature)

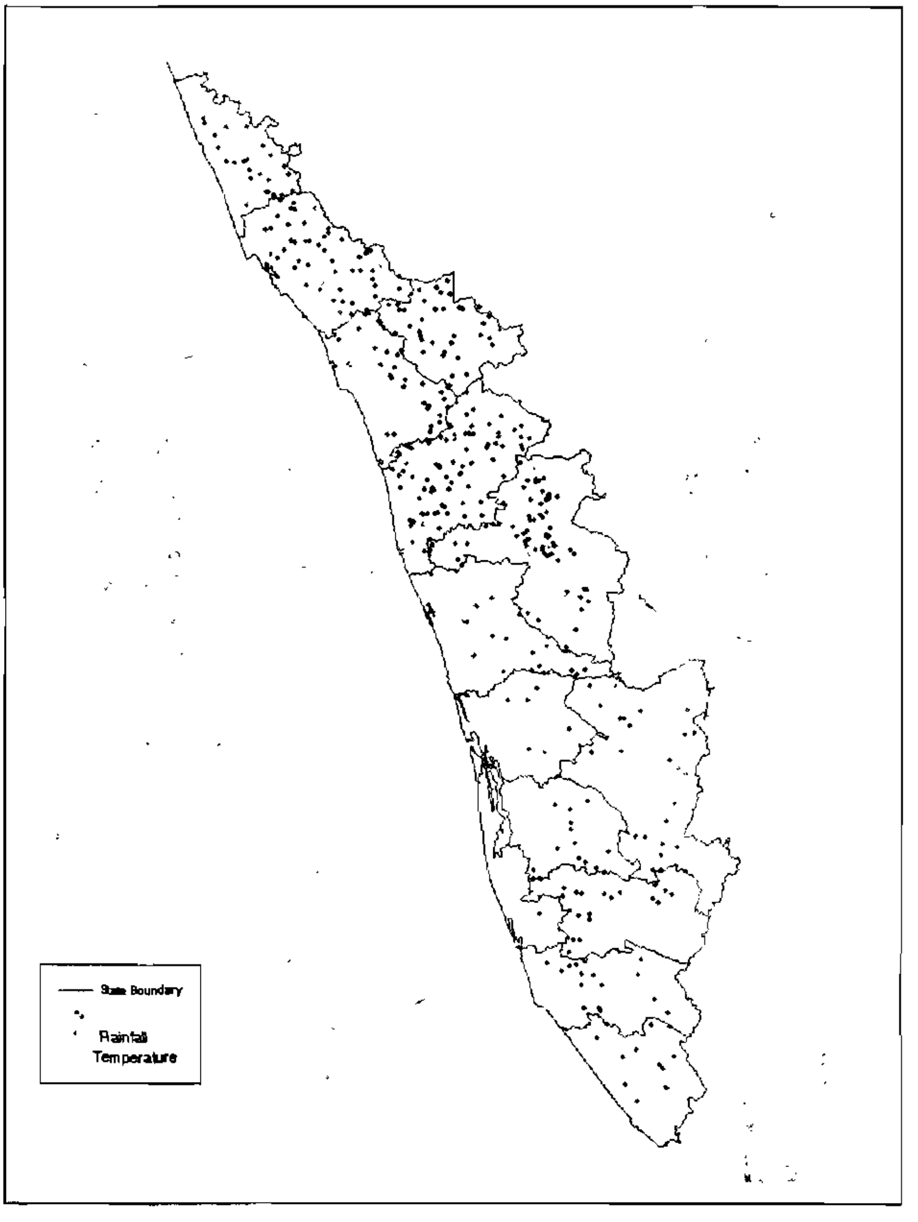
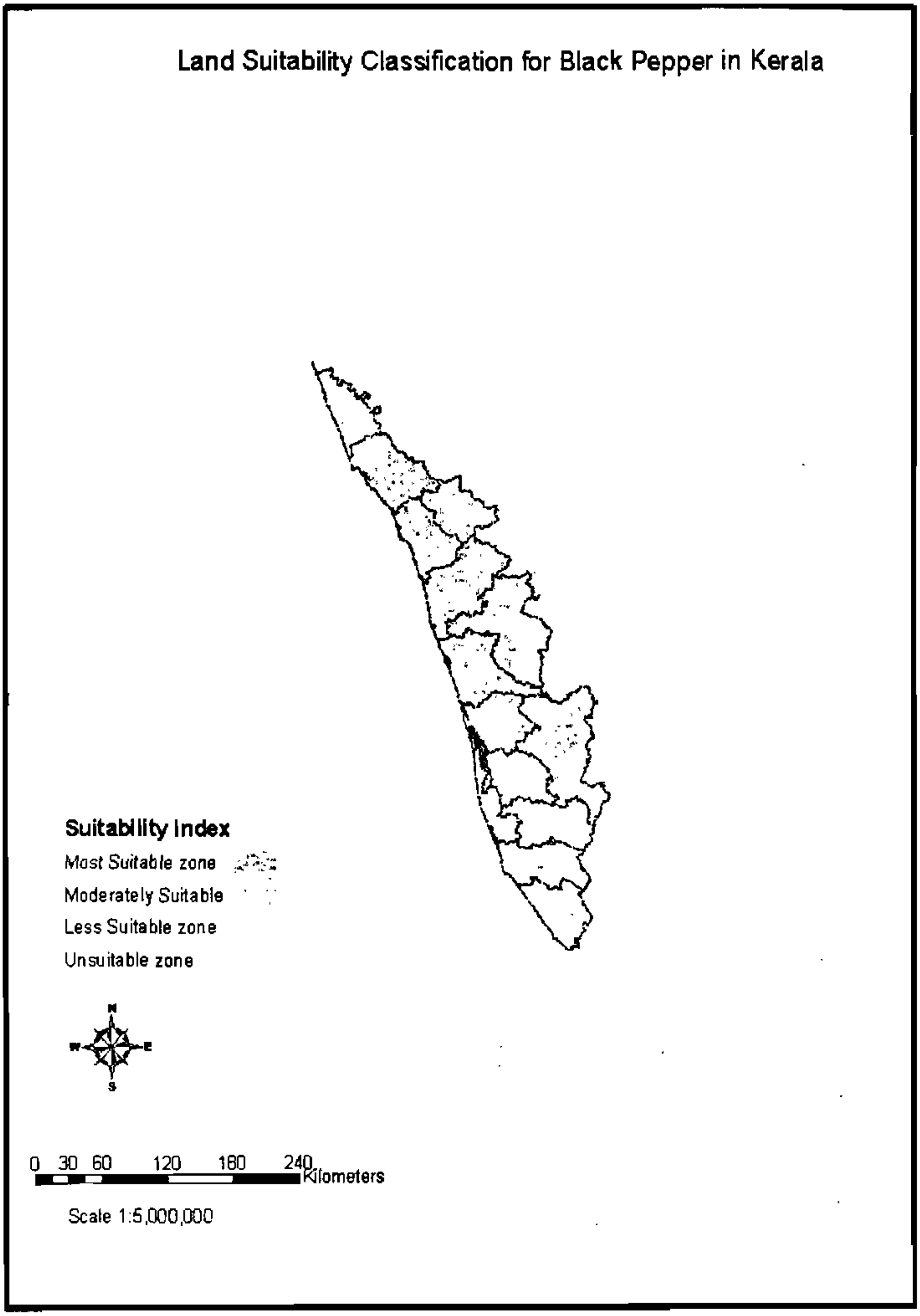


Table 5. Suitability regions in Kerala as per the soil series classification


Land Suitability Classification for Black Pepper in Kerala
Suitability Index
Most Suitable zone
Moderately Suitable
Less Suitable zone
Unsuitable zone
N
W
E
S
0 30 60 120 180 240
Kilometers
Scale 1:5,000,000

Conclusion

It is seen from the above analysis that, most of the regions in Kerala are in the suitable or moderately suitable range. The unsuitable regions are near the coastal belts of Alapuzha with saline sandy textured soils. The most suitable regions in Kerala are mainly in the Charnockite and Laterite genesis landforms for reasons of having optimal pH, good CEC and optimal organic carbon content. Based on this classification, the potential areas can be given more thrust for sustainable production of Black pepper. The above effort is a preliminary work in using geographic datasets to identify suitable pepper growing tracts and augment production through information aided on precision farming to boost pepper production in the country. Timely availability of Geo-referenced data and its use will help overcome the presently prevalent problem of land degradation and land-water scarcity.

References

Lekha V.S. Soil Suitability Evaluation for Black Pepper (Thesis)1997. Published by Dr. Panjabrao Deshmukh Phd MSc Krishi Vidyapeeth, Akola (M.S.)

Resource based Perspective plan 2020 AD. Published by Kerala State Land Use Board, Trivandrum.

Resource Soil Survey and Mapping of Rubber Growing Soils of Kerala and Tamilnadu. Consultancy Project for Rubber Research Institute of India. Published by National Bureau of Soil Survey and Land Use Planning.

4

Pollinator recruitment in relation to flower density in Small Cardamom (*Elettaria Cardamomum* Maton; Zyngiberaceae)

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Abstract

The small cardamom (*Elettaria cardamomum* Maton) is a cross pollinated crop that depends largely on honey bees for pollination. Two species of honey bees, *Apis cerana* and *A. dorsata* play effective roles as pollen vectors in this crop. In the present study we found that the activity of honey bees is zero or negligible when the flower density was less than 45 in a unit area of 13 m^2 comprising of nine adjacent clumps Since the flower density in cardamom is far below this threshold in the beginning of the season and in the end of the season, cardamom flowers are ignored by honey bees. Under such situations, solitary bees like *Amegilla* and *Pithetis* work as efficient pollinators of cardamom and hence, it is suggested that, the habitats of these pollinators need to be conserved for enhancing production in cardamom.

Cardamom (*Elettaria cardamomum* Maton) is a zingiberaceous crop native to the Western Ghats of India and is highly cross-pollinated. It is largely cultivated for its capsules that have a high spice value. Floral morphology, plant architecture and flowering phenology are closely related to foraging behaviour of pollinators. By foraging optimally on a given crop, a pollinator tends to maximise its benefits by gaining highest quantum of energy with least expenditure (MacArthur and Pianka, 1966; Emlen, 1966; Pyke, 1979; 1981; Waddington, 1983). Thus, a patch that has low number of flowers is least attractive to pollinators compared to a rich patch of flowers. In a crop like small cardamom, in which flowering commences somewhere in the middle of May and extends up to the end of September, the number of flowers available per unit area varies considerably with time. Though several earlier studies have shown that honey bees are excellent pollinators of cardamom (Belavadi *et al* 1993;1997;1998; Belavadi and Parvathi 1993; 2001 Parvathi *et al*, 1993), the question of when exactly honey bees get recruited for pollination on cardamom has not been addressed. In this paper, we present data show the relation between pollinator recruitment and flower density and also make attempts to throw light on the possible of role of bees other than *Apis* spp., in the pollination of cardamom.

Material and Methods

The study was conducted at the Regional Research Station, Mudigere, of the University of Agricultural Sciences, Bangalore. The site lies in the Hill Zone of Karnataka (13° 7' N & 75° 37'E) in the heart of the Western Ghats of India. Here, cardamom is grown as a pure crop under the shade of assorted forest trees.

The system that we examined comprised of small cardamom and its pollinators. All our studies were carried out on an improved variety of Malabar type of cardamom called Mudigere-1.

The plant: Cardamom plant grows in clumps of 20 to 25 pseudostems and its flowers are borne on panicles that arise from the base of these pseudostems. In the malabar type, the panicles lie prostrate on the ground. Panicle production commences in December - January. Though panicle growth is linear and is extended over a period of about seven months, maximum growth is in April - May. Flowering in cardamom is between May and October. Peak flowering is in July - August. Each panicle may bear 1 to 5 flowers and during peak flowering about 25 to 30 flowers are seen radially arranged around each clump.

The pollinator: Cardamom flowers were frequented by two species of honeybees, *Apis cerana,* the Indian bee and *Apis dorsata,* the rock bee. Preliminary studies had shown that these two species of bees are the major pollinators of cardamom.

Flowering Phenology of cardamom: Number of flowers produced by individual plants were recorded daily through out the flowering duration commencing in the second week of May till first week of October. The total flowers produced per clump and total number of fruits set were recorded individually for 10 clumps.

Flower Density: Since the density of flowers per clump varied greatly over time, the number of flowers in a unit area of about 16 m^2, comprising of nine clumps were recorded in different weeks commencing from the II week of May till II week of October.

Pollinator recruitment: The number of honey bees actively visiting cardamom flowers in different flower densities was recorded for drawing inference on the recruitment pattern of pollinators. Ad-libitum sampling was done for the number of flowers and numbers of active pollinators on a cluster of nine clumps. This data was used to correlate the number of foraging bees with the flower density.

Role of non Apis *bees in cardamom pollination:* Observations were recorded on the possible role non *Apis* bees play in the pollination of cardamom. Flower visiting behaviour of these bees and the fruit set success were recorded for these species.

Results and Discussion

Per cent fruit set in cardamom: The number of flowers produced per clump varied from 636 to 1654 ($\bar{x}$ = 1156) and the number of fruits set per clump ranged from 208 to 584 ($\bar{x}$ = 331). The per cent fruit set was about 31 (Fig 1). One of the reasons for low fruit set could be inadequate pollination. Inadequate pollination might be due to low populations of honey bees, and hence warrants introduction of bee colonies to cardamom gardens.

Pollinator Recruitment: Once a flower patch is identified by a scout or a group of scouts, it will be communicated to the fellow foragers in the colony through a set of dances. This process will occur only when the flower patch is rich enough, to provide nectar and pollen profitably when compared to the energy that the foragers will have to spend. Hence, when the flower numbers in a unit area is lesser than a threshold limit, it is uneconomical for the bees to forage. Because, they have to spend more time and energy in searching for flowers in order to visit a given number of flowers to fill their crop (honey stomach). Keeping this point in view observations were recorded to find out the relation between the flower densities in cardamom plantations and the number of foraging bee. We found a significant positive correlation between the flower density and forager numbers (r = 0.8885; p = 0.05%; Fig 2).

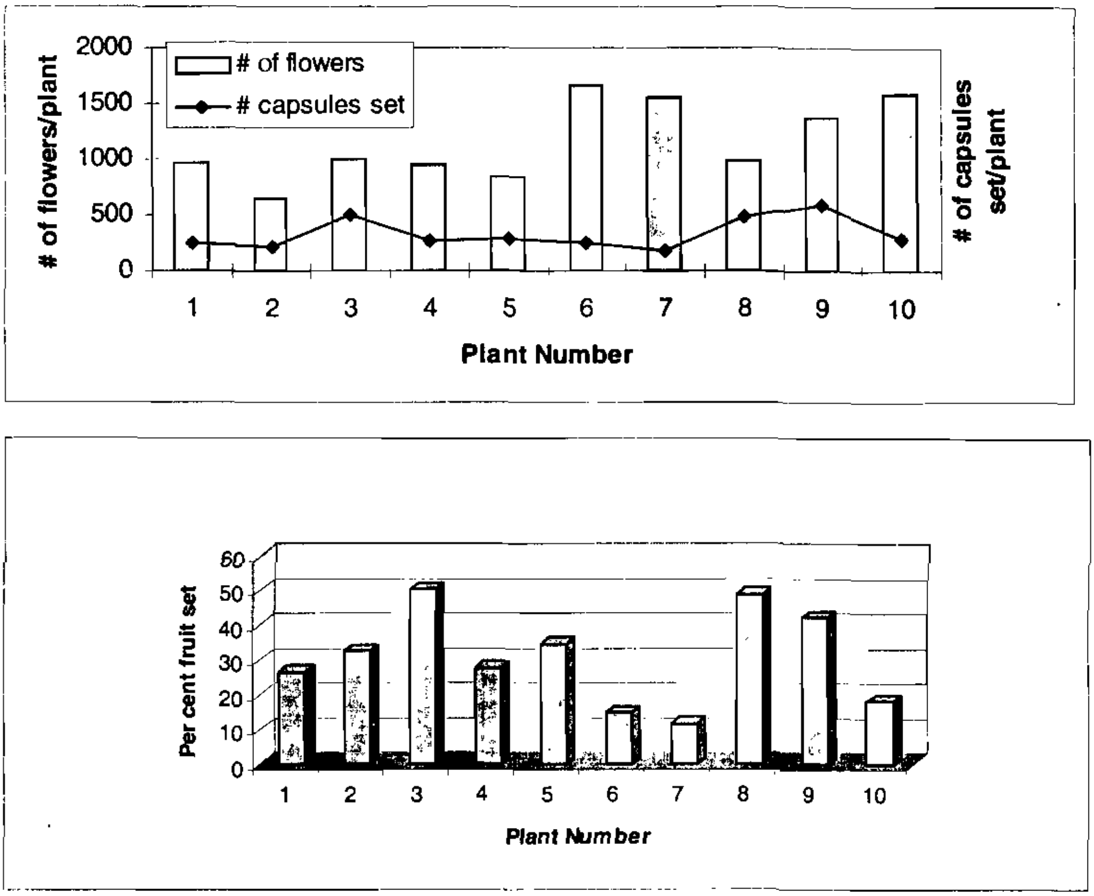

Fig. 1 Per cent fruit set in cardamom

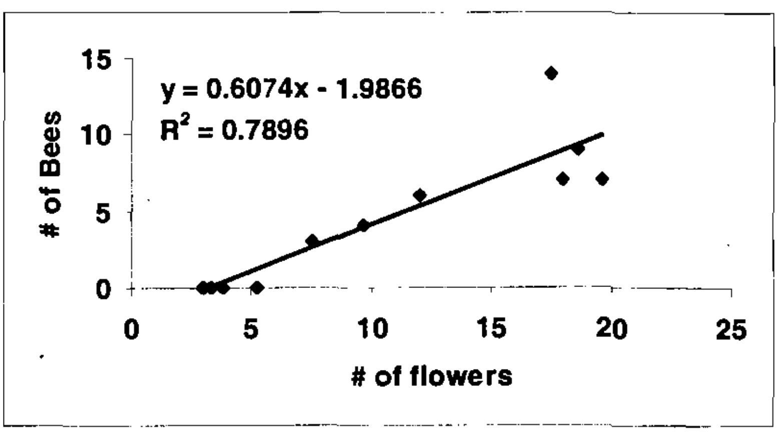

Fig. 2. Relation between Flower density and Number of bees foraging

These studies also indicated that recruitment to cardamom plots will occur only when the flower density is more than 45 flowers/13 m^2, and at lower densities, the flowers may not be visited by honey bees at all. Such a situation exists during the beginning and the end of the flowering season in cardamom (Fig. 3).

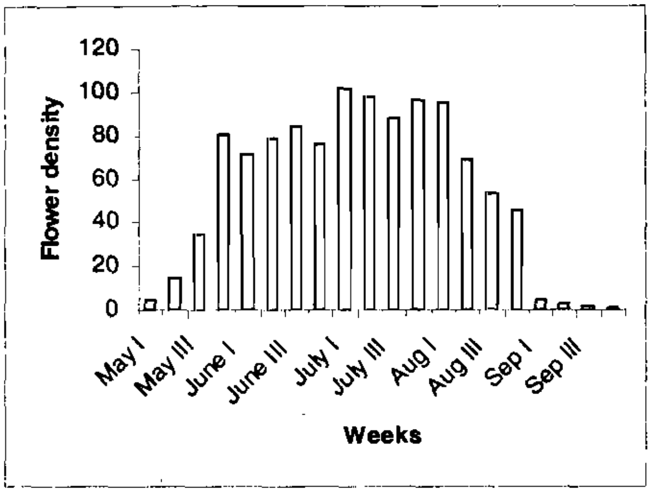

Fig. 3. Flower density across the flowering season in cardamom (expressed as number of flowers/9m^2)

The flower density in the month of May, and during the last week of August and the whole of September will be far below this threshold. In fact, in an earlier study, Belavadi *et al.* (1998) have shown that, bees optimise their energy expenditure while foraging on cardamom by visiting nearest neighbouring flowers and visiting maximum number of flowers by covering a short distance. Hence, when the flower density is sparse, it will be uneconomical for the honeybees to forage on cardamom.

Pollination of cardamom flowers at low densities: Under densities lower than five flowers per clump, cardamom flowers are often visited by a few species of solitary bees. At least two species of *Amegilla* and one species of *Pithetis* (*P. smaragdula*) visit flowers and successfully transfer pollen. In fact, it has been suggested earlier that, honeybees may not be the original pollinators of cardamom and that cardamom might have originally evolved with a different pollinator like *Amegilla* spp. (Belavadi and Parvathi, 2000). *Amegilla* has been shown as an efficient pollinator of cardamom even in Papua New Ginea (Stone and Wilmer, 1989). *Amegilla* and *Pithetis* being solitary bees, can work efficiently at low flower densities and hence, it would be beneficial to study the nesting habits of these bees and conserve their populations, in addition to the populations of honeybees, to enhance production of cardamom.

Acknowledgement

We thank the Director of Research, University of Agricultural Sciences, Bangalore and the Associate Director of Research, Regional Research Station, Mudigere, for encouragement and facilities. The first author thanks the Indian Council of Agricultural Research, for financial assistance.

Reference

Belavadi, V.V. and Parvathi, C., 1993. Landing and departure decisions used by honeybees on cardamom (*Elettaria cardamomum* Maton). In Pollination in Tropics (Eds. G.K. Veeresh, R. Umashaanker and K.N. Ganeshaiah), IUSSI Indian chapter, Bangalore, pp 73-76.

Belavadi, V.V., Chandrappa, H.M., Shadakshari, Y.G. and Parvathi, C., 1993. Isolation distance for seed gardens of cardamom (*Elettaria cardamomum* Maton). In Pollination in Tropics (Eds.

G.K. Veeresh, R. Umashaanker and K.N. Ganeshaiah), IUSSI Indian chapter, Bangalore, pp 241-243.

Belavadi, V.V., Venkateshalu and Vivek, H.R., 1997. Significance of style in cardamom corolla tubes for honey bee pollinators. *Current Science*, 73: 287-290.

Belavadi, V.V., Parvathi, C. and Raju, B., 1998. Optimum foraging by honey bees on cardamom. Paper presented at the XIII Plantation Crops Symposium, PLACROSYM XIII, Coimbatore, 16-18 December, 1998.

Belavadi, V.V. and Parvathi, C., 2000. Pollination in cardamom – Nature's art. Plenary talk delivered at the Centennial Conference on Spices and Aromatic crops, Calicut. 20-22 November, 2000.

Belavadi, V.V. and Parvathi, C., 2001. Pollination in small cardamom (*Elettaria cardamomum* Maton). *J. Palynology*, (Submitted)

Emlen, H.M., 1966. The role of time and energy in food preference. *Am.Nat.*, 611-617.

MacArthur, R.H. and Pianka, E.R., 1966. On optimal use of a patchy environment. *Am. Nat.*, 100: 603-609.

Parvathi, C., Shadakshari, Y.G., Belavadi, V.V. and Chandrappa, H.M., 1993. Foraging behaviour of honeybees on cardamom (*Elettaria cardamomum* Maton). In Pollination in Tropics (Eds. G.K. Veeresh, R. Umashaanker and K.N. Ganeshaiah), IUSSI Indian chapter, Bangalore, pp 99-103.

Pyke, G.H., 1979. Optimal foraging in bumblebees: rule of movement between flowers within inflorescences. *Anim. Behav.*, 27: 1167-1181.

Pyke, G.H., 1981. Optimal foraging in humming birds: Rules of movement between inflorescences. *Anim. Behav.*, 29: 889-896.

Stone, G.M. and Wilmer, P.G., 1989. Pollination of cardamom in Papua New Guinea. J. Apic. Res., 28: 228-237.

Waddington, K.D., 1983. Foraging behaviour of pollinators. In, *Pollination biology* (ed., Leslie Real). Academic Press, New York, pp 213-241.

5

Influence of foliar organic nutrients on growth and yield performance of chilli

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Abstract

Under present circumstances of creative awareness on organic farming, this study brings to light the effective utilization of some organic nutrients viz., amino acid, humic acid and vermi wash to maximize the crop yield in chilli. The experiment was laid out in a two factorial randomised block design. The first factor is the use of organic nutrients viz., amino acid at 0.5 and 0.75 per cent, humic acid at 0.1 and 0.2 per cent and vermi wash at 1:3 and 1:5 dilution and water spray as control. The second factor is the incorporation of recommended dose of fertilizer viz., basal + top dressing and basal alone. Foliar supplementation of organic nutrients significantly improved the yield along with the basal incorporation of chemical fertilizers alone after omission of subsequent incorporation of urea as top-dressing fertilizer. Among the organic supplements, amino acid at 0.75 per cent concentration recorded satisfactorily higher yield than that obtained under normal practice. Hence, it could be concluded that there lays enormous scope to harvest wholesome produce of this valuable spicy vegetable with the application of organic nutrients through foliar means.

Key words: *Capsicum annum*, chilli, organic nutrients.

Introduction

Hot pepper or chilli (*Capsicum annuum* L.) is an important spicy vegetable, which is grown in all states of India covering an area of 888.20 thousand hectares with the production of 921.30 thousand metric tonnes annually with an average productivity of 1.0 metric tonnes per hectare. This crop is chiefly exported to Middle East countries like Iran, Iraq, Saudi Arabia, Oman and Yemen. The recent data from All India Spice Exporters Forum highlights the export of chillies, which earned a foreign exchange of 18,600 lakh rupees during 2000-2001. Among the various technologies to boost the productivity, nutrient management assumes greater significance in maximising the yield of the crop. Balanced use of chemical fertilizers that supplies major nutrients alone will not be able to sustain high productivity due to the emergence of multi nutritional deficiencies. Here comes the use of organic source as foliar supplements that are technically sound, economically attractive, practically feasible and environmentally safe.

Moreover, application of nutrients through foliar sprays demands less quantity of nutrients, with rapid and efficient absorption. Under present circumstances of creative awareness on organic farming, this study brings to light the effective utilization of some organic nutrients viz., amino acid, humic acid and vermi wash to maximize the crop yield in chilli.

Materials and methods

A field experiment was conducted in a sandy loam soil at Sivapuri village located 5 km away from Annamalai University with pH 6.6, EC 0.4 dSm^{-1}, organic carbon 0.42%, available N, P_2O_5 and K_2O; 175.0, 17.0 and 130.0 kg ha^{-1}, respectively and Fe, Mn, Zn and Cu; 3.84, 12.76, 0.85 and 3.53 kg ha^{-1} respectively. The experiment was laid out in a two factorial randomised block design with fourteen treatment combinations. The investigation was carried out in the variety, k2 a popular genotype of the tract. One factor is the use of organic nutrients viz., amino acid at 0.5 (A_1) and 0.75 (A_2) per cent; humic acid at 0.1 (H_1) and 0.2 (H_2) per cent and vermi wash at 1:3 (V_1) and 1:5 (V_2) dilution and water spray as control (WS). The second factor is the use of recommended dose of fertilizer *viz.*, basal and top dressing *(160: 60: 30 kg NPK ha^{-1})* (F_2) and basal dose alone *(80: 60: 30 kg NPK ha^{-1})* (F_1). Six sprays of the foliar nutrients were given at 20 days interval commencing from 30th day after transplanting.

The observations were taken on plant height at flowering and at harvest, number of branches, days taken for fifty per cent flowering, number of fruits per plant, number of seeds per fruit, per cent pericarp, yield per hectare and ascorbic acid content.

Per cent pericarp was calculated by using the formula,

$$\text{Pericarp (\%)} = \frac{\text{Pericarp weight of 5 dried fruits}}{\text{Fruit weight of 5 fruits}} \times 100$$

The ascorbic acid content was calculated as per the procedure of A.O.A.C (1975).

Results and discussion

In the present study, foliar organic nutrients showed better performance in improving the growth attributes under varying degree. Among the various treatment combinations, significant influence on plant height at both the stages (54.70, 96.20 cm respectively) and number of branches (18.22) was observed under foliar application of amino acid at 0.75 per cent with complete RDF. The reason might be due to efficient absorption of amino acid in time and the immediate action of chemical fertilizers. Further, amino acids are the crucial ingredients in the process of protein synthesis which enhances cell multiplication and elongation leading to the increase in plant height and number of branches. This is in concordance with the reports of Auxcilia (1998) in papaya. Moreover, it is evident from earlier reports that nitrogen is an important element in improving the plant height (Nazeer Ahmad and Tanki, 1991) and number of branches (Ramachandran and Subbaiah, 1980) (Table 1).

Regarding the earliness in flowering (Table 1), foliar spray of vermi wash at the dilution ratio of 1:5 took 77.82 days to produce fifty per cent flowering. It was followed by 1:3 dilution of vermi wash. Among the different nutrients, phosphorus plays a major role in inducing earliness in flowering. The desirable result of present study might be due to the favourable effect of organic phosphorus supplied by the vermi wash at an optimum concentration in the plants. Thus it is clearly evident that vermi wash is a source of phosphorus in limited quantity. This corroborates the findings of Ismail (1997). Dilution of the vermi wash by adding higher quantity of water was more effective than the

Table 1. Effect of organic nutrients and inorganic fertilizers on plant height at flowering and at harvest, number of branches and days taken for fifty per cent flowering of chilli.

Fertilizers (F) / Organic nutrients (O)	Plant height at flowering stage (cm)			Plant height at harvest stage (cm)			Number of branches			Days taken for fifty per cent flowering		
	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean
WS	30.00	32.80	31.40	55.83	60.90	58.36	9.67	10.78	10.22	111.51	106.31	108.91
H_1	33.00	42.70	37.85	60.80	71.80	69.30	10.87	14.19	12.53	93.21	93.99	93.60
H_2	43.50	46.80	45.15	80.80	85.70	83.25	14.36	15.47	14.91	92.21	87.01	89.61
A_1	47.20	50.10	48.65	86.00	90.90	88.45	15.63	16.82	16.12	104.77	104.77	104.77
A_2	51.30	54.70	53.00	91.50	96.20	93.85	17.10	18.22	17.66	104.42	99.21	101.81
V_1	33.20	36.50	34.85	62.30	65.80	64.05	10.93	11.97	11.45	86.43	80.89	83.66
V_2	37.00	39.90	38.45	66.00	70.90	68.45	12.13	13.22	12.67	80.42	75.22	77.82
Mean	39.31	43.36		71.89	78.31		12.95	14.38		96.25	92.48	
	S.Ed.	CD (p=0.05)		S.Ed.	CD (p=0.05)		S.Ed.	CD (p=0.05)		S.Ed.	CD (p=0.05)	
O	0.66	1.33		1.45	2.92		0.35	0.70		1.48	2.99	
F	0.35	0.71		0.77	1.56		0.18	0.37		0.79	1.59	
O x F	0.93	2.02		2.06	4.14		0.49	0.99		NS	NS	

concentrated preparation. This shows improved absorption efficiency of the leaves or reducing the concentration of the compounds. This is in agreement with the findings of Karuna *et al.* (1999).

Regarding the yield attributes (Table 2), number of fruits (103.23), number of seeds (90.00) and per cent pericarp (65.27) were comparatively higher in the treatment combination of 0.75 per cent amino acid plus complete application of RDF. This was followed by 0.75 per cent amino acid with basal application of RDF which was on par with 0.5 per cent amino acid along with complete application of RDF.

Table 2. Effect of organic and inorganic fertilizers on number of fruits per plant, number of seeds per fruit and per cent pericarp of chilli.

Fertilizes (F) / Organic nutrients (O)	Number of fruits per plant			Number of seeds per fruit			Per cent pericarp		
	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean
WS	62.83	68.72	65.77	54.47	59.42	56.94	38.25	41.69	40.02
H_1	67.99	85.22	76.60	59.07	73.50	66.28	41.65	52.18	46.91
H_2	86.06	91.99	89.02	74.12	78.72	76.42	53.48	56.82	55.15
A_1	92.61	97.77	95.19	79.90	84.50	82.20	57.02	60.22	58.62
A_2	98.07	103.23	100.65	85.40	90.00	87.70	61.97	65.27	63.62
V_1	68.74	73.90	72.32	59.52	64.12	61.82	41.69	44.99	43.34
V_2	74.90	80.06	77.48	64.30	68.90	66.60	45.55	48.88	47.21
Mean	78.74	85.84		68.11	74.16		48.53	52.86	
	S.Ed.	CD (p=0.05)		S.Ed.	CD (p=0.05)		S.Ed.	CD (p=0.05)	
O	1.36	2.75		1.17	2.35		0.76	1.52	
F	0.73	1.47		0.62	1.25		0.40	0.81	
O x F	1.93	3.89		1.65	3.33		1.07	2.16	

Table 3. Effect of organic nutrients and inorganic fertilizers on fruit yield and ascorbic acid content of hot pepper

Fertilizers (F)/ Organic nutrients (O)	Fruit yield (kg ha^{-1})			Ascorbic acid content (mg 100 g^{-1})		
	F_1	F_2	Mean	F_1	F_2	Mean
WS	1232.83	1335.42	1284.12	106.74	112.58	109.66
H_1	1325.56	1667.83	1496.69	136.73	147.49	142.11
H_2	1692.83	1795.33	1744.08	145.23	155.99	150.61
A_1	1820.25	1923.83	1872.04	113.23	116.67	114.95
A_2	1947.86	2050.32	1999.09	125.17	128.23	126.70
V_1	1335.33	1437.83	1386.83	157.23	165.73	161.48
V_2	1463.06	1565.33	1514.19	166.73	175.23	170.98
Mean	1545.38	1682.27		135.86	143.13	
	S.Ed.	CD (p=0.05)		S.Ed.	CD (p=0.05)	
O	28.76	57.81		1.01	2.04	
F	15.37	30.90		0.54	1.09	
O x F	40.68	81.76		1.57	3.13	

It is evident that amino acid might have influenced directly the plant growth due to the growth promoting action contributing to increase in higher yield and yield attributing characters. Moreover, along with efficient absorption of amino acid, inorganic phosphorus in RDF also might have improved the yield and yield attributing characters (Subhani *et al.*, 1990). Similar trend was observed for highest yield (2050.32) under the above said treatment combination (Table 3).

Among the factorial combinations, the highest ascorbic acid content was recorded in the treatment combination of 1:5 dilution of vermi wash with complete dose of fertilizer (175.23). This was followed by 1:5 dilution with basal dose of fertilizers. It is evident that, phosphorus plays an important role in improving the ascorbic acid content of fruits (Niranjana and Devi, 1990). The reason might be due to the supplementation of organic phosphorus by the vermi wash at an optimum concentration.

Reference

A.O.A.C. 1975. Official methods of analysis. 12th Ed. Association of official agriculture chemists, Washington, D.C., U.S.A.

Auxcilia, J. 1998. Effect of paclobutrazol (PP_{333}) and amino acids at different levels of nitrogen on growth, yield and quality of papaya (*Carica papaya* L.) var. CO.2. Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore.

Ismail, S.A. 1997. The biology of earthworms. Vermicology, Orient London, India. p. 92.

Karuna, K., C.R. Patil, P. Narayanaswamy and Radha, D. Kale. 1999. Stimulatory effect of earthworms body fluid (vermi wash) on crinckle red variety of *Anthurium andreanum* Lind. Crop Res., 17(2):253-257.

Nazeer Ahmed and M.I. Tanki. 1991. Response of chilli (*Capsicum annuum* L.) to nitrogen and phosphorus. Haryana J. Hort. Sci., 20(1-2):114-118.

Niranjana, K.V. and L.S. Devi. 1990. Influence of P and S on yield and quality of chillies. Curr. Res. Univ. Agrl. Sci., 19(6):93-94.

Ramachandran, S. and K.K. Subbaiah. 1980. Studies on the effect of plant density and graded levels of nitrogen on yield components of chillies (*Capsicum annuum* L.). South Indian Hort., 28:178-181.

Subhani, P.M., C. Ravisankar and N. Narayana. 1990. Effect of graded levels and time of application of N and K on flowering, fruiting and yield of irrigated chilli. Cocoa, Arecanut and Spices J., 14(2):70-73.

6

Effect of sowing seasons, varying levels of nitrogen, phosphorus and potassium on growth and seed yield of coriander (*Coriandrum sativum* L.) Cv. Co. 3

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Abstract

A two-year experiment was conducted at Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore to find out the effect of different sowing seasons and varying levels of nitrogen, phosphorus and potassium on growth and seed yield of Co.3 Coriander (*Coriandrum sativum* .L). The crop planted during *rabi* season produced taller plants with more number of branches, umbels, umbellets per plant, seeds per umbel and seed yield in $N_3P_2K_3$ than that planted during *kharif* season. The *rabi* crop has recorded 27% increase in yield over *kharif* crop in the treatment $N_3P_2K_3$. The crop sown during *rabi*, showed an increase in net profit of Rs.6250/= over the *kharif* sown crop.

Key Words: *Coriandrum sativum*, nutrition, season, seed yield.

Introduction

Coriander (*Coriandrum sativum* .L) is a herbaceous plant grown for its fruit and green leaves as a commercial spice crop. The fruits find its use as a carminative, diuretic and aphrodisiac. The leaves are used in ailments like dyspepsia, flatulence and piles. The coriander seed oil is used for flavoring agent for liquors like gin and variety of food stuff. Generally, Coriander is raised as a rainfed crop on marginal and sub marginal lands, where input use depends on the resource and management capacity of the farmers on field scale. Since meager information is available on input use of coriander at Tamil Nadu, a field experiment was conducted to study the influence of seasons of sowing and levels of N, P and K on growth and seed yield of coriander cv.Co.3

Materials and methods

The field experiment was carried out during *kharif* and *rabi* seasons at Department of Spices and Plantation Crops, Horticultural College and Research Institute, TamilNadu Agricultural University, Coimbatore. The soil was clay loam with the available N (88 & 89.5 kg/ha) P (23.0 & 24.3 kg/ha), K (420 & 424.2 kg/ha) status, pH (7.4 & 7.4), EC (0.9 & 0.9 dSm^{-1}) , CEC (20.2 & 20.4 me/100g of soil) for both *kharif* and *rabi* seasons, respectively.

The treatments comprised of 3 levels of nitrogen *viz*., 10, 20 and 30 kg ha^{-1}, 3 levels of phosphorous *viz*., 20, 40 and 60 kg ha^{-1} and three levels of potassium 6, 10 and 20 kg ha^{-1}. The experiment was carried out both in *kharif* and *rabi* seasons. The experiment was laid out in a Factorial Randomized Block Design with 27 treatments and 3 replications. To stabilize fertility level of the experimental field, fodder maize was raised before each experiment. The maize crop was harvested at 45th day before initiation of flowering. Nitrogen was applied in two equal splits, one at the time of sowing and the second on 30 days after sowing. Total quantity of FYM, P_2O_5 and K_2O were given before sowing as per the treatment schedule.

Results and discussion

Between the two seasons of sowing *viz.*, the *kharif* and *rabi*, the mean plant height was taller in $N_3P_3K_3$ (120.63 cm) in *rabi* than *kharif* (125.31 cm) (Table1). The increase in plant height during *rabi* season is due to increased availability of soil moisture around the root zone in clay loam soil that resulted in the increased absorption of nutrients required for cell division and cell elongation. Similarly the mean number of branches both primary and secondary branches were the highest in $N_3P_3K_3$ (29.24 and 45.39 respectively) in *rabi* compared to *kharif* season which had 26.12 and 40.78 respectively (Table.1) in the same treatment. This is due to favourable day temperature that existed during *rabi* season and also due to enhanced nutrient availability around the absorbing root zone (Singh *et al.* (1979).

Rabi season crop recorded high mean number of umbels and umbellets per umbel and the crop the highest number of umbels per plant (91.96) as well as the umbellets per umbel (10.70) in the treatment $N_3P_3K_3$ (Table.1). The crop in *kharif* season had only (77.34) number of umbels per plant and (8.67) umbellets per umbel (Table.1) in the same treatment. This may be due to the fact that the plants would have received an optimum dose of N, P and K, which results in increased number of umbels pe- plant as well as umbellets per umbel (Bhat and Sulikeri, (1992).

Likewise the mean seeds per umbel were the highest in *rabi* with 45.91seeds in $N_3P_3K_3$ whereas *kharif* crop had only 34.47 seeds in the same treatment (Table.1). This is chiefly attributed because of the increased allocation of photosynthates towards the economic part. This could be the possible reason for increase in seeds/umbel. Besides that the quantum of sunshine hours was uniform throughout the day during *rabi* season (Snellgrove *et al.* (1986).

Seed yield was also influenced by the season of sowing and varying levels of fertilizers. The seed yield was the highest 999 kg ha^{-1} in *rabi* in $N_3P_2K_3$ and the lowest in *kharif* 1994 with 746 kg ha^{-1} in the same treatment (Table.2). The increased seed yield may be due to the increased accumulation of nutrients in the plants (Sushama, 1979), production of more photosynthates and translocation, which might have effectively utilized grain development.

The net profit realized was highest (Rs.6,250/=) in $N_3P_3K_3$ in *rabi* season and was comparatively lower as Rs.4,940/= in the same treatment during *kharif* season.

From the present study it can be concluded that both *rabi* and *kharif* seasons the application of nitrogen, phosphorus and potassium at the rate of 20:40:60 kg/ha was found to be best in terms of growth and yield.

Table 1. Effect of season of sowing and varying level of NPK on growth parameters of Co.3 coriander.

Treat ment	Plant height (cm)	No. of primary branches		No. of secondary branches		No. of umbels per plant		No. of umbellets per umbel		No. of seeds per umbel		
	kharif	*rabi*	*kharif*	*rabi*	*kharif*	*rabi*	*kharif*	*rabi*	*kharif*	*rabi*	*kharif*	*rabi*
$N_1P_1K_1$	96.90	97.53	11.15	12.50	25.12	27.15	41.50	43.75	5.25	5.75	20.15	26.15
$N_1P_1K_2$	98.90	99.32	11.75	12.65	26.75	27.13	42.35	45.15	5.75	6.25	21.50	27.15
$N_1P_1K_3$	99.75	98.51	10.92	11.35	25.15	28.13	43.50	45.75	5.92	6.75	22.50	23.50
$N_1P_2K_1$	100.50	101.52	11.23	12.32	26.15	27.15	41.75	43.15	5.75	6.25	21.75	23.50
$N_1P_2K_2$	98.50	99.52	10.95	10.97	27.30	29.50	42.90	43.90	6.32	6.40	23.50	28.50
$N_1P_2K_3$	101.50	103.50	11.95	11.97	28.50	30.15	43.50	45.75	6.51	6.92	23.15	28.15
$N_1P_3K_1$	107.30	99.50	12.65	13.15	29.50	31.75	44.50	47.15	6.72	7.50	21.50	26.35
$N_1P_3K_2$	109.50	106.50	13.65	13.95	30.50	32.75	45.35	52.15	6.95	7.35	23.50	28.50
$N_1P_3K_3$	106.50	108.50	11.95	12.25	31.50	33.50	46.50	49.75	7.01	8.15	27.50	29.50
$N_2P_1K_1$	115.15	113.50	13.25	13.75	32.50	33.75	45.95	49.15	7.92	8.32	28.15	30.15
$N_2P_1K_2$	113.30	115.50	14.35	15.15	33.50	35.72	45.35	50.75	6.92	8.15	27.15	30.15
$N_2P_1K_3$	109.50	111.30	16.50	17.25	34.50	36.15	44.50	51.57	6.82	7.92	28.15	30.25
$N_2P_2K_1$	112.50	115.50	15.75	16.25	33.50	32.19	47.50	53.52	7.50	8.15	29.75	30.25
$N_2P_2K_2$	115.50	117.50	17.15	18.25	34.70	35.50	49.50	55.75	7.72	8.12	29.15	30.15
$N_2P_2K_3$	111.73	113.50	18.95	19.25	36.70	37.50	52.50	57.15	7.15	8.95	30.15	32.15
$N_2P_3K_1$	109.53	111.50	21.52	22.25	37.50	38.50	55.70	60.15	7.35	9.15	31.25	33.15
$N_2P_3K_2$	117.59	119.50	23.52	24.50	33.80	36.15	53.50	61.50	7.31	9.15	32.15	35.15
$N_2P_3K_3$	119.53	121.73	22.70	23.70	36.30	37.15	59.50	65.50	8.10	9.35	33.15	37.50
$N_3P_1K_1$	120.91	121.93	23.50	24.50	37.50	36.15	61.50	67.50	7.50	9.00	30.95	39.15
$N_3P_1K_2$	119.79	123.50	24.50	26.50	36.50	38.50	65.50	69.50	7.20	8.95	32.15	36.15
$N_3P_1K_3$	121.31	123.50	25.15	27.15	37.50	39.50	63.50	75.50	7.30	8.15	33.15	36.15
$N_3P_2K_1$	120.53	124.50	23.15	25.15	38.50	40.15	62.50	80.15	7.80	9.15	31.15	36.15
$N_3P_2K_2$	119.35	127.50	24.15	26.50	37.25	41.25	69.50	85.15	7.90	9.25	32.15	38.50
$N_3P_2K_3$	125.31	130.63	26.13	29.24	40.78	45.39	77.34	91.96	8.61	10.70	34.47	45.91
$N_3P_3K_1$	123.52	128.90	24.72	27.50	37.50	43.50	74.15	89.15	8.15	9.25	32.55	43.15
$N_3P_3K_2$	123.92	126.50	23.92	28.50	36.92	42.90	75.25	88.15	8.05	9.50	31.25	42.15
$N_3P_3K_3$	124.92	128.96	26.05	28.90	39.95	43.92	77.15	90.92	8.52	10.50	33.92	44.91
Sed	11.76	11.97	1.73	2.31	3.61	3.64	6.01	6.91	0.65	0.71	2.7	3.1
CD (5%)	23.15	24.13	4.21	5.15	7.92	8.08	12.41	13.15	1.31	1.42	5.2	6.3

Table 2. Effect of season and NPK on seed yield and economics of coriander Co.3

Treatment	Seed yield (kg/ha)		Net Profit	
	kharif	*rabi*	*kharif*	*rabi*
$N_1P_1K_1$	545	575	2040	2640
$N_1P_1K_2$	523	620	2150	2520
$N_1P_1K_3$	575	625	3150	3725
$N_1P_2K_1$	625	675	3250	3500
$N_1P_2K_2$	650	725	3750	4250
$N_1P_2K_3$	675	695	3850	4350
$N_1P_3K_1$	675	725	3250	4000
$N_1P_3K_2$	700	750	3450	4275
$N_1P_3K_3$	680	690	3650	4290
$N_2P_1K_1$	690	750	3750	4400
$N_2P_1K_2$	650	720	3815	4500
$N_2P_1K_3$	675	725	3915	4700
$N_2P_2K_1$	715	725	4000	5200
$N_2P_2K_2$	700	750	4125	5700
$N_2P_2K_3$	705	755	4257	5900
$N_2P_3K_1$	715	815	4350	6000
$N_2P_3K_2$	690	800	4450	6050
$N_2P_3K_3$	680	850	4570	6000
$N_3P_1K_1$	683	825	4670	6200
$N_3P_1K_2$	711	875	4575	6070
$N_3P_1K_3$	705	900	4679	6090
$N_3P_2K_1$	700	915	4570	6050
$N_3P_2K_2$	695	920	4800	6000
$N_3P_2K_3$	746	999	4940	6250
$N_3P_3K_1$	715	950	4850	6000
$N_3P_3K_2$	725	965	4800	5995
$N_3P_3K_3$	740	997	4870	6005
SED	67.70	76.20		
CD (5%)	141.20	153.15		

References

Bhat V R & Sulikeri G S 1992 Effect of nitrogen, phosphorus and potassium on seed yield and **yield** attributes of coriander (*Coriandrum sativum* L.). Karnataka J. Agric. Sci. 5 (1): (26-30).

Singh B Dhillon G S Singh S & Klor D S 1979 Effect of some agronomical factors on the growth and yield of coriander. J. Res. Punjan Agric. Univ., 16 (4): 389-393.

Snellgrove R C Striblery D P Tiner P B & Lawlor D W 1986 The effect of vesicular arbuscular mycorrhizal infection on photosynthesis and *carbon distribution on leek plants. In:* Gianinazzi rearson, V. Giaminazzi, S. (Eds) mycorrhizae: Physiology and genetics.

Sushama P K 1982 Foliar diagnosis, yield and quality of pepper in relation to nitrogen, phosphorus and potassium M.Sc (Ag.) Thesis, Kerala Agric. University, Trichur.

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Effect of nutrients on growth and yield of leafy type Coriander

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Abstract

Investigation was carried out at Horticultural College & Research Institute, TNAU, Coimbatore on the effect of nutrients on the growth and yield of two leafy type coriander (CS 229 and CS 239) and the results revealed that NPK@60:40:60 kg ha^{-1} along with clipping twice recorded the highest herbage yield. First clipping was done at 35 days after sowing and second at 55 days after sowing. The yield of greens per plant for the genotype CS 229 during first clipping was 5.27g for the treatment without application of fertilizers (absolute control) and it increased to 10.60g when applied with NPK@60:40:60 kg ha^{-1}. Similarly, the yield during second clipping was 2.93g for absolute control and it increased to 8.30g when NPK@60:40:60 kg ha^{-1} was applied. The same trend was noticed in case of the genotype CS 239. The yield of greens was recorded to be 3.74g with the treatment of absolute control and it increased to 6.90g with NPK@60:40:60 kg ha^{-1} at first clipping and during the second clipping the yield was 2.34g in absolute control and it increased to 4.42g with NPK@60:40:60 kg ha^{-1}. The total yield of greens obtained from the two clippings in the two leafy type coriander CS 229 and CS 239 with the fertilizer dose of NPK @60:40:60 kg ha^{-1} were 11.34 and 6.35 t ha^{-1} respectively. The benefit cost ratio was 1:6.75 and 1:3.78 when NPK @60:40:60 kg ha^{-1} was applied whereas it was 1:3.15 and 1:1.73 for absolute control (without fertilizers) for the genotypes CS 229 and CS 239 respectively.

Key words : coriander, nutrition, leaf harvest.

Abbreviation : CS – *Coriandrum sativum,* DAS – Days After Sowing
G_1 – Genotype 1 (CS 229) and G_2 – Genotype 2 (CS 239)

Introduction

Coriander (*Coriandrum sativum* L.) an annual herb, the aromatic tender green leaves are used almost every day in Indian cuisine for flavouring many dishes like soups, sauces, salads and chutney. The leaves are also a good source of vitamin A and vitamin C. The stalks and leaves of coriander plant yields considerable volatile oil of about 0.01 – 0.95%.

Improved varieties for grain have been released all over India for cultivation. However, there is no designated variety for leaf purpose. The same grain types are grown and pulled out 25 to 30 days after sowing and are used as greens. There is a need to develop varieties exclusively for leaf purpose. As coriander leaves are indispensably used in our day to day life, there is a need to identify genotypes exclusively for leaf purpose and to optimise manurial schedule for leafy type coriander. Hence, the present study was undertaken with the following objectives.

- To study the effect of fertilizers & clipping on growth and herbage yield of leafy type.
- To find out the optimum manurial schedule for enhancing the growth and leaf yield.

Materials and methods

Two genotypes were identified and selected based on the previous trial on evaluation of 226 genotypes from the germplasam. Clipping was done for greens at an interval of 20 days, first clipping at thirty five days after sowing and second clipping at fifty five days of sowing. The fertilizer treatments were imposed on incremental basis from the recommended dose (40: 40: 20 of N: P_2O_5: K_2O kg/ha respectively).

Fertilizer schedule

The entire dose of phosphorus (40 kg) and potassium (20 kg) was applied as a basal dose as per the treatment schedule while nitrogen (40 kg)was splitted and applied at 25, 35 and 45 days after sowing.

Experimental details

Components	Details
Genotypes	CS 229, CS 239
Design	FRBD
Replications	2
No. of factors	**2**
Factor 1	Genotype (G1, G2)
Factor 2	Fertilizer
Levels of factors	
Factor 1	2
Factor 2	10

Treatment combination

Recommended fertilizer dose for coriander was taken as the basis for fixing the different levels of NPK on incremental basis along with absolute control (without fertilizer application). With an objective to increase the herbage yield, these treatmental combinations were framed and the details are given below.

G_1T_0	-	G_1	+	Without fertilizer
G_1T_1	-	G_1	+	NPK 40 : 40 : 20 kg ha^{-1}
G_1T_2	-	G_1	+	NPK 40 : 40 : 40 kg ha^{-1}
G_1T_3	-	G_1	+	NPK 40 : 40 : 60 kg ha^{-1}
G_1T_4	-	G_1	+	NPK 60 : 40 : 20 kg ha^{-1}
G_1T_5	-	G_1	+	NPK 60 : 40 : 40 kg ha^{-1}
G_1T_6	-	G_1	+	NPK 60 : 40 : 60 kg ha^{-1}
G_1T_7	-	G_1	+	NPK 60 : 60 : 60 kg ha^{-1}
G_1T_8	-	G_1	+	NPK 120 : 60 : 60 kg ha^{-1}
G_1T_9	-	G_1	+	NPK 180 : 60 : 60 kg ha^{-1}
G_2T_0	-	G_2	+	Without fertilizer
G_2T_1	-	G_2	+	NPK 40 : 40 : 20 kg ha^{-1}
G_2T_2	-	G_2	+	NPK 40 : 40 : 40 kg ha^{-1}

G_2T_3	-	G_2	+	NPK 40 : 40 : 60 kg ha^{-1}
G_2T_4	-	G_2	+	NPK 60 : 40 : 20 kg ha^{-1}
G_2T_5	-	G_2	+	NPK 60 : 40 : 40 kg ha^{-1}
G_2T_6	-	G_2	+	NPK 60 : 40 : 60 kg ha^{-1}
G_2T_7	-	G_2	+	NPK 60 : 60 : 60 kg ha^{-1}
G_2T_8	-	G_2	+	NPK 120 : 60 : 60 kg ha^{-1}
G_2T_9	-	G_2	+	NPK 180 : 60 : 60 kg ha^{-1}

A constant dose of FYM (10 tonnes ha^{-1}) was given irrespective of the treatments.

Results and discussion

The effect of application of nitrogen, phosphorus and potassium fertilizers on growth and yield of greens of coriander genotypes CS 229 and CS 239 were studied at 35 and 55 DAS.

Yield of greens per plant at first clipping on 35 DAS

The plants were uprooted on 35th and 55th day after sowing and their roots removed and the fresh weight of the plants recorded to give the yield of greens per plant. The total herbage yield was arrived by adding the two harvests. The yield of greens per plant at first clipping on 35 DAS was recorded and the results revealed that there were significant differences among the treatments and no significant interaction between treatments and the genotypes (Table 7). For the genotype G1, the treatment T_6 showed the highest weight of greens (10.60 g) and the lowest weight of greens of 5.27 g for the treatment T_0. For the genotype G_2, the treatment T_6 recorded the highest yield of greens per plant (6.90 g) and the lowest yield of greens per plant in T_8 (2.95 g). The treatment T_6 was the best and the treatments T_4, T_5, T_8 and T_{10} were on par with one another.

Table 1. Effect of NPK treatments on green yield per plant (g) at first clipping on 35 days after sowing coriander

Treatments (kg ha^{-1})		Genotype 1 CS 229	Genotype 2 CS 239	Mean
T_0 – Control		5.27	3.74	4.51
T_1 – 40 : 40 : 20		5.82	2.98	4.40
T_2 – 40 : 40 : 40		6.72	2.67	4.69
T_3 – 40 : 40 : 60		7.50	3.66	5.58
T_4 – 60 : 40 : 20		7.87	4.54	6.21
T_5 – 60 : 40 : 40		8.33	4.08	6.21
T_6 – 60 : 40 : 60		10.60	6.90	8.75
T_7 – 60 : 60 : 60		7.67	3.02	5.69
T_8 – 120 : 60 : 60		6.01	2.95	4.91
T_9 – 180 : 60 : 60		4.09	3.32	5.23
Mean		7.38	3.86	5.62
		SEd	CD(0.05)	CD(0.01)
	G	0.21	0.44	0.60
	T	0.47	0.99	1.35
	GT	0.67	NS	NS

Yield on greens per plant at second clipping on 55 DAS

The yield on greens per plant at second clipping recorded on 55 DAS showed that there were highly significant differences among the treatments and also highly significant interaction between treatments and genotypes (Table 2). The genotype G_1 registered the highest (8.30 g) and the lowest (2.93 g) yield of greens per plant for the treatment T_6 and T_0 respectively. The genotype G_2 produced the highest yield of greens per plant (4.42 g) for the treatment T_6 and the lowest of 2.05 g in T_3. The treatments T_1 & T2 were on par with one another.

Table 2. Effect of NPK treatments on green yield per plant (g) at second clipping on 55 days after sowing in coriander

Treatments (kg ha^{-1})	Genotype 1 CS 229	Genotype 2 CS 239	Mean
T_0 – Control	2.93	2.34	2.63
T_1 – 40 : 40 : 20	3.74	2.34	3.04
T_2 – 40 : 40 : 40	3.02	2.35	2.69
T_3 – 40 : 40 : 60	3.98	2.05	3.01
T_4 – 60 : 40 : 20	4.68	2.22	3.45
T_5 – 60 : 40 : 40	5.06	3.08	4.07
T_6 – 60 : 40 : 60	8.30	4.42	6.36
T_7 – 60 : 60 : 60	5.80	3.11	4.46
T_8 – 120 : 60 : 60	6.06	2.54	4.30
T_9 – 180 : 60 : 60	4.09	2.29	3.19
Mean	4.77	2.67	3.72

	SEd	CD(0.05)	CD(0.01)
G	0.14	0.29	0.40
T	0.31	0.66	0.89
GT	0.44	0.93	1.27

Genotypes CS 229 and CS 239 were exceptional as they have an extended vegetative phase and delayed flowering and it was highly suitable to clip on 35 DAS. Formation of leaf initials on the apex gives way to floral initial formation in all the 38 genotypes studied, except the genotypes CS 229 and CS 239. All the other genotypes under scrutiny except the genotypes CS 229 and CS 239, reached physiological maturity to enter reproductive phase at 35 DAS or even earlier. This is in agreement with the previous work of Vedamuthu (1994). In the genotype CS 229 and CS 239, more number of clippings could be taken and from each clipping fresh tender leaves may be plucked. If the plants were left unclipped the crude fiber accumulation would be more and the stem becomes very thick and fibrous which reduces the palatability of the crop.

In the genotypes CS 229 and CS 239, the apical bud proliferated after clipping and hence they exhibited normal vegetative growth, as before clipping. These two types were amenable for more number of cuttings and this character might be due to the genetic make up of the genotypes used. This is in accordance with the work carried out on physiological aspects of many crop plants by Franklin *et al.* (1985). The response of the plants to clipping were also different for the genotype CS 229, wherein the apical bud starts to proliferate after the clipping while for the genotype, CS 239 the axillary bud proliferates after the clipping. The growth parameters such as plant height, number of branches per plant and leaf stem ratio exhibited direct influence on the yield of greens of coriander. The robust vegetative growth is an essential prerequisite for high yield of greens in coriander, the plant height and number of branches per plant. The increase in growth parameters can be attributed to increased absorption of nutrients required for cell division, cell elongation and cell proliferation as nitrogen was made available for the plants. Similar increase in plant height, number of branches per plant due to nitrogen fertilization have been obtained in coriander by Singh *et al. (1979)*, Ghosh *et al.* (1985), Rahman *et al. (1990)*, Sharma and Israel (1991), Bhat *et al.* (1992), Sivakumaran *et al.* (1996), Malav and Yadav (1997) and Nehra (2000) and Pareek *et al. (2000)*. Increasing phosphorus level from 0 to 40 kg ha^{-1} exhibited a profound impact on plant height, number of branches per plant. Present investigation is in corraboration with that of Ghosh *et al.* (1985) and Bhat *et al.* (1992) in coriander.

Estimated yield

The estimated yield of greens varied from 3.16 (T_0) to 6.36 t ha^{-1} (T_6) for the genotype CS 229 and 1.82 (T_0) to 4.34 t ha^{-1} (T_6) for CS 239 at first clipping (Table 3). At the second clipping it ranged between 1.65 (T_0) and 4.98 t ha^{-1} (T_6) for CS 229 and for the genotype CS 239 it ranged between 0.83 (T_0) and 3.06 t ha^{-1} (T_7). The total yield for both the clippings was the highest in T_6 for both the genotype with 11.34 and 6.35 t ha^{-1} respectively. It was the lowest (4.81 & 2.65 t/ha) in T_0 respectively for both the genotypes.

Table 3. Estimated yield of greens (t ha^{-1}) for the genotypes CS 229 and CS 239 from first clipping and second clipping in coriander

Treatments (kg ha^{-1})	First clipping (t ha^{-1})		Second clipping (t ha^{-1})		Total yield (t ha^{-1})	
	G_1 CS 229	G_2 CS 239	G_1 CS 229	G_2 CS 239	G_1 CS 229	G_2 CS 239
T_0 – Control	3.16	1.82	1.65	0.83	4.81	2.65
T_1 – 40 : 40 : 20	3.48	1.95	2.24	1.01	5.72	2.95
T_2 – 40 : 40 : 40	4.03	2.41	1.81	0.96	5.84	3.37
T_3 – 40 : 40 : 60	4.50	2.35	2.38	1.02	6.88	3.37
T_4 – 60 : 40 : 20	4.72	2.91	2.80	1.06	7.52	3.97
T_5 – 60 : 40 : 40	4.99	2.63	3.03	1.43	8.02	4.06
T_6 – 60 : 40 : 60	6.36	4.34	4.98	2.01	11.34	6.35
T_7 – 60 : 60 : 60	4.59	2.42	3.48	3.06	8.07	5.48
T_8 – 120: 60 : 60	4.41	2.30	3.63	1.51	8.04	3.81
T_9 – 180: 60 : 60	4.27	2.33	2.45	1.50	6.72	4.78

Cost benefit ratio

For the genotype CS 229 cost benefit ratio of 1 : 6.75 was obtained when NPK was applied @ 60 :40 : 60 kg ha^{-1} whereas a cost benefit ratio of 1 : 3.15 was recorded for absolute control (Table 4). For the genotype CS 239, a cost benefit ratio of 1:3.78 was registered when NPK was applied @ 60 : 40 : 60 kg ha^{-1} while a cost benefit ratio of 1 : 1.73 was recorded for absolute control.

Table 4. Effect of NPK treatments on cost : **benefit** ratio

Treatments (kg ha^{-1})	Expenditure (Rs.)		Benefit (Rs.)		Cost: benefit ratio	
	G_1 CS 229	G_2 CS 239	G_1 CS 229	G_2 CS 239	G_1 CS 229	G_2 CS 239
T_0 – Control	15256.30	15256.30	48100.30	26500.13	1 : 3.15	1 : 1.73
T_1 – 40:40:20	16317.64	16317.64	57200.82	29500.34	1 : 3.50	1 : 1.80
T_2 – 40:40:40	16455.08	16455.08	58400.42	33700.45	1 : 3.54	1 : 2.04
T_3 – 40:40:60	16594.12	16594.12	68800.02	33700.15	1 : 4.14	1 : 2.03
T_4 – 60:40:20	16610.84	16610.84	75200.12	39700.38	1 : 4.52	1 : 2.39
T_5 – 60:40:40	16649.03	16649.03	80200.64	40600.90	1 : 4.81	1 : 2.43
T_6 – 60:40:60	16787.32	16787.32	113400.03	63500.15	1 : 6.75	1 : 3.78
T_7 – 60:60:60	17183.82	17183.82	80700.42	54800.35	1 : 4.69	1 : 3.18
T_8 – 120:60:60	17763.42	17763.42	80400.62	38100.65	1 : 4.52	1 : 2.14
T_9 – 180:60:60	18343.02	18343.02	67200.80	47800.15	1 : 3.66	1 : 2.60

Effect of clipping and fertilization

In the present study, the yield of greens increased with increasing levels of N, P and K but beyond N_{60}, P_{40}, K_{60} kg ha^{-1}, the yield of greens per plant was lowered. Increased doses of nitrogen from 0 to 60 kg ha^{-1} might substantiate the yield of greens per plant preventing nutrient exhaustion. Hence, the treatment N_{60}, P_{40}, K_{60} can be recommended for coriander when grown for leaf purpose under Coimbatore conditions.

More clippings were possible only if the balanced fertilizer application is followed in herbaceous plants amenable for cutting. The highest herbage yield was obtained in terms of yield of greens per plant both in first and second clipping, when uniform application of NPK was practiced in leafy type of coriander in the present investigation. This is in corroboration with the earlier findings in *Ocimum basilicum* by Youssef *et al.* (1998). Clipping of vegetative top influenced the apical bud dominance, ultimately exerted much influence on growth parameters namely plant height, number of branches per plant, leaf stem ratio than the non clipped treatment.

In the first clipping, yield of greens per plant was higher in the genotype CS 229 than CS 239 but started to decline in the second clipping when nitrogen level was increased from T_0 to T_6 significantly increased the yield of greens per plant with every increment. This is in agreement with the findings of Vuurmans and Grubben (1978), Subbiah and Ramanathan (1982) in amaranthus and Chattopadhyaya (1971) in *Basella alba.*

References

Bhat, V.R., G.S.Sulikeri and N.C. Hulamani. 1992. Effect of NPK on herbage yield of coriander. Spice India, 5(10) : 11 – 13.

Chattopadhyaya, T.K. 1971. Response of *Basella alba* to sources and levels of nitrogen fertilization. Progressive Hort., 9(2): 71 – 75.

Franklin, P.G., R. Brent Pearce and L.M.Roger. 1985. Physiology of crop plants. McGraw Hill Publishers, New York.

Ghosh, D. T.K.Maity, M.G.Som and T.K.Bose. 1985. Effect of nitrogen and phosphorus on the growth and yield of coriander. Indian J. of Agron., 36(1): 111 – 113.

Malav, N.B. and S.N.Yadav. 1997. Effect of row spacing and levels of nitrogen on growth and seed yield of coriander. Ind. Cocoa, Arecanut and Spices J., 21(2): 37 – 41.

Nehra, O.P. 2000. Response of grain amaranth to irrigation and nitrogen application. Haryana J. Agron. 16 (1 & 2): 174 – 175.

Pareek, N.K., N.L.Jat and R.G.Pareek. 2000. Response of coriander to nitrogen and plant growth regulators. Haryana J. Agron. 16 (1 & 2): 104 – 109.

Rahman, M.D., O.R.Srihari Babu and N. Subba Rao. 1990. Effect of graded levels of nitrogen on growth and yield of seed and essential oil of coriander. Ind. Cocoa, Arecanut and Spices J., 13(4): 130 – 133.

Sharma and Israel. 1991. Effect of date of sowing and level of nitrogen and phosphorus on growth and seed yield of coriander (*Coriandrum sativum* L.) Indian J. of Agron., 36: 180 – 184.

Singh, B., G.S.Dhillon, S. Singh and D.S.Kleer. 1979. Effect of some agronomic factors on the growth and yield of coriander. J. Res. Punjab Agric. Univ., 16 : 389 – 393.

Sivakumaran, S., Gururaj Hunsig, H.K.Basavaraj and S. Sridhara. 1996. Study on nutrient uptake, seed and oil yield of coriander as influenced by nitrogen, phosphorus and sulphur. Indian Agri., 40(2): 89 – 92.

Subbiah, K and K.M.Ramanathan. 1982. Influence of N and K on the green yield of CO.1 and CO.2 amaranthus. Madras Agric. J., 69(6) : 356 – 358.

Vedamuthu, P.G.B. 1994. Improvement of seed spices. In: Advances of Horticulture (Eds. Chadha, K.L. and P.Rethinam). 9: 234 – 347.

Vuurmans, J. and G.J.H. Grubben. 1978. Effect of nitrate application on the yield and chemical composition of seven tropical vegetables. Vegetables for the Hot, Humid tropics, 2: 40 – 43.

Youssef, A.A., I.M.Talaati and E.A. Omer. 1998. Physiological response of basil green ruffles (*Ocimum basilicum* L.) to nitrogen fertilisation in different soil types. Egyptian J. of Hort., 25(2): 253 – 269.

8

Investigations on optimum nutrient requirements and planting dates for garlic (*Allium sativum* L.) under Northern dry zone of Karnataka

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Abstract

A field trial was laid out in medium black soil under irrigated condition at KRC., College of Horticulture, Arabhavi, Gokak (Tq), Karnataka during 1998-99 to study the effect of dates of planting and nutrient levels on the yield performance of garlic cv. Belgaum Local. Arabhavi is situated in Northern dry zone (Zone-3) of Karnataka at an altitude of 612 m above MSL receiving about 530 mm average annual rainfall distributed over a period of six months (May – November) with peaks during September (176.6 mm) and October (119.0 mm). Among the seven dates of planting (starting from July second fortnight to November first fortnight), October first fortnight planting was found to be optimum for obtaining higher yield (4.75 t/ha). Variation in fertilizer levels influenced the uptake of nutrients. The highest nutrient uptake (117.76 kg N, 18.33 kg P_2O_5 and 63.38 kg K_2O/ha) was observed in the treatment applied with 75 per cent of RDF (RDF for garlic is 125 : 62.5 : 62.5 kg NPK/ha). Among the three levels of fertilizers tried application of 75 per cent RDF recorded significantly higher bulb yield (4.54 t/ha) revealing the possibility of reducing the recommended dose of fertilizer by 25 per cent under Northern dry zone (Agro climatic zone 3 region 2) of Karnataka

Key words : Garlic, *Allium sativum* L., nutrition, planting time, bulb yield.

Introduction

Garlic (*Allium sativum* L.) is the second most cultivated bulb crop after onion. India ranks third in production of garlic (4.30 lakh tones), next to Korea and China (Anon 1998). Though it can be cultivated both as *kharif and rabi* crop, major production of garlic is during *rabi* season. Karnataka is having an area of 4000 ha with a production of 3000 tonnes. The average garlic yield in India is markedly lower (4300 kg/ha) than the yield recorded in other countries (Anon 1998). Apart from varietal characteristics the date of planting and nutrition are important considerations for accomplishing higher yields of garlic. Season of planting is an important factor in garlic cultivation (Deshi *et al.* 1965). Under suitable agroclimatic conditions mineral nutrition is the main factor which influences the growth and yield of garlic. In modern agriculture, fertilizer constitutes the major portion of cost of cultivation. By judicious application of nutrients it is possible to produce higher yields of garlic. Improvement in the bulb weight and yield of garlic due to fertilizer (N, P & K) application is reported from different agroclimatic conditions (Kumar 1994) under Garhwal (UP) hill conditions; Verma *et al.*1996 under Jabalpur (MP) conditions). No systemic information is available on date of planting and optimum nutritional requirement to obtain

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higher yields of garlic under Northern dry zone (Agroclimatic zone 3 region 2) of Karnataka. Keeping these points in view the present investigation was undertaken.

Materials and methods

A field experiment was carried out at KRC college of Horticulture, Arabhavi, Gokak (Tq), Karnataka during 1998-99 to study the effect of dates of planting and nutrient levels on the performance of garlic cv Belgaum Local. Arabhavi is situated in Northern dry zone (Zone 3) of region 2 of agroclimatic zones of Karnataka at an altitude of 630 m MSL receiving about 530 mm average annual rainfall distributed over a period of 6 months (May to November) with peaks during September (177 mm) and October (119 mm). The experiment was laid out as factorial RBD replicated thrice under irrigated condition on medium black soil of slightly alkaline P^H (8.1). Healthy and bold garlic cloves of Belgaum Local variey were dibbled at 7.5 cm apart in furrows opened at 15 cm apart on different dates as per the treatment requirements. Cultivation practices were followed as per the package of practices of UAS Dharwad. Five plants were tagged in each treatment for recording observations on growth attributes *viz.,* plant height, leaves per plant, leaf length, neck thickness and dry weight of foliage. Uptake of nitrogen and phosphorous by the crop was estimated by modified Kjeldhal's method and Vanadomolybdate yellow colour method respectively (Jackson 1967). Potassium uptake by crop was determined by Photometer method (Muhr *et al.*1965). Yield attributes *viz.,* bulb diameter and number of cloves per bulb were also recorded apart from bulb yield.

Results and discussion

Growth attributes

Results on growth parameters of garlic indicated that, planting during first fortnight of October produced significantly higher plant height (20.59 cm), number of leaves (5.98),leaf length (32.13cm), neck thickness (0.56cm) and dry weight of foliage (o.83g/plant) as given in Table 1. Plant height ranged from 20.59 cm (October first fortnight planting) to 13.91cm (September second fortnight planting) and number of leaves ranged from 5.98 (October first fortnight planting) to 4.51 (September second fortnight planting). There was significant difference among the different levels of fertilizers and application of 75 per cent of RDF produced better plant growth with maximum plant height (19.57cm), leaves per plant (5.31 leaves) and leaf length (30.51cm) when compared to corresponding lower values in the treatment receiving 50 per cent RDF (15.59cm plant height, 4.94 leaves and 29.04 cm leaf length respectively). Growth attributes showed reduced as planting was delayed from $T_1$to T_5 planting (i.e., from July to September). However, the trend reversed in T_6 and T_7 (October and November planting). These findings are in accordance with the findings of Om and Srivastava (1974). Application of fertilizer in garlic produced tremendous effect on growth attributes (Om *et al.* 1978).

Nutrient uptake

The highest uptake of N, P_2O_5 and K_2O (117.76, 18.33 and 63.38 kg/ha respectively) was observed in the treatment receiving 75 per cent RDF (A_2) (Table 2). The treatment with RDF (A_1) reduced nutrient uptake and the lowest uptake was noticed in plots applied with 50 per cent RDF (A_3). Thus excess fertilizer application is toxic and did not enable the plant to develop good canopy. Hence, the plants receiving 75 per cent RDF(A_2) produced better vegetative growth and higher biomass production, while crop receiving 50 per cent RDF(A_3) level of fertilizer failed to produce adequate vegetation of the plant because of low levels of nutrients, hence the uptake was less. Uptake of nutrients by garlic crop also differed significantly due to dates of planting. Nutrient uptake was maximum in October first fortnight planting (132.80, 21.53 and 71.70kg NPK/ha) followed by November first fortnight sown crop and the lowest uptake was recorded in T_5 (September second fortnight) planting. Thus the higher uptake of nutrients and their translocation to different parts of the plant might have helped in better vegetative growth thereby leading to higher yield.

Table 1. Growth attributes as influenced by planting dates and fertilizer levels in garlic cv. Belgaum Local at 60 days after planting (DAP)

Treatments	Plant height (cm)	Leaves per plant (No.)	Leaf length (cm)	Neck thick-ness (cm)	Dry weight of foliage
Dates of planting (T)					
T_1= Second FN of July	20.19	5.87	30.70	0.52	0.74
T_2= First FN of August	18.89	5.38	29.77	0.52	0.73
T_3= Second FN of August	17.44	4.82	28.92	0.43	0.71
T_4= First FN of September	15.20	4.53	28.09	0.36	0.69
T_5= Second FN of September	13.91	4.51	27.24	0.36	0.64
T_6= First FN of October	20.59	5.98	32.13	0.56	0.83
T_7= First FN of November	19.52	5.18	31.43	0.52	0.78
S.Em ±	0.616	0.136	0.154	0.017	0.029
CD at 5 %	1.175	0.389	0.439	0.050	0.083
Fertilizer levels (A)					
A_1= RDF	18.84	5.30	29.72	0.46	0.71
A_2=75 % RDF	19.47	5.31	30.51	0.51	0.81
A_3=50 % RDF	15.59	4.94	29.04	0.44	0.68
S.Em ±	0.403	0.089	0.101	0.011	0.019
CD at 5 %	1.51	0.254	0.287	0.033	0.054
T x A	NS	NS	NS	NS	NS

FN = Fortnight.. RDF = Recommended dose of fertilizer (125 : 62.5 : 62.5 kg NPK/ha)

Yield and yield parameters

Bulb yield of garlic differed significantly due to different dates of planting and fertilizer levels (Table 3). The highest bulb yield of 4.65 tonnes per ha was recorded in first fortnight of October planting (T_6) followed by 4.68 tonnes per ha in plots planted during first fortnight of November (T_7) and the lowest yield of 3.54 tonnes per ha was recorded by planting in the second fortnight of September (T_5). Treatments which produced higher yield also recorded better yield attributing characters like bulb weight (g/plant), bulb diameter and number of cloves per bulb. These results are in conformity with Lawande *et al.* (1993).

Among the three levels of fertilizers tried, treatment with 75 per cent RDF recorded the highest yield per hectare (4.54 t/ha) followed by the treatment supplied with RDF (4.47 t/ha) and the lowest was in the treatment receiving 50 per cent RDF (4.02 t/ha). Increased fertilizer level from A_2 treatment decreased the yield. Similar results of decrease in yield

Table 3. Yield and yield attributes as influenced by planting dates and fertilizer levels in garlic cv. Belgaum Local.

Treatments	Bulb weight (g/plant)				Bulb diameter (cm)				Number of leaves per bulb				Bulb yield (t/ha)			
	RDF (A_1)	75% RDF (A_2)	50% RDF (A_3)	Mean	RDF (A_1)	75% RDF (A_2)	50% RDF (A_3)	Mean	RDF (A_1)	75% RDF (A_2)	50% RDF (A_3)	Mean	RDF (A_1)	75% RDF (A_2)	50% RDF (A_3)	Mean
T_1=Second FN of July	4.66	4.78	3.94	4.46	2.87	2.92	2.34	2.71	9.47	9.57	9.22	9.42	4.69	4.76	4.30	4.58
T_2= First FN of August	4.33	4.85	3.95	4.37	2.33	2.82	1.56	2.24	8.62	11.17	8.34	9.38	4.64	4.69	4.12	4.48
T_3= Second FN of August	4.63	4.72	3.54	4.29	1.78	2.48	1.52	1.93	8.32	8.50	7.86	8.23	4.53	4.62	4.03	4.39
T_4= First FN of September	4.07	4.18	3.88	4.04	1.67	1.79	1.49	1.65	7.77	9.02	7.62	8.13	4.08	4.23	3.51	3.94
T_5= Second FN of *September*	3.43	3.60	3.29	3.44	1.50	1.53	1.44	1.49	7.74	7.74	6.16	7.21	3.72	3.78	3.12	3.54
T_6= First FN of October	4.99	5.38	4.93	5.10	2.81	3.40	2.47	2.89	10.38	12.10	9.81	10.76	4.85	4.88	4.53	4.75
T_7= First FN of November	4.45	4.74	4.16	4.45	2.23	2.96	2.16	2.46	9.67	9.72	8.84	9.41	4.75	4.82	4.49	4.68
Mean	4.36	4.61	3.95		2.17	2.56	1.86		8.85	9.69	8.26		4.47	4.54	4.02	
For comparison of Means of	S.Em±		CD at 5%		S.Em±		CD at 5%		S.Em±		CD at 5%		S.Em±		CD at 5%	
Dates of planting (T)	0.126		0.361		0.103		0.293		0.287		0.820		0.016		0.047	
Fertilizer levels (A)	0.083		0.236		0.067		0.192		0.188		0.537		0.011		0.031	
Interaction (T x A)	*0.219*		*0.626*		*0.178*		*0.508*		*0.497*		*1.902*		*0.029*		*0.081*	

FN = Fortnight. RDF = Recommended dose of fertilizer (125 : 62.5 : 62.5 kg NPK /ha) with increase in N and K have been reported by Selvaraj *et al.* (1993). In the present study there is significant effect of interaction of date of planting and fertilizer levels for yield and yield attributes (Table 3). Significantly higher yield per hectare was recorded in October first fortnight and 75 per cent RDF (4.88 t/ha) combination followed by October first fortnight and RDF (4.82 t/ha). The treatment receiving 75 per cent RDF (A_2) which was optimum for garlic crop, significantly improved yield parameters *viz.*, cloves per bulb (9.69), bulb weight (4.61g) and bulb diameter (2.56 cm). Thus among various dates of planting, October first fortnight planting seems to be optimum for obtaining higher yield (4.75 t/ha). Among three levels of fertilizers tried application of 75 per cent RDF recorded the significantly higher bulb yield (4.54 t/ha), which revealed the possibility of reducing the RDF by 25 per cent to reduce the cost of cultivation.

Table 2. Effect of dates of planting and fertilizer levels on nutrient uptake (kg/ha) by garlic crop (cv. Belgaum Local)

Treatments	Nutrient uptake (kg/ha)		
	Nitrogen	Phosphorous	Potassium
Dates of planting (T)			
T_1= Second FN of July	119.79	19.07	61.09
T_2= First FN of August	113.56	17.09	62.04
T_3= Second FN of August	104.18	16.00	57.31
T_4= First FN of September	92.91	14.36	53.41
T_5= Second FN of September	81.62	12.43	46.18
T_6= First FN of October	132.80	21.53	71.70
T_7= First FN of November	127.24	2.59	69.38
S.Em ±	0.652	0.184	0.286
CD at 5 %	1.863	0.526	0.818
Fertilizer levels (A)			
A_1= RDF	113.25	17.56	60.93
A_2=75 % RDF	117.76	18.33	63.38
A_3=50 % RDF	99.90	15.87	58.74
S.Em ±	0.427	0.121	0.187
CD at 5 %	1.220	0.345	0.534
T x A	NS	NS	NS

FN = Fortnight. RDF = Recommended dose of fertilizer (125 : 62.5 : 62.5 kg NPK/ha)

References

Anonymous 1998 FAO Quarterly Bull.of Statistics. 11:56-57

Jackson M L 1967 Soil chemical analysis. Prenice Hall of India Pvt. Ltd., New Delhi, p 498.

Kumar R 1994 Influence of N and P on growth, yield and micronutrient status of garlic under Garhwal (UP) hill conditions. Haryana J. Hort. Sci. 23:221-225.

Lawande K E, Pawar R D, Supe V S & Kale P N 1993 Response of garlic to different dates of plantings. J. Maharastra Agril. Uni. 18:314-315.

Muhr G R, Dutta N P, Teley V K, Shankar A H & Donahve R L 1965 Soil testing in India. U.S. Agency for International Development, New Delhi. Pp 143-196.

Om H & Srivastava R P 1974 Influence of time of planting on the growth and yield of garlic. Progressive Hort. 6:71-76.

Selvaraj N, Irulappan I, Peter G B & Vedamuthu 1993 Effect of N, K and Mg fertilization on the uptake of nutrients in garlic (*Allium sativum* L.). South Indian Hort. 41:278-281.

Verma D P, Sharma B R, Chadha A P S, Bajpai H K & Bhadauria U P S 1996 Response of garlic (*Allium satium* L.) to nitrogen, phosphorous and potassium levels. Adv. in Plant Sci. 9:37-41.

9

Effect of bio-fertilizers on the growth, yield and essential oil content in rosemary (*Rosmarinus officinalis* L.)

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Abstract

Field experiment on rosemary (*Rosmarinus officinalis* L) was conducted in 2000-2001 to 2001-2002 (partially irrigated) at the medicinal and Aromatic crops section, Department of Horticulture, University of Agricultural sciences, Bangalore. The variety 'French' was used for the experiment. The study included twelve treatment combinations comprising of three levels of each Nitrogen (50, 75 & 100 kg N) and Phosphorus (20, 30 & 40 kg P_2O_5) with a constant level of Potash (K_2O) at 40 kg per hectare along with three bio-fertilizers (*Azotobacter,Azospirillum* and VAM) inoculated either singly or in combination. The results revealed highest cumulative herbage yield, essential oil yield and maximum net returns of rosemary oil by applying 50 percent NP, 100 percent K along with three bio-fertilizers (T_{11} = 18.23t/ha, 219.82lt/ha & cost:benefit ratio of 1:4.9), which was significantly superior over the recommended dosage of fertilizers (control = 13.71t/ha, 140.25lt/ha & cost:benefit ratio of 1:3.15 respectively). This was at par with the treatment involving 50 percent NP, 100 percent K plus micronutrients (Bo & Zn) along with bio-fertilizers (T_{12}). The economics of essential oil production emphasized the safe use of bio-fertilizers in place of recommended dose of chemical fertilizers alone (control). Application of 50 percent NP, 100 percent K along with three bio-fertilizers proved to be the most optimum and economic media for higher monetary returns.

Key words: Bio-fertilizers, *Rosmarinus officinalis*, yield.

Introduction

Rosemary botanically known as *Rosmarinus officinalis* L. belonging to the family Lamiaceae native of Mediterranean regions of Europe, Asia minor and North Africa. The oil is valued for its use in culinary, medicine, perfumery and cosmetic industries. Rosemary oil is also used in aromatherapy. It is an excellent fixative material. The oil also contributes a strong fresh odour, which blends well with various other oil odours and also serves to mask the unpleasant smell of certain other ingredients. Efforts are underway to standardize the agrotechnology for cultivation of rosemary in India which has centered around the extensive use of chemical fertilizers. However, from ecological, health and economic stand point we need to gradually reduce our dependence on them and also to market these products in the west particularly European countries, where the demand is for organically grown herbal products (Amit 2001). Therefore, it has been envisaged that for sustainability of agricultural production in the country, integrated nutrient management appears to be promising. In this connection a field experiment was conducted to study the effects of bio-fertilizers on growth, herbage and oil yields of rosemary.

Materials and Methods

The experiment was carried out at the medicinal and aromatic section of the horticulture department, GKVK, Bangalore enjoying semi-arid tropical climate (12° 58′ N and a longitude of 77° 35′ East with an elevation of 930 M(MSL) for 2 years. The soil of the experimental site was a red sandy loam (alfisols) and uniform in fertility. The soil reaction was near neutral (pH 6.6) with an electrical conductivity of 0.08 *m* Mhos. The soil of the experimental site was having low organic carbon (0.18%), available nitrogen (197kg/ha), phosphorus (15kg/ha) and potassium (275kg/ha) respectively.

The treatments consisted of bio-fertilizers, comprising of *Glomus mosseae* (GM), *Azotobacter chroococum* and *Azospirillum brasilence* singly or in combination with different levels of nitrogen (100,75&50kg/ha) and phosphorus (40,30&20kg/ha) from the recommended level of fertilizer dosage (control) for rosemary. All together they were twelve treatments arranged in a RCBD design with three replications. The fertilizers were given in three splits, one as a basal dose and rest two after each harvest.

Soil based inoculum of *Glomus mosseae* containing the root zone soil and the roots (685 spores per 50gms air dried sample), Lignite based *Azotobacter chroococum* (population $=10^8$ cells /g) and *Azospirillum brasilense* (population = 10^7 cells /gm) each applied at the rate of 10 g each per polybag.The cuttings were planted in these polybags . FYM at the rate of 10 t/ha was applied one month before planting and worked thoroughly into the soil.

Eight weeks old rooted cuttings of rosemary were planted on 22nd September 2000 on one side of the ridge with an inter- row spacing of 60cm and inter-plant spacing of 45cm. During the planting, the first split of nitrogen in the form of Urea (46% N) and full dose of phosphorus (single super phosphate =16%P_2o_5) and muriate of potash (60% K_2o) respectively were applied as a basal dose as per the treatments . The fertilizers were placed in the furrows at 5cm deep and irrigated after planting. Then on the plots was irrigated once a week. Three harvests were taken during the course of the experiment (May 2001, October 2001 and March 2002). The crop was harvested at 15 -20 cm above the ground level and the fresh herbage yield was recorded.

After each harvest the remaining split of nitrogen is added and to the moist irrigated field the bio-fertilizers, *Azotobacter* and *Azospirillum* are added at the rate of 1kg/ha mixed with 20 kgs of compost and 10 kgs of sand thoroughly and applied in the furrows after earthling up and later covered properly. The essential oil content of the fresh herbage was by hydro-distillation using clavenger's apparatus. The quality of the essential oil was determined with the help of Gas chromatograph analysis (G. C. Model: Varian 3700 series). Only a very little amount (1-2μl) of the oil was injected into the injector port of the GC using a micro syringe. The column temperature programme was from 100-00-02-220° C for 60 min. Injector and detector were kept at 250°C and 280°C, respectively. Finally, the essential oil components were identified by comparing peak retention times with those of authentic standards run under identical conditions.

Results and discussion

Herbage and oil yield: Maximum herbage was recorded in the treatment with 50% N, P and full K plus micro-nutrients along with the triple inoculation of bio-fertilizers in all the three harvests which remained at par with most of the inoculated treatments but was significantly superior over the treatments with single inoculation of *Azotobacter chroococum* or *Azospirillum brasilense* or the uninoculated treatments . All the three harvests followed a similar trend (Table1). The lower yield obtained at just the recommended dosage of fertilizers for rosemary, was attributed to the lack of enhanced availability of nutrients, better water uptake and synthesis of some growth regulators in the uninoculated plants which might have contributed to the better growth and yield in the inoculated plants. Similar results were reported in case of patchouli (Manjunath 2001).

Application of 50% N and P, full K along with triple inoculation produced significantly higher fresh herbage , essential oil content and yields compared to that of control (Table 1). Single or dual inoculation of bio-fertilizers with further increase in N and P was not significant. Similar response was reported in patchouli (Manjunath 2001), citronella (Naik 1998) and *Phyllanthus amarus* (Earanna 2001).

Table 2. Effect of bio-fertilizers and different levels of nitrogen and phosphorus on rhizosphere microbial count of rosemary.

Treatments	Azotobacter (x10³CFU/g of soil)	Azospirillum (x10³CFU/g of soil)	VAM Spore Count	VAM Colonization
T_1: 100:40:40 (Control)	22.02	10.50	60.08	24.42
T_2: 100:40:40 + micronutrients (Zn & Bo)	31.01	22.21	120.0	40.18
T_3: 75:40:40+ *Azotobacter*	72.68	25.33	80.0	37.63
T_4: 50:40:40 + *Azotobacter*	68.61	28.01	126.0	38.52
T_5: 75:40:40+ *Azospirillum*	53.60	50.56	128.01	45.60
T_6: 50:40:40 + *Azospirillum*	37.78	49.51	236.01	44.93
T_7: 100:30:40+ VAM	31.01	31.66	285.07	69.71
T_8: 100:20:40+ VAM	44.35	27.56	273.11	71.51
T_9: 75:30:40+ *Azospirillum* + VAM	46.50	37.74	321.02	66.74
T_{10}: 50:30:40+*Azotobacter* +*Azospirillum* + VAM	56.10	52.56	337.35	74.18
T_{11}: 50:20:40+*Azotobacter* +*Azospirillum* + VAM	62.01	41.36	339.01	71.51
T_{12}: 50:20:40+*Azotobacter*+ *Azospirillum* + VAM+ (Zn & Bo)	59.32	40.80	335.9	64.91
F- test	*	*	*	*
SEm ±	1.83	1.10	1.94	1.96
C.D. at 5%	3.91	3.23	5.68	5.77

The microbial population in the rhizosphere soil was high in the single inoculated ones but was at par with the triple inoculated ones (Table 2). Similar trend was in the percent root colonization and spore count (Sumana 1998). These observations reveal the obvious benefits of the VAM fungi and its synergistic interaction with the free nitrogen-fixing bacteria's. The least count was observed in control plots receiving recommended level of fertilizers.

Oil quality: Oil quality was influenced by bio-fertilizers and different levels of N and P. The improved herbage and oil yield may be attributed to the supply of nitrogen as well as growth hormones by *Azotobacter chroococum* , *Azospirillum brasilense* and better P uptake by VAM (Sumana 2000). There was seasonal influence in oil composition (Table 3).

Table 1. Effect of Bio-fertilizers and different levels of nitrogen and Phosphorus on the herbage and oil yield in rosemary.

Treatments	Fresh herbage yield (t/ha)				Oil content (%)			Oil yield (l/ha)			
	I Harvest	II Harvest	III Harvest	Cumulative	I Harvest	II Harvest	III Harvest	I Harvest	II Harvest	III Harvest	Cumulative
T_1: 100:40:40 (Control)	7.71	15.55	17.89	13.71	1.07	0.76	0.90	98.10	104.21	191.45	140.25
T_2: 100:40:40 + micronutrients (Zn&Bo)	8.06	14.79	19.99	14.28	0.93	0.8	1.01	109.23	115.43	211.34	145.33
T_3: 75:40:40+ *Azotobacter*	9.12	14.14	22.21	15.15	1.18	0.9	1.05	111.22	131.22	219.41	144.94
T_4: 50:40:40 + *Azotobacter*	9.0	15.90	19.76	14.88	1.11	0.86	1.13	102.33	142.9	225.61	156.94
T_5: 75:40:40+ *Azospirillum*	9.58	15.55	19.79	14.97	1.13	0.93	1.05	108.42	139.59	207.94	151.98
T_6: 50:40:40 + *Azospirillum*	9.70	14.73	20.11	14.84	1.11	0.92	1.05	114.73	144.09	205.61	154.81
T_7: 100:30:40+ VAM	10.05	16.48	19.96	15.49	1.23	1.05	1.15	121.98	175.2	234.62	177.26
T_8: 100:20:40+ VAM	11.57	16.35	20.69	16.20	1.20	0.96	1.30	138.94	154.85	228.34	174.04
T_9: 75:30:40+ *Azospirillum* + VAM	11.36	18.90	22.21	17.49	1.43	0.98	1.30	152.97	191.8	261.51	197.65
T_{10}: 50:30:40+*Azotobacter* +*Azospirillum* + VAM	12.27	17.07	21.63	16.99	1.36	1.10	1.20	139.64	216.25	290.26	219.82
T_{11}: 50:20:40+*Azotobacter* +*Azospirillum* + VAM	12.51	19.17	23.03	18.23	1.46	0.98	1.21	185.36	182.1	281.86	216.44
T_{12}: 50:20:40+*Azotobacter*+ *Azospirillum* + VAM+ (Zn & Bo)	12.74	22.33	24.44	19.83	1.30	0.99	1.30	166.66	186.07	318.12	223.61
F- test	*	*	*	*	*	*	*	*	*	*	*
SEm ±	0.69	1.47	0.80	0.56	0.08	0.05	0.05	12.38	15.59	13.73	8.92
C.D. at 5%	2.02	4.32	2.37	1.66	0.25	0.16	0.13	34.32	40.74	40.28	26.16

Table 3. *Effect of Bio-fertilizers and different levels of nitrogen and phosphorus on percentage (%) principle components of rosemary oil.*

Treatments	α-pinene		1-8 Cineole		Camphor		Borneol		Verbenone	
	A	B	A	B	A	B	A	B	A	B
T_1: 100:40:40 (Control)	7.98	8.79	16.78	21.81	24.07	27.27	1.59	1.5	10.95	8.43
T_2: 100:40:40 + micronutrients (Zn & Bo)	4.39	10.74	14.27	21.17	28.97	29.01	1.21	1.52	13.56	8.33
T_3: 75:40:40+ Azotobacter	4.83	11.17	20.12	20.38	26.97	26.40	1.13	1.66	10.21	8.43
T_4: 50:40:40 + Azotobacter	8.37	10.55	14.32	21.70	30.07	28.09	1.19	1.55	16.12	8.39
T_5: 75:40:40+ Azospirillum	7.80	10.52	21.42	21.41	28.26	27.48	1.50	1.48	7.46	8.12
T_6: 50:40:40 + Azospirillum	8.45	10.84	17.91	21.99	26.25	28.47	1.78	1.65	11.60	7.56
T_7: 100:30:40+ VAM	9.49	11.19	20.39	22.89	28.63	28.06	1.10	1.63	10.26	7.66
T_8: 100:20:40+ VAM	9.42	11.06	20.32	21.47	28.27	27.30	1.61	1.58	8.90	7.20
T_9: 75:30:40+ Azospirillum + VAM	9.75	10.50	15.80	22.11	31.10	26.53	1.56	1.52	13.52	7.75
T_{10}: 50:30:40+Azotobacter +Azospirillum + VAM	9.76	11.65	17.60	21.62	26.32	27.87	1.6	1.5	10.17	7.90
T_{11}: 50:20:40+Azotobacter +Azospirillum + VAM	13.61	11.78	20.87	20.99	26.79	27.81	1.30	1.6	9.72	7.69
T_{12}: 50:20:40+Azotobacter+ Azospirillum + VAM+ (Zn & Bo)	10.22	11.19	20.15	19.42	27.61	28.01	1.15	1.46	8.72	8.84

A – First season; B- Second season

erences

it A 2001 Marketing of Medicinal Plants Paper publication at the National Seminar on Transfer of Technology of Medicinal and Aromatic Crops. Feb 20-22. pp:1-2.

anna N 2001 VAM association in Medicinal plants of South Eastern Dry Zone of Karnataka and Response of Phyllanthus amarus and Withania somnifera to inoculation with VAM fungi and plant growth promoting Rhizo micro-organisms. Ph.D. thesis, University of Agricultural Sciences, Bangalore.

njunath R 2001 Effect of bio-fertilizers on growth, yield and essential oil content in patchouli (Pogostemon patchouli Pellet.). M.Sc. Thesis, University of Agricultural Sciences, Bangalore.

k K L 1998 Inoculation effect of VAM fungi and phosphate solubilizing bacterium on growth of Java citronella (Cymbopogan winterianus Sowit). M.Sc. thesis, University of Agricultural Sciences, Bangalore.

ana D A 1998 Influence of VAM fungi, and nitrogen fixing and mycorrhization helper bacteria on growth of neem (Azadirachta indica A. Inss.). Ph.D. thesis, University of Agricultural Sciences, Bangalore.

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Production strategies for some high-value essential oils in south India

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Abstract

Essential oil production is gaining importance in south India. Crop diversification, lower returns from several plantation crops and diverse use of essential oils in phytopharmaceuticals and aromatherapy besides their traditional uses in perfumes, cosmetics and flavours have triggered greater interest in the production of quality essential oils in India, especially in south India. CIMAP has generated knowledge and technologies for several commercially viable essential oils in south India. In the present paper some high-value and potential essential oil crops have been discussed. Production strategies for essential oil-bearing crops such as rosemary, coriander, geranium and patchouli have been highlighted. These crops require specific management systems both for field production and distillation. Recent technologies developed by CIMAP for cultivation as well as distillation of these essential oils for these crops have been highlighted.

Rosemary

Rosemary (*Rosmarinus officinalis* L.) is an evergreen, woody aromatic herb with lavender like leaves is valued for its essential oil. It is basically a Mediterranean plant which grows widely in Spain, France, Italy, Algeria and Portugal and to some extent in USA and Yugoslavia. The plant is distilled for rosemary oil which has a characteristic aroma. The leaves of rosemary are used for culinary purpose and rosemary was reported to have medicinal properties such as carminative, stomachic, spasmodic. The leaves were reported to possess antioxidant properties and are used to preserve foodstuffs, especially for the control of *Salmonella* infections in meat products. The antioxidant properties of rosemary extracts have been attributed to its major diterpene, carnosic acid (Bosch & Alegre, 2001). Rosemary oil is also used in Aromatherapy.

Chemistry

Generally two types of rosemary oils have been reported to exist; one with high cineole content which grows mostly in Greece, France, Tunisia and Italy (Lawrence, 1997) and another with low cineole content which grows mostly in Spain, Yugoslavia and some parts of Italy (Lawrence, 1995). Lawrence (1997) reported another rosemary oil with high α–pinene (24-26%) and verbenone (22-27%) contents from Algeria and Carsica. Rosemary oil consists of nearly 200 compounds; the major types of compounds are : aliphatic compounds (10-20), monoterpenes (20-25), 1, 8-cineole (1), monoterpene alcohols (5-10), monoterpene acetates (2-5), monoterpene carbonyls (5-10), sesquiterpenes (15-20), sesquiterpene oxygen derivatives (5-10), benzenoid compounds (5-10), trace compounds (5-10) (Beolens, 1985).

Agronomy

Rosemary has been recently introduced in the agro-climate of Bangalore. The crop could be successfully cultivated in the red soils of semi-arid tropical conditions of Bangalore. Appropriate plant spacings and N applications are needed for deriving high yields of rosemary. A plant spacing of 45 cm x 45 cm in combination with 300 kg N/ha/year resulted in the highest yields of rosemary over three harvests (Table 1).

Table 1. Effect of plant spacing and nitrogen on rosemary

Plant spacing (cm)	Nitrogen level (kg/ha/yr)			
	0	100	200	300
	Herb yield (t/ha/3 harvests)			
45 x 45	25.7	28.9	28.8	57.5
60 x 45	28.1	25.8	32.4	33.6
60 x 60	19.0	19.4	28.7	25.9

C.D. $_{5\%}$ = 14.1. (Source : Prakasa Rao *et al.,* 1999)

The oil content was not affected by either plant spacings or nitrogen applications, which ranged from 0.5 and 0.6 per cent. Field distillation was standardized for this crop with the oil recovery ranging from 0.5 to 0.9 percent with most of the oil recovered within 60 min (Table 2). The early fractions (≤ 60 min) of rosemary oil contained relatively higher concentrations of α–thujene, α-pinene, camphene, β-pinene and 1,8-cineole as compared with later fractions (≥ 60 min) which contained more camphor and bornyl acetate.

Table 2. Recovery pattern and chemical composition of distillation fractions of rosemary oil

Time of distillation (min)	Oil recovery (% of total)	α-thujene	α-pinene	Camphene (% oil)	β-pinene	1,8-cineole	Camphor	Bornyl acetate
0-30	7.9	0.2	15.6	7.8	3.4	30.5	22.2	1.8
30-60	82.1	0.2	16.8	8.7	3.9	30.3	20.8	0.7
60-90	8.0	-	5.7	3.4	1.6	16.4	33.4	7.3
90-120	2.0	-	3.4	2.1	1.0	10.9	26.2	7.9
Composite	-	0.2	15.7	8.2	3.6	29.2	22.1	3.2

Scented geranium (*Pelargonium sp.*)

Scented geranium (*Pelargonium sp.*) is an important aromatic plant introduced in India in the early 1990s by the French. It was introduced in Shevroy hills, but later it was cultivated widely in Nilgiris and Palani hills of Tamil Nadu and recently in the plains of Karnataka, Andhra Pradesh, Maharastra and Uttar Pradesh. More recently it has been introduced in the hills of Uttaranchal by CIMAP. Now in India, two types of the crop namely Algerian/Tunisian and Bourbon/Reunion are generally cultivated. Recently, another type called Kelkar/Egyptian type was also introduced. Geranium oil obtained by steam distillation of fresh herb of geranium is widely used in expensive perfumery and a value added product, rhodinol prepared from this oil.

Chemistry

Geranium oil contains a number of compounds of value in perfumery and fragrances. Recently, Lawrence (1999) compiled analytical data of geranium oils of different origins (Table 1). He examined geranium oil of various origins and found as many as 22 esters in the oils. Composition of two types of geranium oil produced in Bangalore is presented in Table 2 and the chemical composition of these two types of geranium (Bourbon and Kelkar) seems to vary according to seasonal and environmental conditions (Prakasa Rao *et al.* 1995).

Table 1. Comparative percentage composition of geranium oils of different origins

Compound	Bourbon	China	Algeria	Egypt	Morocco	Rwanda
trans-rose oxide	0.21	0.64	0.37	0.34	0.38	0.11
menthone	1.50	1.41	0.88	1.31	0.78	0.20
isomenthone	7.20	5.70	5.38	5.39	5.20	7.00
linalool	12.90	3.96	5.26	9.47	6.80	3.50
guaia-6, 9-diene	3.90	4.40	0.18	0.27	0.15	3.30
citronellol	21.28	40.23	22.90	27.40	19.30	11.30
geraniol	17.45	6.45	17.10	18.00	18.40	5.10
citronellyl formate	8.37	11.35	7.57	6.74	6.02	0.10
citronellyl butyrate	1.26	0.52	1.14	0.75	1.07	0.40
geranyl formate	7.55	1.92	5.90	4.75	6.55	0.20
geranyl acetate	0.39	0.10	1.08	0.61	1.06	0.40
geranyl tiglate	1.34	0.98	2.55	1.48	2.24	0.55
geranyl butyrate	1.04	1.32	1.65	1.09	2.44	2.00
2-phenylethyl tiglate	0.43	0.60	0.76	0.65	1.04	1.00

(Source : Lawrence, 1999)

Agronomy

Agronomy of scented geranium has been standardized for different agro-climatic regions of south India (Narayana *et al.* 1986). Studies on agrotechnologies in north Indian plains have been conducted (Ram *et al.* 1997). Recent developments in agrotechnologies for geranium cultivation in India have been reviewed (Sastry *et al.* 2001, Rajeswara Rao, 2000). Distillation methods have been standardized by CIMAP and recently CIMAP has developed an improved design of distillation unit which increases the geranium oil recovery by 31% and saves 40% fuel (CIMAP, 1999). Studies conducted at CIMAP, Field Station, Bangalore have suggested that most of the oil is recovered within 60 min of distillation and the proportion of geraniol/citronellol changes in various distillation fractions (Table 3) (E.V.S.Prakasa Rao, unpublished). Plant diseases can be limiting factors in the production of geranium oil in the plains of south India. Root rot and wilt disease caused by *Rhizoctonia solani* can be minimized by planting geranium crop in winter and summer planting had increased the disease incidence by 60-70% compared to winter planting (Kalra *et al.* 1992a). Leaf blight of geranium can also cause some economic losses of geranium in south Indian plains and it can be controlled by Captafol (Kalra *et al.* 1992b). Scented geranium can be successfully cultivated as an alternate crop in south Indian hills and plains to derive higher net returns from land.

Table 2. Chemical composition of two types of geranium oil produced in Bangalore

Compound	Kelkar type	Bourbon type
α-pinene	0.05	0.33
β-pinene	0.12	0.14
myrcene	0.45	0.29
α-phellandrene	0.57	0.09
p-cymene	0.11	0.04
limonene	0.48	0.19
(Z)-β-ocimene	0.24	0.12
(E)-β-ocimene	0.35	0.24
cis-linalool oxide (furanoid)	0.08	0.37
trans-linalool oxide (furanoid)	0.06	0.18
terpinolene	0.02	0.20
linalool	17.45	6.33
cis-rose oxide	0.05	1.16
trans-rose oxide	0.04	0.49
menthone	0.34	0.43
isomenthone	9.90	7.66
α-terpineol	0.66	0.35
citronellol + nerol	8.73	29.45
neral	0.04	17.11
geraniol	43.64	
geranial	-	0.37
citronellyl formate	-	6.93
neryl formate	-	0.19
geranyl formate	0.03	0.03
citronellyl acetate	0.18	3.67
geranyl acetate	0.17	0.45
α-ylangene	0.04	0.09
α-copaene	0.10	0.20
β-bourbonene	0.51	0.83
β-caryophyllene	0.15	0.48
citronellyl propionate	0.06	0.06
guaia-6, 9-diene	2.18	0.06
α-humulene	0.08	0.08
geranyl propionate	0.93	0.37
germacrene D	0.06	0.24
citronellyl butyrate	0.07	0.11
geranyl butyrate	0.64	0.81
2-phenylethyl tiglate	0.60	1.10
10-epi-γ-eudesmol	3.05	6.37
citronellyl tiglate	0.62	1.89
geranyl tiglate	1.65	1.78

(Source : Mallavarapu *et al.* 1993)

Table 3. Recovery pattern and chemical composition of distillation fractions of geranium oil

Time (min.)	% Total oil recovered	Ratio of geraniol/citronellol
0-30	72.8	0.70
30-60	15.6	0.77
60-90	7.8	0.72
90-120	3.9	0.67
Composite	0.12*	0.72

* Total recovery of geranium oil from herb

Patchouli (Pogostemon cablin)

Patchouli (*Pogostemon cablin*) is a perennial, aromatic plant which yields patchouli oil on steam distillation of shade-dried leaves. Patchouli is a native of Philippines and is cultivated widely in Indonesia, Malaysia, China and Brazil. Indonesia is a major producer of patchouli oil. In India, very meager quantities of patchouli oil are produced and most of the indigenous requirement of nearly 60 t/annum is imported. It is estimated that the domestic requirement is increasing and 30t of patchouli oil is targeted to be produced by 2005 (Varshney, 2000). There is a great potential to cultivate patchouli as an intercrop in the existing plantations in south India.

Chemistry

A typical Indonesian patchouli oil contains monoterpene hydrocarbons (1.0%), sesquiterpene hydrocarbons (62.0%), oxygenated constituents (37.0%), patchouli alcohol (33.5%), norpatchoulenol (1.1%). This information is useful especially to detect adulteration of patchouli oil (Hefendehl, 1977). Lawrence (1990) examined some samples of patchouli oil of different origins (Table 1). Mookherjee *et al.* (1981) examined the odouriferous portion of patchouli oil which contained β-elemene (1%), caryophyllene (20%), α-guaiene (15%), α -bulnesene (25%), α -guaiene oxide (1%), α-bulnesene oxide (4%), caryophyllene oxide (2%), norpatchoulnol (0.5%), patchouli alcohol (30%), pogostol (1%) and nortetrapatchoulol (0.001%). Chemical composition of pathcouli oil produced from a crop grown at CIMAP, Field Station, Bangalore is given in Table 2.

Table 1. Comparative chemical composition of Patchouli Oil

Compound	1	2	3	4
α-pinene	0.07	0.11	0.03	0.06
β-pinene	0.19	0.30	0.07	0.13
β -patchoulene	2.64	1.97	3.88	6.66
α -gurjunene	2.80	0.36	-	-
β -elemene	0.54	0.65	0.64	0.66
α -guaiene	*11.48*	*13.52*	*15.64*	*11.68*
caryophyllene	3.50	4.20	3.70	2.47
α -patchoulene	3.80	4.47	5.33	5.38
seychellene	10.35	8.84	9.78	12.94
cycloseychellene	0.26	0.24	0.30	0.17
δ-cadinene	1.87	2.37	2.84	1.99
caryophyllene oxide	0.54	0.85	0.58	0.57
α -bulnesene	14.73	16.65	19.67	14.44
1,5-epoxy-α-guaiene	0.10	0.10	0.10	0.10
1, 10-epoxy-α-bulnesene	0.47	0.26	0.21	0.52
norpatchoulenol	0.48	0.79	0.53	0.68
patchouli alcohol	29.66	29.69	25.69	23.82
pogostol	2.59	2.33	1.68	1.57

1= Commercial Sumatran Oil ; 2 = Commercial Javan oil; 3 = West Indian oil; 4 = Costa Rican oil
(Source : Lawrence, 1990)

Table 2. Chemical composition of patchouli oil produced at Bangalore

1. α-patchoulene	3-5%
2. Caryophyllene	2-5%
3. α-guaiene	10-13%
4. α-δ-patchoulene	5-7%
5. Seychellene	4-7%
6. α-bulnesene	11-18%
7. Patchouly alcohol	28-35%

Agronomy

Agrotechnology for the cultivation of patchouli oil in south India has been developed by CIMAP (CIMAP, 1983). Since patchouli is a shade loving crop, it has been suggested to be grown in existing plantation crops as an inter crop. However, patchouli is perceived as a soil-exhausting crop. Therefore, soil fertility management is important in the cultivation of patchouli. Recent studies made on the effect of shade on patchouli have revealed that patchouli leaves contained 67% more chlorophyll under shaded environment (Prakasa Rao *et al.* 1997). Also, the shade increased the oil content and the contents of α-guainene, seychellene and α-bulnesene whereas the patchouli alcohol content reduced in the oil. Application of 200 kg N/ha/year has increased patchouli yields in red sandy-loam soils in semi-arid tropics (Prakasa Rao *et al.* 1998). Water management studies conducted on patchouli in a semi-arid tropical environment has shown that alternate or alternating furrow irrigation methods were found superior to flat bed method (Table 2). It has been observed that patchouli is very sensitive to soil moisture saturation even for short periods. The improved irrigation methods can save considerable (nearly 50%) amount of water.

Table 2. Effect of different irrigation methods on yield of patchouli

Irrigation method	Herb yield (t/ha/2 harvests
Flat bed	8.9
Alternate furrow	12.3
Alternating furrow	11.1
L.S.D. (P=0.05)	1.52

(Source : Prakasa Rao *et al.* 1998)

Harvesting, drying and distillation methods for the extraction of patchouli oil have been standardized at CIMAP. Patchouli has to be distilled for more than 6 hrs. Though most of the oil is recovered within 3-4 hours of distillation, the later distillation fractions contain more patchouli alcohol (nearly 50%) compared to the normal content of about 30% in the patchouli oil (E.V.S.Prakasa Rao, unpublished data).

Patchouli holds a great promise as an intercrop in the existing plantation crops in south India.

Coriander (Coriandrum sativum)

Coriander (*Coriandrum sativum* L.) is an annual herb grown for its leaves, seeds and their essential oil and oleoresins. Coriander is extensively cultivated in India, Russia, Central Europe, Morocco and south western Australia. The coriander grown in Russia and Central Europe (var. macrosporum) has smaller fruits (< 3 mm size) and contains more essential oil than the oriental variety, vulgare (> 3 mm size) which is cultivated for fruit and leaves. They are extensively used for grinding and blending purpose in spice trade. Gujarat, Rajasthan and Andhra Pradesh are the major producers of coriander (Kalra *et al.* communicated). Coriander leaves and seeds are used for culinary flavouring purposes. Essential oil extracted from coriander seeds is used to flavour alcoholic beverages, candies, meat, sauces, tobacco, liquors. Also, coriander oil is used in aromatherapy. The coriander oil also possesses anti-microbial activity.

Chemistry

Lawrence (2001) reviewed the chemical composition of oils of coriander. Worku and Franz (1997) compared the composition of oils obtained from leaves, stems and dried fruits of coriander and found that the fruit has linalool as a major constituent (85.7%) while leaf oil had (E)-2-decenol (49.2%) and decanal (27.3%) as major compounds and the stem oil had (E)-2-decenol (50.8%) and decanol (16.6%) as major compounds. Bandoni *et al.* (1998) compared the composition of coriander oil produced by hydrodistillation and steam distillation and found that they were quite similar. They also compared the composition of a typical coriander oil sample and aged oils whose flavours had deteriorated. In the aged oils, there was a significant decrease in the contents of linalool and γ-terpinene while the contents of linalool oxides and p-cymene have significantly increased. Anitescu *et al.* (1997) examined by GC-MS the comparative chemical composition of coriander oil produced by steam distillation and supercritical fluid CO_2 extraction (SFE). They observed that the most desired oxygenated compounds were higher in oil obtained by SFE process and the aroma of this oil was more intense. Chemical composition of a sample of coriander seed oil produced at CIMAP, field station, Bangalore is given in Table 1.

Table 1. Chemical composition of coriander seed oil produced at Bangalore

Component	Concentration %
α-Pinene	0.5
Limonene	0.5-1.0
γ-Terpinene	0.5-1.5
Linalool	75-80
Camphor	0.5-2.0
Geraniol	1-3
Geranyl acetate	3-6

(Source : S. Ramesh, personal communication)

Agronomy

Indian coriander genotypes are poor in essential oil (0.1-0.4%) and therefore are not considered for cultivation as essential oil crop. CIMAP developed a superior line, S-33 of coriander rich in essential oil (Dimri and Narayana, 1992) and a few lines were further developed at CIMAP which are rich in essential oil and resistant to major diseases (Kalra *et al.* communicated). Agrotechnology of coriander is described (Dimri and Narayana, 1992). Incidence and severity of powdery mildew (*Erysiphe polygoni*) is reduced when the crop is sown early in October (Kalra *et al.* 1997). Application of fertilizers, especially N fertilizers, has increased the yields of coriander seed and oil without affecting the quality of oil (Prakasa Rao *et al.* 1983) (Table 2).

Kalra *et al.* (communicated) reviewed the research done on pests and diseases of coriander. Among insect pests, aphids (*Aphis gossypii*) are major problem which can be controlled by spraying 0.1% monocrotophos or Rogor. Powdery mildew caused by *Erysiphe polygoni* and stem gall caused by *Protomyces macrosporus* are common diseases. An integrated approach to control powdery mildew in essential oil rich cultivars with minimal number of dinocap sprays has been developed at CIMAP by integrating resistant lines, time of application of dinocap and time of sowing. CIMAP is developing some lines of coriander which are resistant to stem gall.

Table 2. N application on seed and oil yields and quality of coriander

N level	Seed yield (kg/ha)	Essential oil yield (kg/ha)	Linalool concentration (%)
0	668	9.3	62.4
50	846	11.9	61.0
100	851	11.9	59.2

(Source : Prakasa Rao *et al.* 1983)

Coriander oil is obtained by steam distillation of the seeds. Grinding of the seed prior to distillation increased the yield of oil by 17-21% and saved 10-15% of steam when compared to the distillation of whole seed. Crushed seed reduced the distillation time by 3-4 hours from the usual time of 12-15 hours (Guenther, 1950).

References

Anitescu G C, Doneanu & Radulescu V 1997 Isolation of coriander oil : Comparison between steam distillation and supercritical fluid extraction. Flav. Fragr. J. 12 : 173-176.

Bandoni A l, Mizrahi &.Juanez M A 1998 Composition and quality of the essential oil of coriander (*Coriandrum sativum* L.) from Argentina. J. Essent. Oil Res. 10 : 581-584.

Boelens M H 1985 The essential oil of *Rosmarinus officinalis* L. Perf. & Flav. 10 : 21-37.

CIMAP 1983 Central Institute of Medicinal and Aromatic Plants, Lucknow. Patchouli and its **cultivation in** India. Farm Bulletin No. 17.

CIMAP 1999 Central Institute of Medicinal and Aromatic Plants Newsletter 26(1 & 2) : 12.

CIMAP 2001 Central Institute of Medicinal and Aromatic Plants. Annual Report (2001-2002) p. 114.

CIMAP 2002. Central Institute of Medicinal and Aromatic Plants. Annual Report (2000-2001) p. 112.

Dimri B P & Narayana M R 1992 Cultivation of coriander in India. Farm Bulletin No. 23, CIMAP pp 8.

Guenther E 1950 The Essential Oils. Vol. IV. D. Van Nostrand Co. Inc., Princeton, NJ. p. 607.

He fendehl F W 1977 Die Analytische bewertung von patchouliol. Kosus. Aerosol. 50 : 159-161.

Kalra A, Agarwal K K, Gupta A K & Khanuja S P S *Coriander as an essential oil crop* (Communicated).

Kalra A, Parameswaran T N & Ravindra N S 1992a Influence of *planting* date on plant losses and yield response of geranium (*Pelargonium graveolens*) to root rot and wilt. J. Agric. Sci. Camb. 118 : 309-314.

Kalra A, Parameswaran T N, Ravindra N S & Singh H B 1997 Influence of planting dates on powdery mildew in coriander cultivars. Tropical Cropology, 1 : 53-58.

Kalra A, Parameswaran T N & Ravindra N S 1992b Fungicidal control of leaf blight of geranium (*Pelargonium graveolens*). Indian J. Agric. Sc. 62(12) : 844-7.

Lawrence B M 1990 Patchouli oil. Progress in Essential oils. Perf. & Flav. 15 : 76-77.

Lawrence B M 2001 Progress in Essential Oils. Perf. & Flav. 26 : 44-48.

Lawrence B M 1977 Progress in Essential Oils. Perf. & Flav. 22 : 71-73.

Lawrence B M 1995 Progress in Essential Oils. Perf. & Flav. 20 : 47-50.

Lawrence B M 1999 Geranium oil : Progress in Essential Oils. Perf. & Flav. 24 : 56-60.

Mallavarapu G R, Prakasa Rao E V S, Ramesh S & Narayana M R 1993 Chemical and Agronomical Investigations of a New Chemotype of Geranium. J. Essent. Oil Res. 5 : 433-438.

Mookherjee B D, Light K K & Hill I D 1981 A study on the odor-structure relationship of patchouli compounds in essential oils. B.D.Mookherjee and C.J.Mussivan eds. Allured Publ. Corp. Wheaton, ILL.

Munne-Bosch S & Alegre L 2001 Subcellular compartmentation of the diterpene carnosic acid and its derivatives in the leaves of rosemary. Plant Physiol. 125(2) : 1094-1102.

Narayana M R, Prakasa Rao E V S, Rajeswara Rao B R & Sastry K P 1986 Geranium cultivation in India : Potentials and Prospects. *Pafai J.* 8 : 25-30.

Prakasa Rao E V S, Narayana M R & Ramesh S 1997 Influence of shade on yield and quality of patchouli (*Pogostemon cablin*) oil. Indian Perf. 41(4) : 164-166.

Prakasa Rao E V S, Puttanna K, Singh M & Ganesha Rao R S 1998 Nutrient and water management for sustainable production of aromatic plants in red soil region of semi-arid tropics. In : Proc. Natl. Sem. On Water and Nutrient Management for Sustainable Production and Quality of Spices. Eds. A.K.Sadanandan *et al.* pp. 80-84.

Prakasa Rao E V S. Ganesha Rao R S & Ramesh S 1999 Agronomic and distillation studies on rosemary (*Rosmarinus officinalis* L.) in a semi-arid tropical environment. J. Herbs, Spices & Med. Plants. 6(3) : 25-30.

Prakasa Rao E V S, Ganesha Rao R S & Ramesh S 1995 Seasonal variation in oil content and its composition in two chemotypes of scented geranium (*Pelargonium* sp.) J. Ess. Oil Res. 7 : 159-163.

Prakasa Rao E V S, Gopinath C T & Ganesha Rao R S 1998 Alternate furrow irrigation for geranium (*Pelargonium graveolens*) and patchouli (*Pogostemon cablin*). J. Med. Arom. Pl. Sci. 20 : 1036-1037.

Prakasa Rao E V S, Singh M, Narayana M R, Ganesha Rao R S & Rajeswara Rao B R 1983 Fertiliser studies in coriander (*Coriandrum sativum* L.) J. Agric. Sci. Camb. 100 : 251-252.

Rajeswara Rao BR 2000 Rose-scented geranium : Indian and international perspective. J. Med. Arom. Pl. Sci. 22 : 302-312.

Ram M, Singh R, Naqvi, A A & Kumar S 1997 Effect of planting time on the yield and quality of essential oil in geranium (*Pelargonium graveolens*). J. Hortl. Sci. 72 : 807-810.

Sastry K P, Prakasa Rao E V S, Rajeswara Rao B R, Muni Ram & Kumar S 2001. Prospects of cultivation of geranium (*Pelargonium sp.*) in India. *In* . Proc. Natl. Symp. on Transfer of Technology of Medicinal & Aromatic Plants, Bangalore, pp. 134-142.

Varshney S C 2000 Vision 2005 : Essential oil industry of India. Indian Perf. 44(3) : 101-118.

Worku T & Franz Ch. 1997. Essential oil yield from different plant organs and various coriander accessions. In : Proc. 27th Intern. Symp. On Ess. Oils, Vienna 1996 (Eds) Ch. Franz *et al.* pp 333-336, Allured Publ, Carol Stream, IL.

11

Effects of organic amendments on yield and quality of black pepper

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Abstract

Experiments conducted at IISR Calicut to study the effect of agricultural lime and organics for bush black pepper during 1993-96 in an acid red laterite soils are discussed. Application of lime at ¾ lime requirement of soil increased the soil pH and yield of black pepper. Further liming decreased soil availability of Fe, Mn and Zn. Studies on the effect of different organic sources to bush black pepper showed that chicken and goat manures are efficient organic sources and are comparable with inorganic NPK fertilizers for increasing yield of black pepper. Pig manure followed by goat manure influenced the oleoresin and piperine content of black pepper.

Key words: bush black pepper, lime, oleoresin, organic manures, piperine, yield.

Introduction

India is the world's largest consumer and exporter of Black pepper. It accounts for more than 40% of the export earnings from all the spices. To meet the international and national demands, an annual growth rate of 4-5% is envisaged (Spices Board, 1997). Pepper growing soils are acidic. Acidity increases with the removal of bases from the soil, when precipitation exceeds evaporation. Application of ammoniacal fertilizer N, further aggravates the soil acidity. Deficiency of Calcium, Magnesium and Al toxicity are the major yield- limiting factors in pepper growing acid soils of low pH (Sadanandan, 2000). Over liming causes Zn deficiency in crops (Boswell et al. 1989). Computation of lime required for neutralizing acid soils, economizes the use of lime. Theoretical calculations of acidity (Shoemaker et al 1961) and application of lime to neutralize the acidity, increases the nutrient availability and crop yields (Gary et al 2001). Lime application has little or no effect for black pepper. (Pillai, et al 1979). Continuous cropping and improper management depletes the soil of its organic matter status that warrants judicious application of organic for sustainable black pepper production. Application of organics enhances the soil pH (Joann et al 2000). Judicious application of amendments, in the wake of the increase in cost of inputs assumes importance. The literature reveals very little information on the effects of organic amendments on yield and quality of pepper in acid soils. The objectives were to determine the optimum liming rates and the best organic sources needed for pepper growing acid soils, for increasing soil nutrient availability and to realize economic yield with quality.

Materials and methods

Experiments were conducted for three consecutive years (1993-'96) in a red lateritic soil, sandy clayey loam texture, having soil pH 5.5, available N, P, K, Ca, Mg, Fe, Mn, Zn, status 68, 16, 44, 607, 46,25, 9, 1.5 mg kg^{-1} respectively under poly house condition at the IISR Experimental Farm, Peruvannamuzhi. The soils were air dried, ground, passed through 2mm sieve and filled at

10kg soil, in earthen pots of 30cm dia. lined with polythene sheet. Three-month-old laterals of bush pepper Cv Karimunda was used as test crop. To studying the effect of lime, the lime requirement of soil, SMB buffer method (Shoemaker et al 1961) was adopted. From the value the amount of lime required for full neutralization of soil was worked out. The treatment consisting of ¼, ½, ¾, and full neutralization points. The quantity of lime so worked was applied and mixed uniformly with the soil. There were five treatments including an untreated control (UC). The design of the experiment was CRD. To studying the effect of organics, four manures *viz.* goat manure (GM), chicken manure (CM), pig manure (PM), farmyard manure (FYM) were used. This was compared with chemical fertilizers (CF) and an untreated control (UC). These manures vary considerably in their physical, chemical and biological properties. The manures were applied based on their N equivalents. Soils samples surface to15cm depth was drawn using soil augur, during March 1995 and 1996 and analyzed for pH, N, P, K, Ca, and Mg by adopting standard procedures (Hesse, 1971). Micronutrients Fe, Mn and Zn were analyzed using AAS. The berry samples collected at crop maturity were dried, powdered and analyzed for oil, oleoresin and piperine content (ASTA, 1967). The data were analyzed statically.

Results and Discussion

Effects of liming on soil availability of nutrients and yield

Data (Table 1) showed that increasing doses of lime significantly increased soil pH, Ca and Mg. The optimum level of lime required was ¾ of lime requirement of the soil and beyond this, the level of soil Zn, Fe and Mn are significantly reduced. Application of lime at full neutralization point though scored maximum yield, the level was on par with lime application at ¾ neutralization point. The importance of liming acid soils to counteract the harmful effects of soil acidity and in managing acid soils in several crops has been reported by many workers. However, Pillai et al 1979, reported that liming has little effect in black pepper, perhaps lime was applied to the soil arbiterally and not on the basis of lime requirement of the soil. The data showed the value of liming acid soils and the rate of application depends up on the degree of acidity. Lime is needed to neutralize the soil pH, augment the nutrient availability, and optimize the yield and quality of the produce. The approach would be to analyze the soil and apply moderate quantities of lime to maintain soil surface pH near neutral.

Effects of different sources of organics on soil nutrient availability and yield

Data (Table 2) showed that irrespective of the sources, application of organic and / or inorganic fertilizers significantly increased the availability of nutrients in the soil compared to untreated control. Among the organics, poultry manure followed by goat manure was superior in increasing in nutrient availability in the soil and yield of black pepper. Pig manures registered maximum Mg availability in the soil. This underlines the significance of organics in acid soils. The effect of organics in increasing the nutrient availability in the soil and yield of pepper was persistent over the years. (Table 3). Though maximum yield was registered by fertilizers treatments, it was on par with chicken manures. Many workers reported that application of organics do play on the quality of crops. Application of organics affects the nutrients to the crops either by controlling directly to the nutrient pool or indirectly by influencing soil chemical and physical environment (Sean clark et al 1998). Among the organic sources, pig manure though influenced oleoresin and piperine in pepper marginally; the differences were not significant statistically.

Table 1. Effect of lime on soil pH, availability of nutrients (mg kg^{-1}) and yield (g pot^{-1}) of black pepper

Treatment	Soil nutrient availability (mg kg^{-1})									Yield (g pot^{-1})		
	pH	N	P	K	Ca	Mg	Fe	Mn	Zn	1995	1996	Mean
UC	5.7	88	27	85	608	46	25	8.6	1.5	60	66	63
Lime @ ¼	6.5	73	28	83	708	60	23	6.0	1.3	140	153	147
Lime @ ½	6.8	78	30	85	1092	66	18	5.8	1.3	141	204	174
Lime @ ¾	6.9	78	35	82	1238	67	15	5.3	1.3	152	229	190
Lime @ Full	7.2	84	33	83	2247	72	13	5.0	1.2	155	230	192
CD 5%	0.15	NS	NS	NS	176	25	4.8	3.1	NS	12.7	11.5	8.3

Table 2. Effect of different sources of organic manures on soil pH and nutrient availability in bush pepper growing pot (mg kg^{-1})

Treatments	Soil availability nutrients							
	pH	N	P	K	Ca	Mg	Fe	Mn
UC	6.1	85	14	42	510	41	25	7.6
GM	6.2	102	41	274	589	82	27	15.8
CM	6.2	106	41	276	546	87	28	17.3
PM	6.1	93	33	251	617	90	26	17.3
FYM	6.2	93	33	260	575	78	26	18.3
CF	6.2	99	71	274	726	53	25	8.1
CD 5%	NS	NS	6	18	176	25	2.6	1.5

Table 3. Effect of different sources of organic manures on yield and quality of black pepper

Treatments	Yield (g/bush)			Quality (%)		
	1995	1996	Mean	Oil	Oleoresin	Piperine
UC	53	60	57	4.0	13.1	5.8
GM	111	227	169	3.3	12.5	6.0
CM	130	231	181	3.1	11.2	4.3
PM	95	199	147	3.3	13.6	6.2
FYM	90	203	147	3.3	9.6	4.8
CF	157	211	185	3.3	10.7	4.7
CD 5%	13.2	9.1	7.5	NS	NS	NS

Reference

ASTA 1968. American Spice Trade Association (ASTA). Official Analytical Methods. 2nd Edn. ASTA, New York, 38 p.

Boswell, F.C., M.B. Parker, and T.P.Gaines. 1989. Soil Zn and pH effects on Zn Concentration of Corn Plants. Commun. Soil Sci. Plant Anal. 20: 1575-1600.

Gary J. Gascho and Myron B. Parker 2001. Long Term Liming Effect on Coast Plain Soils and Crops. Agron. J. 93: 1305-1315

Hesse, P.R. 1971. *A textbook of soil chemical analysis.* John Murray (publishers) Ltd. London, 520 p.

Joann K. Whalen, Chi Chang, George W. Clayton, and Janna P. Care foot. 2000. Cattle manure amendments can increase the pH of Acid Soils. Soil Sci. Soc. Am. J. 64: 1962-1966.

Pillai, V.S., Chandy, K.C., Sasikumaran, S. and Nambiar, P.K.V. 1979. Response of Panniyur-1 variety to nitrogen and lime application. Indian Cocoa, Arecanut and Spices J., 3(2), 35-38.

Sadanandan, A. K. 2000. Agronomy and nutrition of black pepper. In: Black Pepper (Ed.) Ravindran, P. N., Harwood Academic Publishers, New Delhi, pp: 163-223.

Sean Clark, M, William R. Horwath, Carol Shennan and Kate, M. Scow. 1998. Changes in soil chemical properties resulting from organic and low input farming practices, Agronomy J. 90: 662-671.

Shoemaker, H.E. E.O., McLean, and P.F. Pratt. 1961. Buffer methods of determining lime requirements of soils with appreciable amounts of extractable aluminum. Soil Sci. Soc. Amer. Proc. 25: 274- 277

Spices Board 1997. Area and production of spices in India and World, Spices Board, Cochin, 133p.

12

Studies on the effect of different spacing on yield and quality on pepper var. Panniyur-1

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Abstract

An experiment was conducted at Horticultural Research Station, Pechiparai to standardise the spacing requirement for pepper var. Panniyur-1 under high rainfall zone with three levels of spacing viz., 2 x 2m (check), 3 x 3m and 4 x 4m. The studies revealed that 3 x 3m was the optimum spacing with the highest yield of 1.56 kg of dry pepper per vine compared to the check 2 x 2m spacing which registered dry pepper yield of 0.730 kg/vine.

Key words: pepper, spacing, yield.

Introduction

Black pepper (*Piper nigrum* L.) the king of spices is one of the important and earliest known spices produced and exported from India. India is exporting about 32,000 MT of black pepper and earning a foreign exchange of Rs.11,106 lakh rupees. It is cultivated in an area of 1,74,000 ha in India. Normally, pepper vines are trained on arecanut, coconut and forest trees. As a pure crop it is trained in *Erythrina indica* and recent past no spacing trial was conducted to standardise the optimum spacing for pepper var. Panniyur-1 under high rainfall zone. Hence, this investigation was carried out at Horticultural Research Station, Pechiparai in order to standardise the optimum spacing for pepper var. Panniyur-1.

Materials and Methods:

This spacing trial was carried out at Horticultural Research Station, Pechiparai during 1994-2000 to find out the optimum spacing for pepper var. Panniyur-1 under high rainfall zone. The experiment was laid out in randomised block design with three treatments and five replications. The treatment comprised of three spacing levels *viz.*, 2 x 2m (T_1), 3 x 3m (T_2) and 4 x 4m (T_3). Standard cultural practices recommended for pepper was followed uniformly for all experimental plots. The growth and yield data were recorded for four consecutive years from third year onwards and statistically analysed (Panse and Sukhatmae, 1985).

Results and Discussion

Growth: Different spacing levels significantly influenced the plant height and no. of primary branches. 2 x 2m spacing recorded a highest plant height of 4.58m with a minimum of 3.4 primary lateral vines. Whereas 3 x 3m spacing recorded a plant height of 4.08m with a maximum of 4.6 primary lateral vines. The increased plant height in 2 x 2m spacing may be due to the competition for sunlight because of crowdness of vines. (Srinivasan *et. al.,* 1999)

Yield: The no. of spikes/vine, the length of spikes, weight of spikes and no. of grains and weight of the grains/spike were found to be maximum in 3 x 3m spacing. This spacing treatment recorded a maximum of 3.90 kg of wet pepper grains and 1.56 kg of dry pepper grains/vine. This was followed by 4 x 4m spacing (3.2 and 1.28 kg respectively). 2 x 2m spacing recorded a minimum of

2.65 kg of wet and 0.93 kg dry pepper/vine. The lower yield in 2 x 2mt. spacing may be due to the competition for space and nutrients. This is in agreement with the findings of Roy *et. al.*, 1980).

Table 1. Growth performance of pepper var. Panniyur-1 under different spacing levels

Treatment	Spacing levels (m)	Population/ha. (No.)	Plant height (m)	No. of primary lateral (No.)
T_1	2 x 2	2500	4.58	3.4
T_2	3 x 3	1100	4.08	4.6
T_3	4 x 4	625	3.86	4.0
CD (p-0.05)	-	-	0.25	0.42

Table 2. Effect of different spacing on the yield and yield attributes of pepper var. Panniyur-1

Treatment	No. of spikes/ vine	Length of the spike (cm)	No. of grains/ spike	Weight of grains/vine (kg)		Yield t/ha.
				Wet	Dry	
T_1	40.0	9.0	52	2.65	0.730	1.62
T_2	51.6	11.6	64	3.90	1.560	1.72
T_3	46.8	10.4	59	3.20	1.280	0.8
CD(p=0.05)	3.68	0.88	3.20	0.47	0.29	0.32

Summary

Trials conducted at Horticultural Research Station, Pechiparai to standardise the spacing requirement for pepper var. Panniyur-1 under high rainfall zone revealed that, 3 x 3m. was the optimum spacing for better growth and higher yield of 1.56 kg of dry pepper grains/vine.

References

Panse, V.G. and Sukhatmae, 1985. Statistical Methods for Agricultural Workers (4th Ed.) ICAR, New Delhi, P. 97-123.

Roy, A., S.K. Sen, and T.K. Bose, 1980. Proc. Nat. Sem. Pineapple production and utilisation, Calcutta, PP. 9-12.

Srinivasan, K, D. Veeraraghavathatham, V.Kanthasamy and S.Thiruvudainambi, 1999. Effect of spacing, training and pruning in hybrid tomato. South Indian Hort., 47 (1-b), 49 -53.

13

Prospects of pepper cultivation as a mixed crop in oil palm plantations of Andhra Pradesh

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Introduction

Pepper (*Piper nigram* L.) also known as "King of Spices" is the most important spice, originated from the west coast of India. It is mostly grown in Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. Pepper was introduced as a mixed crop in the coffee plantations of the agency areas in north coastal zone of Andhra Pradesh. It is being extensively grown as a mixed crop in the Oil Palm and coconut plantations in the nineties by the progressive farmers of Andhra Pradesh. The productivity of pepper in Andhra Pradesh has been low compared to that of Kerala.

Table 1. Area, Production and Productivity of pepper (1999) - a comparison

Country/State	Area (Ha)	Production (M.T)	Productivity (Kg/ha)
India	1,89,804	70,160	370
Kerala	1,71,230	53,830	314
Andhra Pradesh	4000	960	240

Climatic requirements of pepper

Table 2. Climatic conditions in Kerala and Andhra Pradesh – a comparison

Climate	Rainfed (eg. Kerala)	Irrigated - Andhra Pradesh
Micro-climate	Humid Tropics	Sub tropics, humid to sub humid
Rainfall (mm)	2000-3000	800-1200
Temperature	10-40 °C	20-42 °C
Relative Humidity	60-95 %	40-80 %
Altitude (m above MSL)	1,200	500-800
Latitude	20° North and South latitude	18° North
PH	4.5 – 6.0	5.5 – 8.0
Soils	Well drained loamy soils rich in organic matter	Deltaic Alluvium, red soils with clay base, red loamy coastal sands and saline soils

Climatic and soil requirements of Pepper

The Climate and soil of pepper growing areas of Kerala and Andhra Pradesh are presented in table 2. Although the rainfall in Andhra Pradesh is much less (800-1200 mm), against 2000-3000 mm per annum of Kerala, supplemental irrigation is helping in maintaining higher productivity. Further, the soils of Andhra Pradesh are less leached and have a higher soil fertility status as compared to soils of Kerala.

Package of practices followed in Andhra Pradesh

Varieties: Among the pepper varieties Panniyur –1, 2, 3, Karimunda, Sreekara and Subhakara are commonly grown.

Standards: Black pepper in Andhra Pradesh is grown in plantations of Oil Palm, Coconut, Arecanut, Coffee and Jackfruit using these trees as standards.

Planting: Planting is done with 2-3 noded cuttings each on either side of standard in North and South directions (288-300 vines/ha). Better shoot production is obtained by following "Lowering" technique. Vines are allowed climbing on standard during second year. Flowering and yield commences from third year and economic yields from fifth year onwards. Terminal shoots of the vine are trailed downwards after attaining 15-20 ft. height.

Mulch: Empty fruit bunches, male bunches, dried leaves, coconut husk, banana leaves and dried maize stalk are being used as mulch

Manuring: The fertilizer dose consists of 300 g Urea, 340 g Single Super Phosphate, 450 g Muriate of Potash per vine per year are applied in two splits. In addition 15kg well decomposed Farm Yard Manure is also recommended.

Irrigation: Majority of the farmers are following basin irrigation at weekly intervals, with total number of irrigations of 40 per year.

Plant Protection: Spraying of 1% Bordeaux mixture or Drenching with copper oxy chloride (0.2%) to check *Phytophthora* foot rot during monsoon is adopted.

Flowering: Flowering takes place through out the year due to two types of monsoons active in this area i.e South West & North East and Supplemental irrigations. Harvesting is done when 2-3 berries turn bright orange or purple. The whole spike is hand picked.

Yield: The average yield is 0.95 kgs/vine/year

The following are the strengths, weakness, opportunities and threats to grow pepper as intercrop in Andhra Pradesh

Strengths

The following are the strengths for growing pepper as mixed crop

- Potential of growing pepper as inter/mixed crop in an area of 90,000 ha (coconut) and 33,000 ha (oil palm).
- Temperature and Relative Humidity (RH) within these canopies are ideally suitable for growing pepper, as oil palm and coconut are grown under irrigated conditions
- 30-35% of Photo-synthetically Active Radiation is available at the bottom of oil palm canopy.
- Better flowering and berry development due to Southwest, Northeast and supplemental irrigation.
- Fewer incidences of pest and diseases due to lack of high RH and constant cloud cover.

Weakness

- Some of the weaknesses in pepper cultivation are

- Lack of location specific varieties.
- Lack of quality planting material.
- Lack of knowledge about package of practices.
- Lack of awareness with regard to harvesting and processing techniques.
- Minimal research efforts in evolving suitable agro-techniques.
- Less involvement / networking of marketing facilities by the commodity boards.
- Lack of concerted efforts by the developmental agencies.

Opportunities

- The opportunities with pepper cultivation are
- Well-drained and irrigated soils having perennial plantations like oil palm and coconut - suitable for shade crops.
- Maximum utilization of space and light in plantation.
- Subsidiary / additional source of income.
- 119 Cold storage units in Andhra Pradesh.
- Better marketing opportunities.
- Better scope for value addition and product diversification in view of the international market (WTO & globalization).

Threats

- Some of the threats with pepper cultivation are
- Suppression of farmers interests due to lack of production technologies at their doorsteps.
- Non utilization of potential area (non-traditional areas) may hamper foreign exchange earnings.

Conclusions

Pepper is being grown as rainfed crop in high rainfall areas. The package of practices developed so far have been specific to rainfed condition. Considering the potential of pepper under irrigated condition, there is a need to develop appropriate production practices including location specific varieties. To achieve this, establishing a field research station on pepper in Andhra Pradesh will go a long way.

Looking at the enthusiasm and innovativeness shown by Andhra farmers in adoption of pepper as mixed crop, required market network should be provided by Spices Board, Indian Pepper and Spices Traders Association and Spices Export Promotion Council etc.

Availability of technology in one hand and marketing network in another hand for pepper production in (potential) non traditional areas will pave way for increasing quality spice production and increase in foreign exchange.

References

Coconut statistics (1998) Coconut Development Board, Cochin, Kerala.

Proceedings of National Seminar on pepper held at Calicut (1977) CPCRI, Kasaragod, Kerala.

Spices indica (2001) Silver jubilee souvenir, IISR, Calicut, Kerala.

Spices Production technology (2000) eds. Madan M S and Jose Abraham, Agricultural Technology Information Centre, IISR, Calicut, Kerala.

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Organics and biofertilizers on yield and foliar nutrient uptake in black pepper (*Piper nigrum* L.)

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Abstract

A field experiment was conducted with organics and biofertilizers (*Azospirillum*, phosphobacteria and arbuscular mycorrhizal fungi) along with inorganic fertilizers in black pepper varieties Panniyur 1 and Panniyur 2. The first year data on yield indicated that the treatments had less effect on this character. However, the uptake of foliar nutrients, especially major nutrients were significantly affected by treatments. Foliar N, P and K contents recorded higher values with FYM+inorganic treatment while the uptake of Ca, Mg, S and micronutrients were better with biofertilizer treatments.

Keywords: biofertilizers, foliar nutrients, organics, yield.

Introduction

The demand for organic spices in the international market, especially in the developed countries shows an upward trend. Consumers are willing to pay a premium price for organic produces against conventional products. There is very good scope for production and export of organic spices from India thereby earn considerable foreign exchange. Among spices, black pepper is the most important item exported from India. During 1999-2000, the quantity exported was 42,806 t, which shared 18.13 per cent of the total spice export and 43.69 per cent in value terms (Rajesh *et al.*, 2002).

The use of organic manures in soil improves the physical properties of the soil and balances the nutrient availability to plants. Biofertilizers like *Azospirillum*, Phosphobacteria and AMF are capable of supplementing the chemical fertilizers and help in improving the yield and quality of crops. No detailed investigations integrating the use of organics, biofertilizers and inorganic fertilizers have so far been conducted in black pepper and so the study was undertaken in this crop to know the effectiveness of organics and biofertilizers in yield and quality improvement along with foliar nutrient uptake.

Materials and methods

The experiment was conducted at College of Horticulture, Vellanikkara, Thrissur during 2000-2001. The treatments were imposed on eight year old pepper vines, on the varieties, Panniyur 1(P_1) and Panniyur 2(P_2) in a randomized block design with nine replications. Plants were selected based on last years' yield data and those with similar yield were grouped into same block. There were 13 treatments as listed below.

T_1 - 50 per cent N as farmyard manure (FYM)+ *Azospirillum* + phosphate solubilizing microorganisms + arbuscular mycorrhizal fungi (AMF) + 100 per cent K as inorganic

T_2 - 50 per cent N as FYM + *Azospirillum* + phosphate solubilising microorganisms + AMF + 100 per cent K as wood ash

T_3 - 50 per cent N as FYM + 50 per cent N as neem cake + 100 per cent P and K as inorganic

T_4 - 50 per cent N as FYM + *Azospirillum* + 100 per cent P and K as inorganic

T_5 - 50 per cent N as FYM + *Azospirillum* + 50 per cent P as inorganic + phosphate solubilizing microorganisms + 100 per cent K as inorganic

T_6 - 50 per cent N as FYM + 50 per cent N and 100 per cent P and K as inorganic

T_7 - 50 per cent N as FYM + 50 per cent N as inorganic + phosphate solubilizing r cent K as inorganic

T_8 - 50 per cent N as FYM + 50 per cent N and P and 100 per cent K as inorganic

T_9 - 50 per cent N as FYM + 50 per cent N and P as inorganic + *Azospirillum* + phosphate solubilizing microorganisms + AMF + 100 per cent K as inorganic

T_{10} - 50 per cent N as FYM + 50 per cent NP as inorganic + *Azospirillum* + 100 per cent K as inorganic

T_{11} - 50 per cent N as FYM + 50 per cent NP as inorganic + phosphate solubilizing microorganisms and AMF + 100 per cent K as inorganic

T_{12} - Recommended Package of Practices

T_{13} - Control (No fertilizers)

Commercial cultures of *Azospirillum,* Phosphobacteria and AMF were procured from microbiology division, TNAU, Coimbatore and applied at the rate of 25g $vine^{1}$. The quantity of organics (FYM, neem cake and wood ash) to be applied wascalculated based on the nutrient content in these materials. Similarly, the quantity of N, P and K required for each treatment were fixed based on the recommended package of practices for the crop (50:50:150 g NPK $vine^{-1}$ $year^{-1}$) and applied as urea, mussoriephos and muriate of potash. Full dose of organics and biofertilizers were applied at the first week of July and chemical fertilizers in two splits, one third in July and the rest two third towards the end of September.

Fresh weight of berries was recorded immediately after threshing. Dry berry yield $vine^{-1}$ was calculated by multiplying the green berry weight with drying percentage.

Leaf samples were collected following the procedure suggested by De waard (1969). The colorimetric method suggested by Snell and Snell (1967) was employed for the estimation of total N. Phosphorus was determined colorimetrically by the vanadomolybdo-phosphoric yellow colour method using spectrophotometer (Jackson, 1973). Potassium was estimated using flame photometer (Jackson, 1973) and sulphur in the diacid was determined turbidimetrically using barium chloride (Hart, 1961). An atomic absorption specrophotometer was made use of for determining Ca, Mg and micronutrients (Page, 1982).

Results and discussion

Yield

With respect to yield, the treatments did not show statistical variation (Table1). However, T_6 (FYM + inorganics) and T_9 (FYM + biofertilizers + inorganics) in P_1 (1.323 kg and 1.355 kg respectively) and T_5 (FYM + biofertilizers + inorganics) in P_2 (2.077 kg) recorded higher yields. Treatment 8 (FYM + inorganics) recorded lower yield in both P_1 and P_2.

Table 1. Organics and biofertilizers on yield

Treatments	Dry yield (kg vine^{-1}) Panniyur 1	Dry yield (kg vine^{-1}) Panniyur 2
T_1	0.819	1.336
T_2	1.257	1.169
T_3	0.836	1.510
T_4	1.032	1.579
T_5	1.001	2.077
T_6	1.323	1.034
T_7	1.054	1.136
T_8	0.757	0.751
T_9	1.355	1.427
T_{10}	1.127	0.956
T_{11}	0.934	1.152
T_{12}	1.216	1.470
T_{13}	1.088	1.097
Mean	1.072	1.284
CD(0.05)	NS	NS

NS-Nonsignificant

The same results were obtained from the studies on integrated nutrient management in cardamom conducted at Mudigere and Pampadumpara (AICRPS, 2000). In the first year of harvest, application of organic and inorganic manures in different proportions did not give any difference among the treatments, but in subsequent years, treatments registered significant variation in yield.

The eighth treatment, which consisted of FYM and chemical fertilizers recorded lower yield in both the varieties. However, treatment 6, supplied with 100 per cent P and K and 50 per cent N through inorganic way in addition to 50 per cent N through FYM registered comparatively better yield in variety P_1.

Treatment 9 in P_1 and treatment 5 in P_2 also recorded higher yields. These treatments consisted of organics, inorganics and biofertilizers. The results can be supported by the results on integrated nutrient management by Kanthaswamy *et al.* (1996) in pepper. According to them application of *Azospirillum* and chemical fertilizers as N, P and K in addition to FYM resulted in the highest dry berry yield. Results of three year studies conducted in clove and nutmeg (AICRPS, 2000) also revealed the effectiveness of organic, inorganic and biofertilizer combination in increasing yield.

Post experiment foliar nutrient status (after covariance analysis)

Foliar nutrients did not show pronounced changes especially in micronutrients and the trends observed were not uniform in both the varieties (Table 2 and 3)

Treatment 6 (FYM + chemical fertilizers) alone registered the higher content (1.83%) of foliar N in P_1. The effect on P_2 was not significant. With respect to P uptake also, T_6 recorded the higher value (0.18%). However, the treatments failed to produce any significant effect on P_2. In the content of K, T_{11} followed by T_6 registered higher values (2.21 and 2.19% respectively) in P_1 while

T_3 showed superiority (2.18%) in P_2. The increased K availability in the aforesaid treatment might have been due to application of neem cake. The application of neem cake added organic carbon and potash to the soil and increased the ginger yield (Sadanandan and Iyer, 1986).

Table 2. Post experiment foliar nutrient status (Major nutrients)

Treat ments	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Calcium (%)		Magnesium (%)		Sulphur (%)	
	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
T_1	1.42	1.64	0.12	0.13	1.96	1.95	2.11	1.82	0.47	0.52	0.41	0.39
T_2	1.56	1.45	0.13	0.17	1.83	1.85	1.99	2.00	0.51	0.43	0.49	0.53
T_3	1.22	1.42	0.15	0.17	1.81	2.18	1.86	1.71	0.46	0.45	0.37	0.37
T_4	1.48	1.33	0.15	0.14	1.97	1.82	1.58	1.96	0.50	0.44	0.41	0.38
T_5	1.61	1.58	0.14	0.16	1.97	1.94	1.71	1.74	0.47	0.44	0.37	0.53
T_6	1.83	1.43	0.18	0.14	2.19	2.07	1.84	1.71	0.50	0.47	0.46	0.42
T_7	1.40	1.42	0.14	0.16	1.95	1.95	1.92	1.69	0.44	0.47	0.40	0.46
T_8	1.42	1.30	0.15	0.14	2.00	2.00	1.97	1.59	0.45	0.50	0.40	0.47
T_9	1.45	1.32	0.13	0.16	2.00	2.08	1.81	1.75	0.52	0.45	0.48	0.44
T_{10}	1.57	1.46	0.11	0.19	2.00	1.80	1.98	1.82	0.54	0.42	0.43	0.41
T_{11}	1.54	1.31	0.15	0.16	2.21	2.15	1.66	1.70	0.53	0.41	0.32	0.50
T_{12}	1.46	1.43	0.14	0.16	2.12	2.00	1.99	1.87	0.35	0.44	0.37	0.36
T_{13}	1.26	1.42	0.15	0.15	1.96	1.87	1.73	1.70	0.46	0.39	0.40	0.43
Mean	1.48	1.42	0.14	0.16	2.01	1.97	1.86	1.78	0.48	0.45	0.41	0.44
CD(0.05)	0.219	NS	0.112	NS	0.115	0.318	NS	NS	NS	NS	NS	0.063

NS-Nonsignificant

With regard to secondary nutrients, sulphur alone produced significant treatment effect in P_2. Sulphur uptake by the foliage registered higher values (0.53%) in T_2 (complete organic) and T_5 (FYM + biofertilizers + inorganics). Combined inoculation of *Glomus fasciculatum, Azospirillum braziliens*, phosphobacteria and digested organic supplements resulted in better growth and nutrient uptake in tea (Rajagopal and Ramarethinam, 1997). Similar results were obtained in shola tree species by Kennedy and Chellapillai (1998). Combined inoculation of AMF, *Azospirillum* and phosphobacteria resulted in highest total dry weight, AMF colonisation and total nutrient uptake in all the four species tested.

With respect to foliar micronutrients, the results were not significant. However, Fe content recorded higher values in T_1, T_2 and T_3 in the variety P_2. All the treatments except T_3 are biofertilizer treatments while T_3 consisted of FYM + neem cake + inorganics. Biofertilizer treatments and T_{12} (Package of Practices Recommendations) recorded higher values in Mn content. Micronutrients, Zn and Cu contents registered no difference among treatments. Here some increase was noticed in T_3 alone.

The combined inoculation of AMF and *Azospirillum* led to significantly increased uptake of N, P as well as micronutrients such as Fe, Mn, Cu and Zn in tea (Kumari and Balasubramanian , 1993). Increased uptake of P, Cu and Mn by AMF inoculated plants has been reported by Wang *et al.* (1997) in tea. The increased nutrient uptake in T_{10} (FYM + *Azospirillum* + chemical fertilizers) can be supported by the results of integrated nutrient management studies in betelvine by Mozhiyan and Thamburaj (1998). They were able to obtain highest uptake of N, P, K, Ca and Mg in betelvine with the application of *Azospirillum* along with FYM and N through inorganic way.

Table 3. Post experiment foliar nutrient status (Micronutrients)

Treatments	Iron (ppm)		Manganese (ppm)		Zinc (ppm)		Copper (ppm)	
	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
T_1	461	395	565	493	15.5	18.0	21.7	18.9
T_2	464	434	527	535	16.1	21.5	23.6	21.9
T_3	374	444	505	528	19.1	23.6	25.9	25.3
T_4	361	341	519	503	15.1	18.7	21.1	21.1
T_5	393	343	478	520	15.7	18.8	17.8	20.4
T_6	317	369	441	480	14.2	19.8	23.4	18.8
T_7	389	375	560	478	13.7	20.6	23.1	21.3
T_8	411	358	504	503	17.0	20.6	22.6	28.4
T_9	496	339	499	514	17.4	19.8	22.6	24.4
T_{10}	426	357	531	557	19.0	19.3	27.0	20.1
T_{11}	396	312	501	579	14.9	19.9	20.6	20.3
T_{12}	350	407	546	558	16.2	18.8	23.9	22.5
T_{13}	368	358	461	477	15.2	18.8	23.6	22.9
Mean	400	372	510	517	16.1	19.9	23.5	22.0
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS-Nonsignificant

The first year data on yield indicated that the treatments had less effect on this character. However, the uptake of foliar nutrients, especially major nutrients were significantly affected by treatments. Foliar N, P and K contents recorded higher values with FYM+inorganic treatment, while S uptake was better with biofertilizer treatments. Uptake of Ca, Mg and micronutrients exhibited no significant tratment difference. In general, yield improvement is not usually expected with organics and biofetilizers. However, organic cultivation being more expensive, the higher cost of production could be compensated by the premium price for the organic produce especially in an export oriented crop like black pepper.

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References

AICRPS 2000 *Annual Report 1999-2000.* All India Co-ordinated Research Project on Spices (ICAR), IISR, Calicut, Kerala, India, p.67

De Waard P W F 1969 *Foliar Diagnosis, Nutrition and Yield Stability of Black Pepper (Piper nigrum) in Sarawak.* Commonwealth Department of Agricultural Research, Amsterdam.

Hart M G R 1961 A turbidimetric method for determining element of sulphur. *Analyst* 86:472-475

Jackson M L 1973 *Soil Chemical Analysis.* Prentice Hall, USA.

Kanthaswamy V, Pillai OA, Natarajan S & Thamburaj S 1996 Studies on the nutrient requirement of black pepper (var. Panniyur-1).*South Indian Hort.*44:3-4

Kennedy R N & Chellaipillai K L 1999 Synergistic effect of VAM, Azospirillum and phosphobacteria on growth response and nutrient uptake of shola tree species. *Indian J. Forestry* 21:308-312

Kumari S M P & Balasubramanian A 1993 Effect of combined inoculation of VAM and Azospirillum on the growth and nutrient uptake by coffee seedlings. *Indian Coffee* 57:5-11

Mozhiyan R A & Thamburaj S 1998 Integrated nutrient management in betel vine (*Piper betle* L.) on nutrient uptake. *South Indian Hort.* 46:185-191

Page AL 1982 *Methods of Soil Analysis Part-2.* 2nd ed. *Amer. Soc. Agron. Inc.* Madison, Wisconsin, USA.

Rajagopal B & Ramarethinam S 1997 Influence of combined inoculation of biofertilizers and digested organic supplement on the growth and nutrient uptake in organic tea cultivation. *The Planters Chronicle* 92:7-14

Rajesh S R, Raveendran N & Ajjan N 2002 An analysis: trends in area, production, productivity and export of major spices in India. Spice India 15: 19-22

Sadanandan A K & Iyer R 1986 Effect of organic amendments on rhizome rot of ginger. *Indian Cocoa Arecanut Spices J.* 9:94-95

Snell F.De & Snell T C 1967 *Colorimetric Methods of Analysis.* D Van Nostry and Co., New Delhi.

Wang S S, He SL, Wang D J, Fang D H, Wu G Q &Bie Z L 1997 Effect of VAM fungi on the vegetative growth and physiology of tea trees and the quality of tea. *Acta-Pedologica-Sinica* 34:97-102

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Plant growth hormone effect of azospirillum sp. On bush pepper

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Free living nitrogen fixing bacterium like *Azospirillum* could serve an efficient biofertilizer for nitrogen nourishment to crop plants. Apart from nitrogen fixation, this diazotroph is also capable of producing phytohormones such as IAA and GA. Reynders and Vlasak (1979) obtained *Azospirillum* brasilense strains capable of IAA production under invitro conditions.

In some of the vegetatively propagated plantation crops, especially pepper, the production of IAA by this rhizosphere bacterium is infact beneficial for enhanced root formation and thereby better establishment under field conditions.

In this study out of the 25 different cultivars of pepper used for initial isolation, *Azospirillum* was isolated from 16 cultivars. These 16 isolates along with a culture from TNAU were screened for the production of IAA and gibberillins under in vitro conditions. The native is late 34 produced maximum quantity of IAA equivalent to 69 ml of culture broth. The production of the phtohormone was maximum during the second week of culture growth.(Table 1). However, none of these isolates produced gibberllins under in vitro conditions.

Table 1. Production of IAA (pg/ml) by selected isolates of *Azospirillum*

Azospirillum Isolates	Concentration of IAA at different time intervals				
	Ist Week	2nd Week	3rd Week	4th Week	5th Week
34	45.0	69.0	38.0	31.0	26.0
39	11.5	8.0	8.0	8.0	5.0
41	21.0	28.0	18.0	15.0	11.5
55	15.0	31.0	12.0	11.0	7.0
60	38.0	48.0	29.0	28.0	17.0
64	11.0	25.0	10.0	9.0	6.0
TN culture	33.0	46.0	31.0	29.0	19.0

Mean of 3 replications

Based on the requirement of biotin for growth isolate 34 TN culture were tentatively identified as *Azospirillum* brasilense and A lipeferum respectively. The isolate 34 TN culture had their maximum growth at pH 6.0 and 8.0 respectively.

Azospirillum isolate 34 and TN culture were selected for root induction studies in Panniyur-1 and Karimunda varieties of bush pepper. The percentage of rooted cuttings varied from 23.3-26.8 percent in Panniyur-1 and 17.5-17.9 in Karimunda. However, the bacterial treatment. Between the two varieties of bush pepper, root induction was better in Panniyur-1 variety (Table 2).

Table 2. Effect of Azospirillum inoculation on root induction in bush pepper varieties Panniyur I and Karimunda*

Treatment	Percentage of rooted cuttings		Number of roots per cutting		Dry weight of roots(g)	
	Panniyur-1	Karimunda	Panniyur-1	Karimunda	Panniyur-1	Karimunda
1.Azospirillum treatment						
Broth culture						
34	3.5	16.3	0.8	1.2	0.11	0.37
TN	7.0	0.0	0.5	0.0	0.21	0.00
Carrier based inoculum						
34	23.3	17.9	3.5	2.1	0.68	0.53
TN	3.5	0.3	0.5	0.21	0.21	0.10
2. Hormone treatment						
IBA	26.8	17.5	3.3	1.9	0.59	0.41
Ceradix	7.0	0.0	0.9	0.0	0.16	0.00
3. Control treatment						
Unsterilized potting Mixture	5.4	3.5	0.3	0.3	0.05	0.09
Sterilized potting Mixture	0.0	0.0	0.0	0.0	0.00	0.00
CD(0.01)	14.9	13.6	2.0	1.5	0.40	0.36

*Mean of 10 replications

Table 3. Effect of Azospirillum and fertilizer application on root growth in bush pepper varieties-Panniyur I and Karimunda*

Treatment	Number of roots		Fresh weight of roots (g)		Dry weight of roots (g)	
	Panniyur-1	Karimunda	Panniyur-1	Karimunda	Panniyur-1	Karimunda
G.1 RIwith Azospirillum						
25 g Azo 34 + F	9.4	14.0	11.05	15.72	3.74	5.45
25 g Azo 34 –F	8.4	11.6	9.93	15.10	3.47	5.23
100g Azo 34 + F	10.8	8.4	12.71	9.46	4.62	3.29
100g Azo 34 – F	17.6	12.2	21.58	13.33	7.40	4.63
G.2 RI with IBA						
25 g Azo 34 + F	9.2	9.6	14.90	11.77	5.05	4.10
25 g Azo 34 –F	13.8	11.6	16.74	12.20	5.25	4.25
100g Azo 34 + F	12.0	9.6	16.09	11.46	5.52	3.97
100g Azo 34 – F	9.4	13.8	11.82	15.57	4.04	5.36
G.3 –Control treatment						
25 g Azo 34 + F	7.4	4.8	8.98	4.63	3.07	1.61
25 g Azo 34 –F	4.4	5.8	4.80	6.77	1.62	2.31
100g Azo 34 + F	11.0	6.0	11.43	5.90	3.98	2.05
100g Azo 34 – F	5.0	8.4	6.57	10.94	2.24	3.76
CD(0.05)	7.7	8.3	8.92	10.61	3.09	3.68

*Meanof 5 replications. RI – Root induction. GI, G2, G3 –Group 1, Group 2 and Group 3 plants

This beneficial effect of *Azospirillum* treatment in the formation of higher number of healthy and strong roots was already noticed by Govindan and chandy in 1985.

The study on the establishment and growth of bush pepper was conducted by using 3 sets of rooted cuttings of Panniyur-1 and Karimunda varieities where root induction was drone by using carrier based inoculum of *Azospirillum* and 1000 ppm IBA or without any of the above treatments. These were grown in potting mixture supplemented with 25g or 100g of isolate 34 and with or without chemical fertilizer application.

The beneficial effect of *Azospirillum* inoclusion on growth and yield has been well documented in black pepper by Bopaiah andKhader in 1989.

After 180 days of plant growth, 100 percent establishment was obtained in Panniyur-1 in treatments such as 100 g Azo 34 F of group 1,25 g Azo 34-F 100g Azo 34+F of group 2 plants. In these treatments the number of roots produced per cutting, a fresh dry weight of roots Karimunda, also, in treatments such as 25 g Azo 34-F and 100g Azo 34-F of group 1,100g Azo 34-F of group 2 and 25g Az0 34-F of group 3 plants where 100 percent establishment was obtained, the number of roots produced per cuttings, fresh and dry weights of roots were statistically on par with best treatment for these parameters. (Table 3). The production of new leaves, branches and fresh and dry weight of shoot were significantly high only in Panniyur-1 and these were in the treatments 100 g Azo 34-F of group 1 and 25g Azo 4-F of group 2 plants. But in Karimunda, no such treatment effects were noticed except for fresh and dry weight of branches. In panniyur-1 the total fresh and dry weight of plants were significant also 100g Azo 34-F of group 2 plants.

In most of the treatments where significant results were obtained, chemical fertilizer application has no significant effect on different growth parameters studies. Further, between two varieties, panniyur-1 responded better than Karimunda in rooting, establishment and growth of bush pepper.

A *Azospirillum* inoculation, especially for bush pepper cultivation will be of great advantage since at present bush pepper is mainly cultivated as a homestead crop under post culture conditions.

References

Baca, B.E. *et al* (1993). Characterization of two aromatic amino acid, amino transfereses and production of indole acetic acid in *Azospirillum strains. Soil. Biol.Biochem.26(1):57-63.*

Bopaiah, B.M. and Khader,A(1989). Effect of bio-fertilizers on growth of black pepper. *Indian. J.Agric.Sci.59(10):682 – 683.*

Govindan, M and Chandy, K.C.(1985) utilization of of the diazotroph *Azospirillum* for inducing rooting in peppercutting *(Piper nigrum L) Curr. Sci.* 54(22):1186-1188.

Govindan, M and Purushothaman, D (1984). Production of phytohormones by Nitrogen fixing bacterium *Azospirillum. Res.J.Kerala 22(2):133-138.*

Reynders.L and Vlassak,K. (1979). Conversion of Tryptophan to IAA by *Azospirillum brasilense. Soil Biol.Biochem.11(5):547.*

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Production strategies for optimization of inputs in cardamom (*Elettaria cardamomum* Maton)

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Cardamom (*Elettaria cardamomum* Maton) popularly known as "Queen" of Spices is a native of ever green forests in high ranges of western ghats of South India. It is interesting to note that, though the area under cardamom in India which was highest (105,000 ha) it had the total production of 4250 MT and productivity of 61 kg/ha during the year 1988-89. In the subsequent years, the area under cardamom in India came down and stood at 84,041 ha during 1995-96 but during the said year itself the total production went up (7500 MT) and so also the productivity (120 kg/ha). India produced cardamom of over 9500 MT with productivity of over 150 kg/ha during the year (1999-2000). In the subsequent years too the total production of cardamom in India has crossed 10,000 MT. This trend clearly shows that Indian cardamom growers are adopting intensive scientific cultivation of cardamom by switching over to innovative production technologies. Even though the realisable (potential) yield of 2500 kg/ha could be obtained, the national average yield is 170 kg/ha. This gap has to be bridged by location specific scientific cultivation of cardamom and adoption of appropriate production strategies by optimization of inputs and natural resources.

Constraints and gaps in cardamom production

Senile old plantations, over dependence on monsoon, predominance of small growers (70%), problems of land tenure (lease), deforestation, unprecedented recurring drought and increased cost of cultivation are some of the problems affecting the Indian cardamom industry.

Some of the important critical gaps hindering cardamom production in India from technological perspective are - use of unselected planting material, sparse plant population, improper systems/methods of planting, inadequate shade management and cultural operations, little or no application of fertilizer, inadequate irrigation and improper harvesting and processing, meagre/untimely plant protection measures, ignorance and negligent attitude towards *katte* disease management and lack of comprehensive integrated pest and disease management (Korikanthimath, 1992).

Rainfall plays a dominant role in cardamom production. Cardamom growing belts of high ranges of Western Ghats in India receive rainfall predominantly during South-west monsoon (June - August).

It is often mentioned that the average national yield of cardamom in Guatemala is more (200 kg/ha) compared to India (150 kg/ha). The well distributed (biomodal) rainfall, organised large scale cultivation and targeting more or less the entire cardamom cultivated in the Guatemala for export may be the major contributing factors for increased yield in Guatemala compared to India which experiences unimodal distribution of rainfall, its cultivation comprising with small and marginal farmers and the alarming increase in the demand for internal consumption.

Strategies for optimization of inputs in cardamom production

The technological approaches in bridging the yield gap in cardamom are presented and discussed in this paper.

Planting material production

One of the important reasons for low production in cardamom is the use of unselected planting material. Though cardamom can be propagated both by seeds and rhizomes, the suckers free from pest and diseases are better suited for clonal multiplication of high yielding selections. Large scale propagation of cardamom in most of the areas is through seeds. The inherent draw back of this method is production of heterogenous progeny which is genetically not uniform due to natural cross pollination.

Clonal selection and multiplication

The high degree of variability was noticed in the comprehensive field studies involving 1490 seedling progenies. Of these, 44.2% were poor yielders contributing to 12.5% of the total yield, 36% were medium yielders contributing to 40.1% of the total yield and 14.5% had yield range of 300 to 500 g per plant contributing to 32.1% of the total yield. The high yielding group (500-900 g/plant) was only 4.4% contributing to 15.3% of the total yield (Pattanshetty, 1980; Krishnamurthy, *et al.* 1989). This necessitates the selection and multiplication ot high yielders to replace the poor yielders on a large scale in cardamom plantations to step up productivity.

Clonal multiplications which ensures genetically uniform planting material can be resorted to either by macro i.e. clonal multiplication through rhizome under intensive care in the clonal nursery or through micro propagation by tissue culture under asceptic conditions (Regy Lukose *et al*, 1993), however, the cost of tissue culture plants is high and not within the reach of small and marginal farmers; who constitutes 70 percent of the total producers.

Besides, the selections/clones in cardamom are highly location specific (Madhusoodanan; 1992) under such limitations, clonal multiplication of elite clumps identified from farmer's field itself provides an easy way out. Moreover, plants raised from rhizomes bear earlier than seedling progenies, thus recovering the initial investment of plantations. In view of these practical problems, a rapid clonal multiplication technique was evolved at Cardamom Research Centre, Appangala, Coorg, Karnataka (Korikanthimath, 1992).

As no information was available on the economics of rapid clonal multiplication of cardamom right in the farmer's field, the study conducted by Korikanthimath, (1997) revealed that within a span of 10 months, the rate of multiplication was to the tune of 1:20 with cost per planting unit of Rs.1.11 by resorting to rapid clonal multiplication technique. This method has worked out to be much cheaper than the cost (price) of the tissue cultured plantlets (Rs.12/plant) and even the open pollinated seedlings (Rs.2.5/seeding). Korikanthimath (1999) reported that multiplication of cardamom in trench system of planting recorded as high as 14861 planting units with a rate of multiplication of 1:32, besides, a remarkable yield of 90.25 kg dry cardamom per 0.05 ha with in a short span of 20 months under controlled shade.

In the study carried out for the evaluation of twelve elite clones of cardamom for the yield and yield parameters in clonal nursery, Sl.9 (2038 kg ha^{-1}), Sl.7 (1818.3 kg ha^{-1}) and Sl.4 with 1730 kg ha-1 of dry capsules were significantly superior to control (607.8 kg ha^{-1}). (Korikanthimath *et al.*, 1997e, Korikanthimath *et al.*, 1997f). Correlation between growth and yield parameters , quality characters, dry matter distribution and harvest index had a favaourable effect in case of elite planting material viz. Sl-9, Sl-7, Sl-4 and Sl-5 (Korikanthimath *et al* 1997h; Korikanthimath *et al* 1997i; Korikanthimath and Ravindra Mulge, 1998a).

Further studies on the evaluation of elite lines of cardamom for their yield and yield parameters in the main field (plantation) by Korikanthimath 1995 revealed the variable yield pattern for early yield over two successive seasons of harvest in clones. The clone Sl.7 was the early type which recorded 18.3% of its total yield in first three pickings. The clone Sl.9 was superior with respect total dry capsule yield (2215 kg ha^{-1}) followed by Sl.7 (2184.0 kg ha^{-1}) and Sl.5 (1935.3 kg ha^{-1}) which were significantly high yielders compared to local check (731.5 kg ha^{-1}).

Several studies carried out on selection and field evaluation of elite cardamom lines/ accessions have resulted in identifying location specific clones with better growth, yield and quality attributes. (Korikanthimath *et al*, 1999i; Korikanthimath *et al* 2000k; Prasath *et al* 2001; Korikanthimath *et al* 2002c; Korikanthimath *et al* 1998s; Korikanthimath *et al* 1999e; Korikanthimath *et al*, 1999h; Korikanthimath et al, 2000j; Mohammed Sayyed *et al* 1979).

Propagation by seeds

In order to get quality seedlings, the nursery has to be managed carefully and scientifically. There are two stages in nursery viz., primary nursery and secondary nursery. As far as the seed selection is concerned, it is always desirable to watch the continued performance of selected, individual mother plant, before the final selection. Storing seeds for a long time results in a considerable loss of viability and great delay in germination. Hence, the fresh seeds extracted should be sown immediately for better germination (Abraham 1958; Korikanthimath 1982). The time of sowing of cardamom seeds varies according to places. When cardamom seeds were sown at monthly interval from September to January, best germination was obtained in September (79.8%) and the least was 0.8% in January. (Pattanshetty and Prasad, 1973).

Cardamom seeds possess a hard seed coat which delays its germination. Treating of freshly extracted seeds with 20% nitric acid for ten minutes enhanced the germination (Korikanthimath and Ravindra Mulge, 1998b). It is always advantageous to select the nursery site on gentle slopes having an easy access to perennial source of water (Siddaramaiah, 1967). Soaking the soil in the seed bed to a depth of 15 cm with 1:15 formaldehyde solution is found to be effective in controlling damping off disease of cardamom seedlings (Anon., 1985). The seed rate commonly adopted is 2.5g/m^2 of germination bed for raising 10 months old seedlings (Anon. 1976). Use of mulches in nursery bed has a profound influence on germination (Korikanthimath, 1981). Among the various mulches, paddy straw or *phyllanthese ambilica* leaves are found to be suitable for better germination (Sulikeri and Kologi, 1978).

The seedlings are transplanted into secondary nursery when they attained 4-5 leaves stage. Transplanting of seedlings in the secondary nursery is carried out in December or January in Karnataka and May/June in Kerala. In Karnataka, 10 months old seedlings are used for transplanting in the estates where as in Kerala, it is most common to plant 18-22 months old seedlings. Appropriate technologies like leaf stage of primary seedlings, spacing, fertilizer schedule, suitable materials for covering overhead pandal have been worked out and standardized for raising cardamom seedlings in secondary nursery (Korikanthimath *et al* 2001a; Korikanthimath et *al* 2001).

Planting in the main field

Thorough understanding of various aspects on the preparation of land, systems of planting, spacing (Geometry of planting) have to be followed systematically for better establishment.

The initial work consists of thinning out excess shade trees branches to have an evenly thick over head canopy. If land is sloppy, it is advisable to start clearing from top and work downwards (Korikanthimath, 1983). The study carried out by Korikanthimath, 1986b, revealed that the trench system of planting is superior to pit system of planting as the former has the better effect of retention of soil moisture and development of adequate root system. Contour terrace may be provided for planting cardamom on the steep slopes.

Spacing (Geometry of planting)

The spacing should be decided based on variety and time indented (longevity) of the crop, where it is indented to grow cardamom on a limited short cycle, with regular replanting, it is desirable to plant as closely as possible, so that the early crops may be as high as possible. The field study carried out by Korikanthimath *et al.*, (1998k) with five planting densities *i.e.* 2.0 m x 2.0 m (2500 plants/ha), 2.0 m x 1.5 m (3333 plants/ha), 2.0 m x 1.0 m (5000 plants/ha), 2.0 m x 1.5 m (6666 plants/ha) and 2.0 m x 0.5 m (10,000 plants/ha) revealed that the capsule yield per ha increased significantly up to the plant population of 5000 plants per ha and there after the increase was not that commensurative in longer prospective. Hence, cardamom may be planted at a spacing of 2.0 m x 1.0 m on hill slopes along the contour and 2.0 x 2.0 m in the flat lands (Korikanthimath and Venugopal, 1986). Thus the spacing has to be decided depending upon the lay of the land and also the targeted yield (expected longevity).

Method of planting

The systems of planting vary according to the lay of the land, soil fertility and the probable period which the planters expected to last. Normally, two systems of planting are followed namely trench system and pit system. Trench system of planting has been found to be quite advantageous in areas with moderate slope bestowed with adequate drainage. According to study conducted by Korikanthimath (1986b), the trench system retains the highest percentage of moisture followed by pit system. Pooled analysis of the three crop seasons(1987-88 to 1989-90) under rainfed condition revealed that trench method of planting (294.35 kg ha^{-1}) was significantly superior to pit (256.65 kg ha^{-1}) as per the studies conducted on systems of planting at IISR, Cardamom Research Centre, Appangala, Karnataka. As cardamom is still largely cultivated under rainfed condition (75%), conservation of soil moisture for efficient absorption and utilisation of applied nutrients is quite imperative by resorting to appropriate systems of planting.

Season of planting

Planting during rainy season commencing from June is ideal on steep moderate slopes where the rain water is well drained. The ideal time for planting in low lying areas would be after the cessation of heavy monsoon showers. Early planting will get the benefit of assured and distributed rains in south west monsoon resulting in better establishment and growth (Mayne, 1951).

Planting

Planting can be commenced when the soil is moist. Cloudy days with light drizzling would be ideal for planting. Deep planting should be avoided as it results in suppression of the growth of new shoots. Immediately after planting, the seedlings/ suckers should be supported by staking in order to prevent damage due to wind. The base of the plant is to be mulched with dried fallen leaves of shade trees. The newly planted area should be inspected periodically and gaps should be filled up immediately.

After care and upkeep

After planting cardamom, the young plants should be kept on a regular schedule of cultural operations consisting of mulching, weed control, trashing, raking/ digging, shade regulation, irrigation, manuring and appropriate plant protection measures for keeping the plants in healthy and vigorous condition.

Mulching

Cardamom in India is grown largely as a rainfed crop. Cardamom being a herbaceous perennial crop, it is a quite delicate plant. It cannot withstand the drought condition prevailing for a long period (Korikanthimath, 1988). The pre monsoon showers have become erratic in the recent years, thus the cardamom plants have to face dry spell for 4-5 months. Mulching is the practical solution for conserving the soil moisture (Zachariah, 1976). Mulching has been acclaimed as the best cultural operation for the over all improvement of soil and yield of cardamom. In the long run, mulch cover will help in improving the physical properties of soil, microbial activity, nutritional status *etc.* and results in better yield (Cherian, 1980).

Weed control

Cardamom is a surface feeder, therefore in the first year of planting, frequent weeding is necessary to avoid the root competition between the young seedlings and weeds. As many as 21 dicotyludunous weeds are identified in cardamom estates (Korikanthimath and Venugopal, 1980; Korikanthimath and Venugopal, 1985; Korikanthimath and Venugopal, 1987). Depending on the density of weeds, 2-3 rounds of weeding in a year would be necessary. Since, manual weeding is difficult in big cardamom plantations, the studies carried out on chemical weed control indicated that spraying of paraquat in the interspaces between rows leaving 60 cm around the plant base, would be effective. On an average, 625 ml of paraquat in 500 liters of water is sufficient for one round of application per ha. As the cardamom plants attain growth and their canopy covers the ground, the weed growth will be smothered to a great extent (Korikanthimath, 1986a).

Trashing

It consists of removing old and dry shoots of cardamom plants. From second year onwards, the cardamom plants have to be trashed 2-3 times in a year. Trashing facilitates receipt of adequate sunlight, aeration, reduction in the infestation of thrips and aphids, resulting in over all build up and growth the of crops. It also helps in the pollination by honey bees and formation of green capsules (Korikanthimath and Venugopal, 1986).

Raking/digging

Towards the end of the monsoon rains, light raking or soil digging may be carried out around the plants. The soil mulch thus formed around the plants would help to conserve the soil moisture for the dry periods ahead (Kuttappa, 1969). Digging should be done in new clearance, particularly in one year old plantations which facilitates better root development. However, deep digging should be strictly avoided.

Light earthing up

The rich humus top soil around the plant to a distance of 75 cm may be scraped and applied as a thin layer to the base of the clumps just up to the collar region. It forms the soil mulch and covers the crop roots and rhizomes due to beating action of rain drops. This practice not only keeps the crop roots well covered with soil but also effectively check the walking habit (radial growth) of cardamom (Korikanthimath and Venugopal, 1986).

Shade regulation

Since, cardamom is a shade loving plant, fast growing shade tree species with well spread over head canopy tried in the open vacant areas revealed that, Balangi (*Acrocarpus fraxinifollins*) and red cedar (*Cedrella toona*) could build up quick shade. They were also found to be self regulating wherein they shed leaves in monsoon (rainy season) and put up new flush of leaves from December/January.

Cardamom being herbacious psiophyte (shade loving) in nature, it was generally believed that higher shade has to be maintained in the plantations to protect the plant from scorching sun. But it was found later during the investigations that, too much of shade caused over tillering, lanky growth of tillers and consequently poor yield. On the other hand, the continued denudations of the forest during recent years is exposing the plants to scorching sun, thus adversely affecting the yield (Sulikeri, 1986). In light of this, the study carried out on light intensity levels revealed that medium to high light intensity (45-65%) is ideal for better growth and yield.

For providing adequate light during rainy season, when the intensity of light is less, it is necessary to carry out shade regulation before the onset of monsoon for better productivity (Korikanthimath, 1991). Trees having well distributed branching habit and small leaves are ideal for cardamom. Trees like *Diospyrus ebenum* Koenig, is an ideal shade tree for cardamom (George *et al*, 1984)

Nutrient management

Continuous cultivation of cardamom on the same piece of land leads to depletion of nutrients resulting in poor growth and yield. The studies conducted indicated that, there is a steady absorption and utilisation of nutrients through out the life cycle of cardamom, hence, following regular fertilizer schedule is essential. Soil fertility evaluation in cardamom plantation belts, soil-site suitability evaluation for cardamom and status of major nutrients in cardamom growing soils have been studied in detail. (Shivprasad *et al* 2001; Korikanthimath *et al* 2000c; Korikanthimath *et al* 2002a; Korikanthimath *et al* 2003a).

Since, cardamom is a psiophyte (shade loving) it is often cultivated beneath the mixed type of natural forest trees. Under such situations, it is often felt that the response to applied fertilizer is not consistent. Hence, a detailed study was conducted to establish the response of monoclonal cardamom material under controlled shade of agro shade nets. The experiment was laid out in 3^3 confounded design with nitrogen (0, 50, 100 kg/ha), phosphorus (0, 25,50 kg/ha) and potassium (0, 100, 200 kg/ha) as nutritional treatments in three blocks and two replications. The spacing given was 1.8 m x 0.6 m (9259 plants/ha) with plot size of 3.6 x 3.0 m. The artificial controlled shade was created using coir mat at a height of 2.5 m. Clonal material of Mudigere-1 was planted on 14^{th} February, 1985 in trench method. Influence of major nutrients on growth, yield production and partitioning of dry matter and quality aspects have been studied in detail (Korikanthimath *et al* 1998m; Korikanthimath *et al* 1998l; Korikanthimath *et al* 1998n; Korikanthimath *et al* 1999 g).

A field experiment was carried out by Korikanthimath, (1995a) with an objective to find out optimum plant population with five densities viz., 2500, 3333, 5000, 6666 and 10,000 plants per ha and three levels of fertilizers 50:25:100 kg NPK ha^{-1}, 100:50:200 kg NPK ha^{-1}, 150:75:300 kg NPK ha^{-1}. The study conducted for five years, revealed that fresh yield of capsules per plant increased significantly up to second level of nutrient combinations (100:50:200 kg NPK ha^{-1}) and it decreased significantly with a every increase in plant densities. The dry capsule yield/ha increased significantly with every increase in nutrient combination levels and at 150:75:300 kg NPK ha^{-1}, a maximum average yield of 540.6 kg ha^{-1} was realised. Increasing the planting densities up to 5000 plant/ha at a spacing of 2.0 m x 1.0 m resulted in significant increase in yield (Korikanthimath *et al.*, 1998).

Effect of fertilizer levels on VessicularArbusculat mycorriza colonization in cardamom had a favourable effect on plant growth (Rohini Iyer *et al* 1986).

Among the various yield parameters, number of panicles per clump and yield of fresh capsules per plant were positively and significantly influenced by increased fertilizer levels (Korikanthimath *et al* 1998k, Korikanthimath, *et al.*, 1998m). Geometry of planting (population density) and fertilizer levels had effect on tillering and yield of cardamom (Korikanthimath *et al* 1998o). There was a clear trend of increase in light transmission ratio (LTR) through the canopy with increase in fertilizer levels and decreasing trend with increasing plant population densities (Korikanthimath, *et al.*, 1999f).

A field experiment conducted by Korikanthimath, (1986) with two systems of planting (pit and trench) and five levels of fertilizer (0:0:0; 40:40:80; 80:80:160, 120:120:240 and 160:160:320 kg NPK ha^{-1}) using Cl-37 plant material and a plant population of 5000 plant ha^{-1}, revealed that trench method of planting (294.34 kg ha^{-1}) was significantly superior to pit (256.65 kg ha^{-1}). Based on long term study, fertilizer dose of 120:120:240 kg NPK ha^{-1} may be recommended. A fertilizer dose of 75:75:150 kg NPK ha^{-1} is recommended by the University of Agricultural Sciences, Regional Research Station, Mudigere, Karnataka (Kololgi, 1977).

Selection of index leaf in cardamom for nutrient diagnosis and nutrient uptake pattern were worked out in detail for monitoring precise nutrient management (Korikanthimath *et al* 2000b; Korikanthimath *et al* 2003). The fertilizer requirement has to be worked out based on the soil test, crop response and the targeted yield (Korikanthimath, 1994). Integrated nutrient management is the need of the hour in enhancing the productivity and quality of cardamom.

Irrigation

Erratic distribution of rainfall particularly in summer months (Pre- monsoon) in the cardamom growing tracts of India is of great concern to growers as 75 per cent of the area under cardamom in India is still rainfed. Pre-monsoon showers have a great impact on physiological processes of the cardamom viz., initiation of panicles, flowering and setting of capsules. Cardamom types/varieties exhibit variations in their capacity to tolerate drought indicating possibilities of selection and cultivation of drought tolerant types. Cardamom plants irrigated at 75% available soil moisture recorded better yield. As cardamom is mainly cultivated on undulating topography of hills and hill slopes, overhead (sprinkler) method of irrigation is most suited. Though drip irrigation is receiving attention in recent years, the topography and initial cost need to be considered on long term prospective.

Adequate drainage needs to be provided in the low lying valley bottoms and flat lands in cardamom plantations. There is an urgent need for safe disposal of excess (runoff) water during monsoon as well as harvesting of requisite rain water in suitable structures like check dams, farm ponds etc. to recycle the stored water during critical stages of cardamom growth in summer.

Apart from adopting ground irrigation management practices, there is an urgent need to combat drought by following appropriate strategies like shade management, mixed cropping, trench method of planting, shelter belts earthing up, mulching, weed management, soil conservation practices, trashing etc. Thrust should be given on fertigation for efficient utilisation of both plant nutrients and water (Korikanthimath, 1993b; Korikanthimath and Rajendra Hegde, 1998).

Harvesting and processing

Although the quality of produce is decided in every stage of its production, utmost care is needed on the maturity stage and time of harvesting, pre drying treatments by adopting proper curing methods (Korikanthimath, 1993a). In most of the areas, peak harvest is in October-November. Picking is carried out at intervals of 15 days and completed in 7-8 rounds. The stage of the harvest has direct relationship on recovery of cardamom (Korikanthimath and Naidu, 1986). Different pattern of return inflow in relation to various grades of cardamom and human resource use efficiency in relation to different rounds of harvesting and yield on cardamom have been worked out (Korikanthimath *et al* 2001c; Korikanthimath *et al* 2000e). Curing of cardamom may be taken up by resorting to natural (sun) drying, use of artificial dryers (electrical drier), flue pipe drier, bin drier and melccord drier. Besides the green cardamom, bleaching of cardamom is also followed in certain cases for the local market.

Evolving and implementation of location specific high production technology in farmers field

India being the home of cardamom enjoyed the most prestigious position as a largest producer and exporter of cardamom till the mid 80's. Since, Guatemala has emerged as a keen competitor for Indian cardamom in the international market, India is pushed to second position in the world. As the global market is becoming increasingly competitive, only high productivity and low net cost of production would ensure survival of cardamom industry in India. In light of the above facts and as the cardamom is highly location specific, initially two research cum demonstration plots one each under rainfed and irrigated condition were conducted at Cardamom Research Centre, Appangala, Coorg, Karnataka. These demonstrations recorded an average dry cardamom yield of 162 kg ha^{-1} under rainfed conditions and 650 kg ha^{-1} in irrigated condition, respectively. Based on the above leads strategy for high production technology (HPT) was chalked out in ten research cum demonstrations in Kodagu district of Karnataka in growers plantations with a view to convince the farmers in their own estate about the high production potential by *adopting intensive cultivation practices* (Korikanthimath *et al* 1991). The yield potential obtained in the location specific on farm demonstration trials is as follows

Conventional management followed by HPT

As against the maiden crop of 52 kg ha^{-1} under conventional farmers practices, a maximum yield record of 850 kg (dry) ha^{-1} was obtained by adopting High Production Technology (HPT). In HPT plot an average yield of 438 kg ha^{-1} was obtained against 116.5 kg ha^{-1} under conventional management for eight crop seasons (1985-86 to 1992-93) (Korikanthimath *et al* 1989a; Korikanthimath *et al* 1989b; Korikanthimath, 1996).

Sustained production and performance of cardamom

A highest yield of 1625 kg ha^{-1} was recorded during the fourth year of planting. The average of nine crop seasons yield i.e. 695.66 kg ha^{-1} (dry) obtained in this trial was twelve times more than the national average yield of 58 kg ha^{-1} A net income of Rs. 1,09,147.53/ha (average of 10 crop seasons) was obtained with a production cost of Rs. 60.92 per kg (dry). (Korikanthimath, 1995; Korikanthimath *et al* 1989c, Korikanthimath *et al* 2001d)

Conversion of marshy areas for cultivation of cardamom:

A peak yield of 1510 kg ha^{-1} was realised with an outstanding net return of Rs.4,32,738 /ha in the third year itself. On the whole an average yield of 692.0 kg ha^{-1} for six crop seasons (1993-94 to 1998-99) was obtained (Korikanthimath *et al.*, 1999b).

Performance of cardamom under phased replanting

After harvesting 10 crops of cardamom as furnished in the above study (5.3) the performance of cardamom was further investigated from 1991-92 crop season onwards by following the precision farming. The highest maiden yield of 1775 kg (dry)/ha was recorded in the very second year of replanting which is indeed a remarkable record. An average of 749 kg (dry)/ha was obtained for the five crop seasons (1994-1998) which is 5.83 times more than the national average yield of 128.4 kg/ha during corresponding period.

The discounting cash flow measures viz. Net Present Value (NPV) of Rs. 5,09,296.45, Benefit Cost Ratio (BCR) of 2.78, Pay Back Period (PBP) of 2.15 years and Internal Rate of Return of 82.26% showed that phased replanting of cardamom would be an economically viable and financially feasible proposition. (Korikanthimath, 2000b)

Intensive cultivation of cardamom at high elevation and high rainfall

In this trial an average yield of 309 kg(dry)/ha was obtained four crop seasons (1995-98). This was 2.35 times more than the national average yield of 132.25 kg/ha. The various discounting cash flow measures viz. Net Present Value (NPV) of Rs. 69,297.9; Benefit Cost Ratio (BCR) of 1.48, Pay Back Period (PBP) of 3.12 years and Internal Rate of Return of 48% showed that the cultivation of cardamom even in high elevations and heavy rainfall areas with appropriate timely and intensive care is economically viable and ecologically feasible. (Korikanthimath and Govardahan Rao, 2000b).

Feasibility of cardamom cultivation on the steep slopes of western ghats

A highest maiden yield of 1173 kg/ha (dry) was recorded during the 3rd year after planting. The average of 4 crop seasons (1994-98) is 610 kg (dry)/ha. This is five times more than the Indian national average yield. The economic feasibility measures namely, NPV (Rs. 1,55,476/ha); BCR (2.01) indicated viability and sound investment on cardamom even on steep slopes by resorting to appropriate soil and moisture conservation measures. (Korikanthimath and Hiremath, 2000).

Performance of cardamom under low elevation and rainfall situation

Total yield was 3317.21 kg/ha for all the four cropping seasons put together (1994-95 to 1997-98) with an average of 829.30 kg/ha which is 6.54 times more than the national average yield of 126.75 kg/ha during the corresponding period. The economic and financial feasibility measures namely, NPV (Rs 3,14,162/ha), BCR(2.46) and IRR (128%) showed that investment on introducing cardamom under comparatively low elevation and rainfall situation with assured irrigation facilities is economically viable proposition. (Korikanthimath *et al* 2000f).

Cultivation of cardamom in valley bottoms under ever green forest shade

A maiden and highest yield of 1473 kg(dry)/ha was obtained in the third year after planting (1988-89). An average of 735 kg(dry)/ha yield was noticed for the seventh crop season (1988-89 to 1994-95) which is more than 9.14 times of the India's national average yield of 80.43 kg/ha during the corresponding years. A net income of Rs. 1,45,065.7/ha was obtained with an average production cost of Rs. 87/kg. The discounting cash flow measures viz. Net Present worth (NPW) of Rs. 5,23,455/ha; Benefit Cost Ratio (BCR) of 3.53; Pay Back Period (PBP) of 2.14 years and Internal Rate of Return (IRR) of 59.08% showed that cardamom is an economically viable and feasible crop for cultivation under valley bottoms which retain soil moisture round the year, most suited for optimum growth and yield. (Korikanthimath *et al* 2002b).

Cultivation of cardamom in marshy areas beneath the shade of Neerangi (Salix tetrasperma Willow)

A peak yield of 1463 kg(dry)/ha was obtained during the year 1994-95 with an annual average of 703 kg/ha for four crops seasons (1993-94 - 1996-97) was recorded which is 6.03 times more than the national average yield of 116.5 kg/ha during the corresponding period. The discounting cash flow measures, viz. NPW (Rs. 2,72,100.09/ha); BCR (2.46) and PBP (2.10 years) show the prospects of cultivation of cardamom is successful beneath shade of Neerangi (*Salix tetrasperma* Willow) in marshy areas.

Conversion of upland open vacant areas for profitable cultivation of cardamom by agroforestry approaches

By afforesting the open vacant area with the fast growing dual purpose shade tree species viz., silver oak, a maiden yield of 1025 kg/ha cardamom was obtained in the third year after planting (1995). An average of 682 kg/ha obtained in this trial is 5.15 times more than the national average yield of 132.25 kg/ha during the corresponding period. The discounting cash flow measures, viz. NPW (Rs. 2,72,029.86/ha); BCR (2.93) and PBP (2.3 years) IRR (80.73) suggested the success of cultivation of cardamom in upland, open, vacant areas with agri-silviculture/

agroforestry approach. A total investment of Rs. 64,807.98/ha was made with an average of Rs. 1,25,466.21/ha as net returns. (Korikanthimath *et al* 2003b).

High density trench system of intensive cultivation of cardamom

By resorting to high density trench system of intensive cultivation of cardamom by adopting precison farming a remarkable yield of 1944 kg (dry)/ha was obtained within 30 months of planting. An average of four crop seasons (1995-98) is 886.25 kg/ha. This was 6.33 times more than the current national average yield of 140 kg/ha. (Korikanthimath and Govardhan Rao, 2000a).

Cultivation of cardamom in Homesteads by using seedling progenies

It yielded 32kg and 71 kg dry cardamom per 0.05ha during first and second crop seasons, respectively. A net profit of Rs. 34,033 per 0.05ha was obtained with a BCR of 2.13. (Korikanthimath *et al* 1998d)

Large scale field demonstrations on cardamom

Based on the success obtained, large scale demonstrations were laid out in farmers fields in 1986 in cardamom growing zones of Kodagu and parts of Hassan districts in Karnataka to convince the farmers about HPT programme. These trials were taken up in 42 farmers plantations, covering an area of 94.1 ha by using 1,70,500. Cl.37 seedlings in five distinct zones. The pre planting bench mark survey of HPT cardamom plantations revealed that the average size of plantations was 6.54 ha with in an age group of 17 years. The average yield was 62.4 kg/ha.in the bench mark study. After adoption of HPT, maiden crop obtained in HPT demonstrations was quite promising with an average yield of 494.5 kg (dry)/ha (Korikanthimath, 1992).The above demonstration trials clearly illustrated the tremendous potential to boost cardamom production through adoption of high production technology. In addition, this also has an added advantage of generation of employment potential.

Cropping systems

Plantation and spice crops, a group of commercial crops of perennial nature, committed to land for several decades, cultivated mostly in tropics which have an equitable climate with plentiful precipitation and sunshine. These situations favour plant growth round the year and resultant natural vegetation in the ever green forest. Hence, there is a need to use the available land for effective utilization of horizontal and vertical space and solar energy to get maximum returns per unit time. One of the feasible ways of increasing the farm level income and to withstand the sharp fluctuation in price structure and employment opportunities on such small holdings is to adopt mixed cropping by growing compatible high value perennial crops in the interspaces.

Cardamom, a shade loving plant, is a most ecofriendly plantation crop. It offers a great scope as a mixed crop in coffee plantations in the tropical forests, besides arecanut and coconut which provide an over head shade, most essential for survival and better productivity of cardamom in the high ranges of western ghats in India In light of the above facts, several field trials on mixed cropping of cardamom with coffee in Kodagu, arecanut and coconut near Sirsi in Uttar Kannada district of Karnataka were undertaken to study the crop compatibility *i.e.* ecological feasibility and economic viability. Agro-forestry approaches in cultivation of pepper and cardamom and performance of black pepper trained on different shade trees as live standards were also studied (Korikanthimath and Anke Gowda, 1999; Korikanthimath *et al* 2000h).

Totally three long term field experiments were carried out, mainly mixed cropping of robusta coffee with cardamom (double hedge), mixed cropping of robusta coffee with Coorg mandarin, pepper and cardamom (single hedge) and mixed cropping of arabica coffee and cardamom (single hedge). These three experiments were carried out right in the farmers plantations in Kodagu district of Karnataka. Two more experiments one each on mixed cropping of arecanut with cardamom and mixed cropping of coconut with cardamom were conducted in and around Sirsi, Uttar Kannada District, Karnataka.

The crop combinations of cardamom with coffee, pepper and arecanut and coconut had a better impact on enhancing the over all productivity of the crop combinations (Korikanthimath *et al*, 1997q; Korikanthimath *et al* 1998r; Korikanthimath *et al* 1998q; Korikanthimath, 2000a; Korikanthimath *et al*, 2000l; Korikanthimath 2001). These crop combinations had a better microclimatic and physiological parameters (Korikanthimath *et al* 1998c; Korikanthimath *et al* 1998a; Korikanthimath, *et al*., 1999a, Korikanthimath *et al* 1998b; Korikanthimath *et al* 2000a). Vesicular-Arbuscular mycrorrhizae and phosphate solublizer in robusta coffee and cardamom mixed copping systems had a favourable effect on plant growth and performance (Korikanthimath *et al* 2000d). Organic recycling of farm waste particularly coffee pulp in the mixed cropping of coffee and cardamom had a better impact in enhancing the fertility status (Korikanthimath and Hosmani, 1998; Korikanthimath 2000c; Korikanthimath and Anke Gowda, 2000). Integrated input management in these crop combinations had a better impact on efficient utilization of various cash inputs. Some of the combined cultural operations followed in the crop combinations also could bring down the total cost of cultivation (Korikanthimath *et al*., 1997b; Korikanthimath *et al*., 1997a; Korikanthimath, *et al*., 1997c; Korikanthimath, *et al*., 1998g, Korikanthimath *et al* 1998h). Mixed cropping of cardamom with coffee, arecanut and coconut generated additional gainful employment (Korikanthimath *et al*., 1999c; Korikanthimath *et al*., 1998f; Korikanthimath *et al*., 1998e, Korikanthimath *et al* 2000g). The economic analysis of mixed cropping of coffee, arecanut and coconut is most beneficial than cultivating sole crop (Korikanthimath *et al*., 1998j; Korikanthimath *et al*., 1996; Korikanthimath, *et al*., 1997d; Korikanthimath *et al*., 1998i, Korikanthimath *et al* 2000i). Cultivation of vanilla with coconut has been quite feasible and compatiable in not only harnessing the natural resources but also in generating substantial returns to the farmers per unit area and time. (Korikanthimath *et al* 1999d)

Besides the efficient utilization of natural resources the above multistoreyed cropping systems help in augmenting higher productivity per unit area and time and generation of gainful employment both for the family labour and agricultural farm labourers on a long term sustainable perspective.

The yield gap in cardamom has to be bridged by adoption of each production strategies for optimization of inputs based on the actual need specific to the different location as this crop is highly location specific compared to many other plantation and spice crops. Cardamom causes least disturbance and can be cultivated as most ecofriendly crop for sustained production. There has been a considerable improvement both in production and productivity of cardamom in the recent years. The location specific clonal selection and cultivation of the same by adopting intensive scientific technologies has resulted in sustained production of cardamom. As cardamom is offered with encouraging price for last couple of years it should be the endevour of the cardamom growers to increase the production and productivity so as to meet not only the alarming domestic demand but also to produce surplus for export to earn the precious foreign exchange for India.

Field studies on integrated input management in coffee based spices multistoreyed cropping system involving both Robusta and Arabica (dwarf Cauvery), pepper trained on Silveroak and Balanji (*Acrocarpus fraxinifolius*), ginger and turmeric (in initial stage of establishment) has been found to be quite successful in Coorg district of Karnataka (Korikanthimath *et al* 1995).

References

Anonymous 1976 Cardamom in Karnataka, IJSA Tech. Series No.14, The University of Agricultural Sciences, Hebbal, Bangalore pp 5.

Anonymous 1985. Cardamom package of practices, pamphlet 28. Central Plantation Crops Research Institute, Kasaragod pp 4.

Cherian A 1980 Mulching and moisture preservation in cardamom. Cardamom 12(1):7-9.

George, M.V. Mohammed Sayed, A.A. and Korikanthimath, V.S. 1984, *Diospyrus ebenum* Koenig, and ideal shade tree for cardamom. *Journal of Plantation Crops* 12(2) 160-163.

Kololgi S D 1977 Cardamom research at Mudigere. In towards higher yields in cardamom. Central Plantation Crops Research Institute, Kasaragod, pp.26-29.

Korikanthimath V S 1981 Nursery studies in mulches for use in cardamom primary nursery. Ann. Report, CPCRI, Kasaragod, Kerala.

Korikanthimath V S 1982 Nursery studies in cardamom. Ann. Report, CPCRI, Kasaragod, Kerala

Korikanthimath V S 1983 Production and prospects of cardamom in India. Seminar, Department of Agronomy, UAS, Dharwad - 7th January, 1983.

Korikanthimath V S 1986a Agronomic practices for cardamom. Farmer and Parliament, 21 (2):15-28.

Korikanthimath V S 1986b Systems of planting-cum-fertilizer levels in cardamom under rainfed condition - NRCS Ann. Report, 1986, pp. 30-31. National Research Centre for Spices, Calicut, Kerala.

Korikanthimath V S 1988 Influence of rainfall on the yield of cardamom under different levels of management. Spice India, 1(5):15-16.

Korikanthimath, V.S. 1989. Influence of rainfall on the yield of cardamom under different levels of management. *Spices India* 1(5): 15-16.

Korikanthimath V S 1991 Shade management for high productivity in cardamom *(Elettaria cardamomum* Maton), Spice India 4(2):15-21.

Korikanthimath V S 1992 High Production Technology in cardamom. In Anandaraj M, Sharma Y R and Devashayam S (Eds). Proc. National Seminar on Black pepper and cardamom, Calicut, 16-17 May,1992, pp 20-26, Indian Society for Spices, Calicut, Kerala

Korikanthimath V S 1993a Harvesting and onfarm processing of cardamom. Proc. National Seminar on post harvest technology of spices. Indian Society for Spices, Calicut, Kerala.

Korikanthimath, V.S. 1993b. Irrigation management of Cardamom. In: Satheesan, K.V. (Ed.). National Seminar on "Water Management for Plantation Crops". Centre for Water Resources Development and Management, Calicut, Kerala (3, March, 1993) pp:71-77.

Korikanthimath V S 1994 Nutrition of cardamom. Advance in Horticulture, Vol.9 - Plantation and Spice Crops Part I (1994) Eds. K L Chadha and P Rethinam (c) 1994 Malhotra Publishing House, New Delhi pp 467-477.

Korikanthimath V S 1995a Agronomic investigations on cardamom (*Elettaria cardamomum* Maton). Ph.D. thesis, University of Agricultural Sciences, Dharwad, Karnataka.

Korikanthimath, V.S. 1995b. Economics of sustained production of cardamom (*Elettaria cardamomum* Maton). *Journal of Spices and Aromatic Crops* 4(2):119-128.

Korikanthimath, V.S., 1996. Spurt in cardamom yield and income by switching over from conventional management to high production technology. *Journal of Plantation Crops* 24 (Suppl):840-847.

Korikanthimath V S 1997 Rapid clonal multiplication of cardamom (*Elettaria cardamomum* Maton) - Techniques and Economics. J. Medicinal Aromatic Plants Sci. 19:994-999.

Korikanthimath V S 1999 Rapid clonal multiplication of elite cardamom selection for generating planting material, yield upgradation and its economics. J. Plantn. Crops, 27(1):45-53.

Korikanthimath, V. S. 2000a. Multistoreyed cropping of robusta coffee with cardamom. *Journal of Farming systems Research & Development 6(1&2) : 40-45*

Korikanthimath, V.S. 2000b. Performance and economics of replanted cardamom (*Elettaria cardamomum* Maton) plantation. *Journal of Spices and Aromatic Crops* 9(1):31-36.

Korikanthimath, V.S. 2000c. Studies on chemical composition of robusta coffee pulp and organic recycling in the robusta coffee and cardamom mixed cropping systems. *Crop Research* 20(2):350-354.

Korikanthimath, V.S. 2001. Mixed cropping of Arabica coffee with cardamom. *Journal of Farming systems Research & Development*. 7(1) : 24 – 29.

Korikanthimath, V.S. and Anke Gowda, S.J. 1999. Performance of black pepper (*Piper nigrum* L., var. Panniyur-1) trained on different shade trees as live standards. *Journal of Spices and Aromatic Crops* 8(1):97.

Korikanthimath, V.S. and Anke Gowda, S. J. 2000. Organic recycling of robusta coffee (*Coffea robusta*) mucilage and washed water. *Journal of Farming Systems Research & Development* 6(1&2) : 118-121

Korikanthimath, V.S.,Anke Gowda A. J. and Gaddi A.V. 2001a. Studies on optimum spacing and leaf stage of cardamom (*Elettaria cardamomum* Maton) seedlings for transplanting in secondary nursery. *Indian Journal of Horticulture* 58(3) : 283-285.

Korikanthimath,V. S., Anke Gowda, S. J., Yadukumar, N., Rajendra Hegde and Hosmani, M. M. 1998a. A study on micro climatic and physiological characteristics in coconut and cardamom mixed cropping system. *Annals of Plant Physiology* 11(2): 107-110

Korikanthimath, V.S., Anke Gowda, S.J., Yadukumar, N., Rajendra Hegde and Hosmani,M.M. 1998b. Microclimatic and physiological analysis in coffee cardamom mixed cropping system. *Journal of Spices and Aromatic Crops* 7(2):133-135.

Korikanthimath,V. S., Anke Gowda, S. J., Yadukumar, N., Rajendra Hegde and Hosmani, M. M. 1998c. Mixed cropping of arabica coffee and cardamom: Influence on micro climatic and physiological characteristics. *Journal of Medicinal and Aromatic Plant Sciences* 20(2): 394-396.

Korikanthimath, V.S., Anke Gowda, S.J., Yadukumar, N., Rajendra Hegde and Hosmani, M.M.1999a. Micro-climatic and physiological characteristics of robusta coffee - cardamom, Coorg mandarin and pepper in mixed cropping system. *Indian Journal of Agronomy* 44(2):289-293.

Korikanthimath, V.S., Anke Gowda, S.J., Yedukumar, N., Rajendra Hegde and Hosmani, M.M.2000a. Micro climatic and photosynthetic characteristics in arecanut and cardamom mixed cropping system. *Journal of Spices and Aromatic Crops* 9(1):61-63.

Korikanthimath, V.S., Gaddi, A.V. and Anke Gowda, S.J. 2000b. Studies on nutrient uptake pattern in cardamom. *Indian Journal of Horticulture* 57(2):164-167.

Korikanthimath, V.S., Gaddi, A.V and Anke Gowda, S.J. 2000c. Status of major nutrients in soils of cardamom (*Eletteria cardamomum* Maton) plantations in Kodagu District, Karnataka, India. *Journal of Spices and Aromatic Crops* 9(2): 117-122.

Korikanthimath, V.S., Gaddi A. V. and Anke Gowda S. J. 2001b. Studies on the Fertilizer Management in Cardamom in Secondary Nursery. *Karnataka Journal of Agricultural Sciences*, 14(4): 1147-1148.

Korikanthimath, V.S., Gaddi, A.V. and Anke Gowda, S.J. 2003. Selection of index leaf in cardamom (Elettaria cardamomum Maton) for nutrient diagnosis *Indian Journal of Horticulture* 60(1) : 108-112.

Korikanthimath, V.S., Gaddi, A.V, Anke Gowda, S.J. and Govardhan Rao, 2002a. Soil fertility evaluation in plantation belt of Kodagu district, Karnataka. *Journal of Medicinal and Aromatic Plant Sciences* 24(2) : 407 – 409.

Korikanthimath, V. S., Gaddi A. V., Shivaprasad C. R., Nasre, R. A., Artikoyal, Ramesh M. and Krishnan P. 2003a. Macro and micro-nutrients status of cardamom growing soils of Western Ghat region in Karnataka. *Journal of Plantation Crops* 31(2): 59-61

Korikanthimath, V.S., Gayathri, A.G. Anke Gowda, S.J., Rajendra Hegde and Hosmani, M.M. 2000d. Vesicular-Arbuscular Mycorrhizae and Phosphate Solubilizer in Robusta Coffee and cardamom mixed cropping systems . *Karnataka Journal of Agricultural* Sciences 132(2): 498-499.

Korikanthimath, V.S. and Govardhan Rao, 2000a. High density trench system of cultivation of cardamom. " National Seminar on Hi-tec Horticulture, abstracts" organised by National Academy of Agricultural Sciences, Horticulture Society of India, New Delhi and Indian Institute of Horticultural Research, Bangalore, Hotel Atria, Bangalore 22-28 June,2000 pp. 89.

Korikanthimath, V.S. and Govardhan Rao, 2000b. Intensive cultivation of cardamom in high elevation and high rainfall. *Mysore Journal of Agricultural Sciences* 34(2):240-246.

Korikanthimath, V.S., Govardhan Rao, Gaddi, A. V Hiremath, G.M and Prasath, D. 2000e. Human resource-use efficiency in relation to different rounds of harvesting and yield in cardamom. *Indian Journal of Horticulture* 57(4): 356-359.

Korikanthimath, V.S., Govardhan Rao and Hiremath, G.M. 1999b. Prospects of conversion of marshy areas - a techno-economic feasibility for cardamom cultivation. *Indian Journal of* Horticulture 56(4):360-367.

Korikanthimath V.S; Govardhan Rao, Hiremath G.M. and Prasath, D. 2001c. Differential pattern of return-inflow in relation to various grades of cardamom (*Eletteria cardamoum* Maton). *Jouranl of medicianal and aeromatic plant sciences* 23 : 666-669.

Korikanthimath, V.S., Govardhan Rao and Hiremath, G.M. 2000f. Performance of cardamom (*Elettaria cardamomum* Maton) under low elevations and assured irrigation conditions. *Journal of Plantation Crops* 28(3):201-207.

Korikanthimath, V.S., Govardhan Rao and Hiremath, G.M. 2001d. Long Term Performance of Cardamom - An economic appraisal. *Madras Agricultural Journal* 88(10-12) : 564 – 571.

Korikanthimath, V.S., Govardhan Rao and Hiremath, G.M. 2002b. Cultivation of cardamom (*Elettaria cardamomum* Maton) in valley bottoms under natural forest ever green shade trees. *Journal of Medicinal and Aromatic Plant Sciences.* 24(1) : 53-59.

Korikanthimath V. S., Govardhan Rao and Hiremath G.M. 2003b. Conversion of upland open vacant areas for profitable cultivation of cardamom by agroforestry approaches. *Indian Journal of Horticulture,* 60(2) : 195-202.

Korikanthimath, V.S. and Hiremath, G.M., 2000. Economic feasibility of cardamom cultivation on the steep slopes of western ghats. In: Muraleedharan, N. and Rajkumar, R. (Eds). Recent advances in Plantation Crops Research pp. 456-461. Paper presented at the Thirteenth Plantation Crops Symposium (PLACROSYM-XIII), Coimbatore, Tamil Nadu, organised by UPASI Tea Research Foundation, Tea Research Institute, Valparai, Coimbatore district, Tamil Nadu.

Korikanthimath, V. S., Hiremath, G. M., Hegde, R., Mulge, R. and Hosmani, M. M. 1997a. Comparative input utilization pattern in mono v/s mixed cropping of arecanut with cardamom. *Journal of Maharashtra Agricultural University* 22(2):210-212.

Korikanthimath, V. S., Hiremath, G. M. and Hosmani, M. M. 1998d. Cultivation of cardamom (*Elettaria cardamomum* Maton)in homesteads. *Journal of Spices and Aromatic Crops* 7(1): 1-6.

Korikanthimath, V.S., Hiremath, G.M. and Hosmani, M.M. 1998e. Labour requirement for Arabica Coffee and Cardamom and its relationship with productivity levels in the mixed cropping systems . *Madras Agricultural Journal* 85(7-9):413-417.

Korikanthimath, V.S., Hiremath, G.M. and Hosmani, M.M.1998f. Labour use pattern in mixed cropping of robusta coffee, pepper and cardamom. *Karnataka Journal of Agricultural Sciences* 11(2):445-449.

Korikanthimath, V.S., Hiremath, G.M. and Hosmani, M.M. 1999c. Generation of employment potential in coffee-cardamom based cropping systems. *Journal of Spices and Aromatic Crops* 8(1):29-34.

Korikanthimath, V.S., Hiremath, G.M. and Hosmani, M.M. 2000g. Requirement of labour in the mixed cropping of coconut and cardamom and its relationship with productivity levels. *Crop Research* 20(3):520-524.

Korikanthimath, V.S., Hiremath, G.M. and Rajendra Hegde,2000h. Agro- forestry approaches in cultivation of pepper and cardamom in marginal uplands - an economic evaluation. *Journal of Plantation Crops.* 28(2):167-170.

Korikanthimath, V. S., Hiremath, G. M., Rajendra Hegde, Ravindra Mulge and Hosmani, M. M. 1997b. Input use pattern in mixed cropping of robusta coffee with cardamom. *Karnataka Journal of Agricultural Sciences* 10(3): 653-658.

Korikanthimath, V. S., Hiremath, G. M., Rajendra Hegde; Ravindra Mulge and Hosmani, M. M. 1997c. Input requirement of robusta coffee, pepper and Cardamom. *Mysore Journal of Agricultural Sciences* 31(4): 313-318.

Korikanthimath, V. S., Hiremath, G. M., Rajendra Hegde, Ravindra Mulge and Hosmani, M. M. 1998g. Input requirement in mixed cropping of arabica coffee with cardamom. *South Indian Horticulture* 46 (1&2): 60-64.

Korikanthimath, V.S., Hiremath, G.M., Rajendra Hegde, Ravindra Mulge and Hosmani,M.M. 1998h. Relative requirement of inputs in the mono v/s mixed cropping of coconut with cardamom. *Madras Agricultural Journal* 85(3&4):186-188.

Korikanthimath, V.S., Hiremath, G.M., Venugopal, M.N. and Rajendra Hegde,1999d.Feasibility of cultivation of Vanilla with Coconut. *Journal of Medicinal and Aromatic Plant Sciences* 21(4): 1033-1039.

Korikanthimath, V.S. and Hosmani,M.M. 1998. Organic Recycling of Coffee Pulp in Coffee Based Cropping System. *Mysore Journal of Agricultural Sciences* 32(2):127-130.

Korikanthimath, V. S., Kiresur, V., Hiremath, G. M., Rajendra Hegde and Ravindra Mulge, 1996. Economics of mixed cropping of arabica coffee with cardamom. *Journal of Coffee Research* 26(1): 23-33.

Korikanthimath, V.S., Kiresur, V., Hiremath G.M., Rajendra Hegde, Ravindra Mulge and Hosmani, M.M. 1997d. Economics of mixed cropping of cardamom (*Elettaria cardamomum* Maton) in arecanut (*Areca catechu* L.) gardens. *Journal of Spices and Aromatic Crops* 6(2): 107-113.

Korikanthimath, V. S., Kiresur, V., Hiremath, G.M; Rajendra Hegde, Ravindra Mulge and Hosmani, M.M.1998i. Economics of mixed cropping of coconut with cardamom. *Crop Research* 15 (2&3): 188-195.

Korikanthimath, V. S., Kiresur, V., Hiremath, G. M., Rajendra Hegde., Ravindra Mulge and Hosmani, M. M. 1998j. Economics of mixed cropping of pepper, Coorg mandarin and cardamom in robusta coffee. *Journal of Plantation Crops* 26(2): 149-155.

Korikanthimath, V.S., Kiresur, V., Hiremath, G.M., Rajendra Hegde, Ravindra Mulge and Hosmani, M.M. 2000i. Economics of mix cropping of robusta coffee with cardamom. *Crop Research* 20(3): 513-519.

Korikanthimath, V.S., Mathew, M.J., Ravindra Mulge, Rajendra Hegde and Hosmani, M.M.1999e. Studies on selection of elite lines of Cl-37 seedling progenies of cardamom (*Elettaria cardamomum* Maton). *Journal of Spices and Aromatic Crops* 8(1):57-61.

Korikanthimath,V.S. and Naidu, R. 1986. Influence of stage of harvest on the recovery percentage of cardamom. *Cardamom* 14(2): 5-8.

Korikanthimath, V.S., Prasath, D and Mohamed Sayed, A.A. 2000j. Association of yield attributes among quantitative characters of cardamom(*Elettaria cardamomum* Maton). *Journal of Spices and Aromatic Crops* 9(2):155-156.

Korikanthimath, V.S., Prasath, D and Mohammed Sayed, A.A. 2000k. Evaluation of cardamom accessions in relation to yield, recovery and oil content. *Indian Journal of Horticulture* 57(3): 273-275.

Korikanthimath, V.S. and Rajendra Hegde, 1998. Water management in cardamom - problems and prospects. In: Sadanandan A.K., Krishnamurthy, K.S., Kandiannan, K. and Korikanthimath, V.S. (Eds.). Water and Nutrient Management for Sustainable Production and Quality of Spices, Indian Society for Spices, Calicut, Kerala pp. 111-122 (Organised by Indian Society for Spices held at Madikeri, Kodagu, Karnataka, Octo,1997.

Korikanthimath, V.S., Rajendra Hegde, Hiremath, G.M. and Hosmani, M.M.1998k. Planting density and nutrient levels on yield performance of cardamom. *Karnataka Journal of Agricultural Sciences* 11(3):610-614.

Korikanthimath, V.S., Rajendra Hegde and Hosmani, M.M. 1998l. Effect of NPK nutrients on growth and tiller production in cardamom. *Karnataka Journal of Agricultural Sciences* 11(3):747-750.

Korikanthimath, V. S., Rajendra Hegde and Hosmani, M.M. 1998m. Influence of major nutrients on the yield and yield parameters of cardamom grown under controlled shade. *Journal of Medicinal and Aromatic Plant Sciences* 20(3): 700-702.

Korikanthimath, V.S., Rajendra Hegde and Hosmani, M.M. 1998n. Partitioning of dry matter in cardamom under controlled shade as influenced by nutrition. *Mysore Journal of Agricultural Sciences* 32(3):191-194.

Korikanthimath,V.S., Rajendra Hegde, Ravindra Mulge and Hosmani, M.M. 1998o. Effect of plant density and nutrient levels on tillering and yield in cardamom. *Journal of Tropical Agriculture* 36(1&2):28-30.

Korikanthimath, V.S., Rajendra Hegde, Ravindra Mulge and Hosmani, M.M. 1999f. Effect of planting density and nutrient levels on solar energy interception and growth characters in cardamom (*Elettaria cardamomum* Maton). *Journal of Medicinal and Aromatic Plant Sciences* 21(4):1011-1014.

Korikanthimath, V. S., Rajendra Hegde; Ravindra Mulge and Hosmani, M. M. 1998p. Growth and yield parameters of cardamom (*Elettaria cardamomum* Maton) as influenced by nutrition and planting density. *Journal of Spices and Aromatic Crops* 7(1): 39-42.

Korikanthimath, V.S., Rajendra Hegde, Ravindra Mulge and Hosmani, M.M.1998q. Mixed cropping of Arecanut and cardamom -compatibility and yield pattern. *Karnataka Journal of Agricultural Sciences* 11(3):751-756.

Korikanthimath, V.S., Rajendra Hegde, Ravindra Mulge and Hosmani,M.M. 2001. Coconut based cardamom multistoreyed cropping system - compatibility and yield pattern. *Crop Research* 20(2):343-349.

Korikanthimath, V.S., Rajendra Hegde and Sivaraman, K. 1995. Integrated input management in coffee based spices multistoreyed cropping system. *Indian Coffee* 59(2):3-6.

Korikanthimath, V.S., Rajendra Hegde, Zachariah, J. and Hosmani, M.M.1999g. Quality attributes of cardamom grown under controlled shade as influenced by nutritional levels. *Karnataka Journal of Agricultural Scienc.* 12 (*1-4 combined*):6-9.

Korikanthimath, V.S. and Ravindra Mulge. 1998a. Assessment of elite cardamom lines for dry matter distribution and harvest index. *Journal of Medicinal and Aromatic Plant Sciences* 20(1): 28-31.

Korikanthimath, V.S. and Ravindra Mulge, 1998b. Pre sowing seed treatment to enhance germination in cardamom. *Karnataka Journal of Agricultural Sciences 11(2):540-541.*

Korikanthimath, V.S., Ravindra Mulge and Hosmani, M.M. 1997e. Evaluation of elite cardamom (*Elettaria cardamomum* Maton) for growth parameters in clonal nursery. *Crop Research* 14(2):283-288.

Korikanthimath, V.S., Ravindra Mulge and Hosmani, M.M. 1997f.Preliminary evaluation of elite clones of cardamom (*Elettaria cardamomum* Maton) for yield and yield parameters in clonal nursery. *Journal of Spices and Aromatic Crops* 6 (1):37-41.

Korikanthimath, V.S., Ravindra Mulge and John Zachariah, 1999h. Variation in essential oil constituents in high yielding selections of cardamom. *Journal of Plantation Crops* 27(3):230-232.

Korikanthimath, V.S., Ravindra Mulge, Rajendra Hegde and Hosmani, M.M. 1997g. Coffee-cardamom, black pepper and mandarin mixed cropping system - a case study. *Journal of Spices and Aromatic Crops* 6(1):1-7.

Korikanthimath, V.S., Ravindra Mulge, Rajendra Hegde and Hosmani, M. M. 1997h. Correlation between growth and yield characters in cardamom. *Mysore Journal of Agricultural Sciences* 31(4): 345-347.

Korikanthimath, V. S., Ravindra Mulge; Rajendra Hegde and Hosmani, M. M. 1998r. Crop combination and yield pattern in coffee mix cropped with cardamom. *Journal of Plantation Crops* 26(1):41-49.

Korikanthimath,V.S., Ravindra Mulge, Rajendra Hegde and Hosmani, M.M. 1999i. Correlation between yield and yield parameters in cardamom (*Elettaria cardamomum* Maton). *Journal of Medicinal and Aromatic Plant Sciences* 21(3):700-701.

Korikanthimath,V.S., Ravindra Mulge, Rajendra Hegde and Hosmani, M.M. 2002c. Evaluation of elite lines of cardamom (*Elettaria cardamomum* Maton) for yield and yield parameters. *Indian Journal of Horticulture* 59(3) : 326-330.

Korikanthimath, V.S., Ravindra Mulge and Zachariah, T.J, 1997i. Variation in the yield and quality characters of cardamom (*Elettaria cardamomum* Maton) clones. *Journal of Medicinal and Aromatic Plant Sciences* 19(4):1024-1027.

Korikanthimath, V.S. and Subbarao, G. 1983. Leaf area determination in cardamom (*Elettaria cardamomum* Maton). *Journal of Plantation Crops* 11(2):151-153.

Korikanthimath V S and Venugopal M N 1980 Dicotyledonous yield of cardamom estates. Conference of Indian Society of Weed Science, Abstracts pp-95.

Korikanthimath V S and Venugopal M N 1985 Some weeds of cardamom estates. Indian J.Weed Sci. 17(3):59-60.

Korikanthimath V S and Venugopal M N 1986 High Production Technology in cardamom. National Research Centre for Spices, Calicut, Kerala.

Korikanthimath V S and Venugopal M N 1987 Dicotyledonous weeds of cardamom estates. Indian J. Weed Science, 17(3):59-60.

Korikanthimath, V.S. Venugopal, M.N. and Naidu, R. 1989a. Cardamom Production - A success story. *Spice India* 2(9):19-24.

Korikanthimath, V.S., Venugopal, M.N., Naidu,R. and Sadanandan,A. K. 1989b. Intensive cultivation of cardamom-A case study. *Spice India* 2(2): 5-8.

Korikanthimath V. S., Venugopal, M. N., Naidu, R. and Sadanandan, A. K., 1991. Increasing productivity of cardamom through large scale demonstration of improved technology in farmers fields in Kodagu District of Karnataka *Journal of Plantation Crops* 18 (Suppl.): 399-403.

Korikanthimath, V.S., Venugopal, M.N., Rajendra Hegde and Anke Gowda, S.J. 1998s. Studies on multiple branching panicles in cardamom (*Elettaria cardamomum* Maton). *Journal of Spices and Aromatic Crops* 7(2):125-127.

Korikanthimath,V.S., Venugopal, M.N. and Sadanandan, A.K. 1989c. Labour utilization pattern in relation to other input requirements in cardamom plantations. *Spice India* 11 (2): 5-11.

Krishnamurthy K, Khan M M, Aradhani K K, Venkatesh J, Siddaramaiah AL, Chackravarthy A K and Gurumurthy B R 1989 Three decades of cardamom research at Regional Research Station, Mudigere (1958-1988). Regional Research Station, Mudigere, p. 94.

Kuttappa K M 1969 Cardamom - digging. Cardamom News 2(7):3-5.

Madhusoodanan M J 1992 Elite clones of cardamom. In Sharma Y R, Devasahayam S and Anandaraj M (Eds.), Proc. Black pepper and cardamom pp 65-67. Indian Society for Spices, Calicut, Kerala.

Mohammed Sayed, A.A., Korikanthimath, V.S. and Mathew, A.C. 1979. Evaluation of oil percentage in different varieties/types of cardamom. *Cardamom* 11(1): 33-34.

Pattanshetty H V and Prasad A N 1973 September is the most suitable for sowing cardamom seeds. Curr. Res. 2(5):26.

Pattanshetty H V 1980 Selection and cloning for high productivity in cardamom (*Elettaria cardamomum* Maton). VAR. Minor WATT; Ph.D. Thesis, University of Agricultural Sciences, Bangalore, Karnataka, India.

Prasath, D, Venugopal, M. N and Korikanthimath, V. S. 2001. Variability in cardamom (*Elettaria cardamomum* Maton). *Indian Journal of Plant Genetic Resources* 14(2): 217-219

Regy Lukose, Saju, K.V., Venugopal, M.N. and Korikanthimath, V.S. 1993. Comparative field performance of micro propagated plants of cardamom (*Elettaria cardamomum* Maton). *Indian Journal of Agricultural Sciences* 63(7): 417-418.

Rohini Iyer, Kalpana Sastry, R. and Korikanthimath, V.S. 1986. Effect of Fertilizer levels on Vesicular Arbuscular Mycorrhiza Colonisation in Cardamom. *Journal of Plantation Crops* 16 (Supplement): 429-432.

Shivprasad, C.R., Korikanthimath, V.S., Gaddi, A.V., Niranjan, K.V., Venkatesh, D.H. and Krishnan, P. 2001. Soil-site suitability evaluation for cardamom – A case study. *Journal of Spices and Aromatic Crops* 10 (2) : 99 – 103.

Siddaramaiah 1967 Hints on raising of cardamom nursery in Mysore State. Cardamom News 1(6):4.

Subbarao, G. and Korikanthimath, V.S. 1983. The influence of rainfall on the yield of cardamom (*Elettaria cardamomum* Maton) in Coorg District. *Journal of Plantation Crops* 11(1) 58-69.

Sulikeri G S 1986 Effects of light intensity and soil moisture levels on growth and yield of cardamom (Elettaria cardamomum Maton) var. Minor Watt). Ph.D. (Hort.). Thesis, University of Agril. Sciences, Bangalore.

Sulikeri G S and Kololgi S T 1978 *Phyllenthes amblica* L. leaves - a suitable mulch for cardamom nursery beds. Curr. Res. 7(1):3-4.

Zachariah P K 1976 Mulching in cardamom plantations. Cardamom News, 8(1):3-9.-47.

17

Implication of plant growth regulators on bioregulation of growth and yield in chilli

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Abstract

India is regarded as the prime producer of chilli. It is being exported to over 90 countries. India with an expected population of 1.2 billion by 2005, will be the largest consumer of chilli. About 95 per cent of the produce is consumed domestically and hardly 4-5 per cent is exported. The productivity of this crop has to be increased to meet out both the internal and external market demand. The low yield levels experienced are mainly attributed to abscission of flowers, poor fruit set and premature dropping of fruits. Flower and fruit drop ranges from 20-80 per cent of which major portion occurs due to physiological reasons. The bio regulation of growth, yield and quality by externally supplied chemicals is one of the most exciting research areas of the recent times. In the light of above, an experiment was laid out in a Randomised Block Design with 11 treatments in 3 replications, to study the effect of foliar application of certain plant growth regulators viz., GA_3 at 100 and 250ppm, kinetin at 10 and 25ppm, paclobutrazol at 100 and 150ppm, NAA at 20 and 40ppm and ethrel at 100 and 250ppm along with a control. The treatments were imposed on 30, 60, 90 and 120 days after transplanting. Among the growth regulators tried, paclobutrazol at 150ppm was found to influence the fruit characters such as fruit length, fruit girth, fruit stalk length, number of fruits per plant (103.64), number of seeds per fruit, weight of seeds per fruit and yield. Results of the research conducted in two consecutive seasons confirm the above finding.

Key words: bio regulation, chilli, plant growth regulators.

Introduction

Chilli (*Capsicum annuum* L.) is an important cash crop and also a good source of vitamins and minerals. India being regarded as the land of spices, Indian chilli is exported to over 90 countries. The crop is grown in almost all the states with the average productivity of 1.0 metric tonnes ha^{-1}. The low yield levels are mainly attributed due to physiological reasons. Application of plant growth regulators to boost growth, yield and quality of crop plants is a latest trend in horticulture. The use of these chemicals interfere with genetic stability which may reflect on growth, yield and quality directly. Hence, the present investigation was undertaken to study the effect of certain plant growth regulators on chilli cv. K2.

Materials and methods

The investigation was carried out in the Department of Horticulture, Faculty of Agriculture, Annamalai University from December 2000 to April 2002. The field was laid out in a Randomised Block Design with 11 treatments in three replications. Individual plots of size 5 x 2.5 m (12.5 m^2) were made and the seedlings of variety K2 were transplanted at a spacing of 45 x 75 cm. The treatments include five plant regulators, viz., GA_3 at 100 and 250ppm, kinetin at 10 and 25ppm, paclobutrazol at 100 and 150ppm, NAA at 20 and 40ppm and ethrel at 100 and 250ppm were imposed as foliar spray at four stages i.e., at 30^{th}, 60^{th}, 90^{th} and 120^{th} day after planting along with a control. The biometric observations recorded were statistically analysed as per the methods suggested by Panse and Sukhatme (1978).

Results and discussion

The experimental findings are presented in Tables 1 and 2. The height of main shoot significantly increased (99.42 and 98.95 cm) by GA_3 at 250ppm in first and second crop respectively. These results are in line with those of Maurya and Lal (1987) in green chilli. This may be due to increased cell division in apical meristem and cell elongation brought about by GA_3 as suggested by Sponsel (1985).

The highest response for number of branches was noticed in paclobutrazol at 150ppm, which recorded 82.63 per cent and 89.97 per cent more when compared to control in both the cropping seasons respectively. This result is in conformity with the findings of Baruah *et al.* (1996) in tomato. The possible reason may be due to inhibitory effect of paclobutrazol (retardant) that suppressed the growth of main axis and in turn accelerated the growth and formation of lateral shoots and produced significantly more number of branches.

Earliness in terms of days taken to fifty per cent flowering was found to be favourable in paclobutrazol treated plants especially at 150ppm, which took 45.66 and 44.13 days during first and second crop season respectively. During both the years of experimentation, the dry fruit yield recorded as kg ha^{-1} was desirably highest (2104.09 and 2096.99) due to the application of paclobutrazol at 150ppm. Similar findings has been reported by Asao *et al.* (1996) in tomato and Bist and Rai (1994) in pears.

The maximum number of fruits (102.78) during first and second crop (103.64) was harvested in paclobutrazol (150ppm) treated plants. This might be due to the plant growth regulators which promote the distribution of assimilates vis a vis meristematic activity. The proportion of assimilates allocated to the reproductive structures could have a direct effect on fruit yield. The increased availability of assimilates possibly led to initiation of more floral buds on branches that ultimately contributed to greater number of fruits.

The highest mean values for fruit length (10.26 and 10.29 cm) and girth of the fruit (4.69 and 4.68 cm) were recorded because of spraying paclobutrazol at 150 ppm during both the crop seasons respectively. This result is in line with that of Addo-Quaye *et al.* (1985), who have demonstrated that paclobutrazol changed the pattern of assimilate distribution towards reproductive parts especially to terminal and upper branches of plants. The highest response for number of seeds per fruit was noticed in paclobutrazol at 150ppm, which recorded 88.07 and 88.91 during first and second crop season respectively. The increase in number of seeds may be due to large size of the fruits that ultimately increased the number of seeds.

Although NAA at 20 and 40ppm, GA_3 at 100 and 250ppm and kinetin at 10 and 20ppm had resulted in the considerable improvement of growth and yield of chilli over control, paclobutrazol at 150ppm is adjudged as the best to increase the yield of chilli cv. K2.

Table 1. Effect of growth regulators on plant height (cm) at harvest, number of branches, days taken to fifty per cent flowering and dry fruit yield ha^{-1} of chilli cv. K2

Tr. No.	Growth regulators/ Concentration	Plant height (cm) at harvest		Number of branches		Days taken to fifty per cent flowering		Dry fruit yield ha^{-1}	
		I Crop (2000-2001)	II Crop (2001-2002)	I Crop (2000-2001)	II Crop (2001-2002)	I Crop (2000-2001)	II Crop (2001-2002)	I Crop (2000-2001)	II Crop (2001-2002)
T_1	GA_3 100 ppm	95.35	93.71	14.81	14.64	52.42	53.63	1584.54	1595.45
T_2	GA_3 250 ppm	99.42	98.95	14.96	15.06	50.90	50.71	1680.31	1688.06
T_3	Kinetin 10 ppm	84.83	84.92	13.04	13.14	58.13	57.82	1433.93	1448.16
T_4	Kinetin 20 ppm	86.43	85.84	13.54	13.76	57.46	56.24	1464.88	1472.31
T_5	Paclobutrazol 100 ppm	77.54	76.26	15.63	16.29	48.83	47.51	1792.91	1800.12
T_6	Paclobutrazol 150 ppm	73.63	72.05	17.04	18.01	45.66	44.13	2104.09	2096.99
T_7	NAA 20 ppm	89.75	90.01	14.01	14.52	54.62	55.31	1472.78	1488.23
T_8	NAA 40 ppm	92.30	91.23	14.90	14.90	51.47	52.17	1664.84	1672.36
T_9	Ethrel 100 ppm	80.60	79.84	11.36	11.38	61.13	61.93	1256.73	1263.53
T_{10}	Ethrel 250 ppm	79.82	77.16	11.54	11.47	60.08	60.34	1296.92	1304.21
T_{11}	Control	82.08	81.76	9.33	9.48	68.34	67.53	1064.87	1072.21
	S.Ed.	1.05	1.18	0.27	0.49	1.04	0.76	30.03	30.53
	CD (p=0.05)	2.11	2.38	0.54	0.99	2.04	1.53	60.36	61.37

Table 2. Effect of growth regulators on fruit length, fruit girth, number of fruits per plant and number of seeds per fruit of chilli cv. K2

Tr. No.	Growth regulators/ Concentration	Fruit length (cm)		Fruit girth (cm)		Number of fruits per plant		Number of seeds per fruit	
		I Crop (2000-2001)	II Crop (2001-2002)	I Crop (2000-2001)	II Crop (2001-2002)	I Crop (2000-2001)	II Crop (2001-2002)	I Crop (2000-2001)	II Crop (2001-2002)
T_1	GA_3 100 ppm	7.99	7.99	3.97	3.94	83.72	84.06	77.75	78.43
T_2	GA_3 250 ppm	8.08	8.04	4.02	4.08	90.23	91.52	80.34	81.01
T_3	Kinetin 10 ppm	7.93	7.90	3.82	3.82	77.64	76.93	69.91	70.25
T_4	Kinetin 20 ppm	7.97	7.91	3.91	3.89	79.83	79.15	74.35	75.02
T_5	Paclobutrazol 100 ppm	8.61	8.43	4.26	4.37	94.64	95.03	83.95	84.43
T_6	Paclobutrazol 150 ppm	10.26	10.29	4.69	4.68	102.78	103.64	88.07	88.91
T_7	NAA 20 ppm	7.98	7.96	3.87	3.91	82.92	83.21	77.08	77.60
T_8	NAA 40 ppm	8.04	8.01	4.01	3.95	86.64	87.96	79.42	80.11
T_9	Ethrel 100 ppm	7.88	7.90	3.81	3.79	68.38	70.52	65.67	66.09
T_{10}	Ethrel 250 ppm	7.90	7.87	3.92	3.80	68.68	70.82	66.71	66.84
T_{11}	Control	6.32	6.52	3.01	2.99	52.27	51.63	54.95	53.98
	S.Ed.	0.20	0.19	0.07	0.12	1.19	1.23	1.08	1.30
	CD (p=0.05)	0.41	0.38	0.15	0.25	2.39	2.48	2.17	2.52

References

Addo-Quaye, A.A., R.W. Daniels and D.H. Scarisbrick. 1985. The influence of paclobutrazol on the distribution and utilization of ^{14}C labelled assimilate fixed at anthesis of oilseed rape (*Brassica napus* L.). J. Agric. Sci., 105:365-373.

Asao, R., O.N. Hosokit and O. Htakendok. 1996. Effect of plant growth regulators and root pruning on growth and yield of tomato cultivated hydroponically at high temperature during summer. J. Jap. Soc. Hort. Sci., 65(1):89-94.

Baruah, G.K.S., S.K. Arora and M.L. Pandita. 1996. Effect of paclobutrazol (PP_{333}) on yield and yield attributing characters of tomato (*Lycopersicon esculentum* Mill) under different nitrogen levels. Haryana J. Hort. Sci., 25(1):58-64.

Bist, L.D. and N. Rai. 1994. Residual effect of paclobutrazol and promalin on tree shaping and productivity of 'Gola' pear. Indian J. Hort., 51:41-43.

Maurya, C.P. and H. Lal. 1987. Effect of IAA, NAA and GA on growth and yield of onion (*Allium cepa* L.) and vegetable chilli (*Capsicum annuum* L.). Prog. Hort., 19(3&4):203-206.

Panse, V.G and P.V. Sukhatme. 1978. Statistical Methods for Agricultural Workers. ICAR, Pub., New Delhi. pp.157-165.

Sponsel, V.M. 1985. Gibberellins in *Pisum sativum*, their nature, distribution and involvement in development of the plant. Physiol. Plant, 65:533-538.

18

The growth of *Rosa damacena* Mill and maximization of flower yield and active ingredients in rose with mixed inter cropping of crash crop-Zingiber

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Abstract

An experiment was performed to evaluate the feasibility of mixed intercropping of crash crop with rose (*Rosa damacena* Mill). Rose commercial products, comes in terms of flowering which yields rose essential monoterpene oil(s). Trial for maximization of rose flowering and growth of the plants were laid down in CIMAP research filed form with intercropping of crash crop-Zingiber (*Zingiber officinalis* L.). The inter-cropping of rose with *Zingiber officinalis* local and Haldwani variants were performed in row to row with end to end planting at 0,30,60 and 120 Kg N per hectare in the form of N-NO_3 with four replicates, in a complete randomized block design. Remarkable changes were observed at 120 kg N amendments in rose oil quality and quantity with maximum flowering over control. Significant positive correlation ($r=0.926 \leq p=0.05$) obtained in between flowering and essential monoterpene oil(s), which revealed a better growth of *Rosa damascena* Mill. This experimental results throws a better technological approach of intercropping – Zingiber, with long chained ester compounds of rose oil constituents.

Key words: essential monoterpene oil(s), intercrops, mixed intercropping, rose, Zingiber.

Introduction

Rosa damascena Mill. is economically important, essential monoterpene oil(s) bearing plant. The growth in terms of percentage of flowering is a basic criteria for flowering biomass. The flowers on steam distillation yields essential monoterpene oil(s), commonly known as rose oil (Misra *et al.* 2001). The cultivation of *R. damascena* visualized the bumper flowering percentage consequently comes out in third successful years, after the planting (John *et al.* 1992). Its farming by that times appear to be more cost effectives for returns to the farmers and industrialist will have to wait for economics, marginal farmers will not get returns in terms of money, to 3 years. Moreover, in hills its cultivation effects the farmers land is very limited. Taking into the consideration of the socio economics, the concept of mixed intercropping, comes out (Ram *et al.* 1998; Rajeshwar Rao 2000). Apart from this racio-economical problems. The scientific inputs in this experiment, leads the mixed intercroppings of crash crop Zingiber with rose (*Rose damascena* Mill.) on one hand, can effect the quality and quantity of essential monoterpene oil(s). Secondly, the socio-economical values of the marginal farmers can be solved by getting the returns from the very first year yield of crash crop. So the inputs in terms of money for farmers, can be readily worked out and will not have to wait for *Rosa damascena* ultimate yield essential monoterpene oil(s), for three years. Therefore, the objectives of the present study were to investigate the feasibility of mixed intercrop of crash crop Zingiber (*Zingiber officinallis* L.) with (*Rosa damascena* Mill.) growth, physiology and its essential monoterpene oil(s) quality and quantity in relation to the technological approaches resultant for the produces of rose oil industry and to the farmers inputs and returns. It appears possible to further improve the economics of cultivation of *Rosa damascena* Mill. by crash crops-Zingiber.

Materials and methods

A field experiment was carried out for 3 years (1998, 1999 and 2000) at the CIMAP, Lucknow research farm located at 26°5 N latitude, 80°5E longitude and 120 m above mean sea level. The soil is of entysol type of the experimental farm plot, which is sandy loam in textures with pH 8.2, o.114 d s m^{-1} EC and 0.24% organic carbon content, respectively, with an average micronutrients in 0-20 Cm of the soil profile. Experimental site climate is of sub-tropical in nature. *Rosa damascena* Mill. was grown as main monocrops with short duration crash crop-Zingiber (4-5 months peak period when rose flowering is off) were choosen for mixed intercropping system in this study. 8 treatments combinations of monoculture and intercrops were tested in a randomized block design with 4 replicates, *Rosa damascena* Mill. solo (with 0,30 kg N/ha, 60 Kg N/ha and 120 kg N/ha; with one local (L) and Haldwani (H) variety of Zingiber, which are the current high yielding cultivars for the respective crops of the region. Rooted cuttings, 10 cms of main crop rose having some 3-4 leaves were planted in the plots of 7 x 3.2 m size at 180 x 60 cm plant spacing accommodating 12 plants per plot. Crash crop-Zingiber of local (L) and Haldwani (H) variety of 2 ecotypes of each as mixed intercrops were sown from end to end in each row at the last week of January during the respective consequitive years. A basal dose of Phosphorus and Potash, each at 60 kg/ha as single super phosphate and nuriate potash, respectively were applied in all the plots at the time of planting. The intercrop combinations were kept with 0.0, 30, 60 and 120 kg N/ha were applied in three equal splits.

Soil samples were collected from 0-20 cm soil depth at initial stage (before experimentation) in 1998 and after the harvest of each year, and at the end of the cropping period 2000. The soil samples were analyzed for organic carbon by the method of Walkley and Black rapid titration and available micronutrients Cu, Mn, Zn and Fe [(DTPA extractable); (Jackson 1967)]. Soil EC calculated with 1:1 ratio by electric conductivity meter.

Rosa damascena Mill. growth attributes in terms of flowering % and Zingiber were harvested on March 20th and June 29 in 1998, 1999 and 2000, respectively. The residual effects of Zingiber root exudates and biomass incorporation was also studied as described earlier (Singh *et al* 2001), following in subsequent flowering and also of harvests of the rose as well as Zingiber during the respective years. Hence the various root exudation resource efficiencies were worked out on the basis of 3 flowering percentage and harvests of the crops per year. Essential monoterpene oil(s) content quality and quantity were quantified from the rose flowering and Zingiber rhizomes samples were estimated by the use of clevenger's apparatus and by Gas liquid Chromatography as described earlier (Misra, 1995; 1997). Plant tissue micronutrients concentrations of the samples of the harvests were estimated by the wet digestion of 1 g dried plants samples (Mengel *et al*, 1994) and further analyzed on Atomic absorption and Direct current pharma-emission spectroscopy as described in previous studies (Misra 1996).

Total chlorophyll and CO_2 exchange rate were evaluated for treated *R. damascena* by the modified method of Misra *et al.* 1997 & Arnon (1941) by Licor-6000 photosynthesis analyzer as described in the previous studies (Misra *et al.* 1997).

Statistical analysis

Complete Randomized design treated plants layout and respective means were computed for least significant test (LSD). Correlation coefficients were compared to study the inter-relationship between various characters studied under field conditions.

Results and discussion

Growth and yield of main crop:

Growth attributes characters in *Rosa damascena* showed that the plant height was influenced significantly when grown in mixed inter cropping system (Table 1). Number of flowering shoots and percentage flowering were greatly increased at 120 kg N hectare, followed by number of branches per plants. Number of branches were significantly reduced with the increase in height in *Zingiber officinallis* when compared with *Rosa-damascena* monoculture. This significant increase in height of *R. damascena* in comparison to *Z. officinalis* decrease in branches indicates that fast growing zingiber as intercrops were more competitive with the main crop for growth resources especially the height and micronutrients dinemics, especially the B and Fe (Table 3 and 4) with root exudations which in turn led to increased in plant heights. It is in relation to the light, that shading leads to tallness and due to the modification of the micro-environment under crop species combinations (Trembath and Harper 1973; Sing *et al*, 1986). The improvement in number of branches in monoculture and reduced in intercrops, with the increased in height was the result of heavy leaf formation and covering of ground by intercrops. Leads to the reduced soil temperature and further creates the conductive soil environment for less branching and more leaf formation with increase in height. Similar results were obtained, when the emergence of young temperate plant species requiring low optimum temperature was obtained with less branching and more leaves (Midmore *et al*, 1988). Reduced soil temperature under maize and legume mixed intercropping favoured a rise in rhizosphere bacteria population that promoted the plant growth with root exudation, for better fertility conditions of the soil (Singh *et al.*, 1986). The herb yield in monocultures *R. damascena* flowering essential monoterpene oil(s) were significantly increased with an increasing of 120 Kg N per hectare (Table 1&2). Significant increase in flowering percentage was influenced by *Z. officisialis* intercrops to the extent of 12% and 18%, respectively than the control 0.0 kg N/ha. Furthermore, the root exudation which is non-proteogenic amino acids and sugar forms of *Z. offcinalis* complex of Fe (Singh *et al.* 2001) and Borate complex with B micro element to monoculture (Table 4) enhance the flowering and further resulting into the higher yield of essential monoterpene oil(s). Data on soil nutrient status (Table 3) clearly showed that the yields of *R. damascena* in terms of % flowering and essential oil was improved with mixed intercrops *Zingiber offcinalis* because of the beneficial residual effects.

Table 1. Growth attributes of *Rosa damascena** (main crop) and mixed intercropping systems of intercrop *Zingiber officinalis**.

Treatments	Height (cm)		No. of branches per plant		No. of Flowering shoot		Flowering per plant		% Flowering		Fresh wt. (g/plant)		Kg/hectare yield	
	Rose	Zingiber	Rose	Zingiber	Rose	Zingiber	Rose	Zingiber	Rose	Zingiber	Rose flower	Zingiber rhizome	Rose	Zingiber
Kg N/ha														
(L)	65	22	7	3	5	-	4	-	11	-	3.2	2.92	1.92	2.01
(H)	72	25	11	5*	7	-	5	-	12	-	2.8	2.97	1.97	2.11
30 Kg N/ha														
(L)	69	24	9	7***	7	-	6	-	14	-	3.7	3.01	2.21	2.71*
(H)	76	27	15	8***	8	-	7*	-	16	-	3.2	3.11	2.71	2.79*
60 Kg N/ha														
(L)	71	36***	17***	10***	12*	-	10***	-	18	-	3.4	5.67***	3.1***	4.11*
(H)	81*	39***	26***	12***	16***	-	12***	-	21	-	3.8	5.77***	3.5***	5.02***
120Kg N/ha														
(L)	110***	48***	39***	8***	32***	-	28***	-	38***	-	3.9*	6.27***	3.1***	4.11*
(H)	127***	67***	44***	6*	41***	-	37***	-	40***	-	4.3***	8.21***	3.5***	5.02***
CD 5%	11.12	7.4	7.1	2.11	6.99	-	2.11	-	9.21	-	0.66	1.69	1.11	1.19
1%	19.15	9.6	8.2	4.17	7.21	-	4.71	-	11.71	-	0.74	2.71	1.37	2.53

*Pooled Data of 1998, 1999 and 2000 year.

* ** p significant at 5% and 1% level, respectively

Table 2. Perentage of total oil and % of total oil of *Rosa damascena* with *Zingiber officinalis* under intercropping systems.

Treatments	% oil		% of total oil								
			Rose oil constituents					Zingiber oil constituents			
	Rose	Zingiber	Geraniol	Citronella	Rose oxide	Phenyl ethyl alcohal	C19	α-Pinene	Linalool	Gingeberine	Geraniol acetate
Kg N/ha											
(L)	0.027	0.37	23.01	11.99	0.20	2.09	2.81	17.27	1.27	3.72	6.869
(H)	0.022	0.32	24.07	12.09	0.21	2.01	2.99	18.29	1.29	3.99	6.711
30 Kg N/ha											
(L)	0.024	0.36	28.01*	11.67	0.23***	2.67***	3.11***	20.07***	1.31***	4.01***	6.899
(H)	0.026	0.37	30.04***	11.88	0.23***	2.44***	3.17***	20.01***	1.32***	4.27***	6.911
60 Kg N/ha											
(L)	0.026	0.37	31.17***	13.01	0.23***	2.54***	3.19***	20.07***	1.47***	4.71***	7.007
(H)	0.029	0.38	31.07***	12.02	0.22***	2.67***	3.21***	20.12***	1.49***	4.91***	7.011
120 Kg N/ha											
(L)	0.037***	0.39***	32.21***	14.89***	0.24***	2.99***	3.39***	20.47***	1.51***	5.17***	7.129
(H)	0.041***	0.41***	31.11***	13.71***	0.21	2.97***	3.41***	20.61***	1.51***	5.28***	7.332***
CD 5%	0.007	0.017	4.71	2.11	0.010	0.114	0.19	2.14	0.011	0.247	0.271
1%	0.009	0.019	4.98	2.71	0.012	0.167	0.21	2.41	0.014	0.254	0.279

* ** p Significantly different at 5% and 1% level respectively.

Several workers have noticed that intercrops cereals with monoculture mixed intercropping system increased the availability of soil nutrients especially micro and macronutrients to the subsequent/later maturing crops (Ofori and Stern 1987; Singh 1983; Denso and Papastyliano 1992).

Table 3. Content of micronutrients in the soil, organic carbon and electrical conductivity (EC) of the experimental site of intercropping systems

Treatments	Fe ($\mu g\ ml^{-1}$)	Mn ($\mu g\ ml^{-1}$)	Zn ($\mu g\ ml^{-1}$)	Cu ($\mu g\ ml^{-1}$)	B ($\mu g\ ml^{-1}$)	Organic carbon (%)	EC. (dsm^{-1})
Kg N/ha							
(L)	2.41	2.11	1.21	0.71	0.62	0.11	1.97
(H)	2.42	2.12	1.27	0.74	0.61	0.17	1.99
30 Kg N/ha							
(L)	3.56***	2.17	1.29	0.86***	0.71***	0.17	1.99
(H)	3.56***	2.18	1.37***	0.87***	0.71***	0.19***	2.00
60 Kg N/ha							
(L)	4.11***	2.51***	1.41***	0.84***	0.69	0.14	2.09***
(H)	4.17***	2.53***	1.47***	0.81***	0.68	0.14	1.98
120 Kg N/ha							
(L)	4.11***	2.89***	1.51***	0.816***	0.69	0.21***	1.97
(H)	4.12***	2.91***	1.57***	0.77	0.62	0.24***	1.97
CD 5%	0.91	0.14	0.12	0.08	0.06	0.07	0.08
1%	0.97	0.19	0.17	0.09	0.08	0.08	0.12

* ** p Significantly different at 5% and 1% level, respectively.

Table 4. Content of micronutrients in the plant tissue of *Rosa damascena* with *Zingiber officinalis* intercropping patterns, with total chlorophyll and CO_2 exchange rates.

Treatments	Fe ($\mu g\ g^{-1}$)	Mn ($\mu g\ g^{-1}$)	Zn ($\mu g\ g^{-1}$)	Cu ($\mu g\ g^{-1}$)	B ($\mu g\ g^{-1}$)	Total chlorophyll (mg g^{-1} f. wt.)	CO_2 exchange rate (mg (CO_2) $m^{-1}S^{-1}$)
Kg N/ha							
(L)	340	111	51	12	22	2.21	521
(H)	347	119	52	12	22	2.29	522
30 Kg N/ha							
(L)	399***	172***	58	11	23	3.17***	545
(H)	401***	176***	57	10	24	3.41***	566
60 Kg N/ha							
(L)	409***	152***	59	16***	39	3.47***	580*
(H)	467***	151***	59	16***	42	3.49***	587*
120 Kg							
N/ha	469***	167***	60	12	44	3.59***	602***
(L)	472***	169***	62***	14*	46	3.59***	607***
(H)							
CD 5%	21	12	7	2	9	0.217	52
1%	39	16	11	4	11	0.274	69

* ** p Significantly different at 5% and 1% level, respectively.

Intercrop productivity

Growth attributes of *Zingiber offcinalis* such as height considerably increased till 120 kg N/ha whereas number of branches increased to the 60 kg N/ha treatments, (Table 1) with an overall significant increase of total oil % and % of total oil, α-pinene and gingiberine the main constituents, over control. (Table 4). The sub-optimal N-fertility status (60kg N/ha) allowed to reduce the number of branches of the intercrops with an increase in height and biomass of Zingiber. The other study of mixed intercropping systems of monoculture and intercrops showed a greater advantage under sub optimal N fertilization. (Renolds and Soyrf 1994; Hiebsch 1997).

The observation of this study, that total yield requirement to the main crop was higher in mixed intercropping system then the *R. damascena* solo without effecting the quality and quantity of essential monoterpene oil(s) with more and more ester compound of rose oil constituents non a decane a C 19 compound. Thus the remarkable changes in rose oil quality and quantity with maximum flowering, over control never effected with mixed intercropping of Rose with Zingiber. Moreover, correlation association in between percentage of flowering and total oil ($r=0.925 \leq p=0.05$) revealed a better growth of monoculture *Rosa damascena*. This experimental study, showed that intercropping system was advantageous of productions of essential oil, percentage flowering and Zingiber rhizome yield per unit area over a period of unit time.

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References

Arnon DI 1949 Copper mgymes in isolation of chloroplasts: Pohyphenol oxidase in Beta vnlgaris. Plant Physiology. 24: 1-15.

Danso SKA & Papastylianou I 1992 Evaluations to the nitrogen contribution of legumes to subsequent crops. J. Agric. Sci. 119:13-18.

Fukai S & Trenbath BR 1993 Process determining intercrop productivity and yields of component crops. Field crops Res. 34: 247-271.

Hiebsch 1999 Comparing intercrops with monocultures. In: Agronomic economic research on soil of the tropics. Annual report. North cardina state University, Raleigh, pp. 187-200.

Jackson ML 1967 Soil chemical analysis. Prentice Hall, Englewood, Cliffs, N.J.

John AQ; Sidddique MAA & Pant TM 1992 Effect of different fertilizer levels on the growth and flower production of *Rosa damascena* Mill. Kashmir. Indian Perfumer. 36:196-202.

Mengel K, Bubl W & Soherer 1994 Iron distribution in vine leaves with HCO_3 induced chlorosis. J. Plant Nutr. 7: 715-724.

Midmore DJ, Roca J & Berecios D 1988 Potato (Solanum spp.) in the hot tropics. V. Intercropping with maize and the influence of shode on tuber yields. Field crops Res. 18: 159-176.

Misra A & Khan A 1992 Correlation of iron-deficiency chlorosis in lemongrass (cymbopogon flxuousus steed watts). Agrochimica 36: 350-360.

Misra A 1995 Zinc nutrition related to critical deficiency and toxicity levels for Japanese mint. J. Herbs spices and medicinal plants. 3:37-43.

Misra A 1996 Genotypes variation of Maganese toxicity and tolerance of Japanese mint. J. Herbs species and Medicinal Plants. 4: 3-13.

Misra A, Srivastva NK & Sharma S 1997 Effect of Zn deficiency on net photosynthetic rate, 14-C partitioning, and oil accumulation in leaves of peppermint. Photosynthetica. 33:71-79.

Misra A, Sharma S, Singh Anand & Patra NK 2000 Influence of low pH and Fe on newly introduced pyrethrum for high altitude. Agrotropica. 12:81-86.

Misra A, Kukareja AK, Singh Anand & Patra NK 2001 Influence of photographical and edaphic factors on flowering quality and quantity in rose Indian Perfumer. 45:43-48.

Ofori F & Stern WR 1987 Cereal-legume intercropping systems. Advances in Agronomy. 41:41-90.

Ram M, Ram D, Prasad A & Kumar S 1998 Productivity of citronella java (*Cymbopogon winterianus* with sparing legumes intercrop under subtropical environment. J. Essential Oil Res. 10:269-275.

Rajeshwar Rao BRR 2000 Biomass yield and essential oil yield variations in Java citronella (*Cymbopogon winterianus* Jwatt.) intercropped with food legumes and vegetables. J. Agronomy and Crop Sciences. 185:99-103.

Renolds MP, Sayrf KD & Vivar HF 1994 Intercropping wheat and barley with a n-fixing legume species a method of improving ground cover, N-use efficiency and productivity in low input systems. J. Agric. Sci. 123:175-183.

Singh NB, Singh PP & Navi KPP 1986 Effect of legume intercropping on enrichment of soil nitrogen, factorial activity and productivity of associated maize crops. Experiment Agric. 22:339-344.

Singh Preety, Sirvastava SK & Misra A 2001 Excretion of Butyl Hydrogen Phthalate by iron efficient *Mentha spicata* L. var. MSS-5 under iron stress. J. Plant Biology. 28:111-114.

Singh SP 1983 Summer legume intercrop effects on yield and nitrogen economy of wheat in the succeeding reason. J. Agric. Sci. 101:401-4005.

Trenbath BK & Harper JL 1973 Neighbor effects in the genus Avena. 1. Comparison of crops species. J. Appl. Ecol. 10: 379-400.

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Evaluation of cultivation and distillation of French lavender (*Lavandula stoechas* L.) in a red soil of semi-arid tropical region

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Abstract

French lavender (*Lavandula stoechas* L.) is a perennial, woody herb which yields an essential oil used in perfumery. Camphor and fenchone are the major constituents of oil of French lavender grown in this region. Cultivation and distillation of this herb was explored in a red soil at CIMAP, Field Station, Bangalore for the first time. The plants were propagated by stem cuttings. Sixty days old rooted cuttings were transplanted in field at a spacing of 60 x 60 cm. The performance of the crop was studied and two harvests were taken. Herb yield, oil content and oil yields were recorded. The essential oil was analysed by gas chromatography. The oil content varied from 0.73 to 0.81% in the fresh herb and from 1.6-2.0% in shade dried herb. The herb yields were 6 t/ha and 4 t/ha in the first and second harvests respectively. The GC analysis of the essential oil indicated the presence of camphor (33-34%), fenchone (37-40%), 1 : 8 cineole (9.4-12.2%), camphene (2.7 to 2.9%) and α–pinene (1.4-1.6%). After first harvest, the crop was affected by a leaf and stem blight disease. Application of carbendezim (Bavistin-50) @ 0.1% at fortnightly intervals in 3 sprays during rainy season minimized the disease incidence.

There is a potential to cultivate French lavender in the new agro-climate and nearly 50 kg/ha essential oil can be produced from 2 harvests.

Key words: camphor, chemical composition, cultivation, distillation, french lavender, fenchone, *Lavandula stoechas* L., semi-arid tropics.

Introduction

The lavender oils are distilled from various species of lavandula such as *L. officinalis* Chaix (syn. *L. angustifolia*) *L. hybrida* etc. (Mehta *et al.* 2000). *Lavandula officinalis* oil is superior in perfumery. It contains linalyl acetate, linalool, geraniol, lavandulol etc (Guenther, 1958). The major producers of this oil are Southern France, Spain (main producer), Italy, Dalmatia, Southern Russia. *L. officinalis* is a perennial, woody herb and is adapted to Mediterranean type of climate (Mehta *et al.* 2000). French lavender (*L. stoechas* L.) is a perennial, woody herb which yields an essential oil used in perfumery (Wealth of India, 1962) and it is adapted to tropical and semi-arid conditions. Since there is a need to have a cheaper source of oil resembling lavender oil, French lavender could be considered as an alternative. However, the oil of French lavender has a harsh camphoraceous note. The oil contains camphor (34-36%), camphene (2-3%), α-pinene (0.8-1.5%), fenchone (38%), 1: 8 cineole (10.8%). The present preliminary study was made to evaluate agronomic performance and distillation of French lavender and its chemical composition in a typical red sandy loam soil in semi-arid tropical conditions.

Materials and methods

French lavender cuttings were procured from Dept. of Horticulture, University of Agricultural Sciences, Bangalore. Nursery was raised in March 2000 and rooted cuttings were transplanted in May, at a spacing of 60 x 60 cm in the main field ($150m^2$). NPK was applied @ 100 : 40 : 40. One fourth of N and full dose of P and K were applied as basal dose. The rest of N was applied in 3 splits at 90-day intervals. First harvest was taken after six months of transplanting and second harvest taken four months after the first harvest. Herb yields were recorded. Oil content in the herb was determined in a Clevenger type apparatus. Bulk herb was distilled in a 50-kg capacity field distillation unit. Samples of the herb were shade dried for 15 days and oil content and quality in the shade-dried material were evaluated. The oil samples were analysed by Gas Chromatography. GC analysis was carried out on a Perkin Elmer 8500 gas chromatograph fitted with FID with electronic integrator using a dimethyl polysiloxane column (30 metres x 0.25 mm I.D. and 0.25 micron film thickness). Nitrogen at 10.0 psi inlet pressure was used as carrier gas and programmed from 60°C (5 minutes) to 220°C (3 minutes) at 5°C /minute. Peaks were identified by coinjection with authentic compounds where available and calculation of Kovats indices and comparison with literature values.

Results and discussion

French lavender performed quite well in the present agro-climatic region. The various parameters of its performance are presented in Table 1. The crop yielded 10t herb/ha in two harvests. The first harvest yielded 6 t/ha while the second yielded 4 t/ha. The essential oil content was 0.73 to 0.81% in the laboratory and 0.42-0.50% in the field. Shade dried herb contained 1.5-2% essential oil. At field scale, the essential oil yield was estimated at 30 kg/ha in the first harvest and 20 kg/ha in the second harvest. The crop was affected by a leaf and stem blight disease after the first harvest. This disease could be minimised by spraying carbendazim (Bavistin-50 @ 0.1%) thrice at fortnightly intervals.

Table 1. Performance of French lavender in Bangalore agroclimatic conditions (south Indian semi-arid tropical zone)

Trait	Details
1. Herb yield/plant	250-400 gm
2. Herb yield	
a. First harvest	6 ton/ha
b. Second harvest	4 ton/ha
3. Essential oil content	
a. Laboratory	0.73-0.81%
b. Field	0.42-0.50%
4. Essential oil yield	
a. First harvest	30 kg/ha
b. Second harvest	20 kg /ha

The chemical composition of the oil is presented in Table 2. The major constituents are camphor (34-36%), fenchone (38%) and 1 : 8 cineole (10-11%). Presence of fenchone in the oil of French lavender grown in this agroclimatic region in large concentrations has been recently reported (Syamasundar *et al.* 2002). Shade drying of the herb did not alter concentrations of major constituents; however the concentration of α–pinene has slightly reduced on shade drying (Table 2).

Table 2. Chemical composition of oil of French lavender grown in south Indian semi-arid tropics

Name of compound	Oil from fresh herb (%)	Oil from shade dry herb ((%)
α–pinene	1.50	0.80
Camphene	2.79	2.80
1:8 cineole	8.0-10.0	8.0-11.0
Limonene	1.5-3.0	1.5-3.0
Fenchone	38.53	38.90
Camphor	33.93	36.02

Lavender oils are very important constituents of lotions, toiletries, perfumes, mouthwashes, flavours, insect repellants etc. True lavender oil (*L. angustifolia*) being very costly item, alternative and cheap substitutes need to be explored. In this study, introduction and evaluation of French lavender as an alternative to true lavender has been attempted under a south Indian semi-arid zone to ascertain its performance.

The cultivation of French lavender in south Indian semi-arid conditions holds excellent potential. The oil of French lavender and its derivatives, having wide applications, can be a new essential oil in south India.

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References

Guenther 1958, The Essential Oils Vol. III pp. 504-513.

Mehta V K,.Sastry K P,.Parameswaran T N & Radhakrishnan K 2000 Lavender prospects in Kashmir valley and Tamil Nadu Hills. *J. Med. & Arom. Pl. Sci.* 22 pp. 540-543.

Syamasundar K V, Prakasa Rao E V S, Parameswaran T N, Chandrakala M & Ramesh S 2002 Chemical composition of *Lavandula stoechas* L. grown in a red soil of semi-arid tropical region in India (Communicated).

Wealth of India 1962. Vol. IV p. 47.

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Effect of integrated nutrient management and plant density on growth and yield of *Tagetes minuta* L.

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Abstract

The study was carried out to determine the influence of nutrient sources and plant density on growth and yield of *Tagetes minuta* L. The experimental results revealed that, the application of 90 kg nitrogen and 45 kg each phosphorus and potash and 6 tonnes of Farm Yard Manure per hectare recorded significantly superior values for plant height (46.19 cm), plant spread (743.31 cm^2), number of primary branches (11.30), number of leaves (247.15), number of inflorescence (133.23), herbage yield (7.31 t), flower yield (37.04 q) and oil yield (37.96 l) as compared to fully organically grown crop (24 t FYM/ha). With regard to plant density, closer spacing of 30 cm x 30 cm recorded significantly superior values for herbage (6.81 t/ha), flower (36.75 q/ha) and oil yield (33.01 l) over other spacings. The combination of 90:45:45 kg of nitrogen, phosphorus and potash plus 6 tonnes of Farm Yard Manure with 30 cm x 30 cm spacing found to be ideal to obtain optimum growth and yield in *Tagetes minuta.*

Key words: FYM, nutrients, plant density, *Tagetes minuta.*

Introduction

African marigold (*Tagetes minuta* L. Syn. *T.glandulifera* Schrank) is one of the important annual aromatic herbs belonging to the family, Asteraceae and valued for its essential oil. The crop is considered to be native of South America and found growing wild in South Africa, India, Australia, Kenya, Uruguay, Brazil and France. In India, it has naturalized in North-Western Himalayas between altitude of 1000 and 2500 m (Singh *et al.* 1995). The oil is mainly used in flavour, fragrance and perfumery industries. The oil has been reported to exhibit broncho- dilatory, tranquilizing and anti - inflammatory properties (Chandhoke & Ghatak, 1969). Further, the oil also exhibits an insect repellent activity against ants and mosquito (Maradufu *et al.* 1978). In recent years, there is a greater demand for its oil in the world market. In order to augment the production of the crop in the country, development of suitable package of practices are necessary. Amongst various factors, nutrient sources and plant density are most important ones which influence the herb and oil yield of the crop. As the fertilizers are not only costly, also hazardous to soil and environment, there is need to go for an alternate approach like integrated nutrient management. Keeping all these in view, the present study was taken up to find out the effect of nutrient sources and plant density in *Tagetes minuta.*

Materials and methods

The investigation was carried out at the Division of Horticulture, University of Agricultural Sciences, Gandhi Krishi Vigana Kendra, Bangalore during 2001-2002. The soil of the experimental site was red sandy loam with pH of 6.7, EC of 0.6 dSm^{-1}, organic carbon 0.37 per cent, available nitrogen, phosphorus and potassium at 234.63, 28.32, 172.26 kg/ha, respectively. The treatment consisted of 4 levels of nutrients combination (100% inorganic, 75% inorganic + 25% organic, 50:50% inorganic + organic and 100% organic) of recommended dose of 120:60:60 kg NPK/ha, and 3 levels of spacings (30 cm x 30 cm, 45 cm x 30 cm and 45 cm x 45 cm). The experiment was laid out in Two Factorial Randomized Block Design with three replications. The healthy seedlings of one month old were transplanted to the plots (4.86 m^2) as per the spacing levels. The entire dose of farm yard manure, phosphorus and potassium and half dose of nitrogen was applied as basal dose and remaining half dose of nitrogen at bud initiation stage. Irrigation was given at 4-5 days interval depending on soil moisture condition, and other cultural operations were followed as per the need of the crop. Observations were recorded on growth parameters such as plant height, plant spread, number of primary branches and leaves, and yield parameters of number of inflorescences, herbage, flower and oil yield. The crop was harvested at full bloom stage to get optimum yield. The oil yield was computed based on oil content and expressed in l/ha.

Results and discussion

The influence of nutrient sources and plant density on growth and yield of *Tagetes minuta* are presented in Table 1 and Table 2.

Growth parameters

It was observed that the application of nutrients had significant effect on growth parameters. The application of nutrients at 90 kg N and 45 kg each of P_2O_5 and K_2O along with 6 tonnes of Farm Yard Manure per hectare resulted in the maximum plant height (46.19 cm), plant spread (743.31 cm^2), number of primary branches (11.30) and number of leaves (247.15) at harvest, which was *on par* with application of 120 kg N and 60 kg of each P_2O_5 and K_2O except plant spread. This might be due to the increased nutrients availability to the plants at the approximate time which might have caused increased cell division and cell elongation.

Significant differences were noticed due to plant density with respect to growth parameters. The wider spacing 45 cm x 45 cm resulted in the maximum plant spread (694.62 cm^2), number of primary branches (10.92) and number of leaves (234.37). This might be due to favourable condition for the growth at wider spaced plants. Similar results were observed in Babchi (Lakshmipathaiah 1998). The closer spacing (30 cm x 30 cm) recorded the maximum plant height (46.24 cm) at harvest. Similar findings were observed by Prasad & Saxena (1980) in *Mentha piperita* and Ram *et al.* (1998) in *Tagetes minuta.* This might be due to the lack of sufficient space to grow horizontally and as a result it tends to grow in vertical direction only.

Interaction effect was found to be significant to plant spread only in the treatment combination of 75 per cent inorganic and 25 per cent organic at 45 cm x 45 cm spacing.

Yield parameters

The sources of nutrients significantly influenced the yield parameters. The nutrient combination of 75 per cent inorganic and 25 per cent organic form (90:45:45 kg N, P_2O_5 and K_2O + 6 t FYM/ha) produced the maximum number of inflorescences (133.23), herbage (7.31

t/ha), flower (37.04 q/ha) and oil yield (37.96 l/ha) which was *on par* with 100:60:60 kg N, P_2O_5 and K_2O except for the number of inflorescence. This increase may be due to the availability of nutrients at higher level in the appropriate time of growth. The higher herbage and oil yield, are in agreement with the findings of Chand *et al.* (2001) in Japanese mint, higher flower yield with the findings of Ravindran *et al.* (1986) in *Tagetes erecta.*

Plant density showed significant difference with respect to yield. The closer spacing (30 cm x 30 cm) recorded higher herbage, flower and oil yield (6.81 t/ha. 36.75 q/ha and 33.01 l/ha, respectively). This may be due to maximum plant population per unit area as compared to wider spacing and, effective utilization of nutrients and moisture. The results are supported by the findings of Mallikarjuna (2000) in *Tagetes minuta.* However, the number of inflorescences were maximum (130.85) at wider spacing (45 x 45 cm). This may be due to more spreading and branching at widely spaced plants which in turn might have resulted in more inflorescence. Similar results have been reported by Lakshmipathaiah (1998) in Babchi.

Interaction between nutrients and plant density was found to be significant to number of inflorescences at 45 cm x 45 cm spacing with the same nutrient combination.

Table 1. Growth parameters of *Tagetes minuta* as influenced by source of nutrients and plant density at harvest

Treatments	Plant height (cm)	Plant spread (cm^2)	Number of primary branches	Number of leaves
Nutrients				
100% inorganic	44.39	682.24	10.72	230.98
75% inorganic + 25% organic	46.19	743.31	11.30	247.15
50% inorganic + 50% organic	42.17	531.43	9.40	196.52
100% organic	37.97	306.64	7.47	164.86
CD at 5%	3.70	55.96	0.99	19.26
Plant density				
30 cm x 30 cm	46.24	376.05	8.28	183.42
45 cm x 30 cm	43.33	627.04	9.98	211.85
45 cm x 45 cm	38.48	694.62	10.92	234.37
CD at 5%	3.21	48.47	0.86	16.68

Table 2. Yield parameters of *Tagetes minuta* as influenced by sources of nutrients and plant density

Treatments	No. of inflorescences	Herbage yield (t/ha)	Flower yield (q/ha)	Oil yield (l/ha)
Nutrients				
100% inorganic	119.44	6.79	34.16	33.90
75% inorganic + 25% organic	133.23	7.31	37.04	37.96
50% inorganic + 50% organic	101.47	5.45	28.74	25.47
100% organic	85.46	4.51	23.95	20.70
CD at 5%	8.81	0.71	4.21	4.21
Plant density				
30 cm x 30 cm	93.37	6.81	36.75	33.01
45 cm x 30 cm	105.48	6.29	31.52	30.99
45 cm x 45 cm	130.85	4.95	24.61	24.53
CD at 5%	7.63	0.61	3.64	3.65

Conclusion

The present study suggests that application of nutrients at 75 per cent inorganic and 25 per cent organic combination and closer spacing of 30 cm x 30 cm had pronounced effect on herbage, flower and oil yield of *Tagetes minuta,* whereas, growth parameters were significant at wider spaced plants except plant height. Apart from increase in yield, combined application of nutrients improves the soil properties and reduces the pollution of soil due to reduced fertilizers application.

References

Chandhoke N & Ghatak B J R 1969 Studies on *Tagetes minuta*: Some pharmacological action of the essential oil. Indian J. Med. Res. 57 (5) : 864-876.

Chand S, Anwar M & Patra D D 2001 Influence of combined application of farm yard manure and inorganic fertilizers on herb, essential oil yield and nutrient accumulation in menthol mint (*Mentha arvensis*). J. Med. Arom. Pl. Sc. 23 : 29-33.

Lakshmipathaiah O R 1998 Standardization of cultural practices in Babchi (*Psoralea corylifolia* L.). M.Sc. Thesis, University of Agricultural Sciences, Bangalore, Karnataka.

Mallikarjuna K 2000 Agronomic investigation in African Marigold (*Tagetes minuta* L.). M.Sc. Thesis, University of Agricultural Sciences, Bangalore, Karnataka.

Maradufu A, Lubega R & Dorn F 1978 Isolation of 5(E) – ocimenone a mosquito larvicide from *Tagetes minuta.* J. Nat. Prod. 41 : 181-183.

Prasad S & Saxena M C 1980 Effect of date of planting and row spacing on the growth and development of Pepper mint (*Mentha piperita* L.) in Tarai. Indian J. Pl. Physiol. 23 (2) : 119-120.

Ram P, Patra N K, Singh H B, Singh, H P, Ram M, Kumar B & Kumar S 1998 Effect of planting dates and spacing on oil yield and major yield components of *Tagetes minuta.* J. Med. Arom. Pl. Sci, 20 : 742-745.

Ravindran D V L, Ramarao R & Reddy E N 1986 Effect of spacing and nitrogen levels on growth and yield of African Marigold (*Tagetes erecta* L.). South Indian Hort. 34 : 320-323.

Singh V, Sood R P, Singh B & Kaul V K 1995 African Marigold. In: Chadha K L & Rajendra Gupta (Eds.) *Advances in Horticulture,* vol. 11, Medicinal and Aromatic Crops (pp 789-793). Malhotra Publishing House, New Delhi.

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Effect of biofertilizers on physiological and biochemical parameters of turmeric cv. BSR 2

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Abstract

The investigations on turmeric (*Curcuma longa* L.) were carried out to study the effect of different organic manures and biofertilizers on turmeric with reference to physiological and biochemical parameters. The study revealed that, turmeric showed better response to the application of organic manures and biofertilizers. The highest Area of leaf (LA), Leaf area index (LAI), Photosynthetic rate (PNR), Specific Leaf Weight (SLW), Crop growth rate (CGR), Total dry matter production (TDMP), Harvest index (HI) and biochemical parameters like Chlorophyll, Soluble protein, Total phenols, were higher by the combined application of farmyard manure + azospirillum + phosphobacteria + VAM (M_1S_7). While the application of digested ciorpith compost + azospirillum + phosphobacteria + VAM (M_2S_7) recorded maximum IAA oxidase, Peroxidase activity in turmeric.

Key words: biochemical, farmyard manure, digested coirpith compost and biofertilizers, physiological, turmeric, vermicompost.

Introduction

Turmeric (*Curcuma longa* L.) an herbaceous perennial belonging to the family Zingiberaceae grows with tufted leaves, which is a commercial crop of tropics. It is a sacred, auspicious, dual-purpose spice for Asian countries valued for its food adjunct property and also a source of safe natural colouring agent required by pharmaceutical, confectionary and cosmetic industry. Turmeric being a rhizomatous crop requires a heavy input of fertilizers. Owing to the high cost of fertilizers and sustainable soil management, necessitated the organic forming in turmeric. In addition to this, there is a great demand for the organically grown produce in Western countries. So far a limited work has been standardised for organic farming practice more specially in spice like turmeric. Hence the study was aimed in standardisation of organic manure and biofertilizers on physiological and biochemical parameters turmeric.

Materials and methods

Study was conducted at college orchard, department of spice and plantation crops, Coimbatore. Experiment was laid in split plot design with three replications. The main plot treatments are M_1-Farmyard manure (30 t ha^{-1}), M_2-Vermicompost (10 t ha^{-1}), M_3-Digested coirpith compost (10 t ha^{-1}) and M_4-50 per cent of recommended dose of fertilizer (62.5:30:45 kg N, P_2O_5, K_2O ha^{-1}) and sub plot treatment are S_1-Azospirillum (10 kg ha^{-1}), S_2-Phosphobacteria (10 kg ha^{-1}),S_3-VAM (500 kg ha^{-1}), S_4-Azospirillum (10 kg ha^{-1}) +

Phosphobacteria (10 kg ha^{-1}), S_5-Azospirillum (10 kg ha^{-1}) + VAM (500 kg ha^{-1}), S_6 - Phosphobacteria (10 kg ha^{-1}) + VAM (500 kg ha^{-1}),S_7-Azospirillum (10 kg ha^{-1}) + Phosphobacteria (10 kg ha^{-1}) + VAM (500 kg ha^{-1}) and S_8 -Control (without any inoculation of biofertilizers). The inoculants of Azospirillum (*Azospirillum lipoferum*), Phosphobacteria (*Bacillus megatherium*) and VAM (Vermiculite based inoculums containing *Glomus fasciculatum, G.mossae* and *Gigaspora sp.*) were used. Recommended dose of farmyard manure (30 t ha^{-1}), digested coirpith compost (10 t ha^{-1}) and the vermicompost (5 t ha^{-1}) were applied basally during the last ploughing. The remaining quantity (5 t ha^{-1}) was applied in soil 90 days after of planting and soil was ragged for better mixing. Primary rhizomes of uniform size were selected and adequate quantity of carbohydrate solution (rice gruel) was added with azospirillum and phosphobacteria inoculum separately at the rate of 10 kg ha^{-1}. Then the rhizomes were spread and dried in shade for 30 minutes and the rhizomes were planted at the sides of ridges in the respective plots at a spacing of 45 x 15 cm. The VAM was applied immediately after planting. The untreated rhizomes were planted to serve as control. Calculated quantities of fertilizers were applied as per the treatments. The fertilizers of urea, single superphosphate and muriate of potash were used as source of N, P_2O_5 and K_2O respectively. One fifth of N and K_2O and full dose of P_2O_5 were applied as basal dose. The remaining quantity of N and K were applied as top dressing in split doses at 30, 60, 90 and 120 days after planting. Physiological parameters like Area of leaf (LA), Leaf area index (LAI), Photosynthetic rate (PNR), Specific Leaf Weight (SLW), Crop growth rate (CGR), Total dry matter production (TDMP), Harvest index (HI) and biochemical parameters like Chlorophyll, Soluble protein, Total phenols, IAA oxidase, Peroxidase activity, were recorded at 45 days intervals from 90th days after planting to the harvest of crop.

Results and discussion

Physiological Parameters

Leaf area and leaf area index: Application of farmyard manure + azospirillum + phosphobacteria + VAM (M_1S_7) recorded larger leaf area (520.80 cm^2), while the combined application of digested coirpith compost along with azospirillum, phosphobacteria + VAM (M_3S_7) expressed the lesser leaf area 432.21 cm^2. Similarly the combined application of FYM + azospirillum+ phosphobacteria +VAM (M_1S_7) exerted greater leaf are index (13.26) which was followed (9.71) at 180 days after planting respectively. The greater leaf area and leaf area index may be due to the application of farmyard manure and biofertilizers. Greater the leaf area index results in more interception of light. It is a positive index with direct influence on plant growth. The present investigation is in confirmation with the earlier findings of Shibbles and Webber (1966).

Photosynthetic rate: The combined application of farmyard manure + azospirillum + phosphobacteria + VAM (M_1S_7) showed greater photosynthetic rate (1078.08 mg CO_2 cm^{-2} hr^{-1}) as compared the combined application of digested coirpith compost + azospirillum + phosphobacteria + VAM (M_3S_7) with 975.50 mg CO_2 cm^{-2} hr^{-1} at 180 days after planting respectively. The possible reason may be that FYM contains humic acid, fulvic acid and humin. These organic acids would have stimulated photosynthetic organelles namely chloroplast more particularly number of grana. The higher photosynthetic activity would help the plant for bulking and thereby enhanced the yield. The present work is in corroboration with earlier findings of Forton *et al.* (1985).

Specific leaf weight: The interaction effect indicated that the combined application of farmyard manure + azospirillum + phosphobacteria + VAM (M_1S_7) exerted the highest specific leaf weight of 2.97 gm^{-1} cm^{-2} at 180 days after planting while the application of digested coirpith compost alone without any inoculation of biofertilizer (M_3S_8) recorded lowest specific leaf weight (1.78 1.53 gm^{-1} cm^{-2}). Higher specific leaf weight may be ascribed to the higher cell surface to volume ratio. Hence, lower the mesophyll resistance to CO_2 entry and increase in photoassimilates in leaves. This is in concurrence with work of Dronhoff and Shibbles (1970) in soybean.

Crop growth rate (CGR): 180 days after planting maximum CGR (20.35 g m^2) was obtained by the application of farmyard manure + azospirillum + phosphobacteria + VAM by (M_1S_7). This may be due to that organic carbon, nitrogen, phosphorus in soil was increased significantly due to the increased decomposition products of farmyard manure. Farmyard manure effected the continuous and slow release of nutrients and other organic compounds in soil and that would have increased the efficiency of plants with greater uptake of nutrients. A similar trend was reported by Chakaravarthi (2001).

Total dry matter production and harvest index: The interaction effect with combined application of FYM + azospirillum + phosphobacteria + VAM (M_1S_7) showed the highest total dry matter production (211.99 g $plant^{-1}$) at 180 days after planting. Similarly the harvest index was higher in the same treatment (76.87 %). The possible reason might be that more the number of leaves, greater the leaf area, intercepts more light which inturn produced more photoassimilates. This higher assimilatory power might have resulted in higher dry matter accumulation. This is in consonant with previous works of Khristeva and Yanenka (1962). A higher harvest index was due to fact that humin might have regulated growth by increased photosynthetic activity, by increased mobilization of nutrients to the developing sink. Same line of opinion was observed by Cacco and Agnola (1984) and Ma (1992).

Biochemical parameters

Total cholorophyll content: The combined application of biofertilizers such as azospirillum + phosphobacteria and VAM (M_1S_7) exerted more total chlorophyll content of 1.974 mg g^{-1} and the lower total chlorophyll content was exhibited by the application of digested coirpith compost without any inoculation of biofertilizers (M_3S_8) of 1.305 mg g^{-1} at 180 and days after planting respectively. This may be due to higher chlorophyll content may be due to postponement of senescence and enhancement of uptake of iron. This could have possibly increased the chlorophyll content in plants. The present findings are in agreement with Paricha *et al.* (1977) and Kalarani (1991).

Soluble protein and total phenolics: The combined application farmyard manure + *azospirillum + phosphobacteria* + VAM (M_1S_7) exhibited more soluble protein and phenolics content of 74.19 mg g^{-1} , 3.18 and 3.03 μg g^{-1} respectively at 180 days after planting. This could be due to that increased RNA and DNA polymerase activity might be responsible for higher amounts of soluble protein in plants. While higher total phenolics was due to that humic substances present in farmyard manure are known to contain

Table 1. Effect of organic manures and biofertilizers on physiologicalparameters of turmeric cv BSR2

Treatment	Physiological parameters at 180 days after planting							Yield
	Leaf area (cm^2)	Leaf area index (LAI)	Photosynthetic rate (PNR) (mg CO_2 $cm^{-2}hr^{-1}$)	Specific leaf weight (SLW) ($mg^{-1}cm^{-2}$)	Crop growth rate (CGR) (g m^{-2} day^{-1})	Total dry matter production (g $plant^{-1}$)	Harvest index (per cent)	(Kg ha^{1})
M_1S_1	346.16	5.45	780.77	2.34	17.09	171.73	63.45	24753.00
M_1S_2	386.20	**6.79**	808.92	2.50	19.89	182.36	65.49	25542.67
M_1S_3	436.17	**8.29**	820.58	2.50	19.62	188.44	68.35	26440.67
M_1S_4	423.33	**8.63**	884.99	2.60	19.19	191.07	70.16	27172.00
M_1S_5	436.20	9.73	961.08	2.70	22.04	203.63	72.83	27695.00
M_1S_6	467.53	10.86	970.45	2.91	21.83	208.80	74.64	28616.00
M_1S_7	520.80	13.26	1078.08	3.03	20.35	211.99	76.87	33313.00
M_1S_8	304.74	4.29	753.99	2.28	17.66	164.48	62.28	22767.33
M_2S_1	346.63	4.87	759.08	2.53	18.78	179.05	63.27	24074.00
M_2S_2	376.92	5.60	788.62	2.59	19.02	184.38	65.29	25582.33
M_2S_3	407.76	6.00	824.55	2.65	18.83	191.37	68.12	26694.33
M_2S_4	445.10	8.12	885.54	2.72	19.08	194.14	69.71	28104.67
M_2S_5	408.99	8.14	957.00	2.74	19.68	198.31	71.73	29265.00
M_2S_6	431.49	9.38	925.32	2.84	20.20	203.51	72.84	30258.00
M_2S_7	464.95	9.71	974.83	2.86	20.85	206.82	74.91	31360.67
M_2S_8	316.33	4.29	724.58	1.99	17.09	165.19	61.87	23632.67
M_3S_1	357.73	4.38	776.18	1.96	19.49	174.40	61.88	24429.33
M_3S_2	337.77	4.25	831.87	2.00	18.91	179.94	62.39	27312.67
M_3S_3	359.89	5.14	863.01	2.11	19.88	185.88	62.63	27589.00

	M_3S_4	383.14	**5.39**	889.92	2.50	19.04	190.12	64.47	27974.67
	M_3S_5	366.86	**5.50**	906.56	2.54	19.41	193.11	66.35	28128.67
	M_3S_6	424.14	**7.75**	956.63	2.62	21.22	199.46	69.03	29308.67
	M_3S_7	432.21	**8.78**	975.50	2.65	20.31	201.58	72.56	30294.67
	M_3S_8	324.78	**3.71**	756.89	1.80	17.60	167.97	61.43	23105.33
	M_4S_1	357.50	**4.98**	793.23	1.97	16.58	173.52	63.25	18970.67
	M_4S_2	404.64	**6.10**	810.99	2.10	16.94	178.24	64.65	18636.00
	M_4S_3	410.10	**6.61**	850.61	2.18	17.21	185.02	68.10	19457.33
	M_4S_4	422.37	**8.29**	881.11	2.35	18.97	194.25	69.20	19439.00
	M_4S_5	429.07	**8.50**	905.71	2.59	17.64	196.44	70.98	20405.00
	M_4S_6	444.28	**9.30**	933.71	2.56	18.55	199.92	72.84	20539.33
	M_4S_7	463.47	**9.95**	956.87	2.75	21.24	208.29	75.06	21631.67
	M_4S_8	348.23	**4.38**	772.84	1.83	17.69	167.74	61.75	18943.67
	SEd	12.078	0.279	2.966	0.017	0.307	0.894	0.262	242.857
M	CD (P= 0.05)	29.556	0.682	7.257	0.041	0.752	2.188	0.642	594.277
	SEd	13.171	0.277	5.032	0.022	0.446	0.830	0.454	406.772
S	CD (P= 0.05)	26.385	0.555	10.081	0.044	0.893	1.663	0.909	814.884
	SEd	27.442	0.588	9.870	0.045	0.668	1.792	0.889	798.812
M at S	CD (P=0.05)	NS	1.237	20.168	0.092	1.827	3.788	1.814	1633.019
	SEd	26.342	0.554	10.064	0.044	0.891	1.661	0.908	813.543
S at M	CD (P= 0.05)	52.770	1.110	20.161	0.089	1.785	3.327	1.818	1629.768

Table 2. Effect of organic manures and biofertilizers on biochemical parameters of turmeric cv BSR2

Treatment	Biochemical parameters at 180 days after planting					Yield
	Total chlorophyll (mg g^{-1})	Soluble protein (mg g^{-1})	Total phenols (µ g g^{-1})	IAA oxidase (µg of IAA oxidised g^{-1} hr^{-1})	Peroxidase activity (µg g^{-1} hr^{-1})	(Kgha^{1})
M_1S_1	1.51	64.67	2.43	794.93	0.069	24753.00
M_1S_2	1.60	66.60	2.56	836.10	0.079	25542.67
M_1S_3	1.67	69.50	2.94	856.70	0.081	26440.67
M_1S_4	1.70	71.60	2.97	878.63	0.076	27172.00
M_1S_5	1.76	73.53	3.06	896.93	0.086	27695.00
M_1S_6	1.82	75.33	3.12	919.00	0.091	28616.00
M_1S_7	1.97	77.43	3.18	937.10	0.099	33313.00
M_1S_8	1.46	62.73	2.38	765.13	0.061	22767.33
M_2S_1	1.45	62.70	2.42	795.37	0.053	24074.00
M_2S_2	1.61	64.70	2.47	816.50	0.061	25582.33
M_2S_3	1.52	69.53	2.53	848.89	0.068	26694.33
M_2S_4	1.70	66.50	2.77	874.56	0.086	28104.67
M_2S_5	1.65	71.63	2.95	904.83	0.083	29265.00
M_2S_6	1.72	72.80	3.05	895.83	0.089	30258.00
M_2S_7	1.78	74.50	3.11	914.60	0.092	31360.67
M_2S_8	1.39	60.57	2.95	754.79	0.063	23632.67
M_3S_1	1.37	61.47	2.37	766.16	0.062	24429.33
M_3S_2	1.48	63.67	2.43	795.98	0.066	27312.67

	M_3S_3	1.45	62.17	2.46	815.96	0.071	27589.00
	M_3S_4	1.58	64.53	2.52	846.60	0.076	27974.67
	M_3S_5	1.60	65.20	2.73	857.19	0.084	28128.67
	M_3S_6	1.63	68.50	2.64	874.26	0.075	29308.67
	M_3S_7	1.70	71.53	2.86	896.26	0.091	30294.67
	M_3S_8	1.30	62.47	2.32	748.33	0.063	23105.33
	M_4S_1	1.40	62.73	2.37	798.10	0.071	18970.67
	M_4S_2	1.48	64.83	2.46	817.26	0.061	18636.00
	M_4S_3	1.53	67.77	2.57	848.96	0.07	19457.33
	M_4S_4	1.63	69.53	2.72	867.51	0.071	19439.00
	M_4S_5	1.69	71.70	2.66	896.53	0.084	20405.00
	M_4S_6	1.70	72.47	2.82	906.43	0.092	20539.33
	M_4S_7	1.77	74.53	2.93	917.73	0.091	21631.67
	M_4S_8	1.31	61.80	2.33	794.93	0.061	18943.67
	SEd	0.012	0.345	0.011	2.704	0.0005	242.857
M	CD (P= 0.05)	0.030	0.843	0.026	6.618	0.0012	594.277
	SEd	0.016	0.614	0.009	1.806	0.0006	406.772
S	CD (P= 0.05)	0.033	1.230	0.018	3.618	0.0011	814.884
	SEd	0.033	1.199	0.019	4.328	0.0011	798.812
M at S	CD (P=0.05)	0.068	2.447	0.041	9.420	0.0024	1633.019
	SEd	0.033	1.228	0.018	3.612	0.0011	813.543
S at M	CD (P= 0.05)	0.065	2.460	0.035	7.236	0.0022	1629.768

phenyl alanine and that would have increased the total phenolic content of treated plants than the control. This is in confirmation with earlier findings of Alexander (1961) and Balasubramaniam *et al.* (1989).

IAA oxidase and peroxidase activity: Between interaction effect the application of digested coirpith compost + azospirillum + phosphobacteria + VAM (M_3S_7) exhibited highest IAA oxidase activity of 917.73 µg of IAA oxidised g^{-1} hr^{-1} at 180 days after planting, while the application of FYM (M_1S_8) expressed the lowest IAA oxidase activity (748.33 µg of IAA oxidised g^{-1} hr^{-1}). Similarly, the combined application of digested coirpith compost + azospirillum + phosphobacteria + VAM (M_3S_7) recorded greater peroxidase activity of 0.099 and µg g^{-1} hr^{-1} as against (0.062 µg g^{-1} hr^{-1}) the application of vermicompost without any inoculation of biofertilizers (M_2S_8) at 180 days after planting respectively. This could be due to that growth hormones produced by biofertilizers might have accelerated the efficiency of peroxidase activity in plants. This is in confirmation with earlier works of Dendsay (1989).

Reference

Alexander, M. 1961. Introduction to soil microbiology. Vinod Kumar for Willey Eastern Limited, New Delhi, p.14.

Balasubramaniam, P., S. Chandrasekaran and R. Govindasamy. 1989. Effect of lignite humic acids on the growth and changes in phenolics of rice seedlings (*Oryza sativa* L.) variety IR-50. Proc. Natl. Seminar on Humus Acid in Agriculture, pp.201-207.

Cacco, G. and G.D.Agnola. 1984. Plant growth regulator activity of soluble humic complex. Can. J. Soil Sci., 64: 225-228.

Chakravarthi, K. 2001. Effect of organic manures and seed priming with organics for enhancing yield of rainfed pigeonpea. M.Sc.(Ag.) Thesis submitted to Tamil Nadu Agricultural University, Coimbatore.

Dendsay, J.P.S. 1989. Activation of peroxidase by auxin in cotylesons of *Vigna radiata* L. Indian J. Exp. Biol., 27: 360-362.

Domhoff, G.M. and R.M. Shibles. 1970. Varietal differences in net photosynthesis of soybean leaves. Crop Sci., 10: 42-45.

Forton, C., S. Rapsch and C. Ascaso. 1985. Action of hmic acid preparations of leaf development, mineral element contents and chloroplast ultrastructure of rye grass plants. Photosynthetica, 19: 294-299.

Kalarani, M.K. 1991. Senescence regulation in soybean (*Glycine max* L.). M.Sc.(Ag.) Thesis submitted to Tamil Nadu Agricultural University, Coimabtore.

Khristeva, L.A. and N.V. Luk'Yanenka. 1962. Beneficial effects of humus on plant metabolism. Soviet Soil Sci., 1137.

Ma, J.Y. 1992. Biological effect of paclobutrazol on dry nursed rice seedlings and yield improvement. J. Jilin Agri. Univ., 14(3): 15-18.

Paricha, P.C., B.K. Ghosh and N.C. Sahoo. 1977. Further studies on the significance of cycocel on enhancing drough resistance in rice. Science Culture, 43: 230-231.

Shibles, R.M. and C.R. Weber. 1966. Leaf area, solar radiation interception and drymatter production by soybean. Crop Sci., 5: 575-577.

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Growth and physiological attributes of turmeric varieties (*Curcuma longa* L.) BSR-1 and Co.1 under Coimbatore conditions

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Abstract

The study conducted at Department of Spices and Plantation Crops, Tamil Nadu Agricultural University, Coimbatore, with turmeric varieties BSR-1 and Co-1 on growth and physiological attributes. The results from this study indicated, that among the growth attributes, the BSR-1 variety was found to be more vigorous than Co-1. Physiological parameters like photosynthetic rate, leaf area duration, leaf area index, net assimilation rate and relative growth rate were found to be higher in BSR-1 and Co-1. The yield of BSR-1 (27.4 tonnes/ha) is higher than Co-1 (20.4 tonnes/ha) turmeric.

Key words: dry matter production, leaf area index, photosynthetic rate, relative growth rate.

Introduction

Turmeric is used as primitive medicine, both externally and internally in Southern Asia since time immemorial. It is used as a colouring matter in pharmaceuticals, confectionery and food industries. Turmeric is also used as a natural yellow dye and its powder is used in cosmetics. Besides, rhizomes are used as blood purifier, applied to sprains and wounds. Fresh juice is used as antiparasitic for many skin infections. The area and production under turmeric have been steadily increasing but the productivity has been going down. Of late, growth analysis is regarded as a very useful approach for assessing the net productivity of any crop plant. In case of long duration commercial crops like turmeric, knowledge on growth analysis will give better understanding of growth physiology. With this objective the present investigation on growth and development of turmeric was taken up to find whether the physiological parameters had direct or indirect effect on the yield of turmeric.

Materials and methods

The study was undertaken in the Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore with two varieties *viz.*, Co.1 and BSR-1 in a Randomized Block Design with three replications. The experimental plot size was $10m^2$. Uniform cultural applications were given to the two turmeric varieties as per the recommendations (Anonymous, 1999). The growth parameters *viz.*, plant height, leaf length, leaf width, number of leaves per plant, number of tillers per plant and number of tiller leaves per plant was recorded. Various physiological parameters like photosynthetic rate, leaf area, leaf area index, leaf area duration, net assimilation rate, relative growth rate, crop growth rate and dry matter production were recorded in addition to yield.

Results and discussion

The plant height revealed that the height in both BSR-1 and Co.1 increased as the age of the crop gets advanced. BSR-1 recorded a higher plant height (78.3 cm) than Co.1 (73.5 cm). (Table.1) Likewise the leaf length and leaf breadth was the highest (32.8 cm and 10.7 cm) in BSR-1 at six month after planting. Co.1 had a leaf length of 31.0 cm and leaf breadth of 10.3 cm at the same stage of crop growth. The number of leaves per plant increased from the second month to the seventh month after planting and thereafter it declined. BSR-1 recorded comparatively greater leaf number (12) than Co.1 (11) (Table 1).

The tiller production was higher during the seventh month after planting in both varieties and had the same number of tillers from the sixth month to harvest (2 & 3 tillers uniformly). The tiller leaves was maximum between the sixth and seventh month after planting in both the varieties (11 tiller leaves in both the varieties).

Several growth components such as plant height, leaf length, leaf breadth, number of leaves per plant were found to be significantly higher in the variety BSR-1 than Co.1 in the present investigation. The rhizome yield was also maximum in BSR-1 (24.7 tonnes/ha.) than Co.1 (20.4 tonnes/ha.). Probably the larger plant growth as represented by plant height is related to rhizome yield. Similar findings were also reported by Rathinavel (1983) and Philip & Nair (1983) in turmeric. Many of these differences were clearly marked seven months after planting. This stage may be considered as the physiologically active stage of crop growth for turmeric. (Table 1).

The association of leaf characters with yield was also reported by Philip & Nair (1983). The greater leaf length, leaf breadth and number of leaves might have indirectly influenced the photosynthetic surface of BSR-1. Similar line of work was carried out in Potato by Purohit *et al* (1970). They concluded that the leaf number was positively correlated with tuber yield in potato.

The physiological attributes namely photosynthetic rate per plant was the largest in BSR-1 at the seventh month (1436.82 mg. CO_2 plant $^{-1}$ hr^{-1}) compared to Co.1, which had (12376 mg. CO_2 plant $^{-1}$ hr^{-1}) at the sixth month after planting (Table.2).

The leaf area, leaf area index and the leaf area duration increased up to seventh month after planting and thereafter declined in both BSR-1 and Co.1. Between the two varieties BSR-1 had the highest leaf area (5292.15 sq.cm), leaf area index (7.63) & leaf area duration (203 days). Lower values of leaf area (4716.75 sq.cm), leaf area index (7.14) and leaf area duration (195 days) were recorded by Co.1 (Table 2).

The net assimilation rate increased up to six months and then showed a declining trend up to harvest. BSR-1 recorded the higher net assimilation rate (0.091 mg. dm^{-2} day^{-1}) than Co.1 (0.064 mg. dm^{-2} day^{-1}). The relative growth rate in both the varieties attained its peak value during the fourth and fifth month with values of 0.073 g^{-1} day^{-1} & 0.075 g^{-1} day^{-1} respectively in BSR-1 & Co.1 thereafter it was declined The crop growth rate was higher in BSR-1 (1.18 g.cm^2 day^{-1}) compared to Co.1 (0.86 g.cm^2 day^{-1}) (Table 3).

Table 1. Studies on the growth parameters of BSR-1 and Co.1 turmeric varieties

Months after planting	Plant height (cm)			Leaf length (cm)			Leaf breadth (cm)			No. of leaves per plant			No. of tillers per plant			No. of tiller leaves per plant			Rhizome yield/ha.		
	BSR-1	Co.1	SED CD (5%)	BSR-1	Co.1	SED CD (5%)	BSR-1	Co.1	SED CD (5%)	BSR-1	Co.1	SED CD (5%)	BSR-1	Co.1	SED CD (5%)	BSR-1	Co.1	SED CD (5%)	BSR-1	Co.1	SED CD (5%)
2 MAP	25.2	24.8	2.5	16.9	16.0	1.69	6.8	6.8	0.68	4.0	3.0	0.35	1.0	1.0	0.10	2.0	1.0	0.15	-	-	-
			5.2			3.90			1.36			0.72			0.22			0.30			
3 MAP	42.5	41.7	4.2	25.0	25.4	2.52	9.5	10.0	0.97	6.0	6.0	0.60	1.0	1.0	0.10	3.0	3.0	0.30	-	-	-
			8.6			5.45			1.92			**1.24**			**0.22**			**0.62**			
4 MAP	53.7	51.1	5.2	28.8	29.3	2.90	10.5	10.8	1.06	8.0	7.0	0.75	1.0	2.0	0.15	6.0	5.0	0.56	-	-	-
			10.6			**7.15**			2.20			**1.66**			**0.30**			**1.12**			
5 MAP	62.5	58.6	6.06	32.0	32.1	3.20	10.6	10.7	1.06	10.0	9.0	0.95	2.0	2.0	0.20	7.0	7.0	0.70	-	-	-
			13.0			**7.40**			2.20			**1.95**			**0.40**			**1.50**			
6 MAP	70.4	66.1	6.83	32.8	30.9	3.18	10.2	10.2	1.02	11.0	10.0	1.05	3.0	3.0	0.30	11.0	11.0	1.10	13.27	14.70	1.30
			14.12			**7.24**			2.14			**2.30**			**0.62**			**2.26**			2.80
7 MAP	78.3	73.5	7.50	32.4	31.0	3.17	10.7	10.3	1.04	12.0	11.0	1.15	3.0	3.0	0.30	7.0	8.0	0.25	17.56	17.20	1.75
			15.30			7.20			2.16			2.40			0.62			**1.65**			3.70
8 MAP	78.3	73.5	7.50	32.3	30.9	3.16	10.7	10.2	1.05	8.0	7.0	0.75	3.0	3.0	0.30	5.0	5.0	0.50	21.35	20.00	2.05
			15.30			7.18			2.24			1.60			0.62			1.10			**4.25**
9 MAP	78.3	73.5	7.50	32.2	30.8	3.15	10.5	10.1	1.03	5.0	5.0	0.50	3.0	3.0	0.30	1.0	1.0	0.10	24.10	20.20	2.21
			15.30			7.16			2.18			1.01			0.62			0.24			4.45
10 MAP	78.3	73.5	7.50	32.1	30.7	3.14	10.4	10.0	1.02	1.0	1.0	0.10	3.0	3.0	0.30	1.0	1.0	0.10	24.70	20.40	2.28
			15.30			**7.12**			2.14			**0.22**			0.62			0.24			4.56

Table 2. Studies on the physiological attributes of BSR-1 and Co-1 turmeric varieties

Months after planting	Photosynthetic rate per plant CO_2 plant^{-1} hr^{-1}			*Leaf area sq.cm*			*Leaf area index*			*Leaf area duration (days)*		
	BSR-1	Co.1	SED CD (5%)	BSR-1	Co.1	SED CD (5%)	BSR-1	Co.1	SED CD (5%)	BSR-1	Co.1	SED CD (5%)
2 MAP	-	-	-	293.29	250.92	17.5	0.44	0.37	0.23	-	-	-
						35.3			2.39			
3 MAP	244.06	270.03	25.70	593.29	692.00	57.5	1.77	1.77	0.14	32.0	32.0	3.20
			52.15			100.2			4.14			6.40
4 MAP	533.66	530.34	53.32	1119.52	1192.17	106.2	3.33	3.32	0.30	76.0	76.0	7.60
			110.52			214.5			0.62			14.50
5 MAP	984.49	842.44	91.32	2253.65	2181.5	196.0	4.93	4.77	0.46	124.0	121.0	12.30
			200.54			360.7			0.92			24.35
6 MAP	1176.82	1237.47	123.4	3437.45	3221.5	379.26	5.93	5.53	0.46	163.0	155.0	15.70
			236.5			520.5			0.92			30.30
7 MAP	1436.82	973.07	97.3	4004.14	3729.4	450.0	7.63	7.14	0.65	203.0	195.0	19.80
			185.3			920.5			0.94			36.70
8 MAP	641.75	596.33	59.6	5292.15	4716.5	376.19	5.20	4.60	0.44	192.0	176.0	18.70
			115.5			720.5			1.18			37.50
9 MAP	-	-	-	3494.38	3119.5	300.6	3.40	3.10	0.29	129.0	116.0	11.90
						620.5			1.19			24.50
10 MAP	-	-	-	2289.71	2299.7	189.9	0.80	0.70	0.07	63.0	57.0	5.90
						365.6			0.90			11.20

Table 3. Studies on the physiological characters of BSR-1 and Co-1 turmeric varieties

Months after planting	Net assimilation rate mg.dm^{-2} day^{-1}			Relative growth rate Mg. g^{-1} day^{-1}			Crop growth rate g. cm^{-2} day^{-1}			Total dry matter production g/plant		
	BSR-1	Co.1	SED CD (5%)	BSR-1	Co.1	SED CD (5%)	BSR-1	Co.1	SED CD (5%)	BSR-1	Co.1	SED CD (5%)
2 MAP	-	-	-	-	-	-	-	-	-	4.78	3.97	0.30 0.60
3 MAP	0.02	0.03	0.003 0.007	0.02	0.03	0.003 0.006	0.02	0.02	0.002 0.04	9.12	8.55	0.86 1.15
4 MAP	0.02	0.02	0.002 0.065	0.02	0.02	0.001 0.004	0.04	0.04	0.004 0.08	15.54	15.67	1.56 3.62
5 MAP	0.0165	0.0175	0.0016 0.0032	0.073	0.075	0.007 0.014	0.68	0.69	0.069 0.14	17.81	16.54	1.75 3.80
6 MAP	0.091	0.064	0.0075 0.0015	0.017	0.012	0.01 0.02	1.18	0.86	0.01 0.12	25.82	22.94	2.70 5.90
7 MAP	0.0172	0.0107	0.0017 0.0034	0.013	0.004	0.0013 0.0026	0.50	0.42	0.04 0.08	32.94	24.90	4.20 8.60
8 MAP	0.000026	0.000044	0.0000002 0.0004	0.0033	0.0001	0.0003 0.006	0.97	0.73	0.08 0.16	36.35	25.29	2.70 5.30
9 MAP	0.000038	0.000044	0.000003 0.00006	0.0029	0.0003	0.0002 0.004	0.000163	0.000166	0.000015 0.0002	39.64	28.56	2.95 5.35
10 MAP	0.000010	0.000014	0.000001 0.00002	0.0003	0.00005	0.00003 0.0006	0.000018	0.000023	0.000003 0.00006	40.00	29.01	3.50 7.50

The total dry matter production increased as the age of the crop advanced in both BSR-1 and Co.1. Comparing the two varieties, BSR-1 recorded higher total dry matter production (40.007 g per plant) than C0.1 (29.019 g per plant) (Table 3).

The quantum of photosynthates produced per plant is the major determinant on the biomass production of any crop variety as suggested by (Sestak *et al.* (1971). Evidences in the present study showed that BSR-1 produced significantly higher photosynthates than Co.1. This indicates the superiority of BSR-1 to Co.1. The leaf area also varied between the two varieties. Randhawa *et al.* (1985) indicated that leaf area is an important physiological trait deciding the rhizome yield in turmeric.

The other growth analysis components such as leaf area index, leaf area duration, net assimilation rate, relative growth rate and crop growth rate were higher in BSR-1. The higher crop growth rate in BSR-1 was contributed because of the increased net assimilation rate and leaf area index. In a study carried out by Williams (1972) in cassava higher net assimilation rate considerably improved the relative growth rate.

The net assimilation rate in the present study showed a rapid decrease as the age of crop gets advanced up to the seventh month period when the leaf area index was more. Subsequently, it registered an increase with a concomitant decrease in the leaf area. This might be due to the rapid bulking of the sink at this stage of growth. Earlier reports by Satheesan and Ramadasan (1980) and Moorby (1970) in turmeric and potato are in confirmation with the present work.

The dry matter accumulation increased as the age of the crop gets advanced in both the varieties. The higher dry matter accumulation in BSR-1 would be attributed to the higher plant height, leaf area, leaf number, number of tillers, number of tiller leaves, photosynthetic rate, leaf area index, net assimilation rate and crop growth rate. Satheesan and Ramadasan (1980) opined that higher dry matter turnover in turmeric is a pre-requisite for rhizome yield. This also holds good the present findings.

It can be concluded from the study that the growth and development of two turmeric varieties *viz.*, BSR-1 and Co.1 revealed that among the various growth attributes, the variety BSR.1 was found to be more vigorous in growth and dry matter production than Co.1. Similarly physiological parameters such as photosynthetic rate, leaf area duration, leaf area index, net assimilation rate and relative growth rate were found to be higher in BSR-1 than Co.1. The yield of BSR-1 (24.7 tonnes/ha.) was higher than that of Co.1 (20.4 tonnes/ha.).

References

Anonymous 1999 Crop production guide for horticultural crops. Department of Horticulture and plantation crops Government of Tamil Nadu.

Moorby J 1970 The production, storage and translocation of carbohydrate in developing potato plants. *Ann. Bot.* 34: 297-308.

Philip J & Nair P C S 1983. Morphological and yield characters of turmeric types. Indian Spices, 20 (2): 13-20.

Purohit A N .Mukhtarsingh V N Banerjee R S Kshetrapal R & Singh AK 1970 Physiological studies on Indian potato varieties. I. Regional and seasonal adaptability; Haulm growth, tuber initiation and number. Indian J. Plant Physiol. 13 (2): 240-248.

Randhawa G S Mahey R K & Gill S R S 1985 Leaf area measurements in turmeric (*Curcuma longa* L.). J. Res. Punjab Agric. Univ. 22 (1): 163-166.

Rathinavel M 1983 Effect of potash application and time of harvest on growth, yield and quality of turmeric (*Curcuma longa* L.). Thesis submitted for M.Sc (Hort.) Degree, Tamil Nadu Agricultural University, Coimbatore.

Satheesan K V & A Ramadasan 1980 Growth and productivity of turmeric grown as a pure and as an inter crop in coconut garden. National Seminar on Ginger and Turmeric, Central Plantation Crops Research Institute Regional Station Calicut, Pp. 69-73.

Sestak Z Catsky J & Jarvis P G 1971 Plant photosynthetic production - Manual of methods. (Ed: Junk W) N V Publishers The Hague Pp. 343-391.

Williams C N 1972 Growth and productivity of tapioca III Crop ratio and yield. Expl. Agric. 10: 9-16.

Session II

Biodiversity and Conservation

23

Genetic diversity of cardamom and its conservation in India

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Abstract

Cardamom (*Elettaria cardamomum* Maton) is indigenous to evergreen forests of Western Ghats in South India. Considering the importance of the crop and the serious threat caused by gene erosion mainly due to environmental hazards, incidence of diseases and pests and introduction of high yielding clones for large scale cultivation replacing valuable gene resources which can be utilized in the genetic improvement programmes, survey and collection programme was taken up under the National Agricultural Technology Project (NATP) on Plant Biodiversity, to Reserve Forests, National Parks and Wild Life Sanctuaries in South India. This has resulted in the collection of over 200 cardamom accessions. With this addition, the total germplasm holdings conserved in the clonal repositories rose to 1650. Considering the problems associated with conservation of such a large number of genotypes in the field gene bank, the need of *in vitro* conservation of cardamom is stressed.

Key words: cardamom, conservation, genetic diversity.

Introduction

Cardamom (*Elettaria cardamomum* Maton) is indigenous to evergreen forests of Western Ghats in South India. It is one of the most important spice crops belonging to the family Zingiberaceae. It is a shade loving plant cultivated at an altitude of 600 to 1200 m above MSL with an annual rainfall of 1500 to 4000 mm at a temperature range of 10 to 35°C. Apart from India, tropical countries like Sri Lanka, Tanzania and a few Central American countries cultivate this spice crop. Cardamom was included in the list of Indian spices liable for duty at Alexandria in A.D. 176 (Rosengarten 1969). Erstwhile Travancore Government in 1823 took up active cultivation of cardamom in India. Presently cardamom is cultivated in an area of about 72,444 ha, out of which 40,867 ha are in Kerala, 25,686 ha in Karnataka and 5,891 ha in Tamil Nadu. The outbreeding nature and lack of compatibility barriers brought about an array of variants in this crop. Collection and conservation of diversity and their utilization is the only solution with which the crisis faced by cardamom industry can be solved to a great extent. This paper highlights achievements made in the collection of genetic resources in cardamom and its conservation.

Cardamom being a cross pollinated crop, rich diversity exists in nature with respect to plant growth attributes, capsules colour and shape and yield (Madhusoodanan *et al.* 1994). The wet evergreen forests of Western Ghats of India are considered to be the centre of origin of this crop, as it possesses rich diversity. The geographical distribution of the crop in India extends northwards from Thirunelveli *(Tamil Nadu) to Sirsi in* Karnataka covering over 1000 kms through the high ranges of Kerala (Fig. 1).

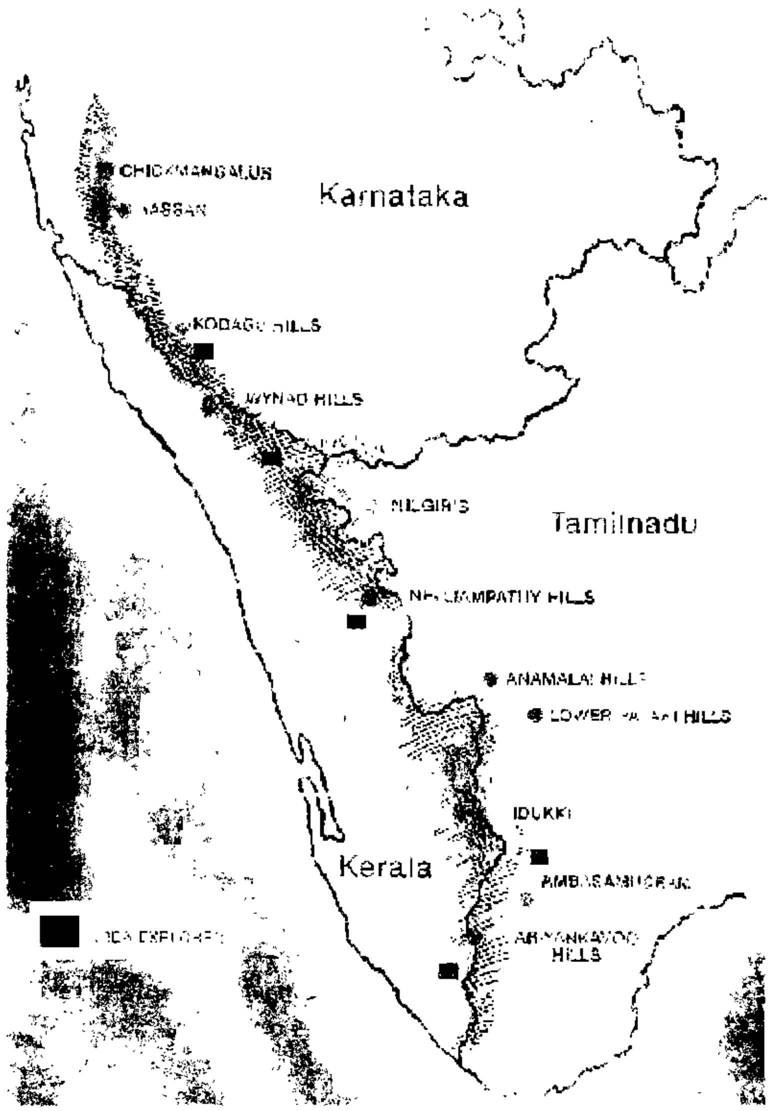

Fig. 1. Cardamom tract

Prior to the existence of the research organizations working on cardamom, surveys conducted by Mayne (1951) and Abraham and Tulasidas (1958) were considered to be the pioneer works in the germplasm exploration of cardamom. The survey made by Mayne (1951) is aimed to record the then existed practices of tapping the resources from wild population. But the survey of Abraham and Tulasidas (1958) provided emphasis on the understanding the geographical distribution and environmental impact on cardamom. Thereafter, by and large germplasm explorations are made independently by collaboratively. At present, over 1600 germplasm holdings of cardamom are maintained in the gene banks. The source of these collections is the plantations and natural habitat. High yield potential, capsules characters such as shape and size and bearing nature of the plants are a few criteria taken into account. The collections are being made based on the passport characters incorporated in the descriptor (Dandin *et al.* 1981). Nevertheless since last decade exploration and collection as well as exchange of germplasm between the organizations are monitored by the All India Co-ordinated Research Project (AICRP) on Spices. AICRP on spices has taken lead for publishing 'Cardamom descriptor' by IBPGRI, Rome. This descriptor is presently being used for characterization and documentation of cardamom germplasm.

In recent years, thrust in the germplasm survey is in locating the resistance source for pests and diseases. Accordingly emphasis has been given to spot out 'escape / tolerant' lines during the survey mission.

Materials and methods

Considering the importance of genetic resources in cardamom, National Bureau of Plant Genetic Resources (NBPGR), New Delhi, has given the mandate of conducting germplasm exploration, collection and conservation of cardamom germplasm under the National Agricultural Technology Project (NATP) on Plant Biodiversity to Indian Cardamom Research Institute (ICRI), Myladumpara. Since the implementation of the project a total of 9 survey trips were conducted for cardamom. The areas covered were Silent Valley National Park, Parambikulam Wild Life Sanctuary, Periyar Tiger Reserve, Kalakkad – Mundanthurai Tiger Reserve, Bhagamandala Reserve Forests and Kannielam tract in the Western Ghats. This has resulted in the collection of 194 accessions and these are referred as NATP collections. With this, total number of germplasm accessions including the pre-NATP collections conserved in the gene bank of ICRI, Myladumpara alone rose to 570. A rich diversity is encountered on various growth and yield attributes and also with regard to capsules quality traits. The diversity conserved were evaluated / being evaluated for further utilization.

Results and discussion

Considerable morphological variability was observed in the cardamom germplasm maintained (Table 1). Three distinct plant types have been encountered and they are erect type, semi-erect type and prostrate type. Variability was also observed in the germplasm belongs to each plant type with regard to yield and yield contributing characters. Among this, a bearing tiller with six panicles, plant with terminal panicles, pink tiller, narrow leaves, compound panicles etc. are the prominent ones. A wide variability has been encountered with regard to the plant growth characters and yield in the cardamom germplasm (Table2.)

Table 1. Nature of variability in cardamom germplasm

Sl. No.	Plant characters	Variations		
1.	Plant type	Prostrate	Semi erect	Erect
2.	Maturity status	Early	Late	
3.	Pseudostem			
	a. Colour	Green	Purple	
	b. Height	Tall	Medium	Dwarf
4.	Leaves			
	a. Nature	Pubescent	Non-pubescent	
	b. Size	Broad (>4cm)	Narrow (>4cm)	
5.	Panicles			
	a. Size	Long (>1m)	Medium(50-75 cm)	Small(<50 cm)
	b. Type	Simple	Compound	
	c. Number	>4	2-4	<2
6.	Capsules			
	a. Pedicel	Long (>1cm)	Short (<1cm)	
	b. Colour	Deep green	Green	Pale green
	c. Shape	Long	Angular	Round
	d. Size	>7 mm	< 7mm	

Seeds of a few genotypes have been procured from exotic sources tropical countries such as Sri Lanka, Tanzania and a few Central American countries and the plants raised from these seeds are being conserved in the clonal repository.

In recent years there is an increased tendency for depletion of cardamom germplasm. The reasons for gene erosion are (1) the deforestation in the natural habitat (2) adoption of improved clones (3) occurrence of adverse environmental conditions for the growth and development of the crop and (4) mortality due to pest and disease (5) lack of proper conservation technology.

Table 2. Variability in cardamom germplasm

Sl. No.	Characters	Range	Mean	SD	CV (%)
1.	Tillers/clump	17.6 - 59.3	33.88	8.16	24.09
2.	Tiller height (cm)	102.2 - 215.6	147.89	24.66	16.68
3.	Leaves/T.tiller	8.5 -16.1	11.69	1.63	14.02
4.	V.buds/clump	0.3 - 6.0	2.83	1.27	44.88
5.	B.tiller/clump	1.2 - 32.5	8.53	5.58	65.42
6.	Panicles/clump	1.2 - 32.5	8.56	5.57	65.07
7.	Racemes/panicle	9.4 - 21.5	14.83	2.78	18.75
8.	Panicle length	11.0 - 50.1	23.68	8.08	34.12
9.	Seeds/capsules	9.4 - 21.5	14.83	2.78	18.75
10.	Yield/clump (g)	10.0 - 2435	299.06	384.01	128.41

Conservation

Systematic surveys for germplasm resulted in the collection of a good number of samples in different centres and they are being conserved in the field gene banks. As the agro-ecological requirements of the crop differs at different locations and therefore *in situ* preservation is not generally practised in cardamom. The conservation of the samples in the gene banks attached to the institutes enables the breeder / personnel to carryout further assessments effectively. Conservation in the field bank becomes problematic due to (a) occupation of large area (b) frequent occurrence of natural calamities and (c) transmission of diseases etc. In this context, *in vitro* techniques offer an innovative means to overcome the serious problems in the germplasm conservation of vegetatively propagated species. As a pre requisite for *in vitro* conservation, protocol for micro propagation of cardamom has been standardized by various firms. *In vitro* protocol for short and medium term conservation of cardamom has been standardized. Tissue cultures of cardamom were stored up to 360 days with 85% survival and up to a maximum period of 420 days with 70% survival in half strength MS medium with $10g^{-1}$ each of sucrose and mannitol (Nirmal Babu *et al.* 1994; Geetha *et al.* 1995). Long-term storage of cardamom germplasm through cryopreservation offers advantage as it ensures long term preservation strategies without using the regeneration potential of plants. Studies in this direction are underway. Conservation of valuable germplasm through *in vitro* means is very important in vegetatively propagated crop species particularly in cardamom where field gene bank occupies large area and maintenance and monitoring of the gene bank often become difficult. However, the *in vitro* conservation technique may not be a suitable substitute for the conventional technology employed in the conservation.

Vegetative propagation along with sexual reproduction in cardamom brings about variability in the population. However indiscriminate collection and deforestation of natural habitat pause thread to cardamom diversity. Therefore, research programmes are to be focused for the collection, conservation and maintenance of these variability for future breeding programmes and at the same time awareness need to be created on the role of natural habit in preserving the cardamom diversity.

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References

Abraham P & Tulsidas G 1958 South Indian cardamom and their agricultural value. ICAR Tech. Bull. 79:1-27.

Dandin S B Madhusoodanan K J & George K V 1981 Cardamom descriptor. Proc. IV th Sym. On Plantation Crops (PLACROSYM) IV: 401 – 406.

Geetha S P Manjula C & Sajina A 1995 *In vitro* conservation of genetic resources of spices: In: Proc. Seventh Kerala Science Congress, January 27-29, Palakkadu. pp. 12-16.

Madhusoodanan K J Kuruvilla K M & Priyadarshan P M 1994 Genetic resources of cardamom. In: Advances in Horticulture. Vol. 9 - Plantation and Spice crops. Part I (Eds. K.L. Chadha & P. Rethinam). Malhotra Publishing House, New Delhi, India. pp. 121-129.

Mayne W W 1951 Report on cardamom cultivation in South India. ICAR Tech. Bull. No. 50.

Nirmal Babu K Minoo D Sajina A Geetha S P Samsudeen K Rema J Mini P M Manjula C John C Z Ravindran P N & Peter K V 1994 Short protocols for micropropagation of spices and aromatic crops. Vol 1. National Research Centre for Spices, Calicut. pp 1-29.

Rosengarten F 1969 The book of spices. Livingston Publication Co., Philadelphia.

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Agrobacterium Rhizogenes mediated transformation of *pogostemon cablin*: regeneration, chemical and molecular characterization of *in-vitro* raised transformants

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Abstract

A successful and efficient plant regeneration procedure has been developed from hairy root cultures of *Pogostemon cablin*. The agropine (A_4) and mannopine (LBA 9402) strains of *Agrobacterium rhizogenes* used for genetic transformation from the leaf explants of *in vitro* grown patchouli plants exhibited 73.6% and 34.9% transformation frequency, respectively. Profuse adventitious shoots regenerated on 67 and 30% of A_4 - and LBA 9402 - initiated hairy root lines, respectively after culturing the hairy roots on half-strength MS medium containing 1.5% sucrose. The maximum number of shoots obtained per explant was 66 using the A_4 strain of *A. rhizogenes*. The transgenic plants showed 80% and 30% survival when established using A_4 and LBA 9402 strains respectively, under green house conditions. The transgenic plants showed an altered phenotype including a short stature, wrinkled leaves and a highly branched root system characteristic of the classical "hairy root" phenotype. The plants tested positive for opine 4 months after transfer to the greenhouse. The essential oil composition of six transgenics showed variation in yield and quality, compared to control plants. The present investigation holds potential for the genetic improvement of patchouli which is highly susceptible to viral and fungal infestations, by introducing genes for desirable traits and isolating insertional mutants showing better agronomic and economic characteristics.

Keywords: essential oil, hairy roots, transgenic plants, molecular characterization patchouli.

Introduction

Pogostemon cablin (Benth.) Syn. *P. patchouli* (Hook) (Family-Lamiaceace) is a native of southeast Asia and a commercially important essential oil-yielding perennial herb. Patchouli oil is one of the most valuable naturally occurring raw materials in the perfumery industry as one of the most effective and enduring fixatives for heavy perfumes.

A restricted area of cultivation in the tropical humid regions of southern India, the narrow genetic base and an extreme susceptibility to various diseases like root knot nematode, mosaic virus and pests are the major reasons for the limited cultivation of this plant in India. Broadening the genetic base for the selection of better adaptable, disease resistant cultivars is one of the important prerequisites for extending the area of cultivation.

The genetic improvement of patchouli through conventional breeding methods is limited because of the non–synchronous and short flowering periods of the plant. Various biotechnological approaches including micropropagation (Padmanabhan *et al.*, 1981; Hart *et al.*, 1970; Sharma *et al.*, 1992), leaf culture, and callus culture (Misra,1996; Padmanabhan *et al.*, 1981) have been attempted for the clonal multiplication and production of virus-free (Kukreja *et al.*, 1990) patchouli plants. Recent progress in genetic engineering together with conventional breeding programs have permitted the introduction of useful traits, such as resistance to insects, virus, pests and various other diseases, herbicide resistance, increased herb yield and improvement in the quality and quantity of essential oils in a large number of commercially important plants including *Pelargonium* sp., *Eucalyptus* sp., *Artemisia absinthium* (Pellegrineschi *et al.*, 1994; Adam, 1987; Kennedy *et al.*, 1993).

Agrobacterium rhizogenes mediated gene transfer holds potential for the production of stable and non-chimeric transformants exhibiting rapid and high-frequency regeneration from hairy roots (Pellegrineschi *et al.*, 1994; Tepfer, 1984). The composition of valuable natural products has also been improved in several plants using this technique and in some cases novel compounds from hairy roots have been isolated (Sauerwein *et al.*, 1991; Granicher *et al.*, 1995; Ishimaru *et al.*, 1990). The need to increase and meet growing demand for patchouli by improving the plant with respect to adaptability, disease resistance and oil yield and quality, prompted the development of a suitable protocol for the rapid and high-frequency regeneration of transgenic plants.

Materials and methods

Bacterial strains: Two strains of *Agrobacterium rhizogenes*, A_4 (courtesy Dr. David Tepfer, France) and LBA 9402 (courtsey Dr. G. Ooms, England) were used in the present study. For transformation experiments, 24-48 h old bacterial suspensions, grown in liquid YMB (Hooykaas *et al.*, 1977) at 28 ± 2°C on a rotary shaker (at 100 rpm) were used.

Expalnt and medium: Nodal explants and terminal buds were grown and maintained under *in vitro* on MS basal medium (Murashige and Skoog, 1962) gelled with 0.8% agar (Hi Media Pvt. Ltd., India) supplemented with 8.7 µM 6-benzylaminopurine (BAP) and 5.71 µM indole-3-acetic acid (IAA) as reported previously (Kukreja *et al.*, 1990). Young expanded leaves were excised and used for transformation studies.

Induction of hairy root cultures and regeneration of transgenics: Leaf explants (second and third from the apex) were wounded with a sterile hypodermic needle dipped in the bacterial suspension. The inoculated leaves were incubated on hormone-free MS basal medium at 22 ± 2°C. After 48 h of co-cultivation, the explants were transferred to fresh medium supplemented with 2.88 µM cephalexin. Control leaves were left untreated and cultured under the same conditions. Hairy roots emerging from the inoculation sites were excised and maintained on half-strength hormone-free MS medium supplemented with 3% sucrose containing the same concentration of antibiotic. Transformation frequency was calculated as follows:

$$\text{Transformation frequency (TF)} = \frac{\text{Number of inoculation sites (pricks) giving hairy roots}}{\text{Total number of inoculations (pricks) created}} \times 100$$

The hairy roots were sub-cultured at 15 d intervals and maintained in the dark at 22 ± 2° C, relative humidity of 55-60% on the same medium with a gradual reduction in the antibiotic concentration for six passages. Roots obtained from *in vitro* grown plantlets of *P. cablin,* maintained on semi-solid half-strength MS medium supplemented with 5.37 µM ∝-naphthalene acetic acid (NAA) served as control roots (Kukreja *et al.*, 1990). Hairy roots (1.5 cm long) were transferred to various strengths (full, half and one-fourth) of semi-solid MS basal medium supplemented with different amounts of sucrose (0.75% - 3%) to determine the best medium for promoting regeneration. Plants raised from nodal callus served as control for comparing morphological and qualitative characters of transformants.

Rooting of transformants and acclimatization of transgenics: In vitro regenerated transgenic shoots with 2-3 expanded leaves were excised and transferred to semi-solid MS medium of various strengths (full, half and one-fourth) supplemented with different levels (0-5.71 µM) of IAA for rhizogenesis. Rooted transgenics were taken out of the culture tubes, washed carefully to remove agar from the roots and transferred to pots containing sand and soil in equal ratio, and maintained under greenhouse conditions. The morphological parameters of transformed and non-transformed plants were measured after 3 months of growth.

Detection of opines: Extraction and detection of opines was performed according to Morgan *et al.* (1987).

Extraction and analysis of the essential oil: Shade dried leaves of transformed and non-transformed plants (100 g / sample) were subjected to hydro-distillation using Clevenger apparatus for 6-8 h (Kumar *et al.*,1986).GLC analysis was carried out on a Varian GC model 3400 gas chromatograph and FID detector using a 30 m x 0.32 mm (0.2 µ film thickness) Supelcowax-10 capillary column with H_2 as the carrier gas at a flow rate of 1ml/min. Oven temperature was initiated at 50°C and raised to 220°C at 6°C/min with an initial hold time of 2 min. Injector and detector temperatures were 210°C and 240°C, respectively. Data was processed on an AIMIL data system (AIMIL Ltd., New Delhi, India). Major components were identified by comparison of their retention times with their authentic standards.

RAPD analysis of transformed and non-transformed plants: Genomic DNA was extracted from 1g fresh weight leaf tissue following a standard protocol (Khanuja *et al.*, 1998). PCR amplification and RAPD analysis of the amplified DNA was done according to Shoyama *et al.* (1997). The primers procured from M/s Bangalore Genie, India were used. The sequence of different MAP primers used were 01- AAATCGGAGC, 02-GTCCTACTGC, 03- GTCCTTAGCG, 04- TGCGCGATCG, 05- AACGTACGCG, 06-GCACGCCGGA, 07- CACCCTGCGC, 08- CTATCGCCGC, O9- CGGGATCCGC, 10-GCGAATTCCG, 11- CCCTGCAGGC, ,12- CCAAGCTTGC, ,13- GTGCAATGAG, 14-AGGATACGTG, 15- AAGATAGCGC, 16- GGATCTGAAC, ,17- TTGTCTCAGG, 18-CATCCCGAAC, 19- GGACTCCACG, 20- AGCCTGACGC.

Results and discussion

Transformed roots of *P. cablin* were initiated 7-8 d after co-culturing leaf explants with A_4 and LBA 9402 strains of *A. rhizogenes* and were maintained on half-strength MS medium containing 3% sucrose (Fig. 1A-B). The transformation frequency with A_4 was 73% whereas that of LBA 9402 was 34%, 12 d after bacterial inoculation. Transformation frequencies were dependent on the bacterial strain used, with A_4 proving to be a better strain than LBA 9402, observed in earlier studies (Davey *et al.*, 1987; Schaerer and Pilet, 1991; Banerjee *et al.*, 1994; Zehra *et al.*, 1998).

Differences in length, copy number and insertion site of Ri T-DNA generally produces variations in growth rate, developmental pattern and plant regeneration capacity (Finnegan and Elory, 1994; Kumpatla et al., 1998). Fifty independently initiated, transformed lines produced using each bacterial strain were isolated and tested for regeneration frequency. Transformed roots spontaneously generated adventitious shoots 3 weeks after transfer to half-strength MS media containing 1.5% sucrose, which proved to be the best medium (Fig. 1C-D). In full-strength MS medium, regeneration was accompanied by callus formation, whereas fewer shoots (a mean of 39.7 shoots/explant) were produced in one-fourth MS medium compared to half-strength MS medium. The regeneration frequency varied drastically, with 67% of the transformed roots initiated by A_4 strain producing a mean of 66.4% shoots / explant 20 d after transfer, compared to 30% of roots initiated by LBA 9402 giving rise to 16.2 shoots / explant (Table 1). The spontaneous regeneration of plants from hairy root cultures has also been reported in other plant species (Tepfer, 1983; Pellegrineschi *et al.*, 1994; Banerjee *et al.*, 1997).

The maximum number of roots (37.3/explant) were formed on semi-solid half - strength MS medium with 1.5% sucrose and 2.85 μM IAA 15 d after inoculation. However, root formation was supported to some extent on all strengths of the culture media. Transformed roots on the optimal medium showed vigorous growth and extensive lateral branching with an average length of 5.63 cm (Fig. 1E, Table 2). Roots developed on hormone-free medium were short, thick and occasionally exhibited callus

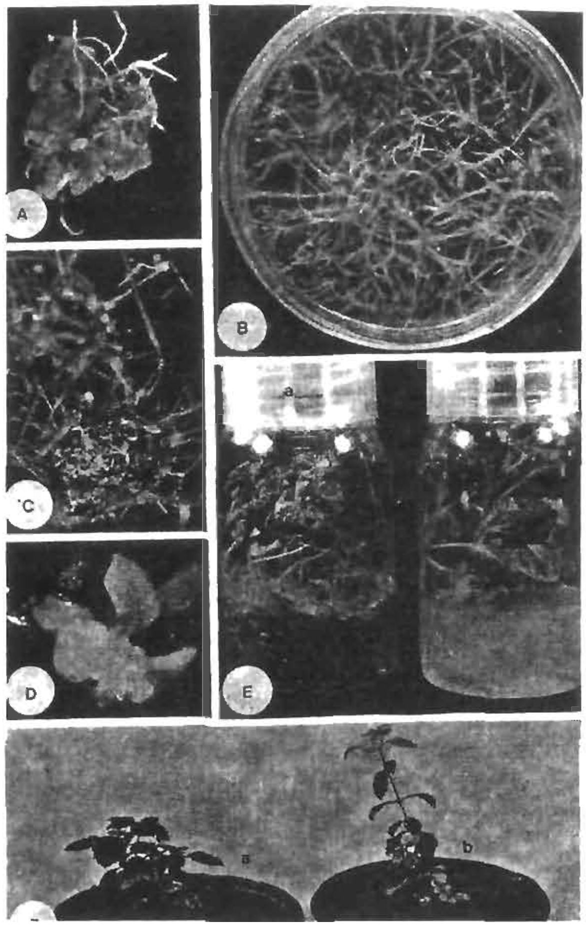


Fig. 1 (A-F). Agrobacterium rhizogenes *mediated transformations in* Pogostemon cablin . A- Induction of hairy roots from leaf explants; B- Growth of hairy roots on half -strength MS medium containing 3% sucrose after 15 d of culture; C- Shoot regeneration from hairy root cultures; D- A close up of the regenerated shoot; E- Rhizogenesis in transformed (a) and non-transformed (b) plant in culture; F- Altered phenotypic behaviour in transformed (a) plant in comparison to the wild type (b) in pots under green house condition.

formation. In contrast roots formed on one-fourth MS medium were thin and long, turned brown, and did not show any branching.

Complete plantlets produced by A_4 and LBA 9402 showed 80% and 30% survival rate, respectively, under greenhouse conditions, whereas the non-transformed plants grown *in vitro* showed 80% survival under similar conditions. Thus, A_4 proved better than LBA 9402 in terms of transformation frequency, regeneration frequency, number of shoots per explant and survival rate. Further experiments were performed only with the plantlets regenerated and established using the A_4 strain. The phenotype observed in the adult plant was the typical "hairy root" phenotype described for other plant species (Pellegrineschi *et al.* 1994). Comparison of the transformed and non-transformed plants showed that transgenic plants were shorter and more compact with an increased number of branches and more leaves per branch (Fig.1F,2). The decrease in plant height correlated with the decrease in internode length as reported previously (Tempe *et al.*, 1989). The increase in the number of the leaves can be considered a potentially positive step toward increasing the total oil yield.

Opine assay of hairy roots originating from both strains showed mannopine in LBA 9402-induced lines. A spot above that of mannopine was detected in all A_4-induced lines, which may correspond to agropine as noted in transformed tomato (Morgan *et al.* 1987) produced using a similar procedure. Opines could not be

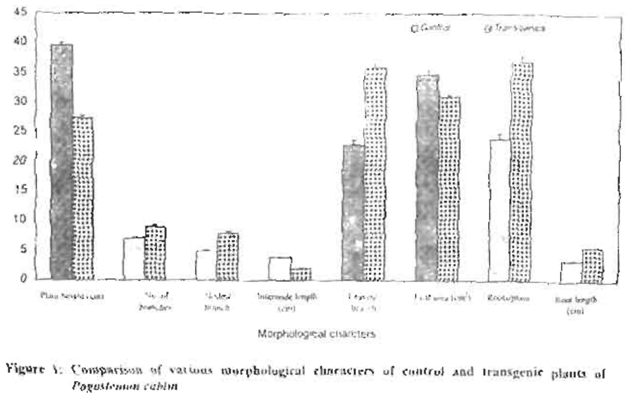
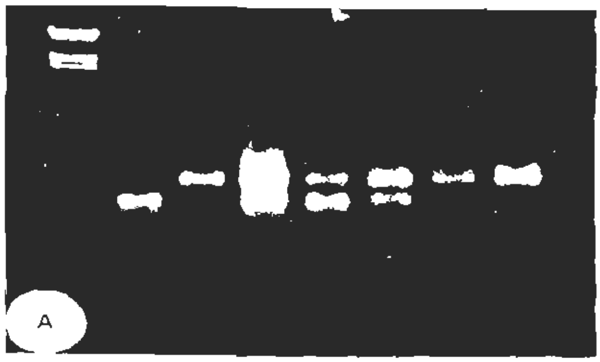
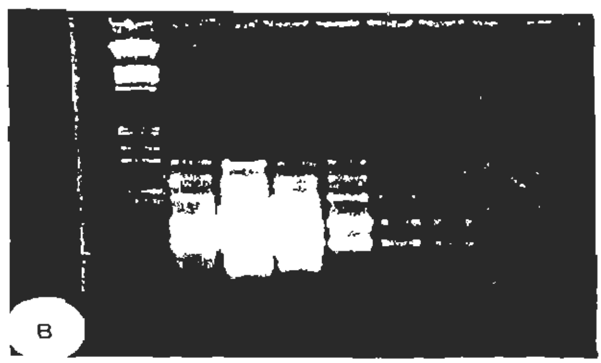


Fig. 2. Comparison of various morphological characters of control and transgenic plants of *Pogostemon cablin*



λ P1 P2 P3 P4 P5 P6 wt



λ P1 P2 P3 P4 P5 P6 wt

Fig. 3 (A, B). PCR profiles of DNA isolated from 6 transgenic plants and their parent Pogostemon cablin amplified with A- primer *MAP 01* and B- primer *05 and resolved* on 1.2% agarose gel. Samples in gel lanes (left to right) are as follows: Lane 1 : marker DNA digested with Hind III; Lane 2 : P1; Lane 3 : P2; Lane 4 : P3; Lane 5 : P4; Lane 6 : P5; Lane 7 : P6; Lane 8 : wild type Pogostemon cablin detected in non-transformed root extracts suggesting the transformed status of the hairy roots. Out of the 10 transgenics successfully transferred to soil, six (P1-P6) showed characteristic differences in morphology compared to wild type plants. The oil content of transgenics varied from 0.4-1.4% (dry weight), the best of which was significantly higher than that in control plants (0.6 - 0.9% dry weight basis). Considering the increase in the number of branches and leaves in all six transformants, an overall increase in the oil yield could be predicted since higher shoot yield is directly proportional to the oil yield per plant (Saxena *et al.*, 2000). Comparing the oil profile of the transformants with that of the control, P1 showed close similarity to the control with respect to major components of the essential oil (Table 3). However, an increase in the oil yield and patchoulal content is definitely a step towards an improvement of the quality of the oil. Ninty two percent of the compounds in commercial oil of patchouli have little or no effect on its fragrance. Sesquiterpenes constitute 45% of the oil of which 40% is represented by patchouli alcohol, the major component of the oil, which accounts for the stability, flavor and, to a certain extent, the fragrance of the oil. Based on these results, transformed regenerant P1 can be compared to the commercial Indonesian plant (patchoulol content ranging from 31.6-36.0%). On the other hand, the oil of the control plant showed a profile similar to that of the Java plant. Oil profiles of other five transgenics exhibited low patchoulol content comparable to the commercial oil of plants grown in Costa Rica and the West Indies containing 23-25% patchoulal (Table 3) (Lawrence 1981).

Table 1. Effect of media composition on the regeneration frequency (%) and number of shoots/explant from the hairy root cultures of *Pogostemon cablin* induced with different strains of *A. rhizogenes*

	Culture medium used					
	MS + 3% sucrose		½ MS + 1.5% sucrose		¼ MS + 0.75% sucrose	
	Percent shoot regeneration frequency**	No.of shoots / explant	Percent shoot Regeneration Frequency	No.of shoots / explant	Percent shoot regeneration trequency	No.of shoots / explant
A_4	24.0± 0.83*	27.0 ±1.39	67.6± 1.98	66.4 ±1.35	42.0± 1.35	39.7 ±1.23
LBA 9402	15.3± 0.83	5.7± 0.42	30.2± 1.41	16.2 ±1.11	22.0 ±0.94	13.3±0.42

**Fifty independently initiated transformed hairy root lines were tested for regeneration frequency.
* ± = Standard error

Table 2. Effect OF iaa on rhizogenesis in the transformed shoots of *Pogostemon cablin* after 15 d of culture

	Culture medium used					
	MS + 3 % sucrose		½ MS + 1.5 % sucrose		¼ MS + 0.75 % sucrose	
	Root number	Root length (cm)	Root number	Root length (cm)	Root number	Root length (cm)
Control	4.33#± 0.16	2.47±0.12	20.0± 0.98	3.93 ±0.07	23.0 ±0.72	4.43±0.10
2.85	1.33*± 0.31	1.60*±0.07	37.3*± 1.03	5.63*±0.11	5.66*±0.42	3.13± 0.02
5.7	3.00±0.27	2.23±0.09	20.6±0.57	4.16 ±0.07	14.7*±0.96	3.43±0.13

*Significant at 5% level with respect to the control. ± = Standard error. # =Value is average of three replicates

Table 3. Oil content (% dry weight) and percent concentration of some major sesquiterpenes in the essential oils of transgenics and control plants of *Pogostemon cablin*

Oil constituents	Regenerated transformed plants						Control
(%)	P1	P2	P3	P4	P5	P6	
Oil content (% dry weight)	1.2	0.95	1.12	0.92	1.4	0.4	0.9
β- patchoulene	1.3	1.88	0.36	2.4	3.6	0.09	1.4
Pogostol	3.0	1.3	1.52	0.8	1.44	0.3	2.8
β-elemene	Trace	0.14	0.1	0.33	0.47	0.01	0.2
α-guaiene	10.9	12.20	14.6	7.9	9.8	5.2	11.2
β-caryophyllene	1.2	2.3	2.6	0.7	1.9	0.5	1.5
Seychellene	7.8	6.6	8.3	9.9	10.2	2.3	6.4
Bulnesene	11.7	13.3	15.2	10.2	10.6	9.4	13.0
Patchoulol	32.0	25.2	24.6	23.1	21.3	8.0	28.2

RAPD analysis with most primers showed the presence of a common band in wild type and transgenic plants. However, primer MAP 01 (5'AAATCGGAGC3') revealed distinct differences between the control and P1 in terms of polymorphic bands (Fig.3A). Primer MAP 05 (5'AACGTACGCG3') produced differences in the banding pattern of transgenics P2 and P6 (Fig.3B), proving that each transformant was genetically different from the wild type.

The results of the present investigation demonstrate that *Pogostemon cablin* is a susceptible host for *A. rhizogenes*. This technology might be exploited to meet the growing demands of this commercially valuable plant.

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References

Adam, S. Obtention de racines transformee's for *Agrobacterium rhizogenes* chez Eucalyptus gonni. In: Annales de Recherches Sylvicoles, AFOCEL, Paris; 1987: 7-12.

Banerjee, S.; Naqvi, A. A.; Mandal, S.; Ahuja, P. S. Transformation of *Withania somnifera* (L) Dunal by *Agrobacterium rhizogenes*: Infectivity and phytochemical studies. Phytother. Res. 8: 452-455; 1994.

Banerjee, S.; Zehra, M.; Gupta, M. M.; Kumar, S. *Agrobacterium rhizogenes* mediated transformation of *Artemisia annua*: production of transgenic plants. Planta Med. 63: 467-469; 1997.

Davey, M. R.; Mulligan, B.J.; Gartland, K. M. A.; Peel, E.; Sargent, A. W.; Morgan, A. J. Transformation of *Solanum* and *Nicotiana* species using an Ri-plasmid vector. J. Exp. Biol. 38:1507-1516; 1987

Finnegan, E.; Elory, D Mc. Transgene inactivation: Plants fight back. Biotechnology12:883-888;1994.

Granicher, F.; Christen, Ph.; Kamalapriza, Ph.; Burger, U. An iridoid diester from *Valeriana officinalis* var. *sambucifolia* hairy roots. Phytochemistry 38: 103-105; 1995.

Hart, J. W.; Woodcock, G. J.; Wilson, Z. Culture and sesquiterpene analysis of cells of regenerated plantlets of *Pogostemon cablin* benth (Patchouli). Ann. Bot. 34: 789-798; 1970.

Hooykaas, P. J. J.; Klapwijk, P.M.; Nuti, P. M.; Shilperoort, R. A.; Rorsch, A. Transfer of the *Agrobacterium tumefaciens* Ti plasmid to avirulent *Agrobacteria* and *Rhizobium* explanta. J. Gen. Microbiol. 98: 477-484; 1977.

Ishimaru, K.; Sudo, H.; Satake, M.; Hasegawa,Y.; Takemoto, T.; Shimomura, K. Amarogentin, amaroswerin and four xanthones from hairy root cultures of *Swertia japonica*. Phytochemistry 29: 1563-1565; 1990.

Kennedy, A. I.; Deans, S. G.; Svoboda, K. P.; Gray, I.; Waterman, P. G. Volatile oils from normal and transformed roots of *Artemisia absynthium*. Phytochemistry 32:1449-1451; 1993.

Khanuja, S. P. S.; Shasnay, A. K.; Darokar, M.P.; Kumar, S. Rapid procedure for isolating somaclones of altered genotypes in *Mentha arvensis*. J. Med. Aroma. Plant Sci. 20: 359-361; 1998.

Kukreja, A. K.; Mathur, A. K.; Zaim, M. Mass production of virus free patchouli plants [*Pogostemon cablin* (Blanco) Benth.] by *in vitro* culture. Trop. Agric. (Trinidad) 67:101-104; 1990.

Kumpatla, S. P.; Chandrasekharan, M. B.; Iyer, L.M.; Hall, T. C. Genome intruder scanning and modulation systems and transgene silencing. Trends Plant Sci. 3: 97-104; 1998.

Lawrence, B.M. Progress in essential oils. Perf. Flav. 6: 73-76; 1981

Misra, M. Regeneration of patchouli (*Pogostemon cablin* Benth) plants from leaf and node callus and evaluation after growth in field. Plant Cell Rep. 15: 991-994; 1996.

Morgan, A. J.; Cox, P. N.; Turner, D. A.; Peel, E.; Davey, M.R. Gartland, K. M. A.; Mulligan, B.J. Transformation of tomato using an Ri-plasmid vector. Plant Sci. 49: 37-49; 1987.

Murashige, T.; Skoog, F. A revised medium for rapid growth and bioassays with tobacco tissue cultures. Physiol. Plant. 15: 473-497;1962.

Padmanabhan, C.C.; Sukumar, S.; Sreerangaswamy, S.R. Patchouli plants differentiated *in vitro* from step tip and callus culture. Curr. Sci 50: 195-197; 1981.

Pellegrineschi, A.; Damon, J.; Valtorta, N.; Paillard, N.; Tepfer, D. Improvement of ornamental characters and fragrance production in lemon scented geranium through genetic transformation by *Agrobacterium rhizogenes*. Biotechnology 12: 64-68; 1994.

Sauerwein, M.; Ishimaru, K.; Shimomura, K. A piperidone alkaloid from *Hyoscyamus albus root* transformed with *Agrobacterium rhizogenes*. Phytochemistry 30:2977-2978; 1991.

Saxena, G.; Banerjee, S.; Rahman, L; Mallavarapu, G. R.; Sharma, S.; Kumar, S. An efficient *in vitro* procedure for micropropagation and generation of somaclones of rose scented *Pelargonium*. Plant Sci. 155: 133-140; 2000.

Schaerer, S.; Pilet, P.E. Roots, explants and protoplasts from pea transformed with strains of *Agrobacterium tumefaciens* and *rhizogenes*. Plant Sci. 78: 247-258;1991.

Sharma, N.; Chandel, K. P. S.; Maheshwari, M. S. Feasibility of mass production of *Pogostemon patchouli* Hook.F. through tissue culture for commercial cultivation. Ind. Perf. 36: 70-74; 1992.

Shoyama, Y.; Zhu, X.; Nakai, R.; Shiraishi, S.; Kohda, H. Micropropagation of *Panax notoginseng* by somatic embryogenesis and RAPD analysis of regenerated plantlets. Plant Cell Rep. 16: 450-453; 1997.

Tempe, J.; Casse-Debart, F. Plant gene vectors and genetic transformation: *Agrobacterium* Ri-plasmids. In: Schell,J. ; Vasil, I.K.(eds.) Cell Culture and Somatic Cell Genetics of Plants, Molecular Biology of Plant Nuclear Genes; New York: Academic Press; 1989:25-49.

Tepfer, D. The potential uses of *Agrobacterium rhizogenes* in the genetic engineering of higher plants: Nature got there first. In: Lurquin, P; Klienhofs, A.(eds.) Genetic engineering in Eukaryotes, NewYork: Plenum Press; 1983: 153-164.

Tepfer, D. Transformation of several species of higher plants by *Agrobacterium rhizogenes*: Sexual transmission of the transformed genotype and phenotype. Cell 47: 959-967; 1984.

Zehra, M.; Banerjee, S.; Naqvi, A. A.; Kumar, S. Variation in the growth and alkaloid production capability of the hairy roots of *Hyoscyamus albus, H. muticus* and their somatic hybrid. Plant Sci. 136: 93-99; 1998.

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Mass multiplication of tamarind through *in vitro* culture

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Abstract

A study on *in vitro* culturing of the axillary buds of tamarind was conducted different media supplemented with various growth regulators. Among the different media tried *viz.*, MS, SH, LS, B5 and WP, the highest bud break per cent(77.96), shoot induction in a shorter period (31.69), the highest number of multiple shoots per culture (2.02) were produced with the longest shoot(3.72) in MS medium. For the multiple shoot induction, MS medium supplemented with sucrose @60g l^{-1} resulted in the highest bud break percentage(90.33) in a lesser duration(23.17 days). Also, the shoot production per bud was also the highest(23.17) with the longest shoot length of 3.44 cm. The growth regulators BAP 3.0 mg l^{-1} + GA_3 0.5 mg l^{-1} were found to be the best combination in MS medium for multiple shoot production. The rooting of multiple shoots were effected in different strengths of MS medium. The half MS medium with 30g l^{-1} of sucrose supplemented with the growth regulators IAA 0.5 mg l^{-1} and IBA 0.5 mg l^{-1} along with activated charcoal (1.0mg l^{-1}) recorded the highest rooting percentage of 48.83 with more number of roots per shoot (3.72) and the higher root length was the highest(1.52cm). Therefore, faster rate of multiplication of tamarind through *in vitro* culture envisages conservation and preservation of elite planting materials.

Key words: Auxillary buds, callus, explants, *in vitro* culture, micro shoot, multiple shoot, primary culture, rooting, secondary culture, shoot elongation.

Introduction

The tissue culture techniques were developed and commercially exploited so far mostly in herbaceous species. Screening of available literature on *in vitro* clonal propagation of tamarind revealed that there are no reports on micropropagation of elite types of tamarind using explants from improved varieties/types of mature trees. Hence, development of a reliable protocol for micropropagation of tamarind genotypes through *in vitro* culture and supply of quality planting material on a large scale will have a great commercial value and impact to the developing horticulture industry in India. Keeping this views in mind, the *in vitro* culture studies using axillary bud explants were undertaken with the objective (i) to standardise the medium and growth regulators for establishment and induction of multiple shoots from axillary buds and (ii) to develop a protocol for *in vitro* rhizogenesis of microshoots.

Materials and methods

The nutrient media used for the study were Murashige and Skoog (MS) medium (1962), Linsmaier and Skoog (LS) medium (1965), B_5 medium (Gamborg ***et al.***, 1968), Schenk and Hilderbrandt (SH) medium (1972) and Woody plant (WP) medium (Lloyd and Mccown, 1980).

Source of explants: Young shoots with axillary buds collected from five year old nursery grown mother plants of tamarind were used as explants.

Different culture media on multiple shoot induction: Ten auxillary buds of cv. PKM 1 of tamarind after complete sterilisation were inoculated in different media namely MS, SH, LS, WP and B_5 medium to study the rate of multiple shoot induction with BAP (3 mg l^{-1}) + GA (0.5 mg l^{-1}) and each of the media supplemented with the growth regulator were replicated for four times.

Plant growth regulator combinations on multiple shoot induction: To study the effect of different growth regulator combinations on multiple shoot induction in the primary culture, the axillary buds were cultured in Murashige and Skoog medium (1962) fortified with different cytokinins *viz.*, BAP, Kinetin, TDZ and the Gibberellin. The treatment were T_0 Control; T_1 BAP 1.0 mg l^{-1}; T_1 BAP 2.0 mg l^{-1}; T_3 BAP 3.0 mg l^{-1}; T_4 BAP 4.0 mg l^{-1}; T_5 BAP 5.0 mg l^{-1}; T_6 BAP 1.0 mg l^{-1} + GA 0.5 mg l^{-1}; T_7 BAP 2.0 mg l^{-1} + GA 0.5 mg l^{-1}; T_8 BAP 3.0 mg l^{-1} + GA 0.5 mg l^{-1}; T_9 BAP 4.0 mg l^{-1} + GA 0.5 mg l^{-1}; T_{10} BAP 5.0 mg l^{-1} + GA 0.5 mg l^{-1}; T_{11} BAP 1.0 mg l^{-1} + GA 1.0 mg l^{-1}; T_{12} BAP 2.0 mg l^{-1} + GA 1.0 mg l^{-1}; T_{13} BAP 3.0 mg l^{-1} + GA 1.0 mg l^{-1}; T_{14} BAP 4.0 mg l^{-1} + GA 1.0 mg l^{-1} and T_{15} BAP 5.0 mg l^{-1} + GA 1.0 mg l^{-1}.

Sucrose on multiple shoot induction in primary culture: This experiment was conducted to study the effect of various concentrations of sucrose on multiple shoot induction in primary culture from axillary buds of cultivar PKM 1, sucrose was added to the shoot proliferation medium (MS + BAP 3 mg l^{-1} + GA 0.5 mg l^{-1}) at concentration of 20, 30, 40, 50, 60, 70 and 80 mg l^{-1}.

Strength of MS-medium on in vitro rhizogenesis of micro shoots: To induce *in vitro* rhizogenesis of axillary bud derived multiple shoots of cv. PKM 1 tamarind, full strength, 3/4th strength, ½ strength and ¼ strength of MS media (1962) were used.

Plant growth regulators on in vitro rhizogenesis of micro shoots: The effect of (half strength) MS medium supplemented with two auxins *viz.*, IBA, IAA and a phenolic compound, phloroglucinol individually and in combinations on rooting of tamarind cv. PKM 1 micro shoots were studied. This experiment had the following 14 treatments. The treatments alone and in combination were T_0 Control; T_1 IBA 0.5 mg l^{-1}; T_2 IBA 1.0 mg l^{-1}; T_3 IBA 1.5 mg l^{-1}; T_4 IBA 2.0 mg l^{-1}; T_5 IAA 0.5 mg l^{-1}; T_6 IAA 1.0 mg l^{-1}; T_7 IAA 1.5 mg l^{-1}; T_8 IAA 2.0 mg l^{-1}; T_9 IBA 0.5 mg l^{-1} + IAA 0.5 mg l^{-1}; T_{10} IBA 1.0 mg l^{-1} + IAA 1.0 mg l^{-1}; T_{11} Phloroglucinol 0.25 mg l^{-1}; T_{12} Phloroglucinol 0.5 mg l^{-1} and T_{13} Phloroglucinol 1.0 mg l^{-1}.

Sucrose concentrations on in vitro rhizogenesis of micro shoots: To study the effect of different sucrose concentrations on *in vitro* rhizogenesis of micro shoots of tamarind cv. PKM 1, sucrose was added at 0, 10, 20, 30, 40, 50 and 60 mg l^{-1} to the MS (half strength) with IAA 0.5 mg l^{-1} and IBA 0.5 mg l^{-1}.

For all the experiments, CRD with the tubes per **culture or treatment was** usedm replicated four times.

The data recorded from the various experiments were subjected to statistical scrutiny as per the methods of Panse and Sukhatme (1978) and the results were interpreted.

Results and discussion

In the present investigation, attempts were made to standardize a protocol for micropropagation of tamarind using the auxillary buds derived from matured tamarind trees of the elite cultivar PKM I.

Effect of different culture media on multiple shoot production: Among the five different media tried for multiple shoot induction, higher explant surivival per cent of 85.03, per cent bud break of 77.96 and earlier bud break (31.69 days) with more number (2.02) and lengthier shoots of 3.27 cm were obtained in MS medium. The MS medium was followed by WP medium recording about 76.09 per cent survival, 58.41 per cent bud break within 38.51 days after culture initiation, producing 1.74 multiple shoots per bud with shoots of 2.79 cm long. The lowest bud break per cent of 34.24 and 43.50 and explant survival per cent of 54.99 and 67.16 was obtained in SH and LS medium respectively. The SH medium produced 1.00 shoot per bud with shoots of 2.29 cm long and the LS medium produced 1.08 shoots per bud within 44.21 days and the shoots were of 2.42 cm long. Further, the findings of Raghava swamy *et al.* (1992) on *in vitro* culture of *Dalbergia latifolia* and Mathur and Mukunthakumar (1992) in *Bauhinia dispinosa* also indicated the superiority of MS medium over other medium for getting increased success. This is in corroboration with the findings of present study.

Effect of BAP and GA3 on multiple shoot induction: The findings of the experiment to study the effect of different concentrations of BAP and its combination with GA_3 for multiple shoot induction from axillary bud explants of tamarind brought out a significant differences among the different BAP and BAP + GA_3 growth regulator treatments for bud break percentage, number of days taken for bud break, number of shoots per bud and mean length of shoots (Table 2).

Bud break percentage: The bud break per cent varied from 20.46 to 89.52 for BAP alone for BAP + GA_3 combination treatments. The greater bud break of 89.52 percentage was obtained in T_8 (BAP 3.0 mg l^{-1} + GA_3 0.5 mg l^{-1}) and the lesser bud break of 20.46 percentage was observed in T_0 (control, without any growth regulator).

Number of days taken for bud break: The days taken for bud break ranged between 28.39 and 48.64. The treatment T_8 (BAP 3.0 mg l^{-1} + GA_3 0.5 mg l^{-1}) recorded the lesser number of 28.39 days for bud break and the higher number of 48.64 days for bud break was recorded in T_0 (control).

Number of shoots per bud: The number of shoots per bud varied from 0.00 to 1.59. The greater number of shoots per bud (1.59) was obtained in T_8 (BAP 3.0 mg l^{-1} + GA_3 0.5 mg l^{-1}), followed by T_{13} (BAP 4.0 mg l^{-1} + GA_3 1.0 mg l^{-1}) and T_{13} (BAP 3.0 mg l^{-1} + GA_3 1.0 mg l^{-1}) with 3.72 cm and 3.51 cm respectively.

Mean length of shoots: The mean length of multiple shoots ranged between 2.55 and 3.92 cm. The higher shoot length of 3.92 cm was noticed in T_{15} (BAP 5.0 mg l^{-1} + GA_3 1.0 mg l^{-1}), followed by T_{14} (BAP 4.0 mg l^{-1} + GA_3 1.0 mg l^{-1}) and T_{13} (BAP 3.0 mg l^{-1} + GA_3 1.0 mg l^{-1}) with 3.72 cm and 3.51 cm respectively.

Multiple shoot production was found to be controlled by the nature and concentration of the growth regulator used. As the cytokinin concentration in the medium increased, the number of shoots per axillary bud got increased while the days taken for bud break was minimized. Such a beneficial effect of cytokinin on multiple shoot regeneration have already been exhibited by Reuveni *et al.* (1990) and Raman *et al.* (1992). The differential response of BAP and GA_3 on induction of multiple shoots in primary culture was evident in the present investigation. Multiple shoot production is influenced not only by the type of cytokinin used, but also by the concentration of cytokinin used. The higher number of multiple shoots per bud (1.59) was recorded in T_9 (BAP 3.0 mg l^{-1} + GA 0.5 mg l^{-1}) and zero in T_0 (control). Similarly, the higher length of multiple shoots of 3.92 cm was recorded in T_{15} (BAP 5.0 mg l^{-1} + GA_3 1.0 mg l^{-1}), but it had less number of multiple shoots (1.27) than T_9. The increase in concentration of BAP beyond 3.0 mg l^{-1} either alone or in combination with GA_3 showed a negative effect on the induction of multiple shoots. This might be due to the inhibitory effect of BAP at supra-optimal levels. Similar opinions were also observed by Thomas (1995) in cashew and Mathur *et al.* (1997) in clove. The addition of GA_3 at 0.5 mg l^{-1} and 1.0 mg l^{-1} significantly influenced the bud break, days taken for bud break and length of the shoots in MS medium. The BAP + GA_3 treatments produced longer shoot length of 3.92 cm. However, increase in GA_3 concentration from 0.5 to 1.0 mg l^{-1} reduced the number of shoots per bud and increased the days taken for bud break. Similarly, Saraswathi (1996) also noted that an increase in GA_3 concentration beyond 2.0 mg l^{-1} reduced the number of shoots per bud and increased the days taken of bud break in *Carica papaya*. It is needless to indicate that BAP is essential for multiple shoot regeneration, but the synergistic effect of BAP + GA_3 stimulate both cell division and cell elongation simultaneously. The same line of results indicating the positive inflence of GA_3 on shoot length was observed by Vijaya and Satyanarayana (1992) in *Rosa* spp. and Saraswathi (1996) in *Carica papaya*.

Influence of sucrose on multiple shoot induction: The effect of addition of eight concentrations of sucrose to the basal shoot multiplication (MS + BAP 3.0 mg l^{-1}) medium on production of multiple shoots from axillary buds of cv. PKM 1of tamarind was tested in this experiment and the results indicated (Table 3) that a significant differences were observed among the treatments for survival percentage, bud break percentage, number of days taken for bud break, number of multiple shoots per bud and mean length of the multiple shoots.

Number of days taken for bud break: The number of days taken for bud break ranged between 23.17 and 45.83. A lesser number of days (23.17) for bud break was recorded in T_6 (60 g l^{-1} of sucrose), followed by 25.00 days in T_7 (70 g l^{-1} of sucrose). The lesser number of days (45.83) for bud break was registered in T_0 (control).

Number of multiple shoots per bud: The number of multiple shoots produced per bud varied from 1.00 to 1.41. The higher number of multiple shoots per bud (1.41) was noticed in T_6

and the lesser number of shoots (1.00) was produced in T_1 (10 g l^{-1} of sucrose). T_0 (control) did not produce any multiple shoot.

Table 1. Effect of different culture media on multiple shoot induction from auxillary buds of the tamarind cv. PKM 1

Treatments		Per cent survival	Per cent bud break	Days taken for bud break	No. of multiple shoots / bud	Length of multiple shoots (cm)
T_1:	MS	85.03	77.96	31.69	2.023	3.274
T_2:	WP	76.09	58.41	38.51	1.744	2.793
T_3 :	B5	73.24	48.73	40.50	1.224	2.505
T_4 :	LS	67.16	43.5	44.21	1.078	2.423
T_5 :	SH	54.99	34.24	46.86	1.000	2.286
SEd		5.17	7.07	1.15	0.063	0.193
CD (P=0.05)		11.01	15.05	2.45	0.134	0.416

Table 2. Influence of growth regulators on multiple shoot induction

Treatments	BAP (mg l^{-1}) +	GA_3 (mg l^{-1})	Per cent bud break	Days taken for bud break	Mean number of shoots / bud	Mean length of shoots (cm)
T_0:	0.0 +	0.0	20.46	48.64	0.00	-
T_1:	1.0 +	0.0	38.14	44.40	1.00	2.55
T_2:	2 .0 +	0.0	51.18	41.05	1.00	2.80
T_3:	3.0 +	0.0	79.38	36.58	1.35	2.95
T_4:	4.0 +	0.0	66.98	37.08	1.45	2.79
T_5:	5.0 +	0.0	63.31	39.62	1.31	2.61
T_6:	1.0 +	0.5	48.02	37.10	1.00	2.75
T_7:	2.0 +	0.5	53.26	33.49	1.23	3.31
T_8:	3.0 +	0.5	89.52	28.39	1.59	3.52
T_9:	4.0 +	0.5	83.11	32.96	1.42	3.07
T_{10}:	5.0 +	0.5	68.62	34.42	1.27	2.86
T_{11}:	1.0 +	1.0	41.65	39.30	1.01	3.86
T_{12}:	2.0 +	1.0	52.89	35.33	1.23	3.66
T_{13}:	3.0 +	1.0	59.65	33.27	1.49	3.51
T_{14}:	4.0 +	1.0	51.34	37.19	1.41	3.72
T_{15} :	5.0 +	1.0	47.95	38.52	1.27	3.92
SEd			4.38	1.14	0.054	0.144
CD (P=0.05)			8.92	2.33	0.096	0.288

Mean length of multiple shoots: The mean length of multiple shoots produced varied from 2.00 to 3.44 cm. The greater shoot length (3.44 cm) was obtained in T_6, followed by T_7 (3.30 cm). The smaller shoot length of 2.00 cm was obtained in T_1.

Tissue culture growth is not only affected by the type of carbon source, but also by the concentration of it in the medium. It is widely accepted that culture of explants require an exogenous source of energy and carbon skeleton (Street, 1969) and the sucrose has been the most effective. Most of the nutrient media used for tissue culture contain sucrose usually at a concentration of 2 to 4 per cent. From the present study, it was found that increasing the sucrose levels from 30 to 60 g l^{-1} caused an increase in bud break percentage and number of shoots per bud. However, this led to a decrease in number of days taken for bud break and survival percentage. At sucrose 60 g l^{-1}, the maximum bud break per cent (90.33) and number of shoots per bud (1.41) and less number of days for bud break (23.17) were noticed. Similar to this study, the promotive effects of higher sucrose levels on lateral bud growth has been well documented by Navarro *et al.* (1975) in *Citrus sinesis*. The addition of sucrose beyond 60 g l^{-1} decreased the bud break percentage and number of shoots per bud and increased the days taken for bud break. This results clearly indicated that lower concentrations of sucrose (20 to 50 g l^{-1}) were inadequate for the axillary shoot proliferation of tamarind and sucrose at a concentration of 60 g l^{-1} was optimum for multiple shoot production. This is in accordance with the findings of Giladi *et al.* (1977) who observed higher incidence of bud emergence and shoot elongation at high sucrose level (5 per cent) than at lower level (2.5 per cent) in *Citrus sinesis* and Thomas (1995), in micro propagation of cashew using cotyledonary segments, suggested the use sucrose at a concentration of 50 g l^{-1}.

Effect of different strengths of MS media on in vitro rhizogenesis: The results of the experiment to study the different strengths of MS media on *in vitro* rhizogenesis of micro shoots of tamarind cv. PKM 1 are furnished in the Table 4.

Rooting percentage: The rooting percentage of microshoots observed in different strengths of MS media ranged from 0.00 to 51.38. The maximum rooting percentage (51.38) was recorded in 1/2 strength MS medium, followed by 41.20 per cent rooting in 3/4th strength MS medium. No rooting was observed in 1/4 th strength MS medium and 35.53 per cent rooting was observed in full strength MS medium.

Number of roots per microshoot: The mean number of roots produced per microshoot in different strengths of MS media varied from 0.00 to 4.09. The maximum number of roots (4.09) per shoot was observed in 1/2 strength MS medium, followed by 3.30 roots per shoot in 3/4th strength MS medium. The minimum number of roots (2.66) was observed in full strength MS medium and no rooting was observed in 1/4 th strength MS medium.

Mean length of the roots: The mean length of the roots varied from 0.65 to 1.35 cm. The maximum root length of 1.35 cm was observed in 1/2 strength MS medium, followed by 0.87 cm in 3/4th strength MS medium. The minimum root length (0.65 cm) was observed in full strength MS medium.

The *in vitro* root induction from the multiple shoot of any crop species was found to be controlled by the kind and the concentration of the auxin used. Such a beneficial effect of auxin on *in vitro* root induction from the micro shoots of *Rosa hybrida* have already been exhibited by Rout *et al.* (1989). With the view to identify a suitable strength of MS medium for *in vitro* root induction from microshoots of tamarind, this experiment was conducted with different strengths of MS media *viz*, full, 3/4th, ½ and 1/4th and tested. The maximum values for rooting percentage (51.38), number of roots per shoot (4.09) and mean length of the root (1.35 cm) were observed in ½ strength MS medium, followed by 3/4th strength and full strength MS. The reason for highest rooting percentage in half MS than full MS may be attributed to the reason that presence of more salts in full MS medium than half MS might have hindered the induction of roots from tamarind microshoots. This result is in line with the reports of Rout and Das (1993) in *Madhuca longifolia*, Purohit and Dave (1996) in *Sterculia urens.*

Growth regulators in vitro rhizogenesis of tamarind microshoots: The results of the experiment to study the influence of some growth regulators on *in vitro* rhizogenesis of tamarind cv. PKM 1 microshoots are provided in the Table 5.

Table 3. Influence of different levels of sucrose on multiple shoot induction

Treatments		Per cent survival	Per cent bud break	Days taken for bud break	Mean number of multiple shoots per bud	Mean length of multiple shoots (cm)
T_0:	0	86.83	23.08	45.83	0.00	-
T_1:	10	84.83	36.58	42.33	1.000	2.000
T_2:	20	81.00	63.33	37.17	1.034	2.174
T_3:	30	79.09	70.50	33.33	1.092	2.405
T_4:	40	75.00	78.33	30.17	1.166	2.801
T_5:	50	75.83	83.50	27.83	1.259	3.045
T_6:	60	75.50	90.33	23.17	1.414	3.438
T_7:	70	65.67	87.50	25.00	1.358	3.301
T_8:	80	64.00	87.00	30.17	1.358	3.245
SEd		3.61	3.07	0.930	0.038	0.088
CD(P=0.05)		7.59	6.45	1.950	0.066	0.172

Table 4. Influence of different strengths of MS media on *in vitro* rhizogenesis

Treatments		Rooting percentage	Mean number of roots per shoot	Mean length of roots (cm)
T1 :	Full	35.53	2.657	0.647
T2 :	3/4 th	41.20	3.303	0.867
T3 :	1/2th	51.38	4.090	1.353
T4 :	1/4th	0.00	0.000	0.000
SEd		0.78	0.147	0.120
CD(P=0.05)		1.80	0.340	0.047

Rooting percentage: The mean rooting percentage in different growth regulator concentrations ranged from 0.00 to 51.92. Among IBA treatments, IBA (2.0 mg l^{-1}) exhibited 38.42 rooting percentage and IBA (0.5 mg l^{-1}) exhibited zero rooting per cent. IAA (2.0 mg l^{-1}) showed 32.18 per cent rooting while IAA (0.5 mg l^{-1}) concentration recorded no rooting. However, the maximum rooting per cent (51.92) was recorded in IBA 0.5 mg l^{-1} + IAA 0.5 mg l^{-1} treatment followed by 44.05 per cent rooting in IBA 1.0 mg l^{-1} + IAA1.0mg l^{-1}. Phloroglucinol at 0.25 mg l^{-1} concentration recorded the maximum of 38.67 per cent rooting, while at 1.0 mg l^{-1} concentration, the per cent rooting was the minimum (19.15).

Number of roots per microshoot: The mean number of roots per microshoot varied from 0.00 to 4.31. The highest number of roots (4.31) was observed in the combination treatment of IBA + IAA each at 0.5 mg l^{-1} concentrations. Phloroglucinol at 1.0 mg l^{-1} produced the minimum number of roots (2.49), while there was no rooting in the treatments containing IBA alone / IAA alone each at a concentration of 0.5 mg l^{-1}.

Table 5 . *Effect of different plant growth regulators on in vitro rhizongenesis*

Treatments Auxins (mg l^{-1})	Rooting percentage	Mean number of roots / multiple shoot	Mean length of roots (cm)
T_0 : Control (without growth regulators)	0.00	0.00	0.00
T_1: IBA (0.5)	0.00	0.00	0.00
T_2: IBA (1.0)	26.55	2.69	0.71
T_3 : IBA (1.5)	33.38	3.26	0.83
T_4: IBA (2.0)	38.42	3.46	1.12
T_5: IAA (0.5)	0.00	0.00	0.00
T_6: IAA (1.0)	28.14	2.47	0.57
T_7: IAA (1.5)	30.03	3.09	0.73
T_8: IAA (2.0)	32.18	3.16	0.92
T_9. IBA (0.5) + IAA (0.5)	51.92	4.31	1.23
T_{10}: IBA (1.0) + IAA (1.0)	44.05	3.40	1.12
T_{11} : Phloroglucinol (0.25)	38.67	3.49	0.86
T_{12}: Phloroglucinol (0.5)	23.67	2.85	0.73
T_{13}: Phloroglucinol (1.0)	19.15	2.49	0.48
SEd	1.07	0.031	0.021
CD (P = 0.05)	2.20	0.064	0.059

Mean length of the roots: The mean length of the roots ranged from 0.71 to 1.23 cm. The maximum root length (1.23 cm) was recorded in IBA + IAA combination treatments (each at 0.5 mg l^{-1} concentrations) followed by IBA + IAA combination treatments (each at 1.0 mg l^{-1} concentrations), where the root length was 1.12 cm. The minimum root length of 0.45 and 0.57 cm was recorded by phloroglucinol (1.0 mg l^{-1}) and IAA (1.0 mg l^{-1}) concentrations respectively.

In the present study, to induce *in vitro* rooting of microshoots of tamarind, certain growth regulators and their combinations viz., IBA, IAA, IBA + IAA and Phloroglucinol were tried. The differential rhizogenetic responses of tamarind microshoots to different growth regulator treatments were observed in this experiment. The maximum rooting percentage was observed in IBA + IAA combination treatments, followed by IBA, IAA and Phloroglucinol treatments. The highest rooting per cent (51.92) more number of rootlets per shoot (4.31) and lengthiest roots (1.23 cm) in IBA + IAA combination might be attributed to the synergistic effect of IBA and IAA in the induction of adventitious root formation than IBA or IAA alone. This result is confirmed by Jaiwal and Gulati (1991) registered high frequency of rooting in tamarind microshoots in MS medium with IAA and IBA.

Sucrose concentrations on in vitro rhizogenesis of microshoots: The results of the experiment with six different sucrose levels to study its influence on *in vitro* rhizogenesis of tamarind cv. PKM 1 are presented in the Table 6.

Rooting percentage: The rooting percentage of tamarind shoots at different sucrose concentrations varied from 0.00 to 48.58. The maximum rooting (48.58) percentage was recorded at a sucrose concentration of 30 g l^{-1}, followed by 43.58 percentage at 20 g l^{-1} concentration. The minimum rooting of 25.33 percentage was recorded at a sucrose concentration of 50 g l^{-1} while no rooting was observed in T_0 (control) and T_6 (sucrose 60 g l^{-1}).

Number of roots per root: The mean number of roots per shoot ranged from 0.00 to 3.60. The maximum number of roots (3.60) was recorded in T_3 with sucrose 30 g l^{-1}, followed by 3.49 roots per shoot in T_4 (40 g l^{-1}). The minimum of 2.32 roots per shoot was recorded in T_1 (10 g l^{-1}).

Table 6. Influence of different sucrose concentrations on *in vitro* rhizogenesis

Tratments Sucrose (g l^{-1})	Rooting percentage	Mean number of roots / shoot	Mean length of roots (cm)
T_0 : 0	0.000	0.00	0.00
T_1 : 10	26.67	2.32	0.79
T_2 : 20	43.58	2.71	1.20
T_3 : 30	48.58	3.60	1.36
T_4 : 40	49.92	3.49	1.26
T_5 : 50	25.33	2.99	0.91
T_6 : 60	0.00	0.00	0.00
SEd	1.00	0.048	0.042
CD (P = 0.05)	2.14	0.103	0.089

Mean length of the roots: The mean length of the roots ranged from 0.79 cm to 1.36 cm. The maximum root length of 1.36 cm was observed in T_3 with 30 g l^{-1}, followed by 1.26 cm in T_4 (40 g l^{-1}). The minimum root length of 0.79 cm was observed in T_1 (10 g l^{-1}).

In the present study, it was found that an increase in sucrose level from 15 g l^{-1} to 30 g l^{-1} in half MS medium recorded the highest rooting percentage (48.58) with more number of roots per shoot (3.60) besides lengthier roots (1.36 cm). When the sucrose concentration in half MS medium was more than 30 g l^{-1} there was a gradual decline in the rooting percentage, mean number of roots per shoot and mean length of the roots. This might to attributed to the inhibitory effect of sucrose on *in vitro* rhizogenesis at supra-optimal concentrations. Similar results were also reported by Amin *et al* (1987) in guava and Thomas (1995) in cashew who obtained highest rooting per cent in ½ MS media with sucrose concentration of 30 g l^{-1} .

References

Amin, N, Muhammad and V.S.Jaiswal. 1987. Rapid clonal propagation of guava through *in vitro* shoot proliferations on nodal explants of mature trees. Plant cell, tissue and organ cult., 95: 235 – 243.

Giladi, I., A. Altman and R.Goren. 1977. Differential response of sucrose, abscisic acid and benzyladenine on shoot growth and callus formation in the bascission zone of excised citrus buds. Plant Physiol., 59: 1161 – 1164.

Jaiwal, K. and A. Gulati. 1991. *In vitro* high frequency plant regeneration of a tree legume. *Tamarindus indica* (L). Plant Cell Rep., 10: 569 – 573.

Mathur, Shashi, L.K. Pareek and N. Chandra. 1997. Regeneration and phenolics in Explants and callus of *syzygium cuminii* (L). Skeels. In: Trends in plant tissue culture and biotechnology – L.K. Pareek – Agro Botanical publishers, New Delhi p(147 – 152).

Navarro, L., C.N.Roistacher and J. Murashige. 1975. Improvement of shoot-tip grafting *in vitro* for virus free citrus. J. Amer. Soc. Hort. Sci., 100: 471 – 479.

Purohit, S.D. and Asish Dave. 1996. Micropropagation of *sterculia urens* Roxb-an endangered tree species. Plant Cell Rep., 15: 704 – 706.

Raghava swamy, V., K. Himabinda and G.K. Lashmisita. 1992. *In vitro* micropropagation of elite rosewood. *Dalbergia latifolia,* Plant Cell Rep., 11: 126 – 131.

Raman, H., H.R.Chopra and H.S.Dhaliwal. 1992. *In vitro* propagation of papaya (*Carica papaya* L.). Preliminary results. Punjab Hort. J., 32 (1-4) : 108 – 113.

Reuveni, O., D.R.Shlesinger and V. Lavi. 1990. *In vitro* clonal propagation of dioecious papaya (*Carica papaya* L). Plant Cell, Tissue and Organ Cult., 20: 41 – 46.

Rout, G.R. and P. Das. 1993. Micropropagation of *Madhuca longifolia* (Koenig) var. *latifolia* Roxb. Plant Cell Rep., 12: 313 – 316.

Rout, G.R., D.K.Debata and P.Das. 1989. *In vitro* masscale propagation of *Rosa hybrida* cv. London. Current Science, 58(15): 876 – 878.

Saraswathi, M.S. 1996. Studies on micropropagation of papaya (*Carica papaya)* through *in vitro* cultures. M.Sc. Thesis, submitted to Tamil Nadu Agricultural University, Coimbatore – 3.

Street, H.E. 1969. Growth in organized and unorganized systems. In: FC steward, Ed. Plant physiology vol. VB. Academic Press, New York pp. 3 – 224.

Thomas, R.J. 1995. Studies on *in vitro* plant regeneration of leguminous trees (*Albizzia* spp.),. Plant Cell Rep., 7: 385 – 388.

Vijaya and Sathyanarayana. 1991. Effect of culture media and growth regulators on *in vitro* propagation of rose. In : Proc. Intl. Sem. New Frontiers in Horti, Bangalore. Nov. 25 – 28, 1990 (Eds.) Prakash, J. and R.L.M.Pierik. Current Plant Science and Biotech in Agriculture, pp. 12.

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Occurrence of useful traits in Vanilla wightiana and attempts to transfer them into *V. planifolia*

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Abstract

Vanilla wightiana Lindl., described as an extremely endangered wild species, has been found to occur densely in the unreserved forests of Eastern Ghats of Andhra Pradesh. Unlike in cultivated vanilla in India, where hand pollination is required for pod formation, the wild species is characterized by its capability for natural fruit set. In addition to this, *V. wightiana* is unique in its ability for natural seed germination in its habitat, a feature that is exceptionally rare in majority of orchid species. Furthermore this species is more adapted to rather adverse climatic conditions such as low rainfall and high temperature typical of that region. The plants were also found to be free of diseases/pests in their natural habitat. To utilize these useful characters of *V. wightiana* effectively, a project has been initiated with the financial support from DBT, New Delhi to transfer these traits to cultivated species by using conventional crosses and also through protoplast fusion. The crosses between *V. wightiana* and *V. planifolia* were successful and hybrid seeds were germinated *in vitro*. Isolation and culture of protoplasts in both the species is also reported.

Key words: interspecific hybrids, natural fruit set, natural seed germination protoplasts, *Vanila planifolia, Vanila wightiana.*

The genus *Vanilla* belongs to the family Orchidaceae and comprises of more than 110 species that are distributed widely in the tropics and sub tropics. *Vanilla planifolia* Andrews. which is the main source of commercial vanillin is the single cultivated species in India.

Cultivated vanilla in India does not show any variability as it probably originated from a single clonal source. Relatively very little work has been done on the improvement of vanilla by breeding (Purseglove *et al,* 1988). For crop improvement programmes, breeders could exploit wild species that are potential sources of desirable traits. This would help to widen the narrow genetic base of cultivated vanilla and to generate improved variant lines. As stated by Purseglove *et al* (1988), inter and intra-specific vanilla hybrids are relatively easy to make. This paper reports the occurrence, morphology and floral characters of one of the wild species of vanilla, viz. *V. wightiana,* its importance as a gene bowl in breeding programmes and the attempts made to transfer the useful traits from wild species to cultivated one using conventional and biotechnological tools.

Information on occurrence of a few wild species of vanilla has been reported. (Rao, 1992, Rao *et al*, 1994, Hemadri and Rao, 1997). Of these, *Vanilla wightiana*. Lindl. a root climber depicted as an extremely endangered wild species has been found to occur in dense patches in the Eastern Ghats, at forest ranges of East Godavari district of Andhra Pradesh. Unreserved forest areas of several villages of East Godavari, neighbouring Visakhapatnam and Chittor districts were found to have this species. This species was also presumed to be a new record for the sub-arid zone of Rayalseema (Hemadri and Rao, 1997). There have been reports that this species is popular as 'Uppuchekka' among local people for its use in veterinary medicine (Hemadri and Rao, 1997). However these authors have also reported that this rare and endangered species of vanilla may be wiped out, if stringent measures are not taken up for preventing cutting of host trees for firewood purposes.

Fig 1. *V. wightiana* in the natural habitat

Fig. 2. Natural germination of seeds in V. wightiana

Vanilla wightiana is characterized by its succulent stem and rudimentary leaves. This species is easily distinguishable from the cultivated species by the presence of vertical grooves on the stem, white flowers and the absence of well-developed leaves (Rao *et al*, 1994). The most important feature of this species is its capability for natural fruit set (Fig.3 & 4), unlike in majority of cultivated vanilla, where hand pollination is indispensable at least in Indian conditions (Rao *et al*, 2000). Another important feature noticed in this species is the common occurrence of natural seed germination in its habitat, a phenomenon that is extremely rare in orchids.

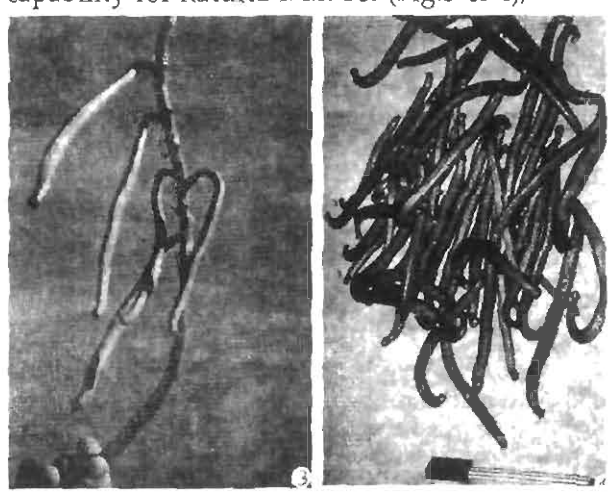

Fig. 3 & 4. Natural fruit set in *V. wightiana*

The characteristics that lead to natural pollination and fruit set in *V. wightiana* were looked into. Flowers were smaller when compared to those of *V. planifolia*. Gynostemium that is attached to the labellum as well as the flap like rostellum appeared much reduced in size when compared to that in *V. planifolia* which may have favoured natural pollination in the wild species. The rostellum, obstructed natural pollination in *V. planifolia*.

Vanillin content

Few kilograms of beans of *V. wightiana* were collected and cured by adopting the bourbon method of curing currently in practice for cultivated species. The analysis reports are not encouraging. Traces of vanillin (up to maximum 0.8%) were recorded during curing as against 1.8 to 2.5% vanillin in the cultivated species.

A disadvantage noticed during curing is the occurrence of fungal infection invariably in all the batches cured which is apparently due to the more fleshy nature of *V. wightiana* beans when compared to those of *V. planifolia*. Anatomical study of the fruit revealed a relatively thicker fruit wall than its counterpart in cultivated species. Due to this nature, appropriate changes in curing steps need to be made to suit *V. wightiana*.

Since *Vanilla wightiana* possesses many promising characters viz. (a) natural fruit set (b) natural seed germination, (c) possible resistance to diseases and pests, it makes this species a gene bowl for breeding programmes of Vanilla. Hence studies were initiated for transferring the useful characters from *V. wightiana* to *V. planifolia* using conventional and biotechnological tools. As a pre-requisite the protocol for micropropagation of this species was also standardized.

Interspecific hybridization

Inter-generic crosses made in between the two species using conventional techniques resulted in 50% of fruit set. However only six mature pods could be recovered because of premature dropping of fruits. Hybrid beans at sixth months and eight months of growth were utilized for developing *in vitro* seed cultures on MS medium supplemented with growth regulators, BAP and NAA at 0.1mg/l each. Vanilla pods were surface disinfested by alcohol flaming and thereafter sectioned to one mm discs. The discs were gently squeezed on to culture medium so that the seeds were uniformly dispersed on the medium surface. The cultures were maintained in dark for an initial four week period before transferring to 16/8 hour cycles at 25^0C. Germination commenced within 50 days of culture initiation. Germinated clusters (Fig. 5) were sub-cultured for further growth and development of plantlets.

Fig. 5. *In vitro* seed cultures of interspecific hybrids

Protoplast Isolation and culture

Protoplasts of *V. planifolia* were isolated from young shoot tips and leaf mesophyll tissues of *in vitro* & *in vivo* grown plantlets as well as callus tissues derived from various explants. Protoplast cultures of *V. wightiana* were established from callus tissues generated from *in vitro* shoot cultures. In the initial stages in *V. planifolia* not more than 1.2x10^5 protoplasts /g leaf tissue could be attained even after several trials in various permutations and combinations of enzymes, probably due to the presence of raphides. However Protoplast yield (Fig. 6) could be *increased considerably to* 3.2 x 10^5/g *of shoot tissues* with medium containing Cellulase 2.0%, Pectinase 1.0% and Hemicellulase 1.0% (Table 1). Efforts for increasing the yield further are being done. In 2-3 cultures, protoplasts seemed to undergo an increase in size, followed by division and microcallus formation. This was observed on modified Gamborg's medium supplemented with BAP (2mg/l), 2,4-D (2mg/l), and IAA (0.5mg/l). Further growth and division of callus was not accomplished. In *V. wightiana,* callus was slow growing and trials on generation of true callus or uniformly friable callus suitable for cell suspensions is under way.

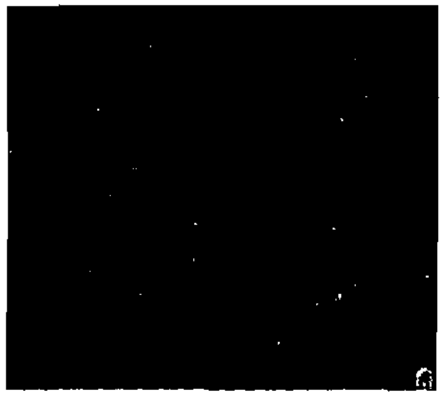

Fig. 6. Protoplasts from the *in vitro* shoot tips of *V. planifolia*

Table 1. Comparative yields of protoplasts in different media combinations in *V. planifolia*

Protoplast source	Enzyme mix (in %)	Osmoticum	Incubation period	Protoplast yield
Mesophyll from in vitro leaf tissues	Cellulase 0.5 Pectinase 0.5	Mannitol 12%	18-24 hr	0.5 x 10^3 /g
-do-	Cellulase 1.0 Pectinase 0.5	-do-	-do-	1.2 x 10^5 /g
Shoot apices	Cellulase 1.0 Pectinase 0.5	Mannitol 14%	16-20 hr	1.8 x 10^5 /g
-do-	Cellulase 1.0 Pectinase 0.5 Hemicell 0.5	-do-	16-18 hr	2.2 x 10^5 /g
-do-	Cellulase 2.0 Pectinase 1.0 Hemicell 1.0	-do-	16-18 hr	3.2 x 10^5 /g

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References

Hemadri K C & Sasibhushana Rao S 1997 Discovery of *Vanilla wightiana* Lindl. an endangered orchid from Chittoor District (A.P.) Indian Medicine (December) PP-4

Purseglove J W, Brown E G., Green C I & Robbins S R J. 1988. Vanilla . In: Spices Vol. 2, Longmann, Scientific and Technical. PP 657 –658

Rao R S, 1992. A rare orchid center in East Godavari District of A.P. Urgent conservation needed. INTACH AP Patrika (3) : 21.

Rao Y S, Kuruvilla K M & Madhusoodanan K J 1994. Collection of *Vanilla wightiana* Lindl – An endangered wild spices from Eastern Ghats of Andhra Pradesh. Indian J. Plant Genetic Resources 7 (2): 257 – 259.

Rao Y S, Mary Mathew K., Madhusoodanan K J, Sudarshan M R, Krishnakumar V & Potty S N, 2000. Natural fruit set in *Vanilla wightiana* Lindl – an endangered species from Andhra Pradesh. Jour. of Spices and Aromatic Crops 9(1): 77.

Rao Y S, Mary Mathew K, Pradip Kumar K, Lakshmanan R, Sree Rama Murthy J & Madhusoodanan K J 2002 Natural seed germination in *Vanilla wightiana* Lindl – an endangered species from Andhra Pradesh . Jour. of Spices and Aromatic Crops (In Press)

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Root distribution pattern of bush pepper (*Piper nigrum* L.)

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Abstract

Root distribution pattern of four-year-old field planted bush pepper (*Piper nigrum* L.) was studied at Peruvannamuzhi farm of Indian Institute of Spices Research by radiotracer technique. One week after ^{32}p application, soil samples were collected at different lateral distances and depth of the plant. Samples were acid digested and ^{32}p was counted in a liquid scintillation counter. The root distribution pattern was deduced from the ^{32}p count of the soil. The root zone upto 30 cm radius and 40 cm depth was found to be the active root zone of bush pepper variety Karimunda grown in the field.

Key words: Bush pepper, .^{32}P, *Piper nigrum* L, plant labeling , root distribution.

Introduction

Black pepper (*Piper nigrum* L) grown by rooting of the plagiotrophic branches is known as "Bush pepper" and it derives its name from its bushy nature of growth. It needs no supports for trailing and can be harvested without climbing. At present the bush pepper is grown in pots in the households, especially in the urban areas. However, considering its shade tolerance (Devadas& Chandini,1999) it may be grown as an under storey crop in coconut plantations and in homesteads. It may also find a place in the kitchen gardens and other large forestry systems. Knowledge of rooting pattern of bush pepper is necessary to determine the spacing between the plants, suggesting efficient methods of fertilizer application, irrigation, scheduling and to decide the suitability of the crop, in inter-cropping systems. Inter-cropping systems developed taking into consideration the vertical and lateral spread of the roots of component crops will be more viable. Root distribution pattern of black pepper vine and its live support in comparison with vine trailed on dry teak pole were studied (Sankar et al. 1988). However, there are no reports on the root system of "bush - pepper" which has different growth pattern as compared to the vine pepper.

There are a number of methods suggested for the study of root systems (Bohm 1979; Atkinson 1974). Methods employing radioisotopes like ^{32}p are recommended as a quick and non-destructive method for studying the root system of the plants (IAEA 1975). As the bush pepper stems were thick, plant injection was not possible. Single root feeding of ^{32}p through the cut end of the root was found to be an efficient method of labeling plants to study the root distribution pattern in coconut (Ray 1979). So the plants were made to absorb the radionuclide through a single root. Considering these, a field trial was conducted to study the distribution of roots of field grown bush-black pepper to different depths and lateral distances from the base of the plant.

Materials and methods

The experiment was conducted at Peruvannamuzhi farm of Indian Institute of Spices Research, Kozhikode during 1997. Soil was clay loam with a pH of 5.2. The soil had 2.2% organic Carbon, 24 $kgha^{-1}$ available phosphorous and 72 $kgha^{-1}$ available potash.

Four year old bush pepper, variety Karimunda grown at a spacing of 2 x 2 m and maintained under uniform fertilizer and cultural management were made use of for this experiment. Ten experimental plants were selected at random in such a way that the plants were surrounded by a row of border plants. Five of experimental plants were labeled with ^{32}P (7400 Bq plant-1) by feeding through a single cut root from a small glass vial. Special care were taken not to spill the radio label solution and contaminate the soil .The second set of five experimental plants were labeled by smearing the ^{32}P solution on two fully matured leaves. (The stem injection with hypodermic syringe, though attempted, was not successful, as the stem was thick and hard). The two methods for labeling the plants were used, as the stem injection technique was not successful. After a week core samples of the soil were taken from around the plant at following distances and depth:. 10 x 20 cm, 10 x 40 cm, 10 x 60 cm, 20 x 20 cm, 20 x 40 cm, 20 x 60 cm, 30 x 20 cm, 30 x 40 cm, 30 x 60 cm, 40 x 20 cm, 40 x 40 cm, 40 x 60 cm

The soil samples were acid digested and the ^{32}p count was recorded in a liquid scintillation counter (Pharmacia) by using the Cerenkov counting technique (Wahid et al. 1985). The counts were statistically analyzed and the counts at various lateral distances and depths were compared by Dunken multiple range test. The root distribution pattern was deduced from the ^{32}P count at different lateral distances and depths around the ^{32}P labeled plants. The percentage of root activity at different lateral distances and depths of the soil were computed as follows (Chandra et al . 1979).

Percentage root activity at a particular radial distance and depth =

$$\frac{\text{Radioactivity of the soil sample for a particular lateral distance and depth}}{\text{Total radioactivity count for all the lateral distances and depths for a plant}} \times 100$$

Results and discussion

The radioactivity counts observed in the soil sampled from various depths and lateral distances around the ^{32}P treated plants (Table 1 & 2) indicate that both single root feeding and leaf smearing was successful in radio labeling bush pepper for study undertaking its root distribution pattern. The ^{32}P counts were more when single root feeding was adapted than in leaf smearing technique. So single root feeding technique adopted in coconut (Ray 1979) may be adopted in bush-pepper for studying the root distribution pattern. The translocation of the radiolabel absorbed by the single root to other roots were satisfactory as is evident from ^{32}P count observed in different lateral distances and depths around the treated plant. Obviously the radioactivity counts observed in the soil around the plants were due to the presence of ^{32}P in the roots and /or root exudations. So abundant radioactivity count at a particular lateral distance and depth around the plant is an indication of the abundance of roots distributed in that particular soil- zone.

The root distribution patterns of many trees were studied by plant injection technique by virtue of its simplicity (does not require any expensive equipment) and sensitiveness (it can detect as little as 1mg of roots present in a 4.375 cm diameter X 15 cm crore) (IAEA 1975).

Table 1. ^{32}P *count in the soil samples of bush pepper treated with* ^{32}P *(single root feeding) and* percentage of root distribution

Depth (cm)	^{32}P counts (cpm)				Total
	Lateral distance (cm)				
	10	20	30	40	
20	863[a]	517[b]	169[e]	86[fg]	1635[a]
	(30)*	(18)	(6)	(3)	(57)
40	368[c]	116[f]	297[d]	46[g]	827[b]
	(13)	(4)	(11)	(2)	(30)
60	251[d]	48[g]	47[g]	31[g]	377[c]
	(9)	(2)	(2)	(1)	(14)
Total	1278[a]	681[b]	513[c]	163[d]	
	(45)	(24)	(19)	(6)	

The interaction means followed by a common letter are not significantly different at 5% levels by DMRT
The total counts followed by a common letter are not significantly different at 5% levels by DMRT
*Values in parentheses are estimated values of root distribution percentage

Table 2. ^{32}P *count in the soil samples of bush pepper treated with* ^{32}P *(leaf smearing) and percentage* of root distribution

Depth (cm)	^{32}P counts (cpm)				Total
	Lateral distance (cm)				
	10	20	30	40	
20	70[b]	173[a]	155[a]	10[c]	408[a]
	(7)*	(18)	(16)	(1)	(42)
40	185[a]	38[bc]	33[bc]	48[bc]	304[b]
	(19)	(4)	(3)	(5)	(31)
60	139[a]	104[b]	13[c]	13[c]	269[c]
	(14)	(1)	(1)	(1)	(27)
Total	394[a]	315[b]	201[c]	71[d]	
	(40)	(32)	(21)	(7)	

The interaction means followed by a common letter are not significantly different at 5% levels by DMRT
The total counts followed by a common letter are not significantly different at 5% levels by DMRT
Values in parentheses are estimated value of root distribution percentage

The maximum count was at a depth of 20 cm when the total counts from all the lateral distance were considered. From the ^{32}P counts it is evident that majority of the roots in field planted bush pepper are concentrated in the surface layer of the soil up to 20 cm depth and 30 cm lateral distance. The roots are also distributed in the deeper layers of 40 and 60 cm within a lateral distance of 10 cm. About 40-60 per cent of the roots were distributed in 20 cm depth and about 30 per cent roots were distributed in 20 to 40 cm depth. Overall 70-87 percent of roots were distributed within 40 cm depth, only 13-27 per cent roots were observed at 60 cm depth. When the lateral distances were considered, 79-

93 per cent roots were distributed within 30 cm lateral distance. The root zone, i.e. upto 30 cm lateral distance and 40 cm depth may be considered as the active root foraging zone of the bush pepper grown in the field. The area outside this root zone may be considered as the passive root foraging zone with relatively few number of roots.

Application of fertilizers and manures may be done within the soil zone of 30 cm lateral distance and upto 40 cm depth where about 64 per cent of the roots are distributed. This proposal is made by taking into consideration the possibility of leaching down of some nutrients into deeper layers, which may be utilized by a few roots present at 60 cm depth. There are no earlier reports on the root zone or root distribution or root activities of bush pepper. There were a few reports on the root activities of vine pepper. Sankar et al. (1988) observed 90 per cent of the root activity within 30 cm radius around the vine in black pepper trailed on *Erithrina* or teak pole. Geetha (1990) also reported similar finding in black pepper vine trailed on teak pole.

Even though this data provide an idea on the general distribution pattern of roots in bush pepper, the data do not differentiate absorbing roots and non-absorbing roots. The distribution pattern of the absorbing roots is possible only by studying the root activity pattern by adopting soil injection techniques (IAEA 1975). This requires relatively large number of plants and treatment of radiolabel in large areas in much higher doses. This may be considered as a future line of work when large experimental plots are established with bush pepper. Nevertheless, the data generated from this study is sufficient to provide preliminary information on the root distribution pattern of bush pepper. This information may be useful while deciding the depth and radius of basins for fertilizer application and irrigation. The inter and intra-specific competition between bush pepper plants if grown in intercropping system could also be deduced from the results.

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References

Atkinson D 1974 Some observation on the distribution of root activity in apple trees Pl. & Soil. 40: 342.

Bohm W 1979 Methods of studying root systems. Springer, New York.

Chandra A, Singh R & Rathore V S 1979 ^{32}P study on root distribution in Eureka round lemon in the sub mountain Himalayan region. Indian J. Agric. Sci. 49: 958–961.

Devadas, M. & Chandini, S. 1999 Growth, yield and quality of bush pepper under different light intensities. Proceedings of the Eleventh Kerala Science Congress. Kasaragod: 271 –273.

Geetha C K 1990 Evaluation of nutrient uptake in black pepper (*Piper nigrum* L.). Ph.D Thesis. Kerala Agricultural University, Vellanikkara, pp. 157.

IAEA 1975. Root activity pattern of some tree crops. Tech Rep series Vol. 170. International Atomic Energy Agency, Vienna: pp. 154.

Racz G J, Rennie D A & Hutcheon W L 1964 The ^{32}P injection method for studying the root system of wheat. Can. J. Soil Science 44: pp100.

Ray P K 1979 Radioisotope studies on coconut nutrition. In: Isotopes and Radiations in research on soil-plant relationships. Proceedings of Colombo symposium, IAEA, Vienna: 573–579.

Rennie D A & Halstead E H 1965 A ^{32}P injection method for quantitative estimation of the distribution and extent of cereal grain roots. In: Isotopes and Radiation in soil-plant nutrition studies. Proceedings of the Ankara symposium, International Atomic Energy Agency, Vienna: pp 489.

Sankar J, Wahid P A & Kamalam N V 1988 Absorption of soil applied radio-phosphorus by black pepper vine and support tree in relation to their root activities. J. Plant. Crops 16: 73–87.

Wahid P A, Kamalam N V & Sankar J 1985. Determination of ^{32}P in wet diagested plant leaves by cerenkove counting. Int. J. Appl. Radiat. Isot., 36: 323–324.

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Studies on the evaluation of cinnamon (*Cinnamomom veerum*) genotypes in high rainfall zone of Kanayakumari district

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Abstract

Nine genotypes of cinnamon (*Cinnamomom verum*) were evaluated to study their performance under high rainfall zone. Among these, the accessions Cv.7 registered the higher mean values in respect of fresh leaf weight (33.313 kg./plant) fresh bark weight (2.567 kg/plant) bark yield (973.24 kg/ha), leaf oil recovery (3.30 per cent) and mean number of sprouts (30.20 no./plant).

Key words: cinnamon, evaluation, genotype.

Introduction

Cinnamon is mainly cultivated for its sweet aromatic bark which used as spice as well as for the oil extracted both from leaf and bark. The oil constitutes of eugenol, and cinnamaldehyde which finds a place in the manufacture of cosmetics, tooth paste and other pharmaceutical preparations. Since it is well exploited in cosmetic and pharmaceutical industries, it is gaining importance and the area under cinnamon is increasing year by year. With this in view, the present investigation was taken up at Horticultural Research Station, Pechiparai, in the high rainfall zone, to evaluate growth and yield attributes of cinnamon accessions.

Materials and Methods

The present investigation was carried out at Horticultural Research Station, Pechiparai during the year 1991-2001. The material comprised of ten elite cinnamon accessions and among which 9 accessions collected from Indian Institute of Spices Research, Calicut and one from local Pechiparai region of Kanyakumari district. These cinnamon types were grown in a Randomised Block Design with three replications. In each replications ten plants were maintained. The plants were coppiced four years after planting *i.e.* during 1995 and thereafter once in two years. Observations on sprouting/regeneration capacity, bark yield, leaf yield, bark recovery, bark oil recovery, leaf oil recovery and bark oleoresin were recorded for four coppiced years (1995, 1997, 1999 and 2001) and statistically analysed (Panse and Sukhatme, 1985).

Results and Discussion

The mean values of yield and quality parameters for 4 coppiced years were presented in tables 1 and 2. The traits exhibited significant differences among them and out of the ten accessions Acc. 203 recorded maximum bark recovery percentage of 34.22 and bark yield of 973.24 kg/ha. The accession cv.44 recorded the lowest yield of 559.94 kg/ha. The leaf yield was also maximum (7357.04 kg/ha) in cv.203.

Studies on the quality parameters showed that cv.203 recorded maximum bark oil (recovery (2.90 %), cinnamaldehyde (73%) and eugenol (6.6%), leaf oil (recovery if (3.3%), cinnamaldehyde (78 %) and eugenol 15 %) and bark oleoresin 10 %. From this study it was concluded that the cinnamon accession Acc. 203 was found to be best for lower elevations.

Table 1. Yield Performance of Cinnamon accessions

Acc. No.	Bark recovery %	Bark Yield (Kg/ha.)				Total yield Kg/ha	Leaf yield Kg / ha
		Quills	Quillings/ featherings	Chips	Dust		
cv. 5	27.42	193.31	188.87	155.54	67.77	605.49	4615.09
cv. 44	26.76	206.65	186.64	115.54	51.10	559.94	3701.85
cv. 53	25.31	214.42	208.86	134.43	104.13	662.16	4986.17
cv. 63	30.32	223.31	217.75	218.86	108.87	768.81	5513.89
cv. 65	30.25	231.09	227.75	277.75	53.32	789.92	5738.32
cv. 89	27.75	203.31	162.20	132.20	58.88	589.94	4000.71
cv.203	34.22	244.42	324.41	306.63	97.76	973.24	7357.04
cv.310	29.90	215.53	292.19	265.52	116.65	889.91	6629.34
cv.312	27.90	211.09	267.75	259.97	71.10	807.69	6173.83
Local	29.07	225.53	223.31	216.64	105.54	771.03	5331.68
CD(p=0.05)	0.82	5.08	8.32	10.27	5.32	37.29	162.73

Table 2. Quality Parameters of cinnamon accessions

Acc. No.	Bark oil			Leaf Oil			Bark
	% recovery	CA %	EG %	% recovery	CA %	EG %	Oleoresin %
cv. 5	2.60	57	5.5	2.80	66	13	8.0
cv. 44	2.30	65	6.0	2.20	68	14	8.8
cv. 53	2.50	68	6.5	2.80	75	15	10.0
cv. 63	2.50	72	6.0	2.80	62	15	8.0
cv. 65	2.50	52	5.0	2.50	60	12	8.0
cv. 89	2.20	58	5.0	2.30	78	14	10.0
cv.203	2.90	73	6.6	3.30	78	15	10.0
cv.310	2.80	53	5.5	3.00	68	14	8.6
cv.312	2.80	58	5.8	3.00	63	14	9.0
Local	2.20	54	5.0	2.60	67	13	8.3
CD(p=0.05)	0.10	--	--	0.10	--	--	--

CA - Cinnamaldehyde, EG - Eugenol

Summary

Attempts were initiated at Horticultural Research Station, Pechiparai during 1991 with ten elite cinnamon types to identify a suitable cinnamon for lower elevations. Among the ten types of cinnamon, the accession Acc. 203 recorded maximum bark yield and oil yield. It has good regeneration capacity, suitable for coppicing at an interval of two years, and tolerant to drought and resistant to pest and diseases. The cinnamon type cv. 203 was found to be highly suitable for lower elevations ranging from 100 - 500m. with high rainfall.

Reference

Panse, V.G. and P.V. Sukhatme. 1985. Statistical Methods for Agricultural Workers (4th Ed.) ICAR, New Delhi, P. 97-123.

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Genetic variability and character association in fenugreek (*Trigonella foenum graecum* L.)

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Genetic studies and crop improvement work on fenugreek are scantly reported from Uttar Pradesh where it processes the major place among seed species and leafy green vegetables. Therefore, an experiment was planned in view of the above said aim and to improve the crop for seed as well as greens.

Materials and methods

The instigation was carried out during Rabi 1997-98 and 1998-99 at the main experiment Station of Vegetables Science. N. D. University of Agriculture and Technology.

Fifty six varieties/strains of fenugreek, collected from the different parts of U.P and other states/institutions at India were included in this investigation. The experiment was laid out in randomized block design with three replications. The seed were sown on 6th Nov. 1997 and 7th Nov. 1998 in two metre single row plants with a spacing of 30 cm x 10 cm. The recommended cultural practices, fertilizers and plant protection were measures applied to raise a healthy crop Observations on ten quantitative traits i.e. days to 50 per cent flowering, plant height, number of branches per plant, number of pods per plant, length of pod, number of grains per pod, days to maturity, test weight, seed yield per plant and yield q/ha were recorded in both the years.

The coefficient of variation for different characters was estimated as suggested by Aljibouri *et al.* (19598). Haritability in broad sense was calculated using the formula suggested by Burton and de-Vane (1953) and genetic advance as given by Johanson *et al.* (1953). Correlation at genotypic, phenotypic and environmental levels were estimated according to Searle (1961) and path coefficient analysis as suggested by Dewey and Lu (1959).

Result and Discussion

The general mean and rage values of the characters showed wide variability in both the years. The character seed yield showed highest range (6.93-19.40 in 1997 and 7.43-19.13 in 1998) followed by 1000-seed weight (7.33-11.50 in 1997 and 7.10-10.53 in 1998), number of grains per pod (12.67-18.73 in 1997 and 13.20 –18.20 in 1998), length of pod (8.13-10.67 in 1997 and 8.23-10.90 in 1998), number of pod per plant (61.97-79.00 in 1997 and 63.23-87.97 in 1998) and number of branches per plant (6.40-8.33 in 1997 and 6.20-8.73 in 1998) with medium range. The seed yield showed very high phenotypic coefficient of variation with high heritability as well as genetic advance during both the years.

In general, the PCV was higher than the GCV for all the traits under study in both the years including considerable role of the environment in phenotypic expression of the character (Table 1). This indicated the possible of obtaining very high selection response in respect of this trait seed yield. The test weight of this traits also show high value of GCV and PCV providing high scope in improvement of seed size through selection. Banyai (1973): Shukla and Sharma (1978): Baswana *et al.* (1984): Pant *et al.* (1996) also observed high range of variability for seed and test weight in the germplasm evaluated by them.

The genotypic correlation coefficient between different character were generally similar in significant to the corresponding phenotypic correlation coefficient values were larger in magnitude than the corresponding phenotypic values. Yield per plant was found to be positively correlation with number of branches per plant appeared as well as genotypic level during both years. Thus branches per plant appeared as most important abiociate at yield in present study. Singh *et al.* (1993). Sade *et al.* (1996) also reported similar results in fenugreek.

None of the other traits had significant correlation in either direction with yield. This is in line to earlier reports of Pant *et al.* (1983); Singh *et al.* (1993): Sade *et al.* (1996); Lowanshi (1996) which indicate significant correlation of yield with several characters.

Path coefficient analysis indicated that number of branches per plant and pods per plant had higher positive direct effect on yield per plant at phenotypic as well as genotypic levels during both the years. Thus number of branches and pods per plant emerged as most important direct contribution to seed yield per plant. The results of earlier studies have also identified these characters as important direct yield component in Methi, (Pant *et al.* 1993; Sade *et al.* 1996; Lownashi *et al.*, 1998). The estimate of indirect effect at phenotypic and genotypic levels were found to be highly contrasting and in consistent over the two year. Therefore, it was not possible to draw any clean cut inference about indirect effect of different traits on yield per plant.

Summary

Investigation were carried out to study the genetic variability and character association in fenugreek in fifty six line of *Trigonella foenum-grecum* L. for ten characters on two years. General mean and range of the character showed wide variability in the both years. The seed yield showed highest range followed by test weight. High heritabilty along with higher genetic advance was recorded for yield for both the years. Yield per plant was found to positively correlated with number of branches per plant at phenotypic as well as genotypic level during both the years. Path co-efficient analysis indicated that number of branches per plant and pod per plant had higher positive direct effect on yield per plant.

References

Alijibouri, H.A.; Miller, P.A. and Robinson. H.I. (1958). Genotypic and environmental variances and co-variances in upland cotton cross of inter specific origin, *Agron. J.*, 50: 633-636.

Banyai, L. (1973). Botanical and quantitative studies on ecotypes of fenugreek *Agrobotanika*, 15: 175-187.

Baswana, K.S.; Pandita, M.L. and Malik, Y.S. (1984). Variability studies in fenugreek, *Haryana, Agron. J. Hort. Sci.*, 13 (1-2): 78-81.

Burton, G.S. and de-Vane, E.W.K. (1953). Estimating heriability in tall fescue (*Festuca aroundincea*) from replicated clonal material. *Agron. J.* 45: 171-181.

Dewey, D.R. and Lu K.) II. (1959). A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.*, 15: 515-518.

Lowannshi, R.K.; Shukla, R.S.; Chaubey, P.C. and Singh, Mrigendra (1996). Source of sink parameters in fenugreek *(Trigonella foenum-graecum* L.). *J. Soils Sci. crops*, 6 (11): 10-14.

Lowanshi, R.K.; Shukla, R.S.; Chaubey, P.C. and Singh , Mrigendra (1998). Association and path coefficient analysis in fenugreek (Trigonella *focnum graecum* L.) Advance in Plant Sciences. 11 (2): 45-50.

Pant, K.C.; Chandel, K.P.S. and Pant, D.C. (1984). Variability and path coefficient analysis in fenugreek. Indian J. Agric. Sci. 54: 655-658.

Pant, K.C.; Chandel, K.P.S.; Singh, B. M. and Saha, S.N. (1983). Diversity in genetic material of *(Trigonella foenum-graecum and Trigoncilla cornicolata) Indian J. Agric. Sci.*, 15: 537-543.

Sade, B.; Akinnerdam, F.; Tamkoe, A. Topal, A; acar, B. and Soylo, S. (1996). Correlation and path analysis of yield and yield components in fenugreek (*Trigonella foenum,- graecum* L.) lines *Turkish J. Agric.* And *Forestry*, 20 (2): 153-156.

Scarle, S.R. (1961). Phenotypic genotypic and environmental correlations *Biometrics.*, 17: 474-480.

Shukla, G.P. and Sharma, R.K. (1978). Genetic variability, correlation and path analysis in fenugreek , *Indian J. Agric. Sci.*, 45: 518-521.

Singh, J.V. Lodhi, G.P.; Arora, R.N.; Jhora, B.S.; Kishor, C.; Thakral, N.K. (1993). Association analysis for some quantitative traits in fenugreek (*Trigonella foenu-gracum* L.) *International J. of Tropical* –Agri. 9 (3): 182-186.

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Evaluation of fenugreek (*Trigonella foenum-graecum* L.) genotypes

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Abstract

Nine Fenugreek (*Trigonella foenum-graecum* L.) were evaluated for their growth and yield for three years during kharif 1998 - 2000. The results of the pooled data have revealed that the accession No. TF 105 from Jobner was found to be the best with the highest mean yield of 573.3 kg per ha. The increase in yield was 10 per cent over the check cultivar Co.1 which produced an yield of 523.4 kg per ha.

Key words: evaluation, fenugreek, genotypes, *Trigonella foenum-graecum* L

Introduction

Fenugreek (*Trigonella foenum-graecum* L.) is an important seed spice which is used as condiment, medicine, green vegetable and fodder. It is native to South East Europe and West Asia. It belongs to the family leguminaceae. In India it is commercially cultivated in Rajasthan, Madhya Pradesh, Gujarat, Uttar Pradesh, Maharashtra and Punjab. The area under fenugreek in India is about 38,485 ha with an annual production and productivity of 49,968 tonnes and 1298 kg per ha respectively (Ghosh *et al.* 1999).

In Tamil Nadu the area under this crop is negligible. The productivity of this spice in the state is very low with about 500 kg per ha which is less than half of the national average. Further, the productivity of the two released cultivators viz., co.1 and Co.2 is not satisfactory. Hence, an attempt was made to evaluate the performance of certain high yielding genotypes of Northern State under the All India Co-ordinated Research Projects with an objective of identifying suitable types for Tamil Nadu under irrigated conditions.

Materials and Methods

The genotypes consisted of nine entries including four each from Jobner and Hissar and one from Coimbatore (Co.1) as check. This trial was conducted for three years (1998 to 2000) in a randomised block design with three replications. The plot size was 4 x 2.4 m and the seeds were sown in flat beds at a spacing of 15 x 10 cm during kharif. The cultural practices were followed as per the standard recommendations for Tamil Nadu (Dept. of Horti. & Plantation Crops, 1999) under irrigated conditions. The pooled data for three years on biometric and yield observations were statistically analysed.

Results and Discussion

The mean performance of the nine fenugreek accessions is presented in the Table 1.

Table 1. Mean performance of fenugreek genotypes

Accessions	Source	Plant height (cm)	No. of Primary branches	No. of Secondary branches	Days to 50% flowering	No. of pods per plant	Yield kg/plot ($10m^2$)	Yield kg/ha
TF 107 (UM301)		35.90	5.9	3.1	30.7	24.5	0.50	494.8
TF 105 (302)	Jobner	53.30	8.5	**4.4**	33.8	35.0	0.58	573.3
TF 112 303)		46.00	**6.3**	**3.9**	36.8	27.6	0.55	548.6
TF 115 (304)		35.00	5.2	**2.8**	32.0	23.0	0.47	474.9
TF 116 (HM 110)		39.47	6.3	3.8	30.2	27.2	0.53	532.2
TF 106 (114)	Hissar	46.77	6.8	**4.1**	29.5	27.1	0.55	549.1
TF 113 (291)		36.03	5.6	**3.3**	36.4	23.3	0.48	482.9
TF 242 (295)		40.33	5.2	**3.4**	29.4	26.0	0.52	528.7
TF 10 (Co.1)	TNAU, Coimbatore	38.33	5.7	**3.4**	35.7	25.8	0.52	523.4
SEd		3.0733	0.53	0.31	0.63	1.44	0.02	20.03
CD @ 5%		6.5155	1.12	0.65	1.33	3.06	0.04	42.45

From the results it was observed that the accessions differed significantly in respect of plant height, number of primary and secondary branches, days to 50 per cent flowering, number of pods per plant and yield.

Among the nine accessions, the Jobner entry TF 105 registered the highest mean values in respect of plant height (53.30 cm), number of primary branches (8.5), number of secondary branches (4.4) and number of pods per plant which in turn effected the highest yield of 573.3 kg compared to 523.4 kg per ha in the check cultivar Co.1. The earlier studies have also revealed that the grain yield in fenugreek was positively associated with plant height, number of branches per plant and pods per plant as reported by Sharma *et al.* (1990) and Sastry *et al.* (2000). Similar experiments conducted at Hissar have also confirmed the superiority of the accession TF 105 (IISR, 1999 b). But contrary to this at Jobner the accession TF 112 was found to be superior than the other types (IISR, 1999 a).

The days to 50 per cent flowering varied from 29.4 to 36.8 days. The Hissar type TF 242 was the earliest to flower closely followed by TF 106. The yield of these types was also better (528.7 and 549.1 kg per ha respectively) than the check cultivar Co.1 (523.4) kg/ha). The accession TF 106 took significantly the least number of days for 50 per cent flowering with a significant increase in yield over check cultivar. Whereas, the other type TF 242 though the earliest to attain 50 per cent flowering, its yield increase was non-significant over check cultivar Co.1.

In general, except the two accessions viz., TF 107 (494.8 kg) and TF 113 (482.9 kg/ha) all the other accessions produced higher grain yield than the check. However, only three accessions viz. TF 105 (573.3 kg), TF (549.1 kg) and TF 112 (548.6 kg/ha) exhibited statistically significant increase in yield over Co.1.

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References

Indian Institute of Spices Research, 1999. Annual Report for 1998-99 of All India Co-ordinated Research Projects on Spices, IISR, Calicut, Kerala, pp:89.

Indian Institute of Spices Research, 1999. Annual Report 1998-99 of All India Co-ordinated Research Projects on Spices, IISR, Calicut, Kerala, pp:93.

Department of Horticulture and Plantation Crops, 1999. Crop production guide for Horticultural Crops. Department of Horticulture and Plantation Crops, Chennai. 126-7.

Ghosh, S.P., R.N.Pal., K.V.Peter and P.N.Ravindran. 1999. Four decades of spices research and development an overview. Indian Spices, 36(4): 11 - 17.

Sastry, D.E.V., B.L. Kunhar and D.Singh. 2000. Association studies for seed yield and its attributes in M4 generation of fenugreek. Contributory papers in Centennial Conference on Spices and Aromatic Plants, Calicut, Kerala, pp. 75 -77.

Sharma, K.C., M.M.Sharma and R.K.Sharma. 1990. Nature of variability and association in fenugreek. Indian J. Genet.50(3): 260 - 62.

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Genetic variability and correlation studies in Turmeric (*Curcuma longa* L.)

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Abstract

Thirty turmeric genotypes were evaluated along with Rajendra Sonia as a local check. during kharif season of 2001 to 2002. to study the mean, range and coefficient of variation for yield and its attributes, correlation coefficient between the different pairs of characters, heritability and expected genetic advance in per cent of mean, genetic divergence, direct and indirect effects of yield attributes on yield. Analysis of variance indicated that mean square due to genotypes were significant for all the characters except for plant girth. The PCV was higher in magnitude than GCV. The considerable range of variation was observed for all the characters. Oleoresin per cent, weight of mother, primary and secondary rhizomes per plant and number of tillers per plant showed very high genetic advance in per cent of mean alongwith high estimates of heritability, GCV and PCV. Weight of fresh rhizome per plant showed positive correlation with dry matter per cent and negative association with Oleoresin per cent. All the 30 genotypes were grouped into 7 cluster by D^2 analysis. The intra-cluster average D^2 value was maximum in cluster II and inter-cluster average D^2 value was maximum in VII and VI. The mean performance of the genotypes revealed that genotypes NDH 59 and NDH 45 were found to be best with respect to rhizome yield pet plant and related attributes as compared to remaining genotypes as well as check.

Key words: *Curcuma longa*, genotype, oleoresin, turmeric.

Introduction

Turmeric (*Curcuma longa* L.) is one of the important spice crop in India. Nevertheless, number of cultivars were released in turmeric, however, systematic effort on introduction and evaluation of improved germplasm has not yet been undertaken in the eastern condition of U.P. where inferior local clones are under cultivation resulting low productivity and less remunerative. Genetic variability and correlation analysis provide information about the relative importance of various yield component in manifestation of high yield and thus helps us in formulation of appropriate selection strategy. The choice of genetically diverse parent for hybridization is an important feature of any crop improvement programme for getting desirable segregents in the segregating generation because the crosses involving divergent parent offer greater possibility of segre gents.

Materials and method

The experiment was carried out at main experiment station of Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad during the Kharif season of 2001-02. Soil of research plot was alkaline in nature having 8.0-8.8 pH. Texture of the soil was silty loam having poor infiltration. Experiment was laid out in Randomized Block Design with three replications using 30 genotypes of turmeric including 29 germplasm and a cultivar Rajendra Sonia used as standard checks. The plants were spaced at 30 x 20 cm. apart Biometric observations were recorded 6 months after planting and rhizome characters were recorded at maturity. The data were analyzed statistically as per procedure suggested by Panse and Sukhatme (1967).

Results and discussion

A significant difference was recorded among the various collections of turmeric germplasm for different plant characters. The highest range of variation was shown by weight of fresh rhizome per plant followed by weight of primary rhizome per plant, whereas, the lowest range was observed with number of primary rhizome per plant. The high magnitude of coefficient of variation as genotypic as well as phenotypic level was observed for oleoresin per cent, weight of mother rhizome per plant, weight of primary and secondary rhizome per plant and number of tillers per plant. Result are in accordance with the finding of Mohanty *et al.* (1981) Jalgoankar *et al.* (1990). All the characters under study reveled higher estimates of heritability in broad sense ranging from 29.9% (Plant girth) to 98.2 % (Weight of Mother rhizome/plant). The coefficient of variation revealed that few characters had an ample scope for bringing crop improvement. If a selection is made the extent of improvement could be 88.01, 71.45, 65.45 and 64.91% for oleoresin per cent, weight of mother rhizome per plant, weight of primary rhizome per plant and weight of secondary rhizome per plant respectively with the 5% selection intensity. Thus, higher magnitude of genetic coefficient, heritability and expected genetic advance revealed the possibility of profitable selection. Predominant genetic variance except weight of fresh rhizome per plant, plant height, weight of mother rhizome per plant, weight of primary rhizome per plant and weight of secondary rhizome per plant also showed that the fluctuation due to environmental effect is undoubtedly tolerate indicating that the predominant effect of relative component of gene action can be coupled with genetic advance and precisely reflect the progress that will result from selection for best individual as described by Johanson *et al.* (1955). The correlation coefficient estimated in all the possible ways among the different characters presented in (Table-3). The genotypic correlation coefficient between different characters were generally same in sign and nature to the corresponding phenotypic correlation coefficient in the experiment. In the present experiment a very strong positive association of weight of fresh rhizome per plant with length of whole clump, weight of secondary rhizome per plant, weight of primary rhizome per plant both genotypic and phenotypic level. Significant correlation of the rhizome yield suggest the scope of direct and indirect effective selections for further improvement. These characters emerged a most important associates of rhizome yield in turmeric. Pandey *et al.* (1993) reported positive correlation of weight of primary rhizome per plant with weight of fresh rhizome per plant. Weight of secondary rhizome per plant exhibited highly significant and positive correlation with weight of fresh rhizome yield, per plant as reported by Jalgoankar, 1990, Singh *et al.* 1993.

All the 30 genotypes grouped into 7 cluster by D^2 analysis. The intra-cluster average D^2 value was maximum in cluster II and inter-cluster average D^2 value was maximum in cluster VII and VI. The findings are in cluster agrement with Prabhakarn (1991). From the present study it was found that NDH-59 for weight of fresh rhizome per plant, and length of mother rhizome, NDH-60 for dry mater per cent and length of whole clump and NDH-61 for plant height and oleoresin per cent were the most promising genotypes.

Table 1. Phenotypic variability of turmeric

Characters	Mean $\pm$ SE	Range	CD at 5%
Plant height (cm)	108.34 $\pm$ 5.94	92.66-127.77	11.88
No. of tillers/clump	2.30 $\pm$ 0.08	1.00-3.55	0.17
No. of leaves/plant	8.26 $\pm$ 0.35	6.19-9.94	0.70
Plant girth (cm)	4.71 $\pm$ 0.24	4.29-5.25	0.48
Length of whole clump (cm)	8.68 $\pm$ 0.33	6.35-10.73	0.67
Diameter of whole clump (cm)	12.28 $\pm$ 0.43	6.44-16.06	0.87
No. of primary rhizome/plant	2.69 $\pm$ 0.09	2.11-3.44	0.18
No. of secondary rhizome/plant	5.23 $\pm$ 0.20	3.89-6.66	0.40
Weight of mother rhizome/plant (g)	42.37 $\pm$ 1.62	15.55-75.55	3.20
Weight of primary rhizome/plant (g)	36.66 $\pm$ 1.81	17.77-76.39	3.62
Weight of secondary rhizome/plant (g)	57.65 $\pm$ 2.20	21.33-97.48	4.40
Length of mother rhizome (cm)	5.70 $\pm$ 0.20	3.35-7.13	0.42
Length of Primary rhizome (cm)	5.29 $\pm$ 0.19	3.89-6.66	0.38
Length of secondary rhizome (cm)	5.53 $\pm$ 0.20	4.11-7.11	0.40
Weight of fresh rhizome per plant (g)	16.13 $\pm$ 15.70	76.66-328.31	31.40
Dry matter %	19.86 $\pm$ 0.46	15.50-20.60	0.93
Oleoresin %	6.60 $\pm$ 0.47	4.00-14.34	0.94

Table 2. *Genotypic and phenotypic coefficient of variance heritability and genetic advance of turmeric*

Characters	Coefficient of variation (%)		Heritebility in broad sense (%)	G.A. per cent in mean
	Phenotypic	Genotypic		
Plant height (cm)	8.19	10.59	59.8	13.03
No. of tillers/clump	29.55	29.96	97.6	60.22
No. of leaves/plant	9.68	10.99	77.5	17.55
Plant girth (cm)	4.06	17.42	19.9	4.56
Length of whole clump (cm)	14.28	15.06	89.9	17.8
Diameter of whole clump (cm)	19.51	19.99	95.3	39.22
No. of primary rhizome per plant	10.41	11.26	85.50	19.82
No. of secondary rhizome per plant	15.78	16.52	91.2	31.04
Weight of mother rhizome per plant (g)	34.99	35.30	98.2	71.45
Weight of primary per plant	32.33	32.89	96.6	65.45
Weight of secondary rhizome per plant (g)	31.85	32.19	97.9	64.91
Length of mother rhizome (cm)	13.62	14.33	90.8	26.66
Length of Primary rhizome (cm)	14.77	15.43	91.6	29.11
Length of secondary rhizome (cm)	12.14	12.93	88.1	23.46
Weight of fresh rhizome per plant (g)	24.57	26.13	88.4	47.57
Dry matter %	6.72	7.34	83.7	12.66
Oleoresin %	47.57	44.44	96.2	88

Table 3. Estimate of genotypic correlation and phenotypic coefficient between different characters in turmeric

Characters		Plant height (cm)	No. of tillers per clump	No. of leaves per plant	Plant girth (cm)	Length of whole clump (cm)	Diameter of whole clump (cm)	No. of primary rhizome per plant	No. of secondary rhizome per plant	Weight of mother rhizome per plant (g)
Plant height (cm)	Geno.		0.196	-0.019	0.299	0.188	0.354	0.120	0.403	0.349
	Pheno.		0.146	-0.006	0.171	0.138	0.259	0.072	0.289	0.266
No. of tillers per clump	Geno.			-0.181	-0.511	0.288	-0.241	0.283	-0.219	-0.233
	Pheno.			0.116	-0.284	0.272	0.231	0.262	-0.204	-0.227
No. of leaves per plant	Geno.				0.444	-0.441	0.237	0.226	0.277	0.428
	Pheno.				0.215	-0.356	0.210	0.187	0.219	0.362*
Plant girth (cm)	Geno.					-0.228	0.281	0.276	0.675	0.617
	Pheno.					-0.103	0.144	0.175	0.384*	0.342
Length of whole clump (cm)	Geno.						0.183	0.308	0.191	0.136
	Pheno.						0.231	0.281	0.175	0.130
Diameter of whole clump (cm)	Geno.							0.110	0.458	0.543
	Pheno.							0.106	0.425*	0.526**
No. of primary rhizome per plant	Geno.								0.243	0.222
	Pheno.								0.249	0.226
No. of secondary rhizome per plant	Geno.									0.705
	Pheno.									0.702**

*** Significnat at 5% and 1% level respectively.

Cont...........

Estimate of genotypic and phenotypic correlation coefficient between different characters in turmeric

Characters		Weight of primary rhizome per plant (g)	Weight of secondary rhizome per plant (g)	Length of mother rhizome (cm)	Length of primary rhizome (cm)	Length of secondary rhizome (cm)	Weight of fresh rhizome per plant (g)	Dry matter (%)	Oleoresin
Plant height (cm)	Genotypic	0.278	0.100	0.480	0.324	-0.185	0.152	0.380	0.459
	Phenotypic	0.208	0.073	0.315	0.232	-0.136	0.072	0.309	0.357
No. of tiller per clump	Genotypic	0.080	-0.157	-0.090	-0.243	-0.400	0.250	0.413	0.257
	Phenotypic	0.076	-0.152	-0.080	-0.227	-0.368*	0.244	0.372*	0.249
No. of leaves per plant	Genotypic	-0.138	0.229	0.244	0.304	0.111	0.033	0.089	-0.039
	Phenotypic	-0.133	0.198	0.220	0.246	0.080	0.031	0.033	-0.026
Plant girth (cm)	Genotypic	0.569	0.423	0.444	0.649	0.535	0.336	-0.145	-0.157
	Phenotypic	0.357	0.241	0.219	0.363*	0.301	-0.209	-0.055	-0.119
Length of whole clump (cm)	Genotypic	0.374	0.203	0.375	0.170	0.214	0.611	0.295	-0.010
	Phenotypic	0.350	0.192	0.418**	0.160	0.197	0.530**	0.243	-0.001
Diameter of whole clump (cm)	Genotypic	0.377	0.557	0.570	0.510	0.538	0.327	-0.017	-0.002
	Phenotypic	0.359*	0.537**	0.585**	0.476**	0.492**	0.291	-0.019	0.007
No. of primary rhizome per plant	Genotypic	0.391	0.355	0.173	0.293	0.009	0.353	0.307	0.007
	Phenotypic	0.377*	0.352	0.164	0.315	0.073	0.311	0.208	0.014
No. of secondary rhizome per plant	Genotypic	0.299	0.302	0.631	0.954	0.438	0.363	-0.013	-0.071
	Phenotypic	0.311	0.323	0.571**	0.950**	0.485**	0.322	-0.020	-0.070
Weight of mother rhizome per plant (g)	Genotypic	0.166	0.345	0.720	0.730	0.266	0.407	-0.153	-0.076
	Phenotypic	0.176	0.356	0.679**	0.730**	0.291	0.379*	-0.146	-0.072
Weight of primary rhizome per plant (g)	Genotypic		0.438	0.231	0.278	0.438	0.479	0.221	-0.054
	Phenotypic		0.440*	0.214	0.293	0.439*	0.449*	0.181	-0.050
Weight of secondary rhizome per plant (g)	Genotypic			0.398	0.330	0.480	0.525	0.005	-0.058
	Phenotypic			0.374*	0.353	0.494**	0.491**	-0.002	-0.054
Length of mother rhizome (cm)	Genotypic				0.654	0.367	0.396	0.109	-0.032
	Phenotypic				0.596**	0.328	0.358	0.086	-0.025
Length of primary rhizome (cm)	Genotypic					0.477	0.320	-0.048	-0.118
	Phenotypic					0.527**	0.291	-0.062	-0.109
Length of secondary rhizome (cm)	Genotypic						0.243	-0.143	-0.174
	Phenotypic						0.219	-0.145	-0.158
Dry matter (%)	Genotypic							0.044	-0.093
	Phenotypic							0.024	-0.090
Oleoresin	Genotypic								0.057
	Phenotypic								0.036

*** Significnat at 5% and 1% level respectively.

References

Johanson, H.W. *Robinson*, H.F. and Comstoc, R.E. 1995 Estimating the **genetic and environmental** *variation in soybean*. Agron J. 47 : 314-8.

Jalgoankar, R. Jamdagni, B.M. and Solvi, M.J. 1990 Genetic variability and correlation stuelies in turmeric Indian Coca Arecent and Spices Journal 14 (1) : 20-22.

Mohanty, D.C. Das, R.C. and Sharma, Y.N. 1981 Varibility of agronomic characters in ginger (Zingiber *officinale*) Orrissa J. of Hort. 9 (1) : 15-17.

Pandey, G and Donbhal, V.K. 1993 Genetic variability, character, association and path analysis for yield component in ginger (Zingiber officinale). Journal of Spices and Aromatic Crops 2 (1 & 2) : 16-20.

Panse. V.G. and Sukhatme, P.V. 1967 Statistical *methods for Agriculture workers. ICAR, Pub. New* Delhi.

Prabhakaran, P.V. 1991. Factor analysis in turmeric (Curcuma longa L.) Annals of Agriculture Research; 12 151-155.

Singh, D.P. 1993 Evaluation and characterization of turmeric (Curcuma longa L.) germplasm. Ph.D. thesis, G.P.B.U.A. & T. Pantnagar 157.

Session III

Biorational Management of Pests & Diseases

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Studies on the incidence and crop loss in yield due to anthracnose disease at the time of spiking in black pepper under coffee based cropping system

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Abstract

Incidence of anthracnose disease caused by *Colletotrichum glosporioides* in black pepper (*Piper nigrum* L.) which was considered to be of minor importance until recently, has now become a major problem causing economic loss to pepper crop in Mudigere taluk of Chikmagalur district. Considering the loss, field experiments on the incidence of this disease was conducted during the year 2000 and 2001 in twelve locations at random, in and around Mudigere. Data on the incidence of the disease was collected from each location, at monthly intervals from May to August, following 0 to 5 standard disease rating scale to assess the intensity of the disease at the time of spike emergence to berry formation. The results revealed that maximum average disease incidence was 6.21 per cent in July and the yield loss was 3.45% per vine.

Key words: Anthracnose, disease incidence, pepper, spike loss.

Introduction

Black pepper (*piper nigrum* L) is one of the most important spice crops in the hill zone of Karnataka and so also in Mudigere taluk of Chikmagalur district grown extensively under coffee based cropping system. In most of the areas panniyur-1, Karimunda and other local varieties are being cultivated and vines were trained on forest trees. These crops in the hill zone normally suffers due foot rot disease. Recently, anthracnose disease due to *Colletotrichum gloeosporioides* has been found causing economic damage, to the crop and has become another set back to farmers.

Unlike foot rot pathogen, this pathogen is also perennial on the host and can be seen on the physiologically active leaves and tender shoots through out the year. But under uncomfortable weather conditions, damage on the spike has also been noticed. Present study was undertaken during 2000-2001 season to know the incidence as well the crop loss due to this disease.

Materials and Methods

The study was conducted in twelve locations in farmers' fields selected at random in Mudigere taluk. Each location was divided into four sectors and in each sector five vines were selected randomly and in each vine at two meters height from the base, five bearing laterals were choosen at one meter length on the eastern side and they were tagged with red tape for easy observation. Hence, there were twenty vines in each location and observations were recorded on a total of 240 vines in all the twelve locations.

The data on the disease incidence was collected from each location at monthly intervals from May to August following standard disease rating scale 0-5 with norms as disease free, trace, low, moderate, severe and very severe (ie.,0-healthy (disease free), 1=1-5% (Trace), 2=5-10% (low), 3=10-25% (Moderate), 4=25-50% (Severe) and 5=>50% (very severe Spike infected). In each vine 10 spikes at random on the disease incidence at the time of spiking to berry formation stage were observed and recorded the same in a proforma.

Finally PDI was worked out by totalling the per cent spike infected and dividing it by the total no.of spikes counted. Similarly, the same method was followed for all the twenty vines in each location and for all the 240 vines in twelve locations and data analysed statistically.

Table 1. PDI for Anthracnose disease of black pepper

Sl. No.	Locations	Per cent disease incidence				
		May	June	July	Aug	Mean PDI
1	Nandipura	1.12	2.60	21.91	10.67	9.10
2	M.G.Halli	0.50	1.93	10.23	7.90	5.14
3	Hesgal	0.33	1.80	8.77	8.30	4.80
4	Chakkod	0.22	1.60	10.40	7.46	4.92
5	Salumara	0.00	0.27	2.93	2.10	1.33
6	Beejuvalli	0.00	0.53	5.33	3.36	2.31
7	Kadumane	0.00	3.22	2.80	2.00	2.67
8	Hoysalalu	0.00	10.13	5.38	3.82	3.44
9	Gabgal	0.00	0.56	1.70	1.00	1.10
10	Daradahalli	0.00	0.39	0.27	0.00	0.33
11	Ousana	0.00	4.00	3.61	2.69	3.43
12	B.Hosahalli	0.00	4.41	1.12	0.00	2.77
	Monthly Mean	0.18[c]	2.62[bc]	6.21[a]	4.11[ab]	3.45

CD @ 5% 2.67

Results and discussion

The data presented in the table-1 shows that the disease incidence was very much low during May (0.18%) as dry weather prevailed without pre-monsoon showers. But subsequently there is increase in trend in the month of June (2.62%) due to monsoon showers. However maximum disease incidence was recorded during July (6.21%) as there were peak monsoon showers along with wind which lead to more spike dropping. Further, as the monsoon has become weak during August which resulted in the decline of disease (4.11%).

Above data clearly revealed that the disease incidence during the month of July is highly significant as compared to other months.

Besides, it was also observed that the incidence of disease was more in Nandipura (9.10%) where shade regulation has not been as compared to other locations where proper shade regulation has been done in time. The disease incidence in these location were very less ranging from 0.33 to 5.11%. Hence regular shade regulation may be essential to avoid higher atmospheric humidity which inturn might reduce the disease incidence. Crop loss has also been estimated by collecting the data from all the locations following the yield para

Table 2. Crop loss estimate due to Anthracnose disease of black pepper.

Sl. No.	Locations	Av.No.of Spikes/ vine	Av.No.of berries/ Spike	100 berries weight (g)		Total yield of berries/ vine (Kgs)	Loss of berry/vine (Kgs)		Total dry yield/ Vine (Kg)	%loss/ Vine
				Fresh	Dry	Fresh (wt)	Fresh	Dry		
1	Nandipura	1785	99.70	12.95	4.32	23.05	2.09	0.70	7.68	9.10
2	M.G.Halli	1960	93.00	14.43	4.81	26.30	1.35	0.45	8.77	5.14
3	Hesgal	2320	100.80	12.64	4.21	29.56	1.42	0.47	9.85	4.80
4	Chakkod	2226	102.10	11.55	3.85	26.25	1.29	0.43	8.75	4.91
5	Salumara	3591	108.00	11.43	3.81	44.33	0.59	0.20	14.78	1.33
6	Beejuvalli	2700	106.80	10.95	3.65	31.58	0.73	0.24	10.53	2.31
7	Kadumane	5680	69.00	10.20	3.36	39.98	1.07	0.36	13.33	2.67
8	Hoysalalu	3160	90.00	10.03	3.20	28.53	0.98	0.33	9.51	3.44
9	Gubgal	7480	84.00	8.27	2.89	51.96	0.57	0.19	17.32	1.10
10	Daradahalli	8428	60.00	9.68	3.09	40.94	0.16	0.05	16.31	0.33
11	Ousuna	3317	87.00	10.74	3.54	30.99	1.06	0.35	10.33	3.43
12	B.Hosahalli	4422	72.00	10.00	3.03	31.84	0.88	0.29	10.61	2.77
	Monthly Mean	3923	89.39	11.08	3.65	34.45	1.10	0.36	11.48	3.45

meters like average no.of spikes/vine, average no.of berries/spike and weight of 100 berries as given in the table 2.

It was seen from the table that for an average no.of spikes (39.23) weighing 34.45 Kgs (Wet yield/vine), there will be a loss of 1.10 kgs which accounts to 3.45% loss due to anthracnose disease incidence and there is significant loss in yield/vine.

However, it is concluded that for every 1% of disease incidence, there will be an economic loss of 0.31 kgs in yield of berries/vine and the crop needs protection from disease to avoid loss.

Reference

Amma, S.P., Nybe, E.V., Sujatha, V.S and Prabhakaran, P.V. 2001. Survey, evaluation and identification of black pepper cultivars. J. Trop. Agri. 39 (I):6-9.

Geetha, C.K. and Nair, P.C.S. 1989. studies on spike shedding in black pepper (*Piper nigrum L.*) CV. Panniyur. S. Indian Hort. 37(5):282-286.

Kurian, P.S., Rajkumar, A.J., Backiyarani, S. and Murgan, M. 2000. Case study of Pollu disease epidemic of black pepper in high ranges of Idukki district. 125h Kerala Science Congress, Proc., Kumily, PP. 497-498.

Radhakrishnan, T.C. and Naik, B.J. 1983. Varietal reaction and loss due to fungal pollu in pepper under coconut shade. Indian cocoa, Arecanut and Spices journal 6(4): 91-92.

Veerabhadrarao, M., 1985. Disease assessment keys. Diseases of fieldcrops and their integrated measures. NPPTI, pp 17-18.

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Evaluation of entomogenous fungus, *Metarhizium anisopliae* (metsch.) sorokin on cardamom root grub, *Basilepta fulvicorne* jacoby under field condition.

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Abstract

The entomogenous fungus, *Metarhizium anisopliae* (Metsch.) Sorokin was evaluated under field condition for its efficacy in causing mortality and reducing cardamom root grub, *Basilepta fulvicorne* Jacoby, @ 25, 50 and 75 gms/plant (with spore load of 10^8 spore/gm) with sorghum as carrier medium. The fungus in carrier medium was mixed with Farm Yard Manure and incorporated around rhizosphere. Insecticide, Chlorpyriphos 20 EC @ 0.04% was also included in the experiment as standard check. *M.anisopliae* was found to cause mortality of root grub as well as reduction in root grub population and was found to be on par with standard chemical insecticide.

Key words: anisopliae, *Basilepta fulvicorne*, cardamom, metarrhizium, root grub.

Introduction

Cardamom root grub, *Basilepta fulvicorne* Jacoby is one of the serious pests, damaging roots and causing yield loss upto 66.2% (Varadarasan, 2001). The pest made its appearance on cardamom during 1985 and subsequently became a serious pest in all cardamom growing areas in late ninteen eighties. The management of the pest is by chemical insecticides *viz.*, application of phorate 10G and chlorpyriphos 20 EC. Eventhough chemical insecticide help in managing the pest, their application is not only recurring but becomes costly, laborious and polluting the environment. Survey of the pest under different agroclimatic conditions indicated that an entomogenous fungus, *Metarhizium anisopliae* (Metsch.) Sorokin infected root grubs; the pathogenicity of *M.anisopliae* on cardamom root grub *B.fulvicorne* was confirmed under laboratory bioassay studies (Varadarasan & Sivasubramonian, 1996). The entomogenous fungus, *M.anisopliae* is reported to be pathogenic to a number of insect pests under field conditions (De La Rosa *et al.*, 1918; David and Easwaramoorthy, 1991; Campbell *et al.*, 2000). In order to reduce insecticide input in cardamom ecosystem and also to evolve bio-rational method of management, an attempt was made to evaluate *M.anisopliae* for its efficacy in causing mortality and in reducing root grub under field condition.

Materials and methods

The experiment was conducted at ICRI farm, Myladumpara during 2000 – 2001 & 2001 – 2002 seasons. Root grub, *B.fulvicorne* with fungal infection were collected from the field, surface sterilized with sodium hypochlorite 0.1% and the fungus was isolated in pure culture using modified sabourd dextrose agar medium (Suseela Bhai *et al.*, 2000). The fungus was multiplied under *in vitro* condition in Potato Dextrose Agar medium, and was further mass cultured in sterilized sorghum grains as carrier medium for the trial under field condition.

The fungus in the carrier medium was examined for spore load and was adjusted to have 1 X 10^8 spores per gram of carrier medium. The fungus in carrier medium was suspended in water and as the spores being hydrophobic in nature, a drop of Tween–80 was added for easy dispersal of the spores in water. This fungal suspension was mixed with well decomposed Farm Yard Manure (FYM); the mixing of the fungus and FYM was adjusted so that every 2 kg of FYM contains 25 gm, 50 gm and 75 gm of fungus culture. Two Kg of FYM with different concentration of the fungus was applied around plant base and incorporated in the soil; the plant base was covered with mulch to keep the rhizosphere with adequate moisture. This experiment was designed in RBD. There were five treatments *viz.*, T_1 – *M.anisopliae* @ 25 gm./plant, T_2 – *M.anisopliae* @ 50 gm./plant, T_3 – *M.anisopliae* @ 75 gm/plant, T_4 – Chlorpyriphos 20 EC @ 0.04% and T_5 – control with four replications. The root grub population was assessed before and 30-days after treatment imposition. During the first season of the experiment, the data on mortality of grub was taken into consideration and in the second season the number of grubs/treatment was taken. The post-treatment count was adjusted with pre-treatment count, and analysis of co-variance was done by taking pre-treatment count as the co-variate. Mean separation was performed using Least Significant Difference (LSD)

Results and discussion

During the first season, the mortality of grubs was assessed in each treatment. All treatment showed significant difference at 10% in the percentage of mortality (Table. 1). All treatments with *M.anisopliae* (T_1, T_2 & T_3) are on par with standard check (T_4 – Chlorpyriphos 20 EC). The mortality was highest in T_3 with *M.anisopliae* @ 75 gm/plant and it is on par with standard check (T_4 – Chlorpyriphos 20 EC @ 0.04% application).

During the second season, the reduction in root grub population was assessed based on the number of live grubs in each of the treatment (table 2). The reduction in root grub population was considerable in T_2 with *M.anisopliae* @ 50 gm/plant and it is on par with standard check (T_4) with chlorpyriphos 20 EC @ 0.04% application.

The results from the two seasons indicate that *M.anisopliae* cause mortality of grubs as well as reduce root grub population under field condition. Since the treatment with *M.anisopliae* is on par with chemical insecticide both in terms of causing mortality and reducing the population, this entomogenous fungus may be a potential candidate in the bio-rational method of pest management under cardamom ecosystem.

Table 1. Evaluation of ***Metarhizium anisopliae*** on root grubs (percentage mortality) 2000 - 2001

Treatments	R_1	R_2	R_3	R_4	Mean	Percentage Mortality *
T_1 *M.anisopliae* @ 25 gm/plant	18.18	28.13	15.38	38.46	25.04	23.44 A (1.370)
T_2 *M.anisopliae* @ 50 gm/plant	47.83	16.66	9.68	11.11	21.32	17.10 AB (1.233)
T_3 *M.anisopliae* @ 75 gm/plant	44.44	57.14	16.36	27.50	36.36	32.66 A (1.514)
T_4 Chlorpyriphos 20 EC @ 0.04%	78.18	66.66	19.35	7.69	42.97	29.65 A (1.472)
T_5 Control	20.00	9.76	10.00	4.76	11.13	9.877 B (0.992)
CD						0.3097

All the values in parentheses are transformed values. Treatment means followed by common letters are not significantly different. *Adjusted with pre-treatment observation

Table 2. Evaluation of *Metarhizium anisopliae* on root grubs (Percentage live grubs) 2001 – 2002

Treatments	R_1	R_2	R_3	R_4	Mean	Percentage live grubs *
T_1 *M.anisopliae* @ 25 gm/plant	4.0	0.7	1.0	3.7	2.4	2.12 B (1.623)
T_2 *M.anisopliae* @ 50 gm/plant	3.7	2.6	6.3	7.7	5.1	4.88 A (2.320)
T_3 *M.anisopliae* @ 75 gm/plant	8.0	4.0	6.7	3.7	5.6	5.45 A (2.442)
T_4 Chlorpyriphos 20 EC @ 0.04%	2.6	2.6	2.3	2.3	2.5	2.46 B (1.717)
T_5 Control	4.0	3.3	3.0	9.3	4.9	4.65 A (2.268)
CD						0.5347

All the values in parentheses are transformed values. Treatment means followed by common letters are not significantly. - Adjusted with pre-treatment observation

Entomogenous fungi are important in the natural regulation of many insect pests (Mc Coy *et al.*, 1988). *M.anisopliae* is successfully used as biocontrol agent on coconut rhinoceros beetle, *Oryctes rhinoceros* (Murali Gopal *et al.*, 2001). Black vine weevil, *Otiorhynchus sulcatus* (F) is effectively controlled by use of *M.anisopliae* (Rombach and Gillespie, 1988); under field evaluation of *M.anisopliae* on cane grubs, the fungus acted slowly and grubs continued to die several months after application (Samson *et al.*, 1997; Goettel and Hohnson, 1992). Cardamom rhizosphere is an ideal niche where moisture condition is congenial for the survival and multiplication of fungus. If artificial inundation of entomogenous fungi for the control of cardamom root grub is done, there is high potential that the fungus attack the grubs and sustain in the rhizosphere for several months and may take care of the recurring root grub invasion in the field. Survey for natural enemy on root grub indicated that grubs were infected with entomogenous nematode – *Heterorhabditis* sp. - and application of chemical insecticide viz., Phorate 10G for management of root grub will have adverse effect on these naturally perpetuating entomogenous nematodes in cardamom ecosystem. The use of entomogenous fungus therefore is safer to the other natural enemies occurring in soil ecosystem.

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References

Campbell L G, Eide J D, Smith L J & Smith G A 2000 Control of sugar beet root maggot with the fungus *Metarhizium anisopliae*. Journal of Sugar Beet Research. 37 : 57 – 69.

David H & Easwaramoorthy S 1991 An evaluation of some microbial agents for the control of white grub infesting sugarcane. In: Advances in Management and conservation of soil fauna (pp 223-229). Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

De La Rosa W, Alatorre R, Barrera J F & Toriello C 1998 Effect of *Beauveria bassiana* and *Metarhizium anisopliae* (Deutromycetes) upon the coffee berry borer (Coleoptera : Scolytidae) under field conditions. J. Economic Entomology. 93 : 1411 – 1414.

Goettel M S & Johnson D L 1992 Environmental impact and safety of fungal biocontrol agents. In: Lomer C J & Prior C (eds) Biological control of locusts and grasshoppers (pp 356 – 361), Wallingford, UK, CAB International.

Mc coy C W, Samson R A & Boucias D G 1988 Entomogenous fungi. In: (Ignoffo C M & Madava N B (eds.) Handbook of Natural Pesticides, vol. V. Microbial insecticides, Part . A: Entomogenous Protozoa and Fungi (pp 151 – 236).CRC Press, Boca Raton.

Murali Gopal, Alka Gupta & Sathiamma B 2001 *Metarhizium anisopliae* (Metsch.) Sorokin., A biocontrol agent on coconut palm rhinoceros beetle. Indian Farming. 51 : 26 – 28.

Rombach M C & Gillespie A T 1988 Entomogenous Hyphomycetes for insect and mite control on greenhouse crops. Biocontrol News and Information. 9 : 7 – 18.

Samson P R, Mc Gill N G, Harris W J, Milner R J & Allsopp P G 1997 Field efficacy of *Metarhizium anisopliae* as a remedial treatment for negatoria and childers cane grub. Proc. Aust. Soc. Sugarcane Technologists. pp 103 – 110.

Suseela Bhai R, Joseph Thomas & Potty S N 2000 A simplified Technique for mass multiplication of *Metarhizium anisopliae*, the green muscardin entomopathogenic fungus. Paper presented in: International Conference on Plantation Crops, 12-15th Decmber 2000, Hyderabad, India.

Varadarasan S 2000 Cardamom root grubs. Technical Bulletin, published by Spices Board, Kochi – 25, India, pp 55.

Varadarasan S & Sivasubramonian T 1996 Studies on natural occurrence of bioagents and their bioassay on cardamom root grub, *Basilepta fulvicorne* Jacoby (Coleoptera : Chrysomelidae); In: Proceedings of International Symposium on plantation crops. J. plantation crops. 24 (supplement) 286 – 290.

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Integrated management of ginger rhizome rot caused by Pythium aphanidermatum

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Abstract

Rhizome rot of ginger caused by *Pythium aphanidermatum* is a serious disease leading to considerable yield loss. Three field trials were conducted at Horticultural Research Station, Pechiparai during 1998 - 2001 with ten treatments including fungicides and biocontrol agents for the management of this disease. The results revealed that metalaxyl 0.1 per cent application three times has recorded the lowest mean per cent disease incidence of 10.78 and this treatment was on par with neem cake + *Pseudomonas fluorescens* application (11.87%) which recorded 75.0 and 72.48 per cent disease reduction over control respectively. These treatments also recorded 37.17 and 35.53 per cent increased yield over control respectively. But highest cost benefit ratio of 1:2.31 was recorded in neem cake plus *P. fluorescens* application followed by 1:2.14 in metalaxyl treatments.

Key words: ginger, *Pseudomonas fluorescens*, rhizome rot.

Introduction

Ginger is one of the minor spices grown in Kanyakumari district of Tamil Nadu. Farmers are usually raising the local varieties in both Ela and land conditions. Rhizome rot of ginger is one of the major disease causing considerable yield loss in both the monsoon periods. The ruling varieties are also highly susceptible to this disease. This disease is caused by *Pythium* spp. of which *P. aphanidermatum* (Edson) Fit sp. as the principle species in India (Randhawa and Nandpuri, 1970). The collar region become soft watery and rot. The affected plants become pale, the tips of the leaves turn yellow, followed by complete yellowing and drying up of leaves. The shoots fall off and cease to produce rhizome.

Rathiah (1987) reported the effectiveness of Ridomil + Captafol combined application. Addition of organic matter in the form of green manures or crop residues to soil can also suppress the growth of pathogenic *Pythium* species (Lumsden *et al.,* 1991). *Trichoderma harzianum* was an effective control agent of damping off caused by *Pythium* sp. (Hubbard *et al.,* 1983).

Materials and methods

Experimental trials were laid out during 1998-99, 1999-2000 and 2000-01 at Horticultural Research Station, Pechiparai under natural unprotected field conditions with ten treatments. The trials were designed in a randomised block design with three replications having a plant density of 40 plants/bed 3 x 1 m size. The bio-control agents were applied as rhizome treatment (RT) as well as soil application (SA) before planting.

Neem cake was applied before planting. The fungicides were applied as rhizome treatment and further soil drenchings were given just before the onset of both Southwest and Northeast monsoon i.e. June first week and October 2nd week.

Results and discussion

The results revealed that all the fungicides and bio-control agents tested in these trials have exhibited their effectiveness on the reduction of ginger rhizome rot and increased the yield. Among them, metalaxyl 0.1 per cent application three time has recorded the least mean per cent disease incidence of 10.78 and this was significantly followed by 11.87 in neem cake with *P. fluorescens* application. These treatments respectively recorded 75.0 and 72.48 per cent reduction over control (Table 1). The reduction in disease by metalaxyl was also reported by Jayasekhar *et al* (2000). These treatments also recorded the higher mean plot yield of 4.18 and 4.12 kg where as in control the yield was 3.04 kg was yielded (Table 2). Fluorescent pseudomonads produce iron sequestering compounds called siderophores which inhibit the growth of microorganisms including *Pythium* spp. by reducing the availability of iron (Whipps and Lumsden, 1991). This type of mechanism might have interfered with *P. aphanidermatum* and reduced the pathogen population and disease incidence.

Table 1. Effect of bio-control agents and fungicides on the incidence of rhizome rot of ginger

	Treatments	Per cent disease incidence (PDI)			Mean	Reduction over control
		1998-99	1999-2000	2000-2001		
T_1	*T.Viride* (Soil application (SA) + Rhizome treatment (RT)	22.5 (28.32)	18.28 (25.33)	24.50 (29.67)	21.76	49.55
T_2	*P. fluorescens* (SA +RT)	17.15 (24.49)	15.45 (23.16)	16.45 (23.94)	16.35	62.10
T_3	*Bacillus subtilis* (SA + RT)	25.63 (30.20)	22.45 (28.32)	21.44 (22.63)	23.17	46.28
T_4	Neem cake alone (750 kg/ha)	40.8 (39.58)	32.00 (34.45)	36.80 (34.45)	36.53	15.30
T_5	$T_1 + T_4$	15.20 (22.95)	13.6 (21.64)	17.15 (24.49)	15.32	64.48
T_6	$T_2 + T_4$	11.40 (19.73)	9.40 (17.85)	14.80 (22.63)	11.87	72.48
T_7	$T_3 + T_4$	20.60 (26.56)	15.20 (22.95)	18.90 (25.77)	18.23	57.73
T_8	Bordeaux mixture 1%	17.15 (24.49)	12.10 (20.36)	14.80 (22.63)	14.68	65.96
T_9	Metalaxyl 0.1%	10.60 (19.00)	9.75 (18.20)	10.60 (19.00)	10.78	75.00
T_{10}	Control	45.0 (42.30)	36.80 (34.45)	47.6 (43.62)	43.13	--
	CD (P=0.05)	2.06	1.94	2.42		

(Figures in parentheses are arcsine transformed values)

Table 2. Yield and Cost benefit ratio on treatment schedule for the control of ginger rhizome rot

	Treatments	Mean * Yield (kg/plot)	Additio-nal yield over control Kg/ha	Cost of additio-nal return @ 10/kg	Cost of chemical including cost of application	Cost benefit ratio
T_1	*T.Viride* (Soil application (SA) + Rhizome treatment (RT)	3.46	1400	14000	9200	1:1.52
T_2	*P. fluorescens* (SA +RT)	3.61	1900	19000	9200	1:2.06
T_3	*Bacillus subtilis* (SA + RT)	3.41	1234	12340	9200	1:1.34
T_4	Neem cake alone (750 kg/ha)	3.25	700	7000	6400	1:1.09
T_5	$T_1 + T_4$	3.86	2734	27340	15600	1:1.75
T_6	$T_2 + T_4$	4.12	3600	36000	15600	1:2.31
T_7	$T_3 + T_4$	3.61	1900	19000	15600	1:1.22
T_8	Bordeaux mixture 1%	3.68	2134	21340	9900	1:2.14
T_9	Metalaxyl 0.1%	4.17	3767	37670	16800	1:2.24
T_{10}	Control	3.04	-	-	-	-
	CD (0.05)	0.19	-	-	-	-

*Mean of three trials

Highest cost benefit ratio of 1:2.31 was recorded in neem cake plus *P. fluorescens* application followed by 1:2.14 in metalaxyl treatments. It was concluded that application of chemical fungicides may be rescheduled by application of rhozome treatment and premonsoon applications of Pseudomonas fluorescense with neem cake for the effective management of rhizome rot of ginger as an eco-friendly approach.

References

Hubbard,J.P., Harman,G.E. and Hadar,Y. 1983. Effect of soil borne *Pseudomonas* spp on the biological control agent, *Trichoderma hamatum*, on pea seeds. Phytopathology, 73: 655-659.

Jayasekhar, M., Prem Joshua, J. and Anchanam Alagia Pillai,O. 2000. Management of rhizome rot of ginger caused by *Pythium aphanidermatum*. Madras Agric.J., 87(1-3):170-171.

Lumsden,R.D. 1991. Mycoparasitism of soil borne plant pathogens. In: The Fungal Community, 2nd edn. (Eds. Wicklow,D.T. and Carroll,G.C.L.) Mareel Dekker, NY.

Randhawa, K.S. and Nandpuri, K.S. 1970. Ginger (Zingiber officinale Rosc.) in India-a review. Punja Horti.J.10. 111-122.

Rathaiah, Y. 1987. Disease of turmeric in Assam. Pesticides. 21(8):15-17.

Whipps,J.M. and Lumsden,R.D. 1991. Biological control of *Pythium* species. Biocont. Sci. Tech., 1: 75-90.

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Management of *Phytophthora* foot rot of black pepper (*Piper nigrum* L.) under arecanut cropping system in Uttara Kannada Dist. of Karnataka

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Abstract

Black pepper vines treated twice (June and August) with potassium phosphonate @ 0.3 per cent alone as spray (3 l/vine) and drench (5 l/vine) or in combination with bioagent i.e., *Trichoderma viride* @ 50 g/vine along with 5 kg of farm yard manure to the basin of the vine reduced the disease incidence of Phytophthora foot rot.

Key words *Phytophthora* foot rot, Potassium Phosphonate, *Trichoderma* spp.

Abbreviation cfu : colony forming unit

Introduction

Black pepper (*Piper nigrum* L.) native to Western Ghats of India is being cultivated as an intercrop in arecanut based multistoried cropping system in Uttara Kannada District of Karnataka. The vines are trained on live standards of arecanut (*Areca catechu* L.) fetch extra revenue to the planter without much additional cost of cultivation.

Since 1978 sudden mortality of the vines due to Phytophthora foot rot (*Phytophthora capsici* Leonian) was the major constraint for cultivation of the crop (Sastry, 1982, Dutta 1984 and Sarma *et al.* 1994). The disease spread in epiphytotic form and eliminated the important popular local cultivars from plantations. The crop is being cultivated in valley situation where the microclimate having very high humidity (80-100 per cent) with low temperature (18-28 ^{0}C) and less sunshine. These conditions are very conducive for survival of the pathogen, its multiplication and spread.

Any single method is not effective in checking the disease. Hence, an integrated management approach comprising phytosanitary measures, cultural, chemical and biological practices andresistant/tolerant cultivars are necessary for effective management of the disease. Biocontrol agents viz., *Trichoderma* spp. suits well in the management of the disease with long lasting combating effect to the pathogen by mechanisms like competition, mycoparasitisum and production of volatile and nonvolatile antibiotics (Chet, 1987). Potassium phosphonate an antifungal compound systematically checked *Phytophthora* infection in black pepper (IISR, 1995). Sarma et al., 1996 showed compatibility with bioagents *i.e., Trichoderma* spp. *Gliocladium virens* and *Pseudomonas fluorescens*. The paper presents the use of potassium phosphonate in combination with biocontrol agent *i.e., Trichoderma viride* for effective management of the disease under arecanut based cropping system.

Material and Methods

The trial was laid out in six gardens in different locations around Sirsi. The soil in these were lateritic with 5.5 to 6.5 pH. range. The variety selected for the trial was Karimalligesara which was highly susceptible to the disease and was 8-10 years old. During the trial period the average rainfall was 2601.43 mm with 112 rainy days distributed from June to December. There were five treatments with thirty vines in each treatment. The treatment consisted of fungicides *viz.*, Bordeaux mixture 1 per cent, copper oxychloride 0.3 per cent, potassium phosphonate [Akomin] 0.3 per cent and bioagent *T. viride* (10^7 cfu 50 g per vine along with 5 kg of farm yard manure (FYM). The vines were treated with fungicides as foliar spray (@ 3 l/ vine) and soil drench (@ 5 l/vine). The antagonistic organism *T. viride* was applied to the basin of the vine without damaging the roots. The treatments were imposed twice during the season i.e., before onset of monsoon (June) and second round at 35 to 40 days after first rounds spray (August). The trial was conducted for four years i.e., from 1997 to 2000. The observation on the per centage of vine infected was recorded and statistically analysed using standard statistical design.

Results and Discussion

The results of the study revealed that the disease incidence on the vines was least (6.42 per cent) in vines treated with potassium phosphonate as foliar spray and soil drench in combination with bioagent *T. viride* (10^7 cfu @ 50 g per vine along with 5 kg of FYM) twice in the season (Table 1). This was followed by vines treated with potassium phosphonate alone as spray and drench (7.36 per cent). Application of biocontrol agent alone i.e., *T. viride* twice in the season also reduced the disease incidence (14.72 per cent). The efficacy of the biocontrol agent was found to be almost on par with Bordeaux mixture 1 per cent spray @ 3l /along copper oxychloride as drenching @ 5 l /vine twice in the season (10.42 per cent). The severity of the disease in the vines were maximum in untreated check (31.92 per cent).

The results were in conformity with the findings of Sarma *et al.* (1996) where they reported that the compatibility of agrochemical potassium phosphonate with bioagent *Trichoderma* spp. in checking the Phytophthora infection in black pepper. Usman *et al.* (1997) revealed that volatile and non volatile metabolites produced by the *Trichoderma* spp. suppressed the growth of the *Phytophthora* spp resulting in reduction of the disease. In black pepper Rajan and Sarma (1997) reported the varying degree of inhibition on the growth of *Phytophthora capsici* by biocontrol agent *Trichoderma* spp. and agrochemical potassium phosphonate. The present finding also showed that the Phytophthora foot rot of black pepper could be managed by integration of agrochemical potassium phosphonate and bioagent *Trichoderma viride* with no residual effect in the produce and at the same time improve the health of the plant.

Acknowledgement

Authors are thankful the Director and Project Co ordinator, Indian Institute of Spices Research, Calicut for their encouragement and guidance. Thanks are due to Indian Council of Agricultural Research for providing financial help.

Table 1. Phytophthora foot rot disease management in black pepper in arecanut cropping system

Treatments	Per cent disease incidence				Mean
	1997	1998	1999	2000	
Control	33.88	17.77	34.44	41.67	31.92
Bordeaux mixture (1 %) spraying and Copper oxy chloride (0.3 %) drenching twice	8.88	6.11	7.22	19.45	10.42
Potassium Phosphonate(0.3 %) spraying and drenching twice	6.66	4.44	6.67	11.67	7.36
Bioagent *(Trichoderma viride)* @ 50 g/vine to the basin of the vine along with 5 Kg of FYM/vine	20.55	7.20	10.56	20.56	14.72
Potassium phosphonate (0.3 %)spray twice and Bioagent *(Trichoderma viride)* @ 50 g/ vine to the basin of the vine along with 5 Kg of FYM	5.29	5.64	5.97	8.76	6.42
S Em ±	0.86	1.28	1.19	1.73	1.27
C D at 5 %	2.52	3.76	3.50	5.10	3.72

References

Baker K F & Cook K J 1974 Biological control of plant pathogen. 433 pp. San Franciso Freman.

Chat 1987 Innovative approaches to plant disease control John Wiley New York.

Dutta P K 1984 Studies on two Phytophthora diseases (Koleroga of arecanut and black pepper wilt) in Shimoga district Karnataka. M.Sc. (Agri) Thesis University of Agricultural Sciences, Bangalore, Karnataka.

Indian Institute of Spices Research Annual Report 1995 (p-21) Calicut, Kerala, India.

Papavizas G V 1985 *Trichoderma* and *Gliocladium*: Biology, ecology and potential for biocontrol. Ann. Rev. Phytopathol. 23 : 23-54.

Rajan P P and Sarma Y R 1997 Compatibility of potassium phosphonate (Akomin –40) with different species of *Trichoderma* and *Gliocladium virensi* in Ed : Edison S, Ramana KV, Sasikumar B, Nirmal Babu K, and Santosh J. Eapen Biotechnology of spices, medicinal and aromatic plants 24-25 April, 1996 Calicut. Indian Society for Spices, (Indian Institute of Spices Research, Calicut -673 012, Kerala) pp.150-155.

Sarma Y R, Anandraj M and Rajan P P 1994 Phytophthora a threat to black pepper present status and future strategies of disease management Spice India 1: 10-13.

Sarma, Y. R. Anandaraj M, Venugopal M. N, Susheela Bai R, Rajan PP, Ramana K V and Santosh J. Eapen 1996 Ecofriendly disease management strategies in spice crop Planters Chronicle January p. 15-18.

Sastry M N L 1982 Studies of species of Phytophthora affecting plantation crops in Karnataka with special reference to Koleroga of arecanut and wilt of black pepper Ph. D Thesis University of Agricultural Sciences, Bangalore, Karnataka.

Usman N M. Balakrishnan P and Sarma YR 1997 Mode of action of Trichoderma and Gliocladium in Ed : Edison S, Ramana K., Sasikumar , Nirmal Babu K, and Santosh J. Eapen Biotechnology of spices, medicinal and aromatic plants 24-25 April, 1996 Calicut. Indian Society for Spices, (Indian Institute of Spices Research, Calicut -673 012, Kerala) pp. 139-145.

Session IV

Value Addition, Marketing and Export Strategies

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GLOBAL MARKET OUTLOOK FOR PEPPER AND OTHER SPICES

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Introduction

Spices are traditional items of international trade. The list of spices differs from country to country. According to American Spice Trade Association (ASTA) list, there are 41 items. Spices Board of India has 52 spices in its list. According to Bureau of Indian Standards, there are 63 items under spices/condiment. As per ISO, 109 items are under this heading. Sesame seed is s spice as per the list of ASTA, but in most of producing countries, it is an oil seed. Onion is considered as vegetable in many countries, but in many other countries as a spice. Hence the figures of total production and export of spices from different sources varies very much.

About IPC

The IPC is in existence since 1972. The organization was started as " Pepper Community" with India, Indonesia and Malaysia as members. Then Brazil joined followed by Thailand and Sri Lanka. Thus the Pepper Community became the International Pepper Community. The member countries accounts for about 70-80 % of the total production and export. Once Vietnam also join in IPC, which we expect will happen soon, the IPC countries will account for about 95% of total production and export of pepper.

IPC publish valuable and up to date information on international trade in pepper. A list of our publication is given as Annex A. (page 9)

As the member countries noticed the remarkable services rendered by IPC so far for the growth of pepper industry, they thought, why not IPC involve in few more spices. The concept of converting International Pepper Community to International Spices Community was accepted in principle about 4 years back. Now the proposal has come to almost a final stage. One of the major issues was what are the spices to be brought under IPC. After detailed discussion, it was decided to include chillies, cassia, cinnamon, turmeric, ginger, nutmeg and mace, cardamoms, clove, vanilla and saffron in addition to pepper. The selection was mainly based on importance of the item in the international trade.

About the topic

Pepper

When we consider the production of pepper during the last 12 years, the lowest production was in 1989 at 183,000 mts and highest was in 2001 at 282,519 mts. The production of pepper showed continuous growth since 1998. In 1998 the production was 205,000 mts. It increased to 218340 mts in 1999. The production again increased to 254,210 in 2000. It further increased to 282,519 in 2001 and projection for 2002 is around 310,000 mts.(rough estimate). Production of pepper from almost all producing countries has contributed to the increase in the global supply.

Vietnam's production was only around less than 10,000 mts in the beginning of this decade. Vietnam's production in 2000 was 36,000 mts, which shoot up to 55,000 mts in 2001 and it is estimated that during 2002 pepper production of Vietnam will be more that 60,000 mts. They are planning to achieve a targeted production of 100,000 mts soon.

Generally around 75% of production of pepper is exported. The consumption in producing countries except in India is insignificant. India consumes about 30-40,000 mts of pepper. World exports of pepper also have shown increasing trend but not in proportion with the increase in production. However the steep decline in pepper prices during the last 3 years cannot be explained purely in terms of increased supply. The pressure and unhealthy competition played an important role in the steep decline of pries.

How to narrow down the gap between supply and demand is the most important issue in respect of pepper. One way is by cut back in production, which is not easily feasible. The only positive way is to increase the world consumption including the consumption in producing countries.

Table 1. Average production and export of pepper during three decades in metric tons

Countries	Seventies		Eighties		Nineties	
	Production	Export	Production	Export	Production	Export
Brazil	23,581	20,290	32,383	31,211	25,370	23,440
India	28,131	22,852	43,639	30,166	60,000	32,077
Indonesia	28,767	25,105	41,056	36,619	49,404	43,407
Malaysia	31,286	31,286	22,046	21,425	19,960	20,831
Sri Lanka	2,075	588	2,218	1,805	5,448	3,799
Thailand			7,789	1,564	8,288	1,928
Vietnam			5,256	3,366	21,123	22,935
Others	5,336	3,304	3,566	1,743	14,432	3,839
World	119,176	103,425	157,953	127,900	204,025	152,257
% (E/P)		87 %		81 %		75 %

Table 2. World pepper exports contrywise 1991 – 2001 (in Mts)

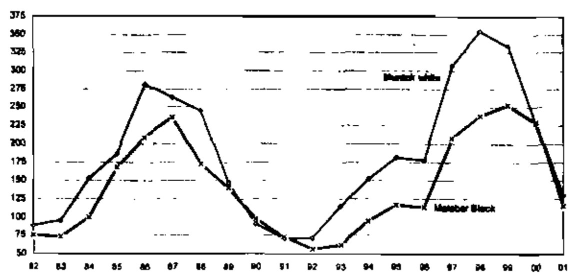
Years	Brazil	India	Indonesia	Malaysia	Vietnam	Srilanka	Others	Total
1991	47,553	18,945	49,665	26,732	16,252	2,052	5,636	166,841
1992	25,702	19,399	61,438	21,932	22,358	2,127	8,299	161,255
1993	24,119	47,228	25,801	15,727	14,801	7,779	8,947	144,402
1994	21,103	34,112	35,134	22,269	16,000	3,377	10,672	142,667
1995	21,259	24,541	56,129	13,991	17,900	2,278	3,103	139,201
1996	23,418	41,138	36,560	19,128	25,300	2,987	3,334	151,865
1997	13,961	37,816	33,011	24,808	23,500	3,279	5,392	141,767
1998	17,250	32,154	38,311	18,699	22,000	5,493	1,822	135,729
1999	19,615	46,437	35,811	21,653	28,000	3,754	4,609	159,879
2000	20,385	22,075	63,938	22,731	36,465	4,855	2,596	173,045
2001	36,785	21,795	60,453	25,990	56,509	2,096	5,800	209,428
Average	24,650	31,422	45,114	21,242	25,371	3,644	5,474	156,916
%	16 %	20 %	29 %	14 %	16 %	2 %	3 %	100 %

Table 2 a. World pepper production countrywise 1991-2001 (in Mts)

Years	Brazil	India	Indonesia	Malaysia	Vietnam	Srilanka	Others	Total
1991	50000	55000	61000	29000	8900	2850	26604	233354
1992	27500	60000	62000	26000	7830	3255	27216	213801
1993	25000	55000	23500	17600	18500	9000	22495	171095
1994	23000	50000	42500	16000	20000	5000	25981	182481
1995	20000	55000	59000	13000	20000	3725	21969	192694
1996	25700	65000	39500	16000	23000	3988	22914	196102
1997	18000	60000	43291	18000	25000	4470	19933	188694
1998	17000	65000	56250	19000	22000	6771	20263	206284
1999	22000	75000	44500	21500	30000	4740	20600	218340
2000	30000	58000	77500	24000	36000	10676	18034	254210
2001	35000	79000	55000	27000	55000	5700	25819	282519
Average	26655	61545	51276	20645	24203	5470	22893	212689
%	13 %	29 %	24 %	10 %	11 %	3 %	11 %	100 %

Other Spices

As mentioned earlier that chillies, ginger, turmeric, cloves, vanilla, cinnamon, cassia, nutmeg/mace, garlic and seed spices like coriander, cumin seeds, celery seeds, fennel, fenugreek, dill seeds, etc are other major spices of the international trade. The issues of pepper are more or less applicable to almost all spices. The production and export of almost all spices have shown increase during the last 10 years.

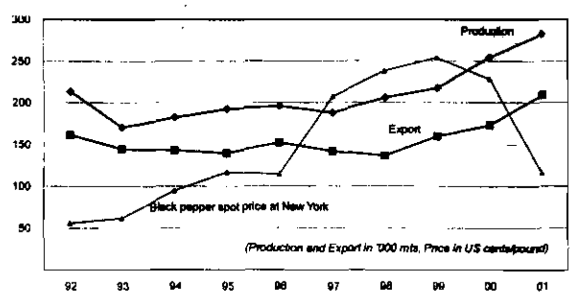


Graph 1. Annual average spot price of pepper at New York during 1982–2001

Major issues

Quality assurance

"Safety first" is the slogan of the buyers. Then what about price. You ask them. The answer will be price first. In short safety and price are equally important for buyers. This has to be tackled. IPC is in the process of upgrading the quality assurance facilities in member countries by fixing IPC standards, fixing test methods, popularizing hygienic production and processing method etc. in respect of pepper. These activities will be extended to other spices when IPC become ISC.



Graph 2. Production, export and price of pepper 1992-2001

Lack of knowledge about different uses of pepper and other spices.

The medicinal uses, the uses in perfumery and many uses as ingredients of different food are not widely known. This is one reason for the low rate of growth in consumption. IPC is taking several measures in this direction by participating in international exhibitions, printing and distributing recipe books and other publicity materials etc. There is ample scope for increasing the consumption of spices, provided proper and well-planed promotional campaigns are under taken.

Value addition

Till recently the producing countries were exporting spices in raw and bulk forms. During the last three decades there has been tremendous improvement in processing and exporting spices in value added forms. Quality assurance itself is helpful for value addition. The specific value added products are oils and oleoresins, branded consumer packs, institutional packs, instant mixes etc. Join venture possibilities in area of value addition has to be further explored. I would like to give caution in respect of oils and oleoresins. India has become a major supplier of oils and oleoresins to the world accounting for about 70% of the world trade. India has very high excess capacity.

Table 3. Average world production and export of selected spices during 1991-1995 and 1996-2000 in metric tons

Spices	1991-1995 (a)		1996-2000 (b)		Shift of (b) on (a)	
	Production	Export	Production	Export	Production	Export
Pepper (Black & White)	198,685	50,873	212,726	152,442	7 %	1 %
Anise, Badian, Fennel, Caraway, Coriander, Cumin etc	298,811	133,273	301,529	67,033	1 %	25 %
Chillies and Peppers, Green	12207,710	880,722	17410,586	242,960	43 %	41 %
Cinnamon (Canella)	72,116	73,321	90,189	78,466	25 %	7 %
Clove, Whole +stems	100,415	36,137	81,114	42,814	-19 %	18 %
Garlic	75,72,176	10,995	92,51,038	52,721	22 %	59 %
Ginger	571,100	143,951	733,180	83,201	28 %	27 %
Mustard Seed	431,572	213,125	500,586	244,724	16 %	15 %
Nutmeg, Mace, Cardmons	59,994	43,318	65,738	51,664	10 %	19 %
Poppy seed	43,494	38,627	53,101	59,242	22 %	53 %
Vanilla	4,242	2,352	5,031	2,632	19 %	12 %
Spices nes	992,809	141,518	1,61,164	188,737	17 %	33 %

Note :Exports including re-export

Source : 1. Pepper – IPC (re-export not included). 2. Others- FAO

Table 4. Average World Export and Import of Selected Spices (1991 – 2000)

Export		Import	
Country	Mts	*Country*	Mts
Pepper (Black & white)			
World	155,489*)	World	216,260
Indonesia	43,709	United States of America	47,788
India	31,706	Singapore	25,288
Vietnam	25,098	Germany	17,353
Brazil	24,397	USSR	14,000
Malaysia	21,243	Netherlands	13,627
Sri Lanka	3,862	France	8,682
Others	5,474	Others	89,552
Anise, Badian, Fennel, Caraway, coriander, Cumin, etc			
World	150,153	World	166,367
India	24,581	United States of America	17,030
Iran, Islamic Rep of	18,466	Sri Lanka	14,236
Turkey	12,810	Singapore	13,324
Syrian Arab Republic	12,480	Germany	10,906
Bulgaria	10,372	Malaysia	10,281
Others	71,444	Others	100,590
Chilies & Peppers, Green			
World	1,061,841	World	972,460
Spain	318,707	United States of America	240,309
Mexico	245,170	Germany	235,591
Netherlands	215,489	France	80,492
United States of America	74,388	Canada	68,457
India	64,775	United Kingdom	61,364
Others	143,312	Others	286,247
Cinnamon (Canella)			
World	75,894	World	71,705
Indonesia	22,632	United States of America	16,428
China	22,479	China, Hong Kong SAR	7,016
Sri Lanka	8,494	Mexico	4,840
China, Hong Kong SAR	6,937	Singapore	4,747
Singapore	6,029	India	4,043
Others	9,324	Others	34,631
Cloves, Whole+Stems			
World	39,475	World	40,989
Singapore	12,812	Singapore	12,092
Madagascar	11,495	India	5,205
Tanzania, United Rep of	4,123	Indonesia	4,370
Indonesia	2,886	United Arab Emirates	2,209
Sri Lanka	1,701	China	1,755
Others	6,460	Others	15,358
Garlic			
World	531,858	World	618,638
China	201,792	Indonesia	93,270
China, Hong Kong SAR	75,130	Brazil	72,054
Argentina	62,316	Malaysia	69,880
Singapore	32,644	Singapore	38,953
Spain	32,404	United States of America	26,626

Others	127,571	Others	317,855
Ginger			
World	163,576	World	158,721
China	62,045	Japan	76,402
Indonesia	36,847	Unites States of America	13,191
India	15,564	United Kingdom	8,092
Thailand	13,382	India	8,038
Brazil	6,309	United Arab Emirates	7,797
Others	29,429	Others	45,201
Mustard Seed			
World	228,924	World	243,159
Canada	156,523	Bangladesh	60,166
Hungary	14,886	United States of America	57,163
Netherlands	11,318	Germany	33,690
Russian Federation	11,152	France	27,367
Czech Republic	10,983	Netherlands	16,849
Others	24,062	Others	47,923
Nutmeg, Mace, Cardamoms			
World	47,491	World	41,757
Guatemala	15,605	Saudi Arabia	6,139
Indonesia	9,382	Netherlands	4,179
Singapore	6,231	India	3,602
Netherlands	2,707	Germany	2,847
India	1,855	United States of America	2,285
Others	11,711	Others	22,705
Poppy Seed			
World	48,934	World	47,977
Czech Republic	15,558	Germany	8,063
Turkey	11,319	Poland	7,294
Netherlands	6,139	Netherlands	5,719
Australia	5,771	United States of America	5,561
Pakistan	5,027	Russian Federation	3,440
Others	5,121	Others	17,901
Vanilla			
World	2,492	World	3,546
Madagascar	642	United States of America	1,496
Indonesia	588	France	390
Germany	198	Germany	321
United States of America	186	United Kingdom	145
Comoros	172	Russian Federation	144
Others	706	Others	1,051
Spices nes			
World	165,128	World	175,581
India	55,169	United Arab Emirates	36,407
United Arab Emirates	20,828	United States of America	16,081
Turkey	11,341	Singapore	7,012
China	10,473	Japan	6,640
United States of America	6,101	United Kingdom	6,611
Others	61,217	Others	102,830

Note : *) re-export not included

Source : 1. Pepper – IPC. 2. Others – FAO

(These statistics are unique and not available from any other single source)

Recommendations

- Generic promotion of pepper, spices and medicinal plants with an emphasis on support for new product development and captive markets for the medicinal properties, herbal remedies, neutraceuticals and natural pharmaceuticals, food colorings, flavors and aromas (IPC, Jakarta, Indonesia) including support of validating through appropriate research and tests known medicinal properties of spices.
- Fast tract project for an international seminar to explore measures to redress structural imbalances between supply and demand, including an assessment of the principal constraints, opportunities and potential solutions for more effective utilization of dynamic growth markets, processing and product development at origin, packaging, marketing and product labeling and harmonized quality standards (IPC, Jakarta, Indonesia/ITC Geneva);
- Development of an Interactive Technology Transfer Information System for Pepper in the Asia and Pacific region- A new CD-ROM Web based approach to dissemination and transfer of technology (IPC, Jakarta, Indonesia/FAO, Rome, Italy);
- New Product Development and Commercial Exploitation of Spices, \Medicinal Herbs and Plants in emerging Nutraceuticala, Natural Pharmaceuticals, Natural Herbal Remedies, Essential Oils, Food Colorings, Flavour and Aromas market;
- Project for the Development of Organic Farming System, Integrated Pest Management, Biocontrol and Regional Certification system to combat herbicide and pesticide residues in spices from the Asia and Pacific region;
- Project for the improvement of Product Quality through improved post harvest technologies to reduce the incidence of Mould, Aflatoxin and Ochratoxin contamination in spices from the Asia and Pacific region.
- Project for the development of Integrated Diversified Farming Systems for Spices in Asia and Pacific countries – Exploring new technologies, genetic improvement and tissue cultures for improved and exotic varieties, seed development, hybridization and demonstration trials for technology transfer and dissemination;
- Fast track project to establish the competitive position, opportunities and threats to vanilla as a natural food flavor ingredient against synthetic substitutes and promotion thereof as an intercrop in suitable agro-climatic regions;
- Fast tract project to establish the competitive position, opportunities and threats for more effective utilization of medicinal herbs and plants.

Conclusion

Consumption of convenience and ethnic foods is expected to increase because more and more people are eager to try the new and varied taste of foreign foods. But there is still a great lack of knowledge about the use of spices and herbs and about their origin. Also the immigrant population is expected to grow further, particularly in developed countries. The usage of spices and herbs by consumers is increasing because they are appreciated as completely natural, rather than artificial, additives. Apart from being directly used by the industrial and catering sectors as well as consumers, they are also the starting points for the production of many flavors and components of flavors.

There is immense scope for increasing the consumption of spices in the pharmaceutical industry if the medicinal properties are clinically proved and popularized. There is bring future for spices like turmeric with high curcuma content, chillies with higher color content and less pungent. Vanilla is another spice, which has high potential as the preference for natural flavor is increasing. Organically produced spices also have increasing demand.

The answer for the question " what is the future outlook for pepper and other spices?" It depends on how far we can achieve in promoting the international consumption of spices. Let us hope and work for the best.

Annexure – A

IPC's Publications

Directory of Exporters and Importers – Pepper and Other Spices.

This publication is also produced in CD-ROM format. It contains the name address, telephone, fax, telex, email, products they deal and neme of the contact person of exporters, importers, agents, brokers, grinders of pepper and pepper products and food processors from all over the world. Index by products, company, activity and country as well as other useful information are also available in this Directory.

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Cardamom Economy of India: Growth and Prospects

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Introduction

Cardamom is an important spice commodity of international commerce ever since the ancient Greek and Roman period. India, the native land of cardamom and Guatemala are the major producers of cardamom in the world. Tanzania, Sri Lanka, Papua New Guinea, Honduras, Costa Rica, El Salvador, Thailand and Vietnam are other cardamom producing countries. In early 1970's, India accounted for nearly 65 per cent of the world production of cardamom but in recent years India's share in the world market declined to less than 28 per cent. Guatemala on the other hand, stepped up its share from 21.5 per cent to more than 64 per cent during the same period (Table 1). India's highest productivity level in years of good crop was three times lesser than the average yield per unit area in Guatemala (250-300 kgs/ha). With multitude of production constraints, Indian cardamom industry is in a vicious circle of "low price – less production – high price - more production – low price". In order to break this vicious circle and enable the country to regain its past glory. there is a need to make a critical evaluation of factors affecting cardamom economy of the country in terms of production, marketing and competitiveness etc. In this article, an attempt is being made in the direction.

Table 1. Production of Cardamom in Major Producing Countries

Period	Per cent share in total by			World Production (mt)
	India	Guatemala	Others*	
1970-71 to 1974-75	65.4	21.5	13.1	4678
1975-76 to 1979-80	53.7	34.5	11.8	6628
1980-81	42.9	48.8	8.3	10250
1984-85	31.9	60.3	7.8	12220
1985-86 to 1989-90	26.5	67.5	6.0	14392
1990-91 to 1994-95	28.4	65.6	6.0	19470
1995-96 to 1997-98	29.8	64.2	6.0	24953
1998-99 to 2000-01	31.4	62.6	6.0	28666

Source: Cardamom Statistics, 1984-85, Govt. of India, Cardamom Board, Cochin.
Spices Statistics, 1991, Govt. of India, Spices Board, Cochin.
Spices Statistics, 1997, Govt. of India, Spices Board, Cochin.
All India Final Estimate of Cardamom – 1997-98, Govt. of India, Ministry of Agriculture
* Estimated figures (actual figures are not available)

Materials and methods

Directorate of Arecanut and Spices Development under the Ministry of Agriculture and Spices Board under the Ministry of Commerce, Government of India provide the official statistics on area, production and productivity of cardamom in India. The trade estimates of production by the Indian Pepper and Spice Trade Association, Kochi is the other source for cardamom statistics in the country. There is wide disparity between the official estimates and trade estimates. Despite the limitations in the estimates, only the official estimates were used for the sake of authenticity. Published literature from various research organizations were made use of to get some broad indications of the possible changes that have been taking place in the crop economy during the last twenty five years and future prospects for the immediate five years in terms of area, production and productivity. Looking to the previous and subsequent normal crop years, 1980-81 was taken as the base year for analysis purpose.

Methodology

To estimate annual growth rates in area, production and prices etc., the exponential model was fitted on the basis of economic and statistical criteria. The following growth model whose equation given below is used for the purpose:

$$Y = e^{**}(b0 + (b1 * t)) \text{ or } \ln(Y) = b0 + (b1 * t).$$

Where, Y is the dependent variable (price), which is estimated in time period 't' in years and 'b' is the growth parameter to be estimated. In this exponential equation 'b' is the growth rate in logarithmic scale.

In order to delineate the impact of area expansion and yield parameters on total production, we have used the technique followed by Libero (1988).

Forecasting

Lack of quality data forced us to choose methodologies, which forecast the future by fitting quantitative models to statistical patterns from historic data for several years. Therefore, univariated methodologies based solely on the history of the variable (one at a time) were tried. Holt Exponential Smoothing model was selected as the best and the forecasting was done for all the three variables i.e. area, production and price. However for forecasting the demand and quantity exported the Box-Jenkins model was used with log transformed data.

The model

Holt's (1957) exponential smoothing model uses a smoothed estimate of the trend as well as the level to produce forecasts. The forecasting equation is:

$$Y(m) = S_t + mT_t \qquad (1)$$

The current smoothed level is added to the linearly extended current smoothed trend as the forecast into the indefinite future.

$$S_t = \alpha Y_t + (1-\alpha)(S_{t-1} + T_{t-1}) \qquad (2)$$

$$T_t = \gamma(S_t - S_{t-1}) + (1-\gamma)T_{t-1} \qquad (3)$$

Where,

m	Forecast lead time
Y_t	Observed value at time t
St	Smoothed level at end of time t
T_t	Smoothed trend at end of time t
γ	Smoothing parameter for trend
α	Smoothing parameter for level of series

Equation 2 shows how the updated value of the smoothed level is computed as the weighted average of new data (first term) and the best estimate of the new level based on old data (second term). In much the same way, equation (3) combines old and new estimates of the one period change of the level, thus defining the current linear (local) trend.

Trends in Area, Production and Productivity of Cardamom in India

The estimated growth index for the time series data on area, production and productivity of cardamom for the period from 1970-71 to 2000-01 are presented in Table 2. A perusal of period-wise performance indicates that significant decline in production was recorded in 1972-73, 1976-77, 1982-83, 1983-84, 1987-88 and 1996-97. Climate exerted greater influence on production, and productivity of cardamom. Ecological changes of the forest habitats and moisture stress due to year-to-year fluctuations in rainfall, both in terms of quantum and distribution are the other factors responsible for considerable fluctuations in production and productivity of the crop. The severe drought that prevailed in certain years affected the yield not only during those years but also in subsequent years. Introduction of irrigation management technologies during summer for the otherwise rain-fed cardamom crop in recent years has stabilized the yield to some extent in certain areas.

Area

Changes in area under the crop over the period from 1970-71 onwards can be grouped as follows (Fig 1):

1. 1970-71 to 1977-78 - Period of no change in the area under cardamom
2. 1978-79 to 1988-89 - Period of increasing trend and
3. 1989-90 to till date - Period of decline.

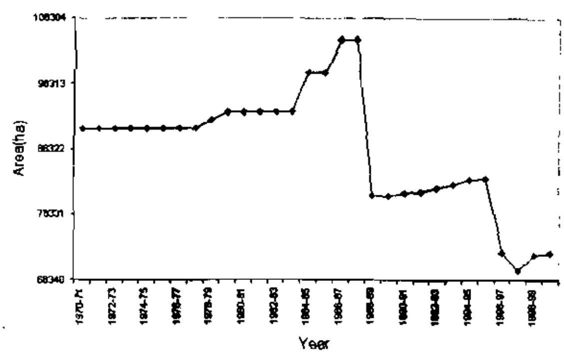

Fig. 1 Area under cardamom in India (1970-2000)

While the area under the crop remained unchanged during the first period for about eight years, there were year-to-year fluctuations in quantity produced, reflecting the climatical effect on productivity. A sudden dip in cardamom area during 1989-90 is not an actual change. It was merely a correction (change) to then existing statistical figures on record. During this year the report of the survey for assessment of area under cardamom in India conducted by Spices Board was published (Spices Board, 1989). Accordingly, the actual enumerated area of 81,113 hectares replaced hither to reported area of 1,05,000ha, which was

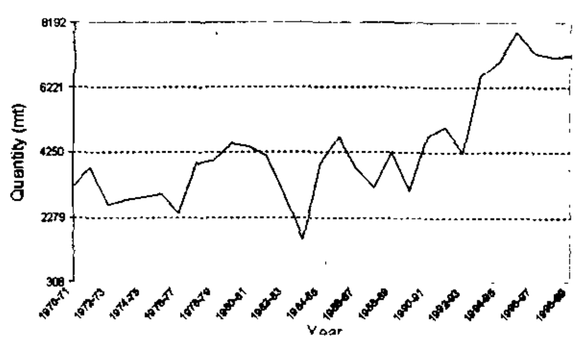

Fig.2. Production trend for cardamom in India (1970-2000)

based on registered area reported by the state government. In the third `period of decline', though there was a marginal improvement during 1992-95, the area under the crop continues to be below the LCL (Lower Confidence Level) of 84818.39ha (fig 1).

Table 2. Area, Production and Productivity in Cardamom (1970-71= 100)

Crop Year	Growth index (1979-80 =100) of Area	Prodction	Yield	Crop Year	Growth index (1979-80 =100) of Area	Prodction	Yield
1970-1971	97.37	72.05	73.99	1986-1987	111.76	86.36	81.14
1971-1972	97.37	86.02	88.36	1987-1988	111.76	72.73	65.09
1972-1973	97.37	60.68	62.33	1988-1989	86.34	96.59	86.44
1973-1974	97.37	63.18	64.89	1989-1990	86.34	70.45	81.61
1974-1975	97.37	65.91	67.69	1990-1991	86.81	107.95	124.36
1975-1976	97.37	68.18	70.02	1991-1992	87.12	113.64	130.45
1976-1977	97.37	54.55	56.03	1992-1993	87.70	96.59	110.14
1977-1978	97.37	88.64	91.03	1993-1994	88.30	150.00	169.89
1978-1979	98.73	90.91	92.08	1994-1995	89.04	159.09	178.69
1979-1980	100.00	102.27	102.28	1995-1996	89.20	179.55	201.30
1980-1981	*100.00*	*100.00*	*100.00*	1996-1997	77.19	165.68	214.65
1981-1982	100.00	93.18	93.19	1997-1998	74.32	162.50	218.66
1982-1983	100.00	65.91	65.92	1998-1999	76.78	162.95	288.28
1983-1984	100.00	36.36	36.37	1999-2000	77.09	212.05	371.56
1984-1985	106.44	88.64	83.28	2000-2001	76.78	238.18	416.40
1985-1986	106.44	106.82	100.36	2001-2002			

Source: Spices Board, Cochin.

Note: Base year-Production 3170 mt, Area-91480 Ha, Productivity-34.65 kg/ha

Source: Data from various issues of `Spices Statistics', Spices Board, Cochin and Agricultural production statistics, Ministry of Agriculture, Govt. of India, Delhi.

Production

A significant feature of cardamom production in India is the cyclical fluctuations in output i.e. after a continuous increase of production and productivity for two to three years a trend of decline sets in and continues before climbing up again. There were cyclical fluctuations during 1973-76, 1978-81 and 1985-87. As it can be observed in fig. 2. the peaks were achieved after gradual increase for two to three years, and then there was a sudden dip. During 1990s, India's production had been showing a consistently increasing trend from 4250 tonnes in 1992-93 to 7900 tonnes in 1995-96, but declined to 6625 tonnes during the subsequent crop year. However, the rate of decline was not as fast as in 70's and 80's. This may be due to improvement in productivity, using improved varieties and better production technology. The increasing trend in production set in from the crop year 1997-98 is being maintained till date and has crossed the 10,000 tonnes mark in the year 2000-01. The favourable climatic conditions coupled with improved technology including irrigation and planned developmental programs are the major factors responsible for increased production. Remunerative price also played a catalytic role in production.

Productivity

The recorded yield level of 34.65kgs/ha during 1970-71 has not shown much improvement till the end of 1980 except for occasional fluctuations towards higher side (up to 48 kgs/ha during 1979-80). It appears that, the yield increase during this period does not seem to have contributed to the increase in production. The entire increases in production being accounted for by area increase. However, the productivity level has improved in 1990s and reached 195 the kg/ha during 2000-2001; i.e. more than four times the productivity of 1980-81.

To understand the contribution of yield and area expansion to the change in total production, the entire study period 1980-81 to 2000-2001) were divided into 4 sub-periods and changes from one sub period to other is worked out and presented in table 3. Except in the first period, in all other periods, change is negative, while it is positive and increasing in the case of production and yield. Thus, it is evident that, the increase in production was solely due to the improvement in yield during the above four periods.

Table 3. Changes in Cardamom (small) production, area and the relative contribution of changes in area and yield on the change in production in India for selected periods.

	1980-81/1984-85 to 1985-86/1989-90	1985-86/1989-90 to 1990-91/1994-95	1990-91/1994-95 to 1995-96/1999-2000	1995-96/1999-2000 to 2000-01
Change in:				
Production[i]	12.72	44.88	40.72	34.91
Area	-0.75	-12.67	-10.11	-2.71
Yield	9.48	72.08	81.41	60.84
*Change in production **due** to:*				
Change in area[ii]	-6.3	-36.54	-34.2	-9.16
Change in yield[iii]	75.61	146.41	174.34	158.7

Source: Spices Board, Cochin.

Note: Analysed based on the method followed by Libero et.al., (1988).

The figures for productivity are a matter of major concern, as it has direct bearing on the cost efficiency and profitability of cardamom cultivation. The estimated negative sign for area and positive sign for yield in all the periods indicated the improvement in productivity i.e. with less area under the crop more quantity is produced. It also indicates the bright future waiting for Indian cardamom economy.

State-wise Area, Production and Productivity

The cardamom belt of India is in the Western Ghats regions of Kerala, Karnataka and Tamil Nadu. Table 4 presents the area, production and productivity of cardamom in different States of India. It is clear from the table that Kerala accounts for the major share of area and production of cardamom in India, and that this remained more or less unchanged over the last three decades. Over the years though productivity per unit area has gone up in all the States, Kerala registered comparatively better performance than the other two cardamom producing states.

Production constraints

The major reasons attributed for low productivity of cardamom in India are (Anon, 1996; George, 1976 and Cherian, 1977).

1. Recurring climatic vagaries, especially drought in the absence of irrigation practice.
2. Absence of regular replantation activities – Under the mixed cropping system farmer is happy with the additional income from the aged cardamom plants, where as replanting with improved high yielding varieties and adoption of high production technologies – though better varieties and practically proved package of practices available to enhance yield level up to 600 kg/ha.
3. Deforestation and resultant changes in the ecological conditions prevailing in the growing area – leading to conversion of cardamom land to other competing crops like pepper etc.
4. Problems of pests and diseases (Katte disease is still the major problem).
5. Remote location of plantations restricts movement of input and output.
6. System of land tenure – does not allow long term planning for improvement by the actual producer who works on the land.

Table 4. *State wise Area, Production and Productivity of Cardamom in India*

Year	Variables	Kerala		Karnataka		Tamil Nadu		India
		Actual	(%)	Actual	(%)	Actual	(%)	
	Area	55190	60.33	28220	30.81	8070	8.81	91480
1970-1971	Production	2130	67.19	805	25.39	235	7.41	3170
	Productivity	38.59		28.53		29.12		34.65
	Area	56380	60.01	28220	30.03	9350	9.95	93950
1980-1981	Production	3100	70.45	1000	22.73	300	6.82	4400
	Productivity	54.98		28.22		32.09		46.83
	Area	43826	53.74	31605	38.75	6123	7.51	81554
1990-1991	Production	3450	72.63	800	16.84	500	10.53	4750
	Productivity	78.72		25.31		81.66		58.24
1995-1996	Area	44248	52.80	33743	40.27	5811	6.93	83802
	Production	5380	68.10	1745	22.09	755	9.56	7900
	Productivity							
	Area	41288	57.09	25947	35.88	5085	7.03	72320
2000-2001	Production	7580	72.33	2100	20.04	800	7.63	10480
	Productivity	247		109		217		195

Source : Spices statistics (various issues), Spices Board, Government of India, Cochin
Note: Area: Ha, Production: MT, Productivity: Kg/Ha

Marketing

Cardamom domestic trade in India is what may be called a regulated trade. Cardamom (Licensing and marketing) Rules 1987 was introduced with a view to streamline the system of marketing in general and bringing about control in the form of restricting the entry of persons into the different functional categories, namely exporters, dealers and auctioneers. More than 70% of the produce sold through the auction centers. However, lot size less than 20 kgs are not coming to the auction centers for economic reasons.

Price Analysis

Analysis of the structure and behaviour of farm prices is of considerable interest in the context of finding ways and means for increasing production and productivity. Prices often act as a guide to indicate the change in production decisions.

Unlike in other spice commodity like black pepper, long-term storage is not possible in the case of cardamom. This necessitates market clearance within the crop year, thereby ruling out speculations. Within these limits the formation of prices in the domestic market takes place in the following manner: Depending upon the length of the summer, severity of drought, pre-monsoon showers and the quantum of rainfall during the June-July period, the well-experienced traders forecast the crop prospects for the forthcoming season. This is aided by the fact that many of the dealers and exporters are also plantation owners. If the expected production is much lower than the normal production, a significantly higher price than that was ruling in the previous year set at the beginning of the season. If on the other hand the expected production is much higher than the normal production, a much lower price is set (Nair *et. al.* 1989). Peak prices (prices ruling during the peak sales season) for the years do not deviate very much from the opening prices in most of the years, but do deviate in abnormal years when production is low and forecast go wrong. Wide variation in prices (especially in an upward direction) is associated with sharp decrease in production.

The export value of cardamom usually depends on its major quality aspects of colour and size. Export traders are keen to acquire as much as possible of the output in the peak harvest season as high quality harvest (with good colour) comes in the middle of the season. This is what makes for the peak prices in the peak-harvesting period, which in turn, becomes the peak sales period. This period broadly falls during September – December. The analysis of relationship between price, lot size and quality reveals that, during the peak season, quality (68%) explains the price variation across different lots and the changes in lot size explain the price variation during the slack season (Joseph, 1985). Accordingly, the formation of auction prices occurs.

Price Transmission

Regarding transmission of price from one level of the marketing system to other, Joseph (1985) reported that the export price leads the domestic price with a lag of about one-month. But according to Nair *et. al.* (1989) though there is trend synchronization between export prices and auction prices, a month to month correspondence does not hold. However, there exists an asymmetry, that a rise in the export price is not always paralleled by a corresponding increase in the domestic price, whereas a fall in the export price is transferred entirely to the domestic price. At times the domestic

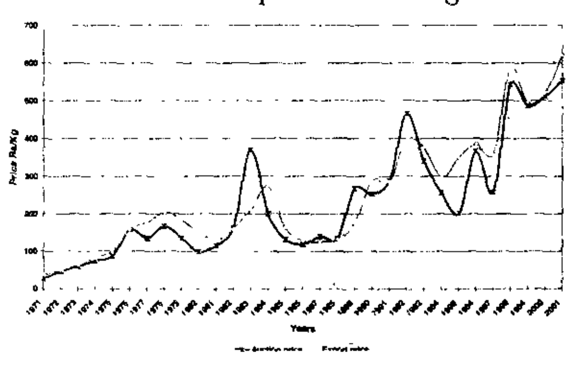

Fig.3. Trend in prices of Cardamom (1971-2001)

(wholesale) price used to be more than the export price indicating the strong domestic market. Therefore, an attempt is made to analyse the trends in auction, wholesale and f.o.b. prices of cardamom during the period from 1971-72 to 2000-01. As it can be seen from fig. 3, all the three price variants of cardamom shows an overall upward trend with cyclical variations and short-term fluctuations.

The summary results for analysis of price transmission models presented in table 5 provides enough evidence to accept the fact that the change in export price transmitted to farm price and whole sale price. Therefore, it can be construed that, cardamom marketing in India is efficient in transmitting price information from one market level to other. The first model shows that a rupee change in export price is estimated to have given rise to 0.88-rupee change in farm prices. The second model shows that a rupee change in export price is estimated to have give rise to 1.00 rupee change in wholesale price and third model shows that a rupee change in wholesale price has given rise to 0.83 rupee change in farm price.

Table 5. Estimated Price Transmission Models

Model No.	Estimated Equation	R^2
1.	Pa = 10.0360 + .8766pe	.742
2.	Pw = -12.645 + 1.0019pe	.784
3.	Pa = 28.8991 + .8336pw	.871

Cyclical movement in cardamom price

A perusal of the period wise movement of cardamom prices brings out an important aspect of cyclical fluctuation of prices, which seems to occur in the following manner: prices remain stable or tend to increase during a certain period followed by a sharp fall. They remain low for the next few years, then start moving up and continue to increase or remain stable for another period; the process of decline and subsequent increase repeats itself. Period of this cycle is worked out to be around 11 years (Nair *et. al.* 1989). These cyclical fluctuations have a significant bearing on the conditions of supply side (area and production).

When the log transformed data on production and farm price for the period from 1971 to 2001 graphed together as in fig 4.; it was observed that both curves were moving in proportionately opposite to each other. The pattern observed in graph can be interpreted as either the price response to supply, or the supply response to price. When the supply swindled in years 1983 and 1992, peak of the price cycle was achieved. But in certain years the price response is much sharper than the supply response to price. As regards supply response to price, it is not immediate, but reflected in jumps over a period causing alternate occurrence of over and short supply. The upswings and downswings in prices are clearly related to these gaps and excess in supply. The length of the upswing is about six years, as the newly planted or replanted field reach peak yielding stage by sixth year only. Thus the jumps in production from one cluster to the next may be interpreted as increases in area taken place about five or six years prior to that period. With such an interpretation, it may be seen that the jumps in production correspond to the early phase of the upswing in prices. The significance of the above correspondence is that, once the farmers ascertain the upswing, they respond to it by bringing new area under the crop by replanting or new planting, or by adopting better crop production practices. Cardamom is a crop, which respond well to the agronomical practices including fertilizer application.

Competitiveness

Productivity and cost of cultivation plays crucial role in deciding the competitiveness of product in the global market. The Central American country, Guatemala enjoyed comparative advantage over India mainly due to two factors: higher productivity and lower wages. As regards productivity per unit area in India, it was mere 47 kg/ha during the 1980s, when it was 91 kg/ha in Guatemala. Until 1990s Guatemala could maintain the productivity advantage, which led to cost advantage. As regards actual production cost, it was Rs.30-40/kg (1980s) when it was Rs.70-90/kg in India (Krishna 1984); which adds another 225% cost advantage to Guatemala over India. Consequently, Guatemala has been able to compete successfully with India in the world market on price front. The price of cardamom from Guatemala in recent years has been about US $5-7 per kg lower than that from India. Besides, the quality of cardamom produced in Guatemala is comparable in characteristics with the exports from India. Such advantages helped Guatemala exporters to penetrate into the prime markets for Indian cardamom. Recent advances in cardamom production technology helped India to increase productivity per unit area. Many progressive farmers have achieved more than 1400 kgs/ha and the highest yield achieved during 1997-98 was 1925/ha in Idukki district of Kerala (Anon, 1999) indicating the existing potential to improve production in the country. However, the labour component in the production cost, which accounts upto 60% during the establishment stage and more than 40% there after in the total production cost makes Indian cardamom much costlier in the international market. Studies have shown that expenditure on labour has positive correlation with yield/ha (Mahabala *et. al.* 1991). The estimated cost of production during 2001-02 in India ranges from Rs.213 (Kerala) to 222 (Karnataka) per Kg. depending upon the area and cropping system followed (Madan, 2003). Due to non-availability of skilled labour for harvesting and post-harvest handling (including on-farm processing), the employment of unskilled labourers resulted in less recovery of 17-19% only against the desirable 25% recovery. Thus, an avoidable post-harvest loss of around 6.8% is also responsible for reduction in productivity.

Export performance

Historically speaking cardamom began to be cultivated in India primarily as an export crop. Till the end of 1960s, cardamom was in the sellers market in the world trade and India was the leader in both production and export. Guatemala stepped up its production from mid 1960's and began capturing India's traditional markets in the Middle East. In 1977-78 Guatemala overtook India in cardamom export and is dominating the world market

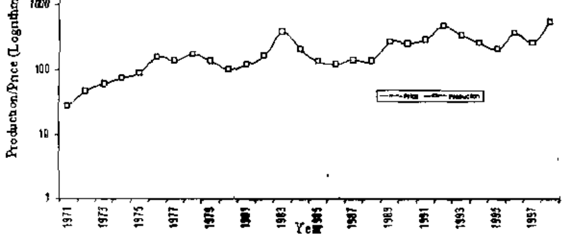

Fig. 4. Trend in cardamom production and farm price

for cardamom till date. Table 6 shows the export of cardamom as per cent of total production from India. The trend in export of cardamom from India depicted in the form of graph in fig. reveals the fact that export was in proportion to the production till 1985-86. There after, there was a consecutive fall in export during 1986-87 and 1987-88. Though the level of production went up, quantity exported remained low. The gap between production and export started widening and the trend still goes on. During this period, there was a heavy flow of cardamom from Guatemala into the world market; their overall export quantity has more than doubled. So, India could not compete with its competitor. Export promotion schemes such as airfreight subsidy to Middle East countries, excemption of cess and export assistance of Rs.35/kg etc. could not help much to enhance export quantity.

Table 6. Cardamom Exports from India (1970-71 to 2000-01)

Year	Quantity exported (MT)	Growth index	Export value ('000 Rupees)	Growth index	Export as per cent to total production
1970-71	1705	72.71	112000	32.23	53.79
1971-72	2141	91.30	80000	23.02	56.57
1972-73	1384	59.02	68000	19.57	51.84
1973-74	1813	77.31	115000	33.09	65.22
1974-75	1626	69.34	133000	38.27	56.07
1975-76	1941	82.77	194000	55.82	64.7
1976-77	893	38.08	140314	40.37	37.21
1977-78	2763	117.83	484363	139.37	70.85
1978-79	2876	122.64	583536	167.91	71.9
1979-80	2636	112.41	485581	139.72	58.58
1980-81	*2345*	*100.00*	*347539*	*100*	*53.3*
1981-82	2325	99.15	301969	86.89	56.71
1982-83	1032	44.01	163690	47.10	35.59
1983-84	258	11.00	54423	15.66	16.13
1984-85	2383	101.62	648653	186.64	61.1
1985-86	3272	139.53	534599	153.82	69.62
1986-87	1447	61.71	184953	53.22	38.08
1987-88	270	11.51	34003	9.78	8.44
1988-89	787	33.56	103736	29.85	18.52
1989-90	180	7.68	30668	8.82	5.81
1990-91	379	16.16	102224	29.41	7.98
1991-92	544	23.20	155741	44.81	10.88
1992-93	190	8.10	75057	21.60	4.47
1993-94	387	16.50	145483	41.86	5.86
1994-95	257	10.96	76261	21.94	3.67
1995-96	527	22.47	129697	37.32	4.75
1996-97	226	9.64	86967	25.02	3.1
1997-98	370	15.78	126678	36.45	4.15
1998-99	476	20.30	252527	72.66	6.62
1999-00	646	27.55	320184	92.13	5.92
2000-01	1100	46.91	565470	162.71	10.5

Source : Various Issues of Spices Statistics, Spices Board, Govt. of India. * Midterm estimate by Spices Board

As it can be seen from the above table, domestic market has absorbed almost the entire production. In the absence of household consumption data to estimate the quantum of domestic consumption, deducting the quantity exported from total production gives the quantity consumed within the country. This domestic demand was estimated to be around 3500 tons during 1988-89 (i.e. 82.4% of the total production) and during 1997-98 the domestic market has consumed around 6850 MTs accounting 95 per cent of the production in the country. Thus derived domestic demand during 1997-98 is around 6850 Mt., which is more than half of the world demand. The estimated demand was around 7200 tones in 1998 (Anon 1998).

Direction of Indian Exports

Till the end of 1980's more than 80 per cent export of Indian cardamom was to the Middle East Arab countries, which was having increasing demand in the 80's because of the enormous increase in the per capita incomes of these countries. But, in recent years, i.e. nineties the share of Middle East market in Indian exports in general have shown a decreasing trend. Further, there was a change over from quality consciousness to price sensitivity. Cardamom from Guatemala, which was, priced $4-5/kg less than the Indian cardamom, was readily accepted. The result was, India has lost its traditional market. India has lost its East European market also, after the collapse of erstwhile USSR. Japan is the only consistent market for Indian cardamom in recent years. In 1995-96 more than 60% of the total export (226 Mt.) from India was to Japan. India tops the suppliers of cardamom to Japan with 66%, followed by Guatemala and Vietnam. Japan buys the second grade of Alleppy Green cardamom from India. It is also worth noting that Japanese buyers maintained consistency in purchase of Indian cardamom even in years of high price. Saudi Arabia and Kuwait are the other markets. Export of cardamom during 1996-97 was to the tune of 240 tonnes valued Rs. 9.21 crores compared to 500 tonnes valued Rs.12.40 crores of 1995-96. The two major countries to which cardamom exported during the year have been

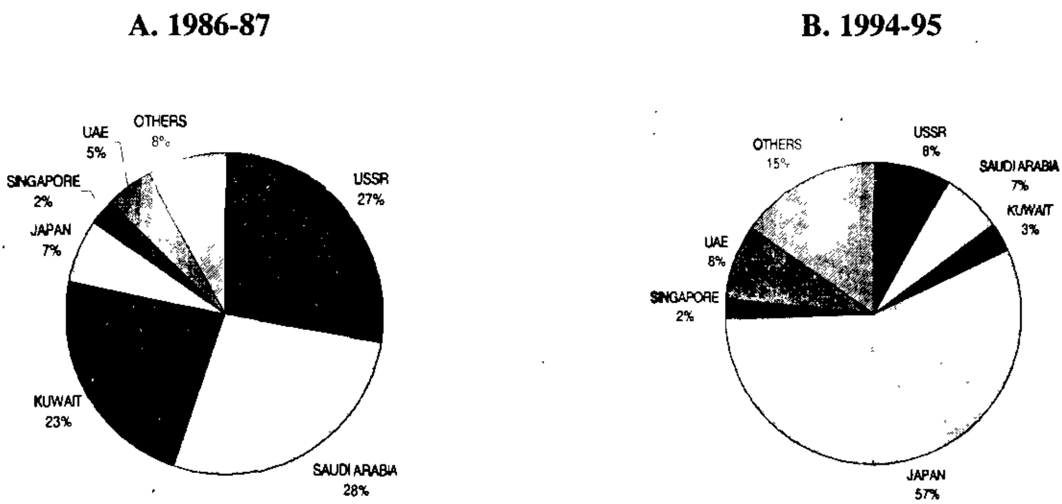

Fig. 5. Direction of Indian export of cardamom during 1986-87 and 1994-95

Japan – 163 tonnes and Saudi Arabia 45 tonnes. Direction of Indian export of cardamom during the years 1991-92 and 1995-96 is presented in fig 5a and 5b. Guatemala usually produces 12,000 to 14,000 tonnes. It is reported that their domestic requirement is almost negligible. Hence their entire produce is pushed to the international markets at a very competitive price. On an average India has imported 157 tones of cardamom between 1996-97 and 2001-02. It was maximum during the crop year 2001-02 (310 tonnes).

Fore casting the future

While the demand side is influenced by many other factors including the overall economic development, the supply side is influenced not only by economic factors but also by agro-climatic, biotic, and abiotic stress factors in the growing region. The response to price change gets reflected in the form of change in supply after 5-6 years only. Keeping this fact in mind the forecast was made to understand the overall direction in which the supply (area and production) will move and price fluctuates. Forecast is made with upper and lower confidence limits. The upper confidence limit is calculated for 97.5 per cent and the lower for 2.5% i.e. the actual should fall inside the confidence band 95% of the time.

Demand

The major markets for cardamom are Saudi Arabia, Kuwait, Jordan, Qatar, UAE, USSR and Western Europe. Other important importers include West Germany, Pakistan, UK, Japan and Iran. The highest consumption of cardamom takes place in the Middle East where it is used in the preparation of their traditional drink 'gahwa'. This market accounts for 80% of the total world consumption (UNCTAD, 1985). In Europe, Scandinavian countries use cardamom to flavour bread and pastries. Cardamom is imported in raw and ground forms for use in food manufacturing and special blends. Among the producing countries, India consumes the largest quantity in the world.

The growth equation fitted for the consumption trend in the country is:

$$\ln Dt = 6.7110 + 0.0725T \qquad R2 = .815$$

Accordingly, the estimated growth rate is 7.3% per annum. Thus, the growth rate in demand is much more than the growth rates in production. Under the circumstances, it is unlikely that India can reclaim its position as the world's largest producer and exporter because an increasing percentage of production will be consumed domestically leaving nothing much for export. Though there is a shift in the consumption pattern of Middle East countries from high quality Indian cardamom to cheaper Guatemala cardamom, there is no reduction in quantity consumed. Further, new markets are emerging for this commodity. While the household consumption sector remains intact, rather increasing along with the population growth, the recent development of new uses in industrial sector (food and non food) also expected to enhance the demand for the commodity. The global import demand for cardamom is expected to be around 20000mt in 2005.

Projections of supply

Projections made for production and price is given in table 7. Though both area and production are expected to grow slowly in the immediate future, the growth in production is expected to be more pronounced than in area indicating the improvement in yield per unit area. As per the cyclical movement discussed earlier, after the peak so achieved in 1995-96, three-year period of decline is already over, it is the turn of increasing trend to reach the next peak in the cycle. If the present trend is any indication the expected production level will be above 12000 tons; and the area expansion is expected to touch 90000 ha during the same period. The improvement in internal and international price will catalyze the supply to jump in the usual fashion discussed earlier.

Table 7. Forecasted production and price of cardamom in India

Year	Predicted Production (MT/Ha)			Predicted Price (Rs./Kg)		
	Lower limit	Historic	Upper limit	Lower limit	Historic	Upper limit
1999	5279	7561	9843	76.31	384.24	668.51
2000	5091	7692	10292	86.16	396.06	682.31
2001	4926	7822	10719	95.84	407.88	696.29
2002	4777	7953	11130	105.32	419.71	710.46
2003	4639	8084	11529	114.6	431.54	724.82
2004	4511	8215	11919	123.69	443.36	739.38
2005	4390	8345	12301	132.57	455.19	754.15

The forecasted prices indicate that the prevailing higher market price is expected to continue in the near future and there is also a possibility for the price to cross the Rs.1000/kg mark before falling down as per the usual cyclical fluctuations. Availability of less exportable surplus will have direct effect on the export. The forecasted standard scenario indicates that the trend prevailing for the last five years will continue for the five years to come i.e. the export will remain low. The alternative scenario will be an increased import of cheaper Guatemala cardamom and increase to meet domestic demand and in export of quality Indian cardamom to avail the benefit of prevailing better price in the world market.

Conclusion and policy issues

The objective of this article is to analyze the performance of the cardamom industry in terms of area, production, and productivity, export prices and their inter-relationship. In this, the movement of prices, price cycles and supply response to price variation etc. has been considered. Finally, an attempt is also made to quantify the uncertain future using forecasting models. The following are the main findings:

1. While the increase in production during the 80s was mainly due to increase in area, during the 90s the increase in production is due to improvement in productivity. However, the yield gap that exists between the potential productivity level and average achieved level of productivity in the country indicates the possibility of improving yield level considerably.
2. There is a definite pattern of cyclical fluctuation in prices mainly due to the producers' response to price by new and replanting, which will yield after a certain time lags. Thus the cyclical fluctuations in prices have an implicit bearing on the condition of supply through farmer's response.

3. In the export front, country has lost most of its traditional markets to Guatemala mainly because of the incompetitive price of the Indian cardamom in the international market. Guatemala derives its price competitiveness mainly from less production cost and high productivity per unit area.
4. In the changed scenario, Japan is the steady and reliable market for Indian cardamom. Due to decline in oil prices and consequent fall in purchasing power the Middle East market has changed from quality conscious to price sensitive.
5. The forecasted future and the hanging scenario because of the comparative advantage in opportunity cost enjoyed by the Indian farmer indicate that there will be a steady increase in supply (production & yield). Finally, the price expected to either move up or to remain steady at the present level.

The future scenario presented here can change drastically as a result of innovative product development, diversification of some entirely new application if discovered for cardamom or its products. Imaginative product development programs have to be initiated to boost up the consumption pattern. Attractive formulations backed up by catchy advertisements can do wonder in this field.

References

Anonymous (2003). Economics of Cardamom cultivation. *Draft Annual Report*, Indian Institute of Spices Research, Calicut.

Anonymous (1996) Alternative crops for cardamom, *Report of the Expert Committee*, Spices Board, Cochin.

Cherian, A. (1977) Environmental ecology – an important factor in cardamom cultivation. Cardamom, 9 (1), 9–11.

George, K.V. (1976) Production constraints in cardamom. Cardamom News, 8 (3), 9–16. John, K. (2000) Nigallanni green gold at cardamom productivity helm with precision farming techniques. In spices and Aromatic Plants, pp.105–106, Indian Society for Spices, Calicut.

Joseph, K.J. (1985) Marketing and price formation of cardamom in Kerala, M.Phil thesis submitted to the Jawaharlal Nehru University, New Delhi.

Korikanthimath, V.S. (1992) High production technology in cardamom. In. Y.R Sarma,

S. Devasahayam, and M. Anandaraj (eds) Black Pepper and Cardamom: Problems and Prospects, Indian Society for Spices, Calicut, pp. 20–30.

Librero, Aida, R., Nineveth E. Emlano and Myrna, B. Ocompo (1988). Estimating returns to research investment in mango in the Philippines. Los Banos, Laguna; Philippino Council for Agriculture, Forestry and Natural Resources Research and Development, 1988, 114p.

Krishna, K.V.S. (1979) Harvesting of cardamom in Idukki district. Cardamom, 2, 3–8.

Mahabala, G.S., Bisaliah, S. and Chengappa, P.G. (1990) Resource use efficiency and age-return relationship in cardamom plantations. J. Plantation Crops, 20 (Supplement), 359–365.

Nair, K.N., Narayana, D. and P.Sivanandan, (1989). Ecology or Economics in Cardamom development. Occasional paper, Centre for Development Studies, Trivandrum.

Radhakrishnan, C. (1993) Economics of pepper production in India. Report of the Research Project Sponsored by Spices Board, Government of India, Spices Board, Cochin.

Spices Board, (1990) Status paper on spices. Spices Board, Ministry of Commerce, Government of India, Cochin, Kerala.

Spices Board, (1991) Report of the survey for assessment of area under small cardamom in India.

Spices Board, (2000) Draft Annual Report (1999–2000). Spices Board, Ministry of Commerce, Govt. of India, Cochin, p. 22.

Thomas, E.K., Indiradevi, P. and Jessy Thomas, K. (1990) Performance of Indian cardamom-an analytical note. Spices India, 3(6), 19–23.

UNCTAD/GATT, (1982) Spices: a survey of the world market, International Trade Centre, Geneva.

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An insight in non-tariff barrier in export of spices: Pesticide Residues

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Introduction

As the demand for spices is increasing globally there is enormous potential in the export market of these commodities In the case of pesticide residues in food, if no national standards have been set, then the limit of detection of that particular pesticide is taken as MRL without considering the food factor. The lack of codex MRLs therefore creates a major problem in international trade of spices. Realizing the problem, the task of generating residue data from supervised field trials by following good agricultural practices (GAPs) and monitoring data had been undertaken by AICRP on pesticide residues. The Coimbatore, Vellayani, Jaipur and few other centers of the project have conducted supervised field trials on cardamom, chilli, black pepper & coriander. Data on residues of acephate, cypermethrin, dicofol, dimethoate, endosulfan, fenvalerate, malathion, mancozeb, monocrotophos, phosalone, phosphamidon, quinalphos and triazophos on chilli; endosulfan, fenthion, mancozeb methyl parathion, monocrotophos and quinalphos on cardamon; endosulfan, monocrotophos and phosphamidon on coriander and dimethoate, mancozeb and quinalphos on pepper is available with AICRP on Pesticide Residues. Based on this data pre-harvest interval (PHI) and MRLs, pesticides–spices combination have been proposed to the Ministry of Health.

Details of work done by AICRP on Pesticide Residues

In order to recommend Maximum Residue Limit for specific pesticide-spices set supervised field trials using good agricultural practice were carried out at different coordinating centers of the project.

Supervised field trials on

Cardamom

Cardamom accounts for the 60% of the world trade. Supervised field trials on residue of fenthion, monocrotophos, quinalphos, endosulfan and mancozeb were conducted at Coimbatore and Vellayani centers of the project (Table-1). On the basis of these trials, the safe waiting period has been found to be 10-14 days for endosulfan, 9 days for mancozeb, 20 days for fenthion, 20-24 days for monocrotophos and 22-25 days for quinalphos (Table 2).

Table 1. Supervised field trials on cardamom

Insecticide	Place	Year	Variety	Dose g ai/ha	Treatment	Plot size sq m	Replic-ates	Analytical method
Endosulfan	Coimbatore	1989	Malabar	700 1400		2x2	2	GC-ECD
Mancozeb	Vellayani	1993	Malabar	2000 4000	At fruit setting stage	4x10	2	Spectrophotometric
	Coimbatore	1991	Malabar	1250 2500	At flowering and early fruiting stage	4x10	3	Spectrophotometric
Fenthion	Coimbatore	1985	Malabar	500 1000	At flowering and early fruiting stage	2x2	2	GC-NPD
Monocrotophos	Coimbatore	1986	Malabar	500 1000	At flowering and early fruiting stage	2x2	2	GC-NPD
	Vellayani	1987	Malabar	500 1000	At flowering and early fruiting stage	2x2	2	GC-NPD
	Vellayani	1988	Malabar	500 1000	At flowering and early fruiting stage	2x2	2	GC-NPD
Quinalphos	Coimbatore	1986	Malabar	500 1000	At flowering and early fruiting stage	2x2	2	GC-NPD
	Vellayani	1987	Malabar	500 1000	At flowering and early fruiting stage	2x2	2	GC-NPD
	Vellayani	1988	Malabar	500 1000	At flowering and early fruiting stage	2x2	2	GC-NPD

Table 2. Residues of pesticides on cardamom

Insecticide	Place	Year	Dose g ai/ha	Residues ($mg\ kg^{-1}$) Days after application in pods					SWP	Reference
				1	3	7	15	30		
Endosulfan	Coimbatore	1989	700 1400	3.555 8.985	2.415 2.860	1.915 1.965	1.040 1.345	0.846 0.935	14.33 10.35	Annual Report, TNAU, 1988-90
Mancozeb	Vellayani	1993	2000 4000	7.07 14.76	4.69 10.58	3.16 8.05				Annual Report, Vellayani, 1991-93
	Coimbatore	1991	1250 2500	22.06 27.75	14.78 21.65	5.53 6.75	3.31 4.31	0.99 1.19	9.16	Annual Report, TNAU, 1991-93
Fenthion	Coimbatore	1985	500	3.338	1.948		0.420	0.1766	20	Annual Report, TNAU, 1987-88
Monocrotophos	Coimbatore	1986	500 1000	1.177 1.995	0.782 1.054	0.667 0.758	0.532 0.692	0.484 0.5278	20	Annual Report, TNAU, 1987-88
	Vellayani	1987	500 1000	3.43 7.26	2.12 4.05	1.07 1.98			23 24	Annual Report, Vellayani, 1987
	Vellayani	1988	500 1000	2.032 3.533	1.838 2.20	0.877 1.221				Annual Report, Vellayani, 1988-89
Quinalphos	Coimbatore	1986	500 1000	2.246 3.427	1.423 2.582	0.462 0.942	0.388 1.561	0.241 0.5144	25	Annual Report, TNAU, 1987-88
	Vellayani	1987	500 1000	0.46 0.73	0.27 0.39	0.09 0.17			22 23	Annual Report, Vellayani, 1987
	Vellayani	1988	500 1000	2.633 3.805	2.134 2.040	0.576 0.914				Annual Report, Vellayani, 1988-89

Pepper

Supervised field trials on the persistence and dissipation of mancozeb, dimethoate and quinalphos residues on pepper were carried out at TNAU Coimbatore and KAU,

Table 3. *Supervised field trials on Pepper*

Insecticide	Place	Year	Variety	Dose g ai/ha	Treatment	Plot size m^2	Replic -ates	Analytical method
Mancozeb	Coimbatore	1991	Panniyur	1250 2500	At flowering and early fruiting stage		3	Spectroph otometric
	Vellayani	1993	Panniyur	2000 4000	Tender spike formation and berry maturation stage	4x10	2	Spectroph otometric
Dimethoate	Coimbatore	1986	Panniyur	600 1200	First at flowering and one month thereafter	4x10	4	GC-NPD
	Vellyani	1987	Kottanadan	500 1000	Since 28 days till harvesting 6 spray	40	3	GC-NPD
	Vattappara	1988	Kottanadan	500 1000	First at flowering and one month thereafter	4x10	3	GC-NPD
Quinalphos	Vellyani	1987	Kottanadan	500 1000	Since 28 days till harvesting 6 spray	40	3	GLC
	Vattappara	1988	Kottanadan	500 1000	First at flowering and one month thereafter	4x10	3	GC-NPD

Table 4. Residues of pesticides on pepper

Insecticide	Place	Year	Dose g ai/ha	Residues (mg kg^{-1}) Days after application in pods					SWP	Reference
				1	3	7	15	30		
Mancozeb	Coimbatore	1991	1250 2500	26 79 35.59	17.19 28.53	9.19 14.99	5.43 9.23	2.72 6.52	14.54	Annual Report, TNAU, 1991-93
	Vellayani	1993	2000 4000	9.80 13.46	6.37 10.75	5.49 8.90				Annual Report, Vellayani, 1991-93
Dimethoate	Coimbatore	1986	600 1200	1.267 1.296	0.606 0.873	0.117 0.315	0.083 0.192	0.019 0.108	14	Annual Report, TNAU, 1987-88
	Vellyani	1987	500 1000	5.64 6.34	4.17 5.21	0.81 1.73	0.0005 0.002		5 6	Annual Report, Vellayani, 1987
	Vattappara	1988	500 1000	2.001 2.669	1.539 2.196	1.017 1.260				Annual Report, Vellayani, 1988-89
Quinalphos	Vellyani	1987	500 1000	0.58 0.81	0.45 0.70	0.37 0.63			12 19	Annual Report, Vellayani, 1987
	Vattappara	1988	500 1000	0.763 1.453	0.561 0.869	0.269 0.644			6 7	Annual Report, Vellayani, 1988-89

Vellayani (Table 3). The waiting periods worked out show marked variation between the two places, which varied from 7-12 days for quinalphos, from 5-14 days for dimethoate and 14.5 days for mancozeb (Table 4).

Chillies

Chilli export is particularly affected by the presence of pesticide residue. Supervised field trials on chilli has been conducted for a number of pesticides at RAU, Jaipur, ANGRAU, Hyderabad, TNAU, Coimbatore (Table 5 & 6).

Table 5. Supervised field trials on Chillies

Insecticide	Place	Year	Variety	Dose ai/ha	Treatment	Replic-ates	Analytical method
Dicofol	*Coimbatore*	*1995*	*Gundu*	500 1000	At flowering stage and 15 days thereafter.		GC-ECD
Quinalphos	Coimbatore	1994	Gundu	500 1000	At flowering stage and 15 days thereafter.		GC-NPD
Lindane	Coimbatore	1995	Gundu	350 700	At flowering stage and 15 days thereafter.		GC-ECD
Mancozeb	Coimbatore	1995	Gundu	350 700	At flowering stage		Spectrophoto metric
Acephate	Hyderabad	1996	Sindhur	1500	At fruiting & harvesting stage	3	GC-NPD
Cypermethrin	Hyderabad	1996	Sindhur	300	At fruiting & harvesting stage	3	GC-ECD
Malathion	Jaipur	1991	Local	625 1250	At fruiting & harvesting stage	3	GC-NPD
	Jaipur	1992	Local	625 1250	At fruiting & harvesting stage	3	GC-NPD
Methyl demeton	Jaipur	1991	Local	250 500	At fruiting & harvesting stage	3	GC-NPD
Phosphmidon	Jaipur	1991	Local	210 420	At fruiting & harvesting stage	3	GC-NPD
Triazophos	Hyderabad	1996	Sindhur	0.70	At fruiting & harvesting stage	3	GC-NPD

Fixing of maximum residues limit (MRL) of different pesticides on spices

Based on supervised field trails conducted by AICRP on Pesticide Residue and after the analysis of toxicological and residue data, the following maximum residue limits have been proposed. The Registration committee has approved the waiting period and maximum residue limit in respect of following pesticides on chilli , cardamom and pepper.

Monitoring of pesticide residues on spices

Monitoring data of pesticide residues in market samples of spices is also required by JMPR for consideration for the elaboration of codex MRLs. Monitoring of spices samples for the pesticide residues was also started by AICRP on Pesticide Residues. During the year 2000, ninety nine samples of chilli, turmeric, cumin, pepper, cardamon, fennel, coriander and fenugreek were analyzed, out of which 42% samples were found

Table 6. Residues of pesticides on chillies

Insecticide	Place	Year	Dose g ai/ha	Residues (mg kg^{-1}) Days after application in pods					Reference
				0	1	3	7	15	
Dicofol	Coimbatore	1995	500	6.68	3.21	1.84	0.42	BDL	Annual Report,
			1000	12.0	6.08	2.86	0.82	BDL	TNAU, 1996-97
Quinalphos	Coimbatore	1994	500	4.11	2.07	0.91	0.36	0.015	Annual Report,
			1000	7.78	3.97	0.36	0.57	0.060	TNAU, 1995-96
Lindane	Coimbatore	1995	350	2.60	2.12	1.31	0.75	0.29	Annual Report,
			700	4.55	3.61	2.39	1.11	0.60	TNAU, 1996-97
Mancozeb	Coimbatore	1995	350	12.2	6.40	4.62	2.05	0.09	Annual Report,
			700	14.87	8.9	5.73	2.75	0.15	TNAU, 1996-97
Acephate	Hyderabad	1996	1500	0.19	0.11	0.02		ND	Annual Report, APAU, 1996-98
Cypermethrin	Hyderabad	1996	300	0.85	0.58	0.42		ND	Annual Report, APAU, 1996-98
Malathion	Jaipur	1991	625	11.0	3.15	1.57	ND		Annual Report,
			1250	14.7	5.16	2.26	ND		RAU, 1991-92
	Jaipur	1992	625	10.88	3.06	1.53	ND		Annual Report,
			1250	15.10	5.43	2.43	ND		RAU, 1991-92
Methyl demeton	Jaipur	1991	250	8.4		4.2		0.30	Annual Report,
			500	14.32		10.28		0.8	RAU, 1991-92
Phosphmidon	Jaipur	1991	210	3.72	2.37	1.79		ND	Annual Report,
			420	4.97	3.77	2.78		0.12	RAU, 1991-92
Triazophos	Hyderabad	1996	0.70	0.70	0.43	0.22		0.11	Annual Report, APAU, 1996-98

Maximum residue limit (MRL) and preharvest intervals (PHI) proposed

Crops	Pesticides	PHI (days)	MRL (PPM)
Chilli	Acephate	10	0.1
	Cypermethrin	10	0.5
	Dicofol	15	1.0
	Do,etjpate	15	0.5
	Endosulfan	10	1.0
	Fenvalerate	25	0.5
	Malathion	15	0.5
	Mancozeb	10	1.0
	Monocrotophos	15	0.2
	Phosalone	15	0.2
	Phosphomidon	15	0.2
	Quinalphos	25	0.2
	triazophos	15	0.2
Cardamom	Endosulfan	30	1.0
	Fenthion	30	0.5
	Mancozeb	30	2.0
	Methyl parthion	30	0.5
	Monocrotophos	30	0.5
	Quinalphos	30	0.5
Pepper	Dimethoate	30	0.5
	Mancozen	30	5.0
	Quinalphos	30	0.5

contaminated with residues of DDT, HCH, endosulfan, methyl parathion, quinalphos, monocrotophos and mancozeb and during the year 2001, 37% of the 92 samples of different spices were found contaminated with residues of HCH, chlorthalonil, chlorpyriphos, endosulfan, methyl parathion, quinalphos, monocrotophos and mancozeb.

References

All India Coordinated Research Project on Pesticide Residue, Annual Report, TNAU, Coimbatore, 1987-88.

All India Coordinated Research Project on Pesticide Residue, Annual Report, TNAU, Coimbatore, 1988-90

All India Coordinated Research Project on Pesticide Residue, Annual Report, TNAU, Coimbatore, 1991-93.

All India Coordinated Research Project on Pesticide Residue, Annual Report, TNAU, Coimbatore, 1995-96.

All India Coordinated Research Project on Pesticide Residue, Annual Report, TNAU, Coimbatore, 1996-98.

All India Coordinated Research Project on Pesticide Residue, Annual Report, Vellayani, 1987

All India Coordinated Research Project on Pesticide Residue, Annual Report, Vellayani, 1988-89

All India Coordinated Research Project on Pesticide Residue, Annual Report, Vellayani, 1991-93

All India Coordinated Research Project on Pesticide Residue, Annual Report, RAU, Jaipur, 1991-92

All India Coordinated Research Project on Pesticide Residue, Annual Report, APAU, Hyderabad, 1996-98

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Studies on spouted bed drying of cardamom (*Elettaria cardamomum* Maton.) capsules on flavour and aroma compounds

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Abstract

Studies were conducted on drying of cardamom (*Elettria cardamomum* Maton.) through spouted bed drier to assess the different quality parameters viz., volatile oil and aroma compounds. It was found that quality of the cardamom capsules dried by intermittent spouting process was found to be superior on confirmation with gas chromatographic studies for the aroma compounds like 1,8 cineole, terpinyl acetate and other fractions on chromatographic separation. It was observed that maximum recovery of volatile oil was attained by cardamom sample dried at an air temperature of 40^0 C with draft tube height of 40 cm with 5 cm separation distance and slant angle of 60^0. In the case of intermittent spouting, 10 to 15 per cent increase in oleoresin content was observed compared to continuous spouting samples. It was revealed that all variables viz., tempering, slant angle, air temperature, separation distance and draft tube height had significant effect on flavour quality of cardamom.

Key words: cardamom, drying, 1,8 cineole, terpinyl acetate, intermittent spouting.

Introduction

Cardamom, the queen of spices, is native to evergreen forests of Western Ghats region of India. It is cultivated in about 84,000 ha with the total production of around 12,350 MT mainly confined to southern states like Kerala, Karnataka and Tamil Nadu accounting for 60, 30 and 10 % of the total area respectively. To meet the stupendous growth in domestic demand and the export potential of quality cardamom, the base of the cardamom production has to be strengthened by better processing and post harvest techniques.

Drying is one of the important unit operations as it determines the colour of the end product, which is the most important quality character. Besides colour, it decides the quality constituents responsible for cardamom (Elaichi) flavour viz., 1,8 cineole, terpinyl acetate, linalool and their fractions, which are collectively responsible for flavour quality of cardamom capsules. Conventional kiln drying of cardamom restricts the control on temperature, humidity and aeration inside the kiln chamber and this may influence the quality constituents of cardamom capsules. Unlike the volatile oil of ginger, the other spice from the *Zingiberacae* family, the cardamom oil has volatile mono or sesquiterpene hydrocarbons and is dominantly made up of oxygenated compounds, all of which are potential aroma compounds. The major compounds in cardamom oil is 1,8 cineole, terpinyl acetate, pinene, sabinene, myrcene, linalyl acetate, linalool etc. which makes the cardamom volatile a unique combination .

Materials and methods

Raw materials

Freshly harvested cardamom, Mysore variety, procured from Cardamom Research Station, Kerala Agricultural University, Pampadumpara, was used in the experiments. Immediately after harvest, they were washed thoroughly in running water to remove adhering extraneous matter. Immature and pest affected cardamom capsules were removed. Washed and cleaned cardamom capsules were taken for the experimental purpose.

Based on the results obtained from preliminary studies on fluidized bed drying of cardamom (Balakrishnan, 1995), it was found that spouted bed drying system was better for cardamom in terms of the quality of the end product and hence a batch type spouted bed drier was designed and developed.

Flavour quality of cardamom

The most significant component of cardamom is the volatile oil with its characteristic aroma, described generally as camphory, sweet, aromatic spicy. The capillary column gas chromatographic analysis has shown over 150 components; except for a few high boiling components, many of the major compounds numbering about 30 have been identified (Bernhard *et al.* 1971). While many of the identified compounds – alcohols, esters and aldehydes are commonly found in many spice oils, the dominance of the ether, 1,8-cineole and the esters, α-terpinyl and linalyl acetates in the composition, make the cardamom volatiles a unique combination. The ratio of 1,8-cineole to α-terpinyl acetate in the range of 0.7 to 1.4 is a fairly good index of the purity and authenticity of cardamom volatile oil (Wijesekara & Jayawardena, 1973).

Purseglove *et al.* (1981) have pointed out that the necessity of complete distillation of cardamom to obtain the full flavour character of the oil. They have shown that at least 4 hours distillation is required to produce the full ester content of the oil. The steam distillation process yields 2.3 per cent of oil of large cardamom seed and liquid CO_2 extraction processes (60 bar 20ºC) gave 2.1% of the extract (Sumanjeet kaur *et al.* 1993). The essential oil composition of both the processes was compared by thin layer and gas chromatographic analysis to identify the major constituents. During hydro distillation of cardamom seeds, the oil and corresponding water layers were analyzed at various time intervals. It was found that terpinyl acetate was the major compound present in the water-soluble fraction along with farnesol and neryl acetate (Nirmala Menon & Sreekumar, 1994).

The volatile oil content was estimated by hydro distillation method using Clevenger apparatus (ASTA, 1997). 50 g of the cardamom powder was weighed and transferred to the round bottom flask. 500 ml distilled water was mixed thoroughly and transferred to the Clevenger apparatus. Distillation rate of 1 to 2 drops per second was maintained.

On boiling, the oil was collected in the receiver of the apparatus, which contains distilled water.

$$Volume\ of\ oil, \%(v/w) = \frac{Volume\ of\ oil\ (ml)}{Weight\ of\ sample\ (g)} \ x\ 100$$

Oleoresin content from cardamom is estimated by using soxhlet apparatus. The content was calculated by using the formula suggested by ASTA (1997)

$$Oleoresin, \% = \frac{Weight\ of\ residue}{Weight\ of\ sample} \ x\ 100$$

Fractionation of volatile oil compounds was estimated by gas chromatographic method. Essential oil profile was carried out in a HS – 40 Perkin Elmer Auto system gas chromatograph equipped with 1022 PE Nelson GC plus integrator. 0.5µl of cardamom oil was taken from a micro syringe and injected. The sample was carried by a carrier gas (N_2) to the Flame Ionization Detector (FID), where the mixture of hydrogen and air ignited the volatile compound by a OV–17 packed column having a boiling point of above 500°C. The volatile compounds were released one by one based on their retention time and boiling point. The ionic signals were converted in to electronic signals and the peaks were identified based on chromatogram of authentic standards. The volatile compounds were identified by GC analysis under the following conditions.

Oven programme	:	70 –210°C @ 5 °C/min
Detector	:	Flame Ionization Detector (FID)
Detector temperature	:	300 °C
Injection port temperature	:	200°C
Column	:	OV – 17 packed column
Carrier gas	:	Nitrogen

Results and discussion

Effect of spouted bed drying on volatile oil

The effect of drying on volatile oil content of cardamom dried in spouted bed drier at different conditions has been represented in Figures 1 and 2. It could be inferred that drying has significant effect on essential oil content of cardamom. It was observed that maximum recovery of volatile oil of 9.1 per cent was attained by cardamom sample dried at an air temperature of 40^0 C with draft tube height of 40 cm with 5 cm separation distance and slant angle of 60^0, whereas minimum recovery of 6.7 per cent was obtained in samples dried at an air temperature of 50^0 with draft tube height of 60 cm with 7.5 cm separation distance and slant angle of 45^0 under continuous spouting condition. It can be concluded that higher air temperature was found to have a profound effect on volatile oil content due to loss of flavour. Further the volatile content decreased with decrease in slant angle. This might be due to the fact that the required airflow rate was higher at a slant angle of 45^0 than 60^0 at the same separation distance. Moreover, it was evident from the results that draft tube height increases with decrease in volatile content. This was because the cardamom capsules spout more time in spout, absorbs more heat and has a higher temperature.

In case of intermittent spouting, the recovery of volatile oil content was maximum i.e. 9.7 per cent in sample at an air temperature of 40^0 with draft tube height of 40 cm with 5 cm separation distance and slant angle of 60^0. The bed temperature in the case of intermittent drying was lower than that in the continuous case, as a result of the cooling effect during the tempering period. It was worth pointing out that observations made during the experiments have shown that intermittent drying prevents thermally – originated particle damage as compared to the continuous process at the same inlet air temperature and superficial velocity. This means that short time drying periods separated with equal or shorter tempering periods yielded better product quality than long time continuous drying as a result of the reduced exposure to hot streams with the resulting lower temperature and moisture gradients inside the particles. The latter also reduces drying – induced stresses and splitting of capsules.

Effect of variables on volatile oil of cardamom

Analysis of variance revealed that all variables viz., tempering, slant angle, air temperature, separation distance and draft tube height had significant effect ($p \leq 0.01$) on volatile oil of cardamom. Though the process variables were independently significant ($p \leq 0.01$), there was no interaction between different process variables excepting slant angle and air temperature.

The mean values for different process variables are presented in Table 1. It can be seen that the volatile oil content increased when the cardamom is dried by intermittent spouting. It is evident from the table 2 that as slant angle varied from 45 to 60°, the mean value of volatile oil increased from 184.3 to 199.0. This is due to the higher airflow rates at a slant angle of 45^0 than 60°, which resulted in loss of volatile oil.

Table 1. Mean table for volatile oil

Variables	Levels	Mean	SE	CD
Tempering period (min.)	0	183.40	0.037	0.107
	30	199.90		
Slant angle (degree)	45	184.30	0.037	0.107
	60	199.0		
Air temperature (°C)	40	200.10	0.037	0.107
	50	183.20		
Separation distance (cm)	5	193.60	0.037	0.107
	7.5	189.70		
Draft tube height (cm)	40	134.00	0.045	0.131
	50	126.00		
	60	123.30		

As seen from table 1, the mean value of volatile oil content decreased with an increase in air temperature. The possible cause for this trend may be because of the exposure of cardamom capsules to higher temperature and resulted in loss of flavour. Table 1 indicates that cardamom dried at 5 and 7.5 cm separation distances are on par with each other. From the table 1, it is clear that cardamom dried at 50 and 60 cm draft tube height are on par with each other, but cardamom dried at 40 cm draft tube height gave better yield of volatile oil than 50 and 60 cm draft tube height.

Table 1 shows that an increase in air temperature decreased the yield of volatile oil at same slant angle. Similarly when the slant angle increased from 45 to 60°, the volatile oil content also increased at same air temperature.

Effect of spouted bed drying on oleoresin yield

Oleoresin content as a function of drying air temperature and tempering is shown in Figures 3 and 4. It was observed that increase in air temperature resulted in the reduction of oleoresin per cent. This may be due to the reduction in volatile oil and 1,8-cineole. But in the case of intermitted spouting, the retention of oleoresin is more when compared to the continuous spouting samples. This might be due to the retention of other constituents of oleoresin, that is pigments and resins, along with volatile oil and 1,8-cineole. In the case of intermittent spouting, 10 to 15 per cent increase in oleoresin content was observed compared to continuous spouting samples and it might be due to the fact that supplying hot air periodically rather than continuously results in a better yield of oleoresin with out drying induced splitting of capsules.

Gas chromatographic analysis of volatile oil

Gas chromatography has shown to be a powerful tool in the analysis of volatile oils for monitoring source, purity and adulteration. As far as cardamom oil is concerned, 1,8-cineole was considered to be the important compound. The ratio of 1,8 – cineole to other compounds has been suggested as a quality index. It was considered that 1,8 – cineole and α - terpinyl acetate, together with the terpene alcohols (linalool, α - terpineol) were important for the evaluation of the aroma quality of cardamom. The GC conditions which gave the best separation for the estimation of 1,8-cineole and esters are recommended for routine evaluation of aroma quality of cardamoms.

Table 2 shows the effect of drying on gas chromatographic analysis of volatile oil. The major component 1,8-cineole with its campharaceous, cool odour was present at high concentration of 32 per cent in the sample dried at an air temperature of 40°C with draft tube height of 40 cm with 7.5 cm separation distance and slant angle of 60° followed by 33.57 per cent at an air temperature of 50°C under the same conditions in intermittent spouting. From the results, it was observed that there was no significant difference between the samples when the air temperature is increased from 40° to 50°C.

The aroma of the other major component, α - terpinyl acetate, was described as mildy herbaceous, sweet, representing the odour and spicy nature of cardamom. From the table 2, high concentration of 40.84 per cent was observed in the sample dried at an air temperature of 40°C with draft tube height of 40 cm with 5 cm separation distance and slant angle of 60° followed by 39.10 per cent at draft tube height of 50 cm with 7.5 cm separation distance at the same air temperature under intermittent spouting. It was evident from the results that there was no significant difference in concentration between the

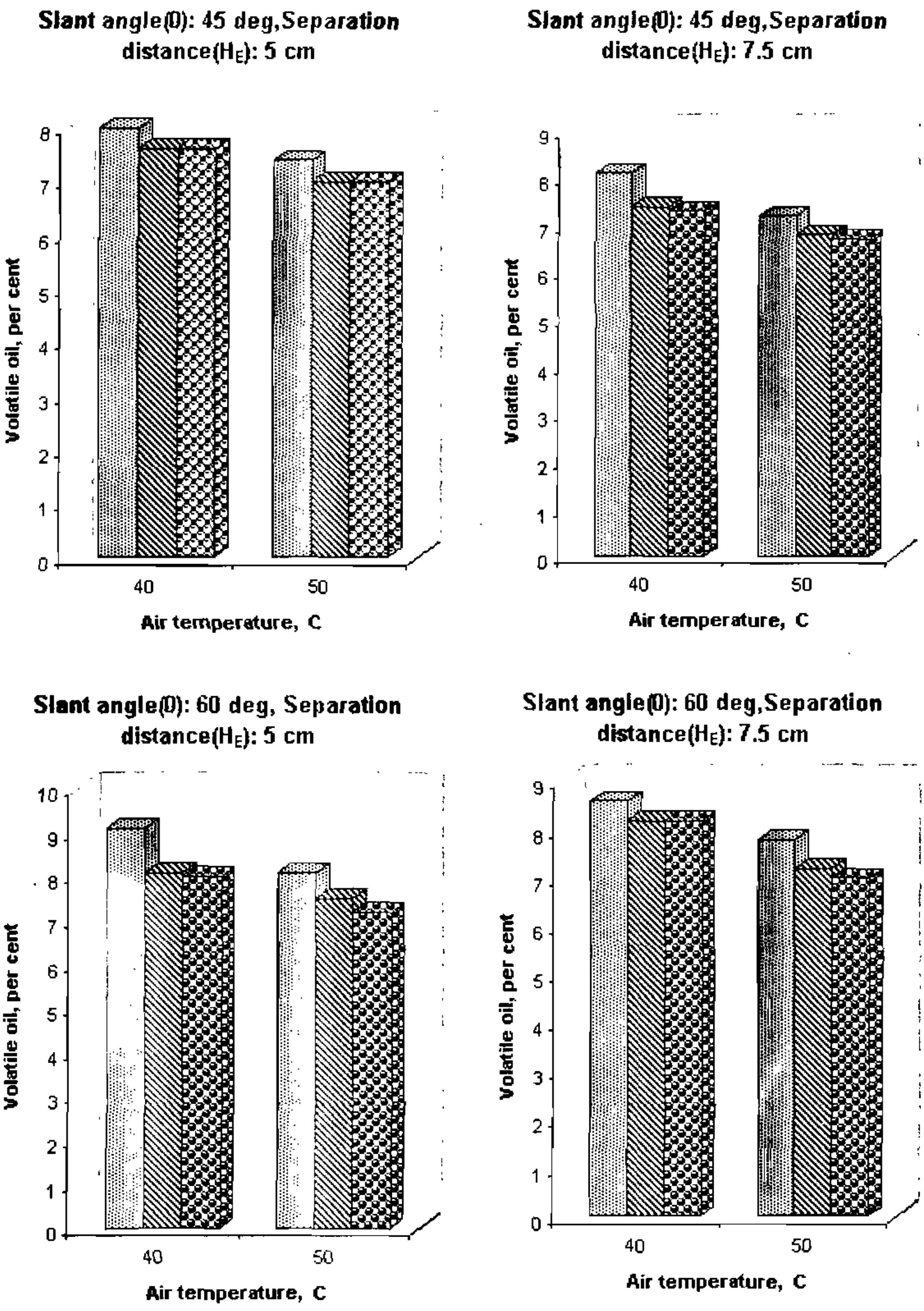

Fig. 1. Effect of temperature on volatile oil content at indicated draft tube heights

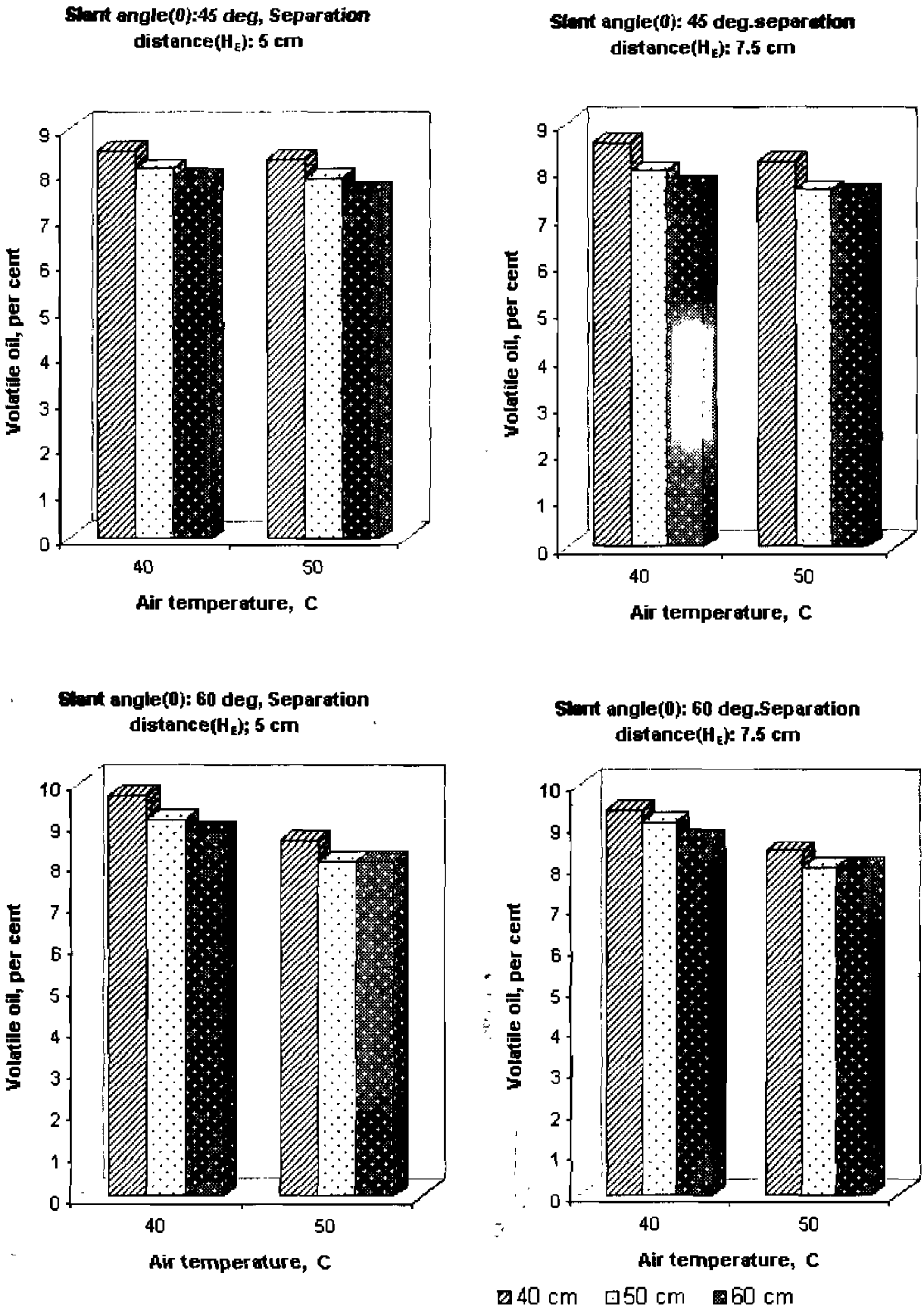

Fig. 2. Effect of temperature on volatile oil at indicated draft tube heights with tempering for 30 min.

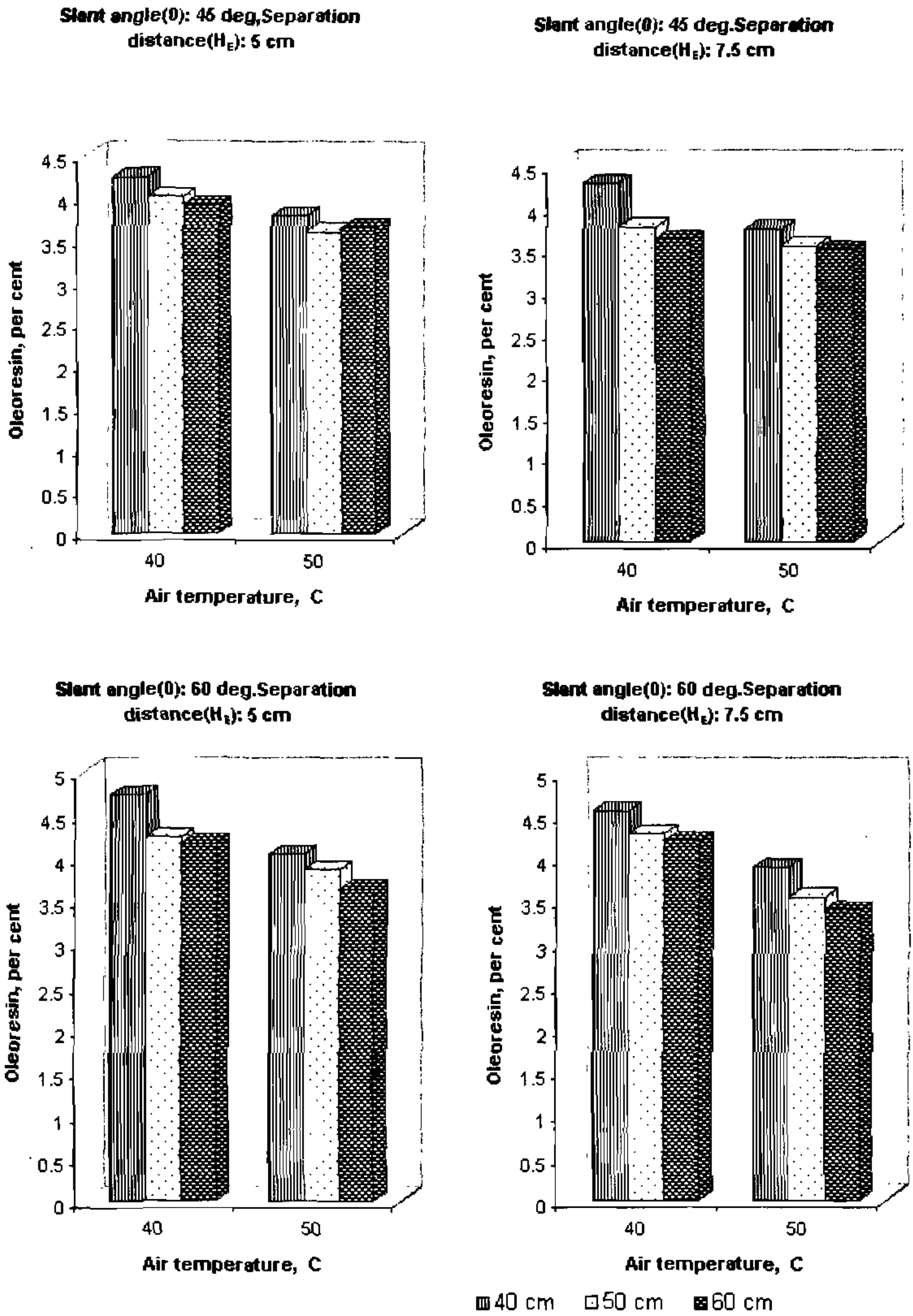

Fig. 3. Effect of temperature on oleoresin at indicated draft tube heights

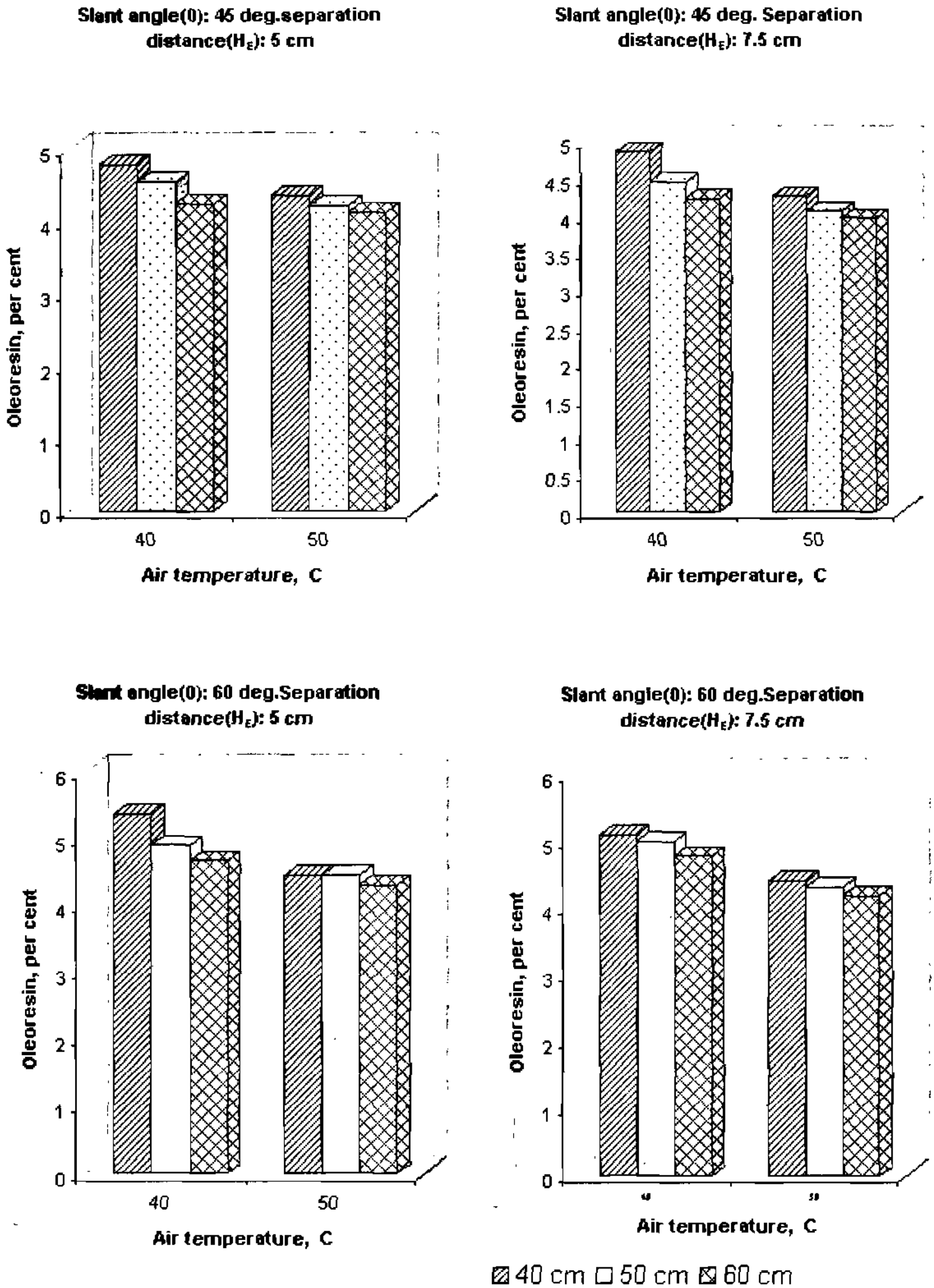

Fig. 4. Effect of temperature on oleoresin at indicated draft tube heights with tempering for 30 min.

samples dried at 40 and 50 cm draft tube height. The samples dried at 45⁰ slant angle in all conditions recorded lower concentration than the samples dried at 60⁰ slant angle. This might be due to the fact that the volatile oil content was lower in the case of samples dried at a slant angle of 45⁰ than 60⁰. It was found that the ratio of α - terpinyl acetate to 1,8-cineole was in the range between 0.85 to 1.48 under intermittent spouting. The oils derived from 45° slant angle samples exhibited lowest ratio while that for 60° slant angle samples have high values. The same trend was maintained if linalyl acetate, linalool and *α - terpineol were also taken in the numerator. Similar results were reported by* Wijesekara & Jayawardana (1973).

Table 2. Effect of spouted bed drying on gas chromatographic analysis of volatile oil

Slant angle (deg)	Separation distance (cm)	Draft tube height (cm)	Temperature (⁰C)	1,8 – cineole (%)	α - terpinyl acetate (%)	Linalool (%)	Linanyl acatate (%)	α-terpineol (%)
		40	40	31.18	36.43	1.84	2.33	3.18
45	5	50	40	25.61	35.54	2.52	5.63	2.20
		60	40	28.50	31.23	6.50	2.57	5.96
		40	40	29.78	35.12	2.66	2.56	4.15
45	7.5	50	40	27.40	36.86	2.92	2.91	4.58
		60	40	27.49	30.52	6.42	2.42	4.96
		40	40	30.30	40.84	2.71	2.81	4.36
60	5	50	40	30.28	36.68	4.47	2.22	4.16
		60	40	29.60	36.53	2.81	2.57	5.83
		40	40	34.44	37.02	1.57	2.28	2.80
60	7.5	50	40	32.02	39.10	1.79	2.32	3.17
		60	40	27.06	37.52	6.32	2.38	4.81
		40	50	31.92	27.18	2.92	1.86	5.91
45	5	50	50	27.33	30.32	6.21	2.41	6.36
		60	50	27.80	28.76	7.24	2.61	6.45
		40	50	25.14	36.28	7.73	2.29	6.28
45	7.5	50	50	26.12	29.50	7.56	2.27	8.65
		60	50	24.05	27.80	8.72	2.81	8.58
		40	50	33.46	35.36	1.92	2.51	5.07
60	5	50	50	24.54	36.39	0.31	7.41	6.19
		60	50	26.87	34.36	2.91	2.67	6.09
		40	50	33.57	36.39	1.92	2.08	3.08
60	7.5	50	50	26.25	36.74	8.01	2.46	4.71
		60	50	28.17	32.24	4.08	2.43	4.87

References

ASTA 1997 Official analytical methods of the American Spice Trade Association, Fourth Edition

Balakrishnan M 1995 Investigation on drying characteristics of cardamom. M.E. (Ag.) Thesis, Dept. of Agrl. Processing, TNAU, Coimbatore.

Bernhard R A, Wijesekara R O B & Chichester C O 1971 Terpenoids of cardamom oil and their comparative distribution among varieties. Phytochemistry 10 : 177.

Nirmala Menon A & Sreekumar M M 1994 A study on cardamom oil distillation. Indian Perfumer 38(4) : 153-157.

Purseglove J W, Borwn E G, Green G L & Robbins S R J 1981 Cardamom - Chemistry. Spices, Vol. I, Tropical Agricultural Series, Longman, London, 1: 605.

Sumanjeet Kaur, Naik S N and Maheswari R C 1993 Composition of essential oil of large cardomom isolated by liquid CO_2 extract and steam distillation. Indian Perfumer 37(3) : 249-252.

Wijesekera R O B & Jayawardena A L 1973 Recent development in the production of spices and their essential oils in ceylon. In : Proc. Conf. Spices, Tropical Products Institute, London. 159.

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Paprika : A very good natural food colourant Influence of season and growth environment on yield parameter and quality in paprika (*Capsicum annuum* var. *longum* L.)

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Abstract

Investigations were carried out to assess the performance of paprika variety Kt-Pl-19 (*Capsicum annuum*) as influenced by season and growth environments. The crop was screened for commercial cultivation at Department of Spices & Plantation Crops, Horticultural College & Research Institute, Tamil Nadu Agricultural University, Coimbatore during summer and winter in both open and shade conditions (shade net and coconut shade) during 2000 - 2001. The results revealed that appreciable variation for the traits like plant height, number of branches, leaf area, single fruit weight, number of fruits per plant in different growth environments (in open, under shade net and coconut shade conditions) and seasons (summer and winter). The comparison of different morphological, physiological and yield attributes indicated that paprika variety Kt-Pl-19 is performing better in respect of yield (13.22 tonnes/ ha) under coconut shade in winter.

Capsanthin registered comparatively higher ASTA units under shaded condition than open condition. The highest colour value were recorded under shade net (138.90 ASTA) followed by coconut shade (138.70 ASTA). Ascorbic acid was comparatively lesser (90.20 mg/100g) under shade condition in winter. All the fruit characters invariably exhibited highly significant and positive correlation with fruit yield per plant in all the conditions. Hence, paprika variety Kt-Pl-19 can be grown under coconut shade or shade net for higher productivity. The study revealed that the adverse effect of high temperature and light intensity on plant growth and yield potential can be minimised by means of shade.

Key words: food colourant, influence of season, open, paprika, shade.

Introduction

Natural food colourants are added to food products to impart high aesthetic appeal to the foods. Pigment extracts of annatto, paprika, saffron and turmeric have been used in food industry since generation (Sampath *et al.*, 1981). Paprika is one of the leading natural colourants next to turmeric and grape colour extracts (Anon., 1999). Paprika contains remarkable amount of the colouring material (carotenoid), and is used as colourant in processed food as they get the nod over synthetic products in the food colourant market (Anon., 1999). Dried paprika powder and paprika oleoresin are the natural colour sources exempt from certification and can be used directly (Marmion, 1979). The application of paprika (*Capsicum annuum*) and its oleoresin as a colour additive frequently over laps its use as a spice. The commercial importance of paprika both as a spice and a vegetable with large-scale cultivation in both tropical and temperate regions are increasing. The present investigation was taken up to tap out the possible opportunities for increasing the productivity of paprika. Under different environments, to assess the environmental influence, planting was done in open, under shade net and coconut shade.

Materials and methods

The present investigation was carried out to study the performance of paprika (*Capsicum annuum* var. *longum*) variety Kt-Pl-19 under shade net, coconut shade and open. Studies were under taken at the Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. The seeds of paprika variety Kt-Pl-19 were obtained from the Regional Research Station, IARI, Katrain-Himachal Pradesh for experimentation.

Components		Details
Experimental design	:	Factorial Randomized Block Design (FRBD)
Number of treatments	:	3
Number of replications	:	7
Number of plants/ treatment	:	a) Open condition - 105 plants b) Shadenet condition - 105 plants c) Coconut shade - 105 plants
Total number of plants	:	315
Spacing	:	60cm x 30cm
Plot size	:	2m x 2m.

One month old seedlings were transplanted at a spacing of 60cm x 30cm in all the three treatments (in open, under shade net and coconut shade) adopting fifteen plants per plot. The following fertilizer recommendations were followed for all the three treatments.

Time of application	Inorganic fertilizer ($kg / 85m^2$)		
	N	P	K
Basal dose	0.51	0.85	0.51
Top dress 3 weeks after transplanting	0.17	0.00	0.17
Top dress 6 weeks after transplanting	0.34	0.00	0.34
Total	1.02	0.85	1.02

The plots were irrigated at an interval of 4 – 6 days. Physiologically matured red ripened fruits were harvested periodically and observations were recorded on the following yield parameters.

1. Number of fruits per plant
2. Fruit length
3. Fruit breadth
4. Fruit weight
5. Number of seeds per fruit
6. Weight of seeds
7. Pulp weight
8. Yield per plant

Quality attributes

1. Capsanthin
2. Oleoresin
3. Ascorbic acid

The statistical scrutiny of data and the calculation of correlation coefficient were done by adopting the standard procedures of Panse and Sukhatme (1957).

Results and discussion

Quantitative characters

Fruit length: The data on fruit length are presented in Table. 1. The fruit length varied from 8.71 to 16.14 cm. There was significant difference in fruit length among the seasons and growth environments. The mean fruit length recorded in summer and winter were 11.90 and 14.52 cm whereas it was 10.93, 14.14 and 14.60 cm for open, shade net and coconut shade conditions. In summer, the highest length was 14.00 cm under shade net followed by 13.00 cm under coconut shade. In winter under coconut shade, the plants have recorded the mean fruit length of 16.14 cm whereas it was 14.30 cm and 13.14 cm under shade net and open condition respectively. The shortest length of 8.71 cm was recorded in summer under open condition.

Fruit girth: The fruit girth ranged between 6.86 and 9.99 cm. There was significant difference for both seasons and growth environments. The mean girth of fruit registered in summer and winter were 8.65 and 9.80 cm. The mean fruit girth was 8.11, 9.90 and 9.63 cm under open, shade net and coconut shade conditions respectively. In summer, the lengthier fruit girth was observed (9.81 cm) under shade net closely followed by coconut shade (9.29 cm). However, the shortest of 6.86 cm was recorded in open condition. In winter the girth of fruit was 9.36, 9.99 and 9.97 cm in open, shade net and coconut shade respectively, but on par with each other (Table 1).

Fruit weight: The fruit weight ranged between 16.90 and 24.90 g. There was significant difference among the seasons and growth environments for fruit weight. The mean fruit weight for summer and winter were 18.86 g and 23.90 g respectively. The growth environments namely, open, shade net, coconut shade registered fruit weight of 20.06, 22.80, and 21.30 g respectively. In summer, under open condition the fruit weight was 16.90 g whereas shade net and coconut shade recorded 20.71 and 19.00 g respectively. However, in winter the weight of fruit was found on par in open (23.25), under shade net (24.90) and coconut shade (23.50) as given in Table 1.

Pulp weight: The pulp weight ranged between 12.50 and 26.43 g. There was significant difference among the seasons and growth environments. In summer the high pulp weight was observed (18.71 g) under shade net. However, during winter season the pulp weight was maximum (26.43 g) under coconut shade when shade net and open condition registered 22.43 and 20.71 g respectively. The mean pulp weight recorded in summer and winter were 15.90 and 23.20 g and that of growth environments were 16.60, 20.60 and 21.43 g in open, under shade net and coconut shade respectively (Table 1).

Number of seeds per fruit: The mean seed number ranged between 118.00 and 150.14. The mean seed number 125.05 and 143.52 was observed in summer and winter and that of growth environments namely open, shade net and coconut shade were 126.71, 135.64 and 140.50 respectively. In summer the mean seed number was high (130.86) under coconut shade and low in open (118.00). Whereas, in winter, the number of seed was larger (150.14) under coconut shade and followed by (145.00) shade net and open condition (135.43). A greater mean seed number of 150.14 was observed in the fruits harvested under coconut shade and minimum number of 118.00 in summer under open condition. There was significant difference among the seasons and growth environments(Table 2).

Weight of seed per fruit: The mean weight of seed ranged between 1.00 and 2.34 g. Significant difference was noted between seasons and growth environments. The mean seed weight observed in winter and summer were 2.09 and 1.34 g, whereas for open, shade net and coconut shade, the seed weight was 1.41, 1.84 and 1.90 g respectively. In summer under shade net the seed weight was heavier with 1.56 g followed by coconut shade with 1.46 g. In winter season higher seed weight (2.34 g) was recorded under coconut shade and lower (1.82 g) in open condition. A greater seed weight (2.34 g) was obtained under coconut shade in winter season and the lower seed weight (1.00 g) was recorded in open during summer season (Table 2).

Table 2. Effect of seasons and growth environments on number and weight of seed in paprika variety KT-PL -19

Character	Number of seeds / fruit			Weight of seed / fruit (g)		
Season / Treatment	Summer	Winter	Mean	Summer	Winter	Mean
T_1	118.00	135.43	126.71	1.00	1.82	1.41
T_2	126.30	145.00	135.64	1.56	2.12	1.84
T_3	130.86	150.14	140.50	1.46	2.34	1.90
Mean	125.05	143.52	134.30	1.34	2.09	1.72
	S	T	S X T	S	T	S X T
SE d	5.47	6.70	9.48	0.01	0.02	0.01
CD(0.05)	11.18	13.70	18.43	0.06	0.08	0.02

T_1 - In open condition; T_2 - Under shade net condition; T_3 - Under coconut shade condition.

Number of fruits per plant: The fruit number varied from 4.00 to 15.00. The mean number of fruit recorded in summer and winter were 8.34 and 12.00 where as under open, shade net and coconut shade it was 6.50, 11.30 and 12.71 respectively. In summer the fruit number recorded was higher under shade net (10.60) followed by coconut shade (10.42) and greater of 4.00 under open condition. While in winter the number of fruits was more (15.00) under coconut shade and low (9.00) in open condition. The number of fruit per plant under coconut shade was high (15.00) in winter and less (4.00) in observed under open condition in summer. There was significance among the seasons and growth environments (Table 3).

Yield of fruits: The yield ranged between 1.01 and 5.29 kg per plot. In summer and winter the mean yield recorded were 2.42 to 4.30 kg and that of open, shade net and coconut shade were 2.07, 3.88 and 4.13 kg per plot respectively. In summer under shade net the plants recorded the highest yield of 3.28 kg followed by 2.97 kg and 1.01 kg under coconut shade and open condition. In winter, the plants under coconut shade recorded higher yield of 5.29 kg followed by 4.48 kg and 3.13 kg under shade net and open condition respectively (Table 3).

The calculated yield per hectare ranged between 2.52 and 7.83 tonnes. In summer and winter the mean yield registered were 6.05 to 10.75 tonnes and that of open, shade net and coconut shade were 5.17, 9.70 and 10.33 tonnes respectively. In summer, under shade net, the plants expressed the higher yield of 8.21 tonnes followed by 7.43 tonnes and 2.52 tonnes under coconut shade and open condition respectively. In winter, the plants under coconut shade recorded the heavier yield of 13.22 tonnes followed by 11.19 tonnes and 7.83 tonnes under shade net and open condition respectively.

The yield per plot is decided by the important parameters like number of fruits/plant, fruit length, and fruit girth and fruit weight. Prevailing weather parameters significantly influenced the number of fruits per plant. The higher number of fruits per plant was recorded in winter season. The lower number of fruit was obtained in the crop planted in summer in open condition. The significant reduction in number of fruits per plant in summer might be due to poor fruit set under high temperature and precipitation during the cropping season. Gill and Gill (1995) also reported that high temperature and low humidity is detrimental to pollen viability and fruit set in chillies. The adverse effect of rains on flowering and fruit set was also observed in chilli by Nagarathnam and Rajamani (1963) and Padda and Singh (1971). The number of fruits produced under coconut shade and shade net was greater, as the growth of the plant was more vigorous in both the conditions. The paprika plant grown under coconut shade produced the highest number of fruits per plant as the vegetative phase should better exposure to optimum temperature, which could have encouraged better development of the source (leaves). This could help in higher source strength for increased canopy to perform photosynthesis and such photosynthates would have been partitioned effectively for optimum economic yield by increasing the number of fruits. In the present study, paprika exhibited poor establishment under open condition as a result of high temperature prevailed during summer. High temperature favoured flower abortion especially when the high radiation was experienced immediately after flowering. This present investigation is in accordance with the study conducted in tomota by Kinet (1997).

Pearce *et al.* (1993) have also reported the influence of unfavourable environments on fruit expansion rate. Fruit girth is another important yield contributing character as it is positively correlated with yield. The fruit girth was broader in plants under coconut shade and shade net conditions compared to open due to favourable temperature. Fruits should both linear and circumferential growth. The weight of fruit at harvest was significantly influenced by the seasons. The crop grown in winter season produced the highest fruit weight, which was significantly higher than summer season. Similar findings were obtained for fruit weight at harvest in brinjal by Mohanty (2000). The lowest fruit weight was due to reduced fruit size in open condition. The fruit from shade had more weight than fruits form open. The increase in number of fruits due to improved fruit set at high humidity did not lead to a reduction in mean fruit weight. This response might be due to an increase in the assimilation rate of plants carrying fruits (Hall and Milthorpe, 1978).

Table 1. Effect of seasons and growth environments on fruit characters in paprika variety KT-PL -19

Character	Fruit weight (g)			Fruit length (cm)			Fruit girth (cm)			Pulp weight (g)		
Season / Treatment	Summer	Winter	Mean	Summer	Winter	Mean	Summer	Winter	Mean	Summer	Winter	Mean
T_1	16.90	23.25	20.06	8.71	13.14	10.93	6.86	9.36	8.11	12.50	20.71	16.60
T_2	20.71	24.90	22.80	14.00	14.30	14.14	9.81	9.99	9.90	18.71	22.43	20.60
T_3	19.00	23.50	21.30	13.00	16.14	14.60	9.29	9.97	9.63	16.43	26.43	21.43
Mean	18.86	23.90	21.36	11.90	14.52	13.21	8.65	9.80	9.21	15.90	23.20	19.54
	S	T	S X T	S	T	S X T	S	T	S X T	S	T	S X T
SE d	0.81	0.99	1.41	0.24	0.29	0.65	0.17	0.21	0.29	0.44	0.55	0.77
CD(0.05)	1.66	2.03	2.87	0.49	0.59	0.80	0.35	0.43	0.60	0.91	1.11	1.58

T_1 - In open condition; T_2 - Under shade net condition; T_3 - Under coconut shade condition .

Table 3. Effect of seasons and growth environments on yield and yield component in paprika variety KT-PL -19

Character	Number of fruits per plant			Yield per plot (kg)			Calculated yield per hectare (tonnes)		
Season / Treatment	Summer	Winter	Mean	Summer	Winter	Mean	Summer	Winter	Mean
T_1	4.00	9.00	6.50	1.01	3.13	2.07	2.52	7.83	5.17
T_2	10.60	12.00	11.30	3.28	4.48	3.88	8.21	11.19	9.70
T_3	10.42	15.00	12.71	2.97	5.29	4.13	7.43	13.22	10.33
Mean	8.34	12.00	10.20	2.42	4.30	3.36	6.05	10.75	8.40
	S	T	S X T	S	T	S X T	S	T	S X T
SEd	1.000	1.23	1.74	0.008	0.009	0.13	0.006	**0.08**	**0.01**
CD(0.05)	2.06	2.52	3.56	0.016	0.19	0.27	0.14	0.17	0.02

T_1 - In open condition; T_2 - Under shade net condition; T_3 - Under coconut shade condition .

Quality parameters

Capsanthin: The capsanthin ranged between 113.50 and 138.90 ASTA units. The mean capsanthin of 116.40 and 132.20 ASTA units were recorded in summer and winter whereas it was 116.40, 128.50 and 128.03 ASTA units in open, shade net and coconut shade conditions. There was significant difference for both seasons and growth environments. In summer higher capsanthin content of 118.09 ASTA was observed under shade net followed by 117.50 ASTA under coconut shade. Whereas, in winter season, the fruits recorded a maximum 138.90 ASTA under shade net but on par under coconut shade (138.70ASTA). However, in open condition, the capsanthin content registered lower (119.20 ASTA). The highest colour value (138.90 ASTA) was recorded under shade net while the lowest in open (113.50 ASTA) in summer. (Table 4)

Oleoresin: The oleoresin content varied from 8.80 to 12.50 per cent with grand mean of 10.74 per cent. A high oleoresin content of 12.00 per cent was observed under coconut shade in summer followed by 10.00 per cent under shade net and lower of 8.80 per cent in open. Whereas, in winter season, the oleoresin content was high (12.50 per cent) under shade net closely followed by coconut shade (11.14 per cent). Significant difference were observed among the seasons and growth environments. The mean oleoresin content in summer and winter were 10.26 and 11.21 per cent respectively while it was 9.40 per cent in open and 11.25 under shade net and 11.57 per cent under coconut shade. The high oleoresin content was recorded under shade net in winter and lowest in open during summer season (Table 4).

Table 4. Effect of seasons and growth environments on quality and biochemical constituents in paprika variety KT-PL -19

Character	Capsanthin (ASTA units)			Oleoresin (%)			Ascorbic acid (mg/100g)		
Season / Treatment	Summer	Winter	Mean	Summer	Winter	Mean	Summer	Winter	Mean
T_1	113.50	119.20	116.40	8.80	10.00	9.40	96.40	92.80	94.60
T_2	118.09	138.90	128.50	10.00	12.50	11.25	94.70	90.20	92.50
T_3	117.50	138.70	128.03	12.00	11.14	11.57	95.10	90.96	93.10
Mean	116.40	132.20	124.30	10.26	11.21	10.74	95.40	91.32	93.40
	S	T	S X T	S	T	S X T	S	T	S X T
SE d	0.203	0.248	0.351	0.203	0.248	0.352	0.088	0.109	0.154
CD(0.05)	0.413	0.506	0.716	0.415	0.508	0.718	0.181	0.222	0.314

T_1 - In open condition; T_2 - Under shade net condition; T_3 - Under coconut shade condition.

Ascorbic acid: The ascorbic acid content ranged between 90.20 and 96.40 mg/100g fruit. The mean ascorbic acid content of 95.40 and 91.32 mg/ 100 g was obtained for summer and winter, whereas the ascorbic acid content in open, shade net and coconut shade were 94.60, 92.50 and 93.10 mg / 100g respectively. There was significant difference among the seasons and growth environments. The ascorbic acid content was 96.40 mg / 100g in open during summer followed by 95.10 and 94.70 mg / 100g under coconut shade and shade net conditions. Similar trend was noticed in winter too with higher (92.80 mg / 100g), in open and lower 90.20 mg / 100g under shade net conditions. A higher ascorbic acid content recorded was 96.40 mg / 100 g under open in summer while the minimum of 90.20 mg / 100g under shade net in winter (Table 4).

Seasoning paprika is an important vegetable spice. Factors determining its quality include colour (red) and antioxidant capacity. Red colour retention in paprika was strongly related to total bio-antioxidant content. It was concluded that a reduction in antioxidant content, was related to colour retention in paprika (Carvajal, 1998). In the present study, Paprika colour was estimated using visual estimation and determination of carotenoid. The development of extractable colour in *Capsicum annuum* fruits was compared between the plants grown in open, under shade net and coconut shade conditions in summer and winter. Variation in fruit colour induced by season and growth environment was also determined.

The present work showed higher colour value (ASTA units) in fruits developed under shaded conditions, than in open condition. This may be due to the favourable weather condition, which enhanced the fruit quality and thereby colour. The shade reduced the light intensity and there by incidence of sunlight on fruits, and improved the colour. The colour was less in open due to oxidation of pigments by high light intensity. There was comparable difference in extractable colour (ASTA units), tint, and red colour were noticed in both the seasons. The present findings are in accordance with Gomez *et al.* (1998) who stated that colour loss was more rapid at high temperature in open air than greenhouse grown plants, which produced more deeply coloured paprika, although loss in colour may be meager. He also reported that improved quality of bell pepper fruit was due to increased air temperature and more total heat units under the tunnels. It was found that crop raised during summer expressed a lower colour value which may be due to inhibition of chlorophyll degradation as observed by Rylski and Aloni (1994). On the contrary they further reported that low temperature caused insufficient coloration. The oleoresin content was more in fruits harvested from plants under shade conditions than in open, which might be due to favourable condition and non-deterioration and inactivation of metabolic substances.

Ascorbic acid contents were reduced at high temperature in both the seasons. The present findings are in confirmation with the earlier findings of Twomey and Ridge (1970) and Mehta (1973) which showed that the reduction of ascorbic acid content in tomato may be due to high temperatures. On the contrary, Sharma and Tewari (1993) observed high ascorbic acid at high temperature in a group of cherry tomato genotypes. They attributed this due to better partitioning efficiency of these genotypes, thereby allowing more availability of carbohydrate in the form of sugar. On the other hand, in the present study, there was an increase in acidity in the fruits developed inside the shade net when compared to those in coconut shade and in open field. This was very much pronounced in summer season than in winter season. The higher temperature, in the open field would have encouraged more respiration, which ultimately would have resulted in higher utilization of organic acid in the catabolic process. The planting season (winter) produced greater seed number per fruit, while smaller seed number per fruit was recorded in summer season. A higher seed number per fruit in winter season might be due to the prevalence of favourable temperature, during the cropping period. The lower seed number per fruit in summer season might be due to high temperature experienced at the time of seed set. Mohanty (2000) obtained the similar results for seed number in brinjal while studying the effect of different environments on fruit set and seed number per fruit under Punjab conditions. Bhuvaneswari (2001) also supported this view of variation in seed weight per fruit in chilli crop. Natarajan *et al.* (1988), Usharani (1997) and Kumar *et al.* (1999) are also in the line of confirmation of the present work. The highest seed weight per fruit was obtained in winter and the lowest in summer season. The higher seed weight per fruit in winter might be due to the optimum temperature for fruit and seed set during the season. The probable cause of lower seed weight per fruit in summer could be due to poor seed set caused by the desiccation of pollen grains at high temperature. The reduction in seed weight may be due to high temperature. This is in confirmity with the previous findings of Bhuvaneswari (2001), Natarajan *et al.* (1988), Usharani (1997) and Kumar *et al.* (1999).

Table 5. Correlation coefficient between yield and its component characters under different growth environments paprika variety KT-PL -19

Character	Summer			Winter		
	Open	Shade	Coconut shade	Open	Shade	Coconut shade
Number of fruits	0.696**	0.914**	0.925**	0.736**	0.942**	0.956**
Fruit length (cm)	0.159	0.579**	0.513*	-0.054	0.759**	0.428
Fruit girth (cm)	-0.494*	0.003	0.353	0.223	0.563*	0.674**
Fruit weight (g)	-0.081	0.465*	0.007	0.286	0.675**	0.780**
Seed number	0.378	-0.071	-0.060	-0.325	0.588**	0.487*
Seed weight (g)	0.234	0.537*	0.475*	0.291	-0.140	0.143
Pulp weight (g)	-0.277	0.469*	-0.118	-0.455	0.646**	0.658**

* Significant at 5% ** Significant at 1%

Table 6. Effect of seasons and growth environments on relative humidity (%) at different growth stages in paprika variety KT-PL -19

Stages	Vegetative stage			Flowering stage			Harvest stage		
Season / Treatment	Summer	Winter	Mean	Summer	Winter	Mean	Summer	Winter	Mean
T_1	35.30	36.44	35.87	34.80	37.90	36.35	32.20	35.70	33.95
T_2	35.71	37.20	36.45	35.54	38.00	36.77	34.40	37.60	36.00
T_3	35.85	37.57	36.71	37.20	38.06	37.63	35.70	37.77	36.73
Mean	35.62	37.07	36.35	35.85	37.98	36.92	34.10	37.02	35.56
	S	T	S X T	S	T	S X T	S	T	S X T
SE d	0.14	0.18	0.25	0.12	0.15	0.21	0.10	0.13	0.19
CD(0.05)	0.30	0.37	0.53	0.26	0.31	0.44	0.22	0.27	0.39

T_1 - In open condition; T_2 - Under shade net condition; T_3 - Under coconut shade condition .

References

Anonymous, 1999. Focus on food colours. Nandhini Chemical Journal, 6(7) : 12-15.

Anonymous, 2000 Production and export potential of paprika. Farm Digest, 76 : 5-7

Bhuvaneswari, G. 2001. Genotype x Environment interaction for seed yield and its qualitiy in chilli (*Capsicum annuum* L.) M.Sc. Thesis submitted to the Punjab Agricultural University, Ludhiana, India.

Carvajal, M., J. L. Gimenez, F. Riquelme and C. F. Akaraz. 1998. Antioxidant content and colour level in different varieties of red pepper (*Capsicum annuum* L.) affected by plant-leaf Ti4+ spray and processing. Acta Alimentaria (Budapest), 27(4): 365 – 375.

Cockshull, K.E., C.J. Graves and C.R..J. Cave. 1992. The influence of shading on yield of glasshouse tomatoes.J.Hort. Sci., 67(1) : 11-24.

Gill, B.S and S. Gill. 1995. Hybrid seed production through natural open pollination in chilli (*Capsicum annuum* L.). J. Applied Seed Production., 13: 37-38.

Gomez, R., J.E. Pardo, F. Navarro and R. Varan. 1998. Colour differences in paprika pepper varieties cultivated in a green house and in open air. J. Sci. Food and Agric., 77(2) : 268-272.

Hall, A. J. and F.L. Milthorpe. 1978. Assimilate source-sink relationships in *Capsicum annuum* l. III. The effects of fruit excision on photosynthesis and leaf and stem carbohydrate. Australian J. Plant. Physiol., 5 : 1-13.

Kinet, J.M. 1997. Effect of light conditions on the development of inflorescence in tomato. Scientia Hort., 6 : 15-26.

Kumar, K., K.S. Basaevana and P.S. Pratap. 1999. Evaluation of different genotypes of chilli (*Capsicum annuum* L.) Harayana J. Hort. Sci., 28 : 207-210.

Marmion, D.M. 1979. Handbook of U.S. colorants for Foods, Drugs and Cosmetics, John Woley and Sons, Inc., New York.

Metha, A.K. 1973. Effect on growth regulators on summer tomato. M.Sc. Thesis, G.B. Pant Univ. of Agric. and Tech., Pant Nagar.

Mohanty, S.K. 2000. Evaluation of brinjal (*Solanum melongena* L.) cultivars for seed production potential under different environments. M.Sc. Thesis, Punjab Agricultural Univ., Ludhiana,India.

Nagarathnam, A.K and T.S. Rajamani. 1963. studies on fruit setting in chillies (*Capsicum annuum* L.). Madras Agric.J., 50 : 138-139.

Natarajan, S., C.M. Pappiah, P. Rangasamy and P.M.M. David. 1988. Evaluation of chilli (*Capsicum annuum* L.) genotypes under semi-dry condition. South Indian Hort., 86 : 8-12.

Padda, D.S. and Singh, J. 1971. Studies on some important aspects of floral biology in chillies. Indian J. Agric. Res., 5 : 217-218.

Pearce, B. D., R.I. Grange and K. Hardwick. 1993. The growth of young tomato fruits. II. Environmental influences on glass house crops grown in rock wool or nutrient film. J. Hort. Sci., 68 : 13-23.

Rylski, I. and B. Aloni. 1994. Flowering, fruit set, fruit development and quality under different environmental conditions in tomato and pepper crops. Acta Hort., 366 : 45-55.

Sampath, S.R., N. Krishnamurthy, S. Shivashankar, R. Shankaranayan, S. Rao and Y.S. Lewis. 1981. Natural food colours. Indian Food Packer, 13 : 97-104

Sharma, N.K. and R.S. Tewari. 1993. Effects of dates of planting on quality characters in tomato. Harayana. J. Hort. Sci., 22(2) : 158-160.

Twomey, D.G and B.D. Ridge. 1970. Note on ascorbic acid content of English early tomatoes. J. Sci. Fd. Agric., 21 : 314.

Usharani. P. 1997. Seed recovery, seed production, seed predication and variability studies in chilli, Madras Agric. J., 84 : 139-143.

Verma, T.S. and S. Joshi. 2000. Status of paprika development in India. Indian J. Arecanut, Spices and Medicinal Plants, 2 (2) : 40-44.

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Chemical composition of *Lavandula stoechas* L. grown in a red soil of semiarid tropical region in India

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Abstract

Lavandula stoechas L. generally known as French lavender, native of Mediterranean region is introduced and cultivated for its essential oil. Chemical examination of the essential oil obtained from the plant showed variations in the composition of the constituents compared to earlier reports. GC, GC/MS and chemical studies indicated the presence of fenchone, camphor, 1,8-cineole, α-pinene and camphene as the major compounds. Detailed investigation of the compounds in comparison with the previously reported data is presented.

Key word: 1,8-cineole, camphor, fenchone, leaf oil, essential oil composition, Labiatae, *Lavandula stoechas*,.
Abbreviations: GC – Gas chromatography, GC-MS – Gas chromatography–mass spectrometry.

Introduction

The genus *Lavandula* belonging to the genus Labiatae is an important source of spices and essential oils. This genus contains about 28 species, out of which three species viz., *L. angustifolia, L. latifolia* and *L. intermedia* are important. Lavender and its products, due to their delicate flavor are widely used in food, liquors, pharmaceuticals and cosmetics. *L. stoechas* popularly known French lavender in the trade is widely cultivated in Mediterranean regions. Major producers of this oil are southern France, Spain, Italy, Dalmatia and sourthern Russia. French lavender differs from spike lavender, *L. latifolia* oil in having fenchone content, instead of borneol with a harsh odour note. Granger *et. al.* (1973) reported that the oil obtained from the French origin exclusively of fenchone and camphor. Kokkalou (1988) reported fenchone, pinocarvyl acetate, camphor, eucalptol and myrthenal as major compounds from the oil collected from Greece. *L. stoechas* has been use for a long time on traditional medicine as an anticonvulsant and antispasmodic (Gilan *et al* 2000.). Perrucci *et al* (1996) reported the acaricidal activities of *L. stoechas*. The essential oil and leaf infusions are used against diabetes, menstrual pains, kidney stones, carbuncles, otitis and hypertension, by traditional therapists, is prescribed in colic and chest affections and for relieving biliousness and nervous headaches. It is also used as moth repellent. The chemical examination of this oil was undertaken to study any variations in the oil composition of the material cultivated in the semiarid tropical region of south India. The oil obtained by hydro-distillation was examined and identified by using GC and GC/MS. The composition of the oil with respect to earlier reports is discussed in this paper.

Materials and methods

The aerial parts of fully-grown plants of *L. stoechas* at the CIMAP Field Station, Bangalore were collected during March 2001. The voucher specimen is deposited at CIMAP Field Station, Bangalore. The freshly collected material was subjected to hydrodistillation in a Clevenger-type apparatus for 4 hr. The pale yellow coloured oil was obtained in 0.8 % yield. The oil with camphor odour with a harsh note was dried over anhydrous Na_2SO_4 and stored at 4°-5°C in a refrigerator until analysed.

Table 1. Composition of *Lavandula stoechas* oil

S.No.	Kovat Index	Name of the compound	% composition
1	923	tricyclene	0.19
2	934	◉-Pinene	1.92
3	949	camphene	3.22
4	961	verbenene	0.07
5	969	sabinene	0.10
6	976	◉-Pinene	0.27
7	981	Myrcene	0.22
8	999	◉-3-carene	0.09
9	1026	1,8-cineole	10.07
10	1053	◉-terpinene	0.10
11	1080	fenchone	26.61
12	1084	terpenolene	0.30
13	1089	linalool	0.73
14	1110	*endo*-fenchol	0.50
15	1117	*exo*-fenchol	0.07
16	1137	camphor	32.96
17	1139	◉-terpineol	0.53
18	1143	*trans*-verbenol	0.05
19	1152	myrtenol	0.38
20	1158	isoborneol	0.40
21	1165	borneol	0.38
22	1178	myrtenol	0.41
23	1185	verbenone	0.27
24	1206	*trans*-carveol	0.10
25	1210	*endo*-fenchyl acetate	0.26
26	1220	*exo*-fenchyl acetate	0.22
27	1274	*trans*-pinocarvyl acetate	2.08
28	1428	◉-caryophyllene	0.11
29	1573	caryophyllene oxide	0.08
30	1583	viridiflorol	0.19

Analysis : GC analysis was carried out on a Perkin-Elmer 8500 gas chromatograph equipped with FID using BP-1 (diethyl polysiloxane) column (30 m x 0.25 mm i.d. and 0.25 micron m film thickness) and nitrogen as carrier gas at 10 psi inlet pressure. Temperature programming was done from 60°-220°C at 5°C/min (BP-1 column). The split ratio was 1:80. GC/MS analysis was carried out on a Hewlett-Packard 5890 gas chromatograph interfaced with a quadrupole mass spectrometer MSA 5970 using fused capillary column HP-1 (25m x

0.33 ⊛m film thickness). Oven temperature, the injector and detector temperatures were maintained same as in GC analysis. Helium was used as carrier gas.

Component identification was done by comparison of their Kovats retention indices on BP-1 column (relative to C8-C23 alkanes) with literature values Adams (1995) Davies (1990), peak enrichment on co-injection with authentic samples wherever possible and by comparison of the mass spectra of the peaks with the published data. Peak area percentages were calculated on BP-1 column without the use of correction factors.

Results and discussion

The essential oil obtained by hydro-distillation showed the presence of nearly 77 peaks. The chemical composition of the essential oil of the aerial parts of the herb *L. stoechas* was summarized in Table I. Nearly 30 compounds of the oil accounting for more than 82% of the oil were identified. As can be seen from the data, the oil is mostly composed of large part of monoterpenes, and very less sesquiterpene portion. The major constituents of the oil are camphene, camphor, fenchone, 1,8-cineole, ⊛-pinene. Camphor (32.9%)was found to be more and fenchone was less (26.6%) when compared to earlier reports (30.8-48.7%), Kokkalou (1988), Skoula *et. al* (1996). Myrtenyl acetate was not detected in this oil; instead pinocarvyl acetate was present to an extent of 2.08 %. Though the study indicates that the French lavender, cultivated in this region resembles *L. stoechas* grown in Spain or Greece it has higher camphor content and it may be a different chemotype and can be exploited as a very good source for fenchone and camphor.

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References

Adams R P 1995 Identification of Essential Oil Components by Gas Chromatography/Mass Spectroscopy. Allured Publ. Corp., Carol Stream II.

Davies N W 1990 Gas chromatographic retention indices of monoterpenes and sesquiterpenes on methyl silicone and Carbowax 20M phases. J. Chromatogr., 503: 1-24.

Gilani A.H., Aziz N., Khan M.A., Shaheen F., Jabeen Q., Siddiqui B.S. and Herzig J.W. 2000 Ethnopharmacological evaluation of the anticonvulsant, sedative and antispasmodic activities of Lavandula stoechas L Journal of Ethnopharmacology. 71: 161-167

Granger R. Passet J and Teulade-Arbousset G 1973 Trav.Soc. Pharm., Montellier 33:355-360. Chem. Abstract 80: 118214c (1973)

Kokkalou E 1998 The constituents of essential ol from Lavandula stoechas growing wild in Greece. Planta medica 47: 58-59.

Perricci S, cioni PL, Flamin G, Morelli I and Macchioni 1996 Biological activity of some essential oils and their constituents against mite (Tyrophagus longior) pests of stored foods Alpicoltura 579-584.

Skoula, M, Abidi, C, Kokkalou, E 1996 Essential Oil Variation of Lavandula stoechas L. ssp. stoechas Growing Wild in Crete (Greece).Biochemical systematics and ecology, 24:255-260.

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Lycopene and volatile oil constituents – changes during storage of mace (*Myristica fragrans*) powder

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Abstract

Myristica fragrans is unique among spices as it produces two products of commercial importance viz., nutmeg the kernel of the seed and mace, the dried aril that surrounds the seed. Fresh mace has a brilliant red colour due to the pigment lycopene. Lycopene is a carotenoid present in tomatoes, watermelon, apricots, pink grapefruit, red oranges & guava. The objective of the study is to investigate the effect of storage of powdered mace on its lycopene content, essential oil content and its chemical profile. Powdered mace was kept in six different storage systems. Powdered mace was stored for a period of one month and frequent samples were drawn to estimate the colour value, essential oil content and the profile of oil. It was found that the extent of degradation was similar in all the six containers and only 25% of lycopene was retained after 28 days. The degradation in lycopene content can be attributed to isomerization and oxidation. As mace is used in confectionery and pharmaceutical products, this change in configuration is a very critical factor in the value-addition of mace. The yield of oil and its GC profile was followed for one month. 85% of the essential oil was retained at the end of one month. Among the five major components studied in oil, two of them showed an increase (pinene-33.25% & sabinene-45.78%) while the other three components had a decrease (safrole-27.69%, myristicin-63.5% and elemicin-57.39%) in its concentration. This increase in concentration of the monoterpene hydrocarbons (pinene & sabinene) may be relative while the decrease in the aromatic ethers (safrole, myristicin and elemicin) may be due to chemical transformations.

Introduction

Myristica fragrans is unique among spices as it produces two products of commercial importance viz., nutmeg the kernel of the seed and mace, the dried aril that surrounds the seed. Fresh mace has a brilliant red colour due to the pigment lycopene.

Lycopene is a carotenoid present in tomatoes, watermelon, apricots, pink grapefruit, red oranges & guava. It is an acyclic isomer of beta-carotene with 11 conjugated and 2 unconjugated double bonds. It is mainly present in tissues as All Trans Lycopene (ATL). Lycopene is a phytochemical with potent nutraceutical properties. Lycopene's configuration enables it to inactivate free radicals. Free radicals formed during cell metabolism are highly aggressive and cause permanent damage. As an antioxidant, it is twice as potent as Vitamin A and ten times as effective as Vitamin E. Non-oxidative activity of lycopene is regulation of gap junction between cells. It participates in a host of chemical reactions that are believed to prevent carcinogenesis and atherosclerosis. Anguelova and

Warthesen (2000a) have established the effectiveness of lycopene as an antioxidant. Thus the degradation of lycopene not only affects the attractive color, but also the nutritive value. Anguelova and Warthesen (2000b) have evaluated the chemical stability of lycopene in tomato powders during storage.

The essential oil of mace is very much similar to that of nutmeg. The oil is responsible for most of the pharmaceutical properties of the spice. It is used in the treatment of many illnesses ranging from those affecting digestive system to nervous systems. The major chemical constituents of the essential oil are α-pinene, sabinene, safrole, myristicin, elemicin etc.

The objective of the study is to investigate the effect of storage of powdered mace on its lycopene content, essential oil content and its chemical profile.

Materials and methods

Dry powdered mace was kept in six different storage systems as follows.

1) Paper cover 2) Polyethylene cover with paper lining 3) Polythene cover with brown paper lining 4) Transparent bottle 5) Opaque bottle and 6) Amber-colored bottle. Powdered mace was stored for a period of one month in these different containers and frequent samples were drawn to estimate the lycopene content. Lycopene content was estimated by standard procedure (Sadasivam & Manikam 1992).

The same mace sample was stored in airtight amber-colored bottles for extraction of essential oil. It was extracted by hydrodistillation following the Clevenger method (AOAC 1975). Percentage of the oil was computed using volume/weight (v/w) basis. Gas Chromatographic separation of the oil samples were carried out in Perkin Elmer Autosystem Gas Chromatograph equipped with PE Nelson 1022 GC Plus Integrator. The column oven was programmed as 70-220°C @ 5°C/minute. The detector used was FID and the column was SE-30. The carrier gas was nitrogen @ 30ml/minute, the detector temperature was 300° C and the injection port temperature was 200°C. Compounds in the oil were identified by comparison with the Retention Time (Rt.) of authentic standards

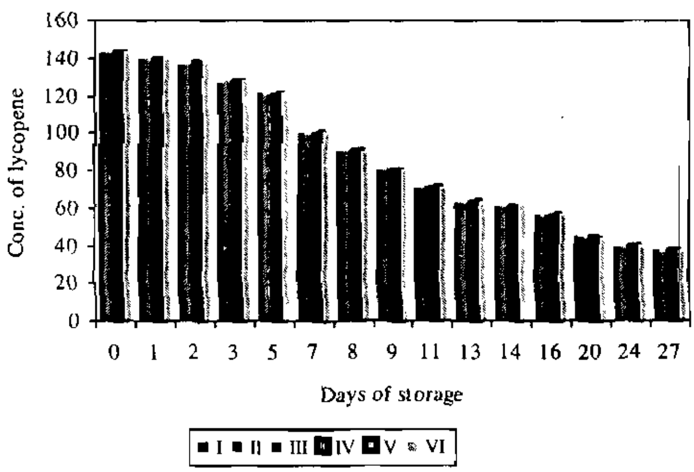

Fig.1. Degradation of lycopene in different storage systems

Results and Discussions

In all the six storage systems, the rate of degradation of lycopene was similar as given in fig.1. Figure 2 shows the decrease in lycopene content during storage. Only 25% of the lycopene was retained after 28 days. The degradation in lycopene content can be attributed to isomerization and oxidation. All Trans Lycopene (ATL), which is the most stable form of lycopene, first undergoes isomerization to mono cis lycopene and poly cis lycopene. These compounds are subsequently oxidized to form aldehydes and ketones which impart an off-flavour (Boskovic 1979). Mace is used in confectionery and pharmaceutical products and lycopene is a potent antioxidant. Thus the change in configuration is a very critical factor in the value-addition of mace.

The essential oil content of stored mace sample showed a decrease of only 15% in one month. (fig.3). The GC profile of the oil samples showed that among the five major components of the oil, two of them had an increase (pinene-33.25% & sabinene-45.78%) in its relative concentration while the other three components had a decrease (safrole-27.69%, myristicin-63.5% and elemicin-57.39%) in its concentration. The results obtained are expressed in

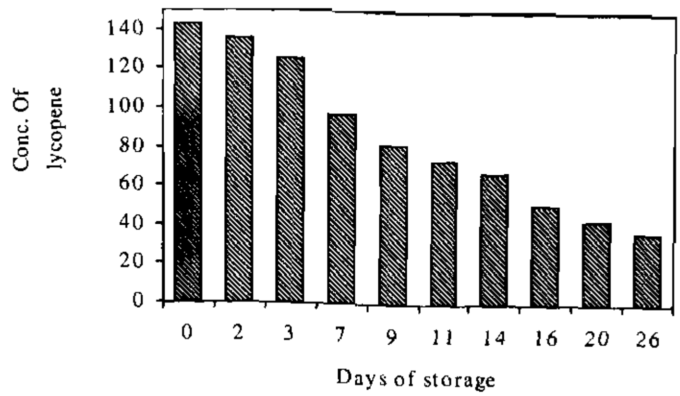

Fig. 2. Degradation of lycopene on storage

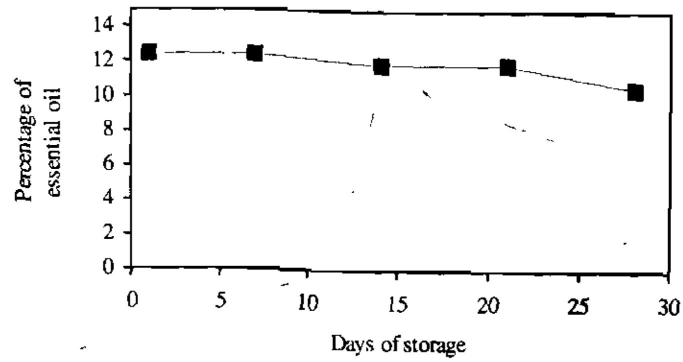

Fig. 3. Loss of essential oil on storage

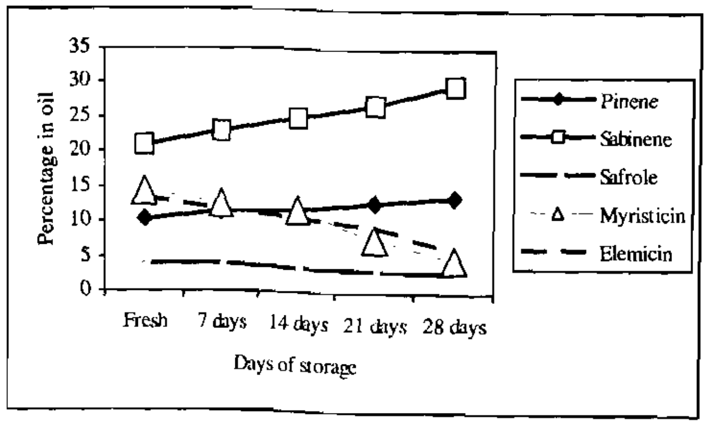

Fig. 4. Changes in major chemical constituents in oil during storage

fig. 4. This increase in α-pinene and sabinene concentrations may be relative while the decrease in the aromatic ethers may be due to chemical transformations.

Thus it is inferred that storage of mace powder over a period of one month affects lycopene, the major color component of mace.

The essential oil did not show much reduction during storage. However, two of the major monoterpene hydrocarbons (pinene and sabinene) had a relative increase in its concentration and the aromatic ethers (safrole, myristicin and elemicin) had a reduction in its contents.

References

Anguelova T & Warthesen J J 2000a Degradation of lycopene, alpha-carotene, and beta-carotene during lipid peroxidation. J. of Food Sci. 65:71-75

Anguelova T & Warthesen J J 2000b Lycopene stability in tomato powders. J. of Food Sci 65: 67-70.

AOAC Official Methods of Analysis 1975 12th Ed. Association of Official Analytical Chemists, Washington DC.

Boskovic M A 1979 Fate of lycopene in dehydrated tomato products: carotenoid isomerization in food systems. J. of Food Sci 44:84-86.

Sadasivam S & Manikam A 1992 Biochemical Methods for Agricultural Sciences, Wiley Eastern Limited, New Delhi

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Curcumin and oleoresin content of BSR-1 and Co-1 turmeric varieties at different stages of harvest

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Abstract

A study was undertaken at Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore to assess the essential oil, curcumin and oleoresin content at different stages of crop growth in BSR-1 and Co.1 turmeric varieties. The results revealed that the essential oil content was found to decrease as the crop reached maturity. The reduction from the seventh to the tenth month was found to be higher. The highest essential oil content of 4.10 per cent, curcumin content of 3.61 per cent and oleoresin content of 9.31 per cent was recorded in BSR-1 during seventh month for essential oil (3.4%) and curcumin content (4.3%) and oleoresin (9.10%) of Co-1 turmeric.

Key words: curcumin, essential oil, oleoresin.

Introduction

The essential oil of turmeric has therapeutic values, especially for its bactericidal, pesticidal, antifungal and antimicrobial activity. Besides, the oil has several useful applications, especially in toothpastes, mouthwashes, pain balms and cosmetics. The essential oil content in turmeric rhizomes ranges from 3.5 to 5.8 per cent. The essential oil, which is orange- yellow in colour, has a strong peppery aroma. Curcumin the most active principle of colour has softening effect besides therapeutic properties. It is an ingredient in toothpaste, facial cream, mouthwashes and in cosmetics. Its presence varies with variety, season and the study was undertaken to assess the essential oil and oleoresin yield at different stages of crop growth of BSR.1 and Co.1 turmeric.

Materials and methods

A field experiment was carried out at Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore in a Randomized Block Design with three replications. The soil is clayey loam. The study was aimed for evaluation of essential oil at different stages of harvest. The plot size adopted was 5 x 2m^2. Uniform cultural practices were carried out for both the varieties as per the recommendations (Anonymous, 1999). The turmeric rhizomes were harvested from seven months after planting at monthly interval and essential oil content of the ground rhizome powder of the two varieties was estimated by fractional distillation adopting Soxhlet apparatus as per ASTA (1960). The oil content was expressed as percentage on moisture free basis. The curcumin and oleoresin content of ground rhizome powder of the two turmeric varieties was estimated by following ASTA (1960) method and expressed as percentage on moisture free basis.

Results and discussion

The essential oil content was found to decrease as the crop reached maturity (Table 1). The reduction from the seventh to tenth month was in increasing trend. The variety BSR-1 has recorded the highest essential oil content of 4.10 per cent during seventh month after planting and thereafter started reducing. During the tenth month, the essential oil content was found to be very less (3.01 per cent). Similar trend was observed in Co.1 that recorded a higher essential oil content of 3.41% on the seventh month after planting and afterwards started declining reaching a lower level of 3 per cent in the tenth month. Higher curcumin content of 4.69 per cent was recorded in BSR-1 at seventh month after planting. Similarly Co.1 also recorded higher curcumin percent of 4.33 at seventh month after planting. As the age of plants get advanced, the curcumin content reduced. Harvesting at tenth month recorded the lowest curcumin content in both BSR-1 (3.61 per cent) and Co.1 (3.27 per cent). Similar trend was observed in oleoresin content also with BSR-1 having 9.31 per cent and Co.1 with 9.10 per cent at seventh month. During the tenth month oleoresin content dropped down to 8.27 per cent in BSR-1 and 8.10 per cent in Co.1. This shows that biosynthesis of essential oil, curcumin and oleoresin in turmeric reaches a climax by about the seventh month and no more addition of essential oil takes place even though the rhizomes may increase in size. The same trend was observed by Gupta (1979) and Jayachandran *et al.* (1980) in Ginger and Rathinavel (1983) in turmeric. The rate of decrease in the quality components however was rapid between the ninth and tenth month after planting due to rapid decline in source-sink relationship. Hence, there is no much difference in the quality was noticed when the crop was harvested from eight months after planting. From this investigation it could be concluded that seven months after planting is the optimum period for turmeric harvest to achieve yield in terms of essential oil, curcumin and oleoresin.

Table 1. Essential oil, curcumin and oleoresin content of BSR-1 and Co.1 turmeric rhizomes

Varieties	Months after planting				
	7	8	9	10	
Essential oil (%)					
BSR -1	4.10	3.90	3.50	3.01	SED 0.36 CD (5%) 0.79
Co-1	3.41	3.30	3.20	3.00	SED 0.32 CD (5%) 0.76
Curcumin (%)					
BSR -1	4.60	4.31	3.95	3.61	SED 0.41 CD (5%) 0.86
Co-1	4.33	3.95	3.62	3.27	SED 0.38 CD (5%) 0.79
Oleoresin (%)					
BSR -1	9.31	8.95	8.50	8.27	SED 0.88 CD (5%) 1.76
Co-1	9.10	8.97	8.45	8.10	SED 0.86 CD (5%) 1.74

References

Anonymous 1999 Crop production guide for horticultural crops. Department of Horticulture and plantation crops Government of Tamil Nadu.

A S T A 1960 Official Analytical Methods of the American Spice Trade Association. American Spice Trade Association New York Pp. 41- 42, 53.

Gupta R 1974 Processed ginger for new products. Indian Farming, 23 (12): 7-9.

Jayachandran B K Vijayagopal P D & Sethumadhavan P 1980 Maturity studies on ginger (*Zingiber officinale* Rosco.) Variety Rio-de Janeiro. Indian Cocoa Areca & Spices J. 3:56-58.

Rathinavel M 1983 Effect of potash application and time of harvest on growth, yield and quality of turmeric (*Curcuma longa* L.) Thesis submitted for M.Sc. (Hort.) Degree, Tamil Nadu Agricultural University Coimbatore.

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Possible causes for darkening of tamarind pulp during storage

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Abstract

Experiments were carried out at the department of Spices and Plantation crops, Horticulture College and Research Institute, Tamil Nadu Agricultural University, Coimbatore to asses the cause of darkening in tamarind pulp during storage. Various bio-chemical parameters were monitored at regular intervals using standard methods over a period of one year and the results were correlated The multiple correlation data revealed that a positive and significant relationship existed between browning of pulp and acidity (0.749**) moisture (0.796**), total sugars (0.713**), reducing sugars (0.848**) and free amino acids (0.625**). The total soluble solids, total phenols, carbohydrates, proteins and anthocyanin pigments were found to have non-significant relationship with the browning of pulp at the end of the storage period of 360 days. The regression equation indicated that the above parameters influenced the browning of the pulp to a tune of 87 per cent.

The darkening of tamarind fruit pulp during the period of storage may be due to the combined enzymatic and non-enzymatic Maillard reaction. The enzymatic reaction might have taken place in the initial stage. During the process of preparing the fruit pulp for storage, the rupture of cell walls might have activated the enzymes resulting in enzymatic browning.. Subsequently, non-enzymatic browning might have set in due to the presence of high amounts of total carbohydrates, total sugars, reducing sugars, protein and free amino acids. The presence of anthocyanin in the fruit pulp might have formed the substrate for the phenolase activity leading to the conversion of anthocyanin to melanin pigments causing the brown pigmentation.

Key words: bio- chemical changes, browning, Maillard reaction, post harvest deterioration, sugar – amine condensation, tamarind.

Introduction

The tamarind fruit pulp is the chief agent for souring curries, sauces, chutneys and certain beverages throughout the greater part of India. It is a common article of trade and is preserved and stored for marketing in a number of ways. Tamarind has many problems associated with quality parameters owing to high moisture level, seed, fibre and rind contents. Immature fruits are used for chutney and ripe fruit pulp is an important ingredient in South Indian vegetable dishes to induce sourness. These fruits also make excellent chutney. It is believed that continuous use of tamarind in daily food reduces the chances of stone formation in urinary system of human beings. . However, the quality of the stocks get deteriorated after one or two months on account of faster discolouration and also due to moisture at the time of packing. quality deterioration is considered due to poor post- harvest management practices including processing (George and Rao 1997).with a view to findout the reason fr the quality deterioration of tamarind pulp during storage, particularly the darkening of the pulp from golden brown to dark brown / black, this study was taken up.

Materials and Methods

In the study undertaken at the department of spices and plantation crops, Horticulture College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. Firstly an elite tree of consistent performance was selected. The fruits from that tree was harvested on full maturity without causing any injury to the pods at the time of harvest. The fruit pulp separated after drying the pods for three days under sunlight was packed in polyethylene bags and stored. At 30 days interval, the pulp was drawn and assessed for the various biochemical parameters. Completely randomised blocks design was adopted with three replications and the results were correlated with the dependent variable Y-browning and other independent biochemical parameters.

Results and discussion

The multiple correlation data revealed that a positive and significant relationship existed between browning of pulp and acidity (0.749**) moisture (0.796**), total sugars (0.713**), reducing sugars (0.848**) and free amino acids (0.625**)(Table-1). The total soluble solids, total phenols, carbohydrates, proteins and anthocyanin pigments were found to have non-significant relationship with the browning of pulp at the end of the storage period of 360 days. The regression equation indicated that the above parameters influenced the browning of the pulp to a tune of 87 per cent (Table-2).

The browning of the fruit pulp was less in treatments with the low moisture per cent, whereas in all the other treatments that allowed moisture absorbtion, browning was intense. Thus, as observed from the correlation and regression equation, the moisture content heavily influenced the browning. The multiple correlation elucidated that during the period of storage, the moisture content of the pulp (r = 0.796**) on 360th day of storage) was positive and significant which may be related to the browning of tamarind pulp. The better availability of moisture would have favoured enzymatic oxidation thereby resulting in darkening of the produce. The present finding is in accordance with the work of Hendel *et al.* (1955) in potato. They expressed the increase in the storage stability of dried potatoes when the moisture content was reduced from 7 to 4 per cent. The present investigation is in concurrence with the observation of Molaison et al. (1962), who reported that dehydrated sweet potatoes maintained their quality longer when their moisture level was maintained below 4 per cent. In the present study, it was observed that higher moisture content favoured browning of tamarind pulp which deviates from the works of Coultate (1984), who expressed that in the presence of amino compounds, the browning of sugars occurs rapidly at low water concentrations.

The total soluble solid content of the pulp increased gradually with the time of storage and possessed a positive significant correlation with that of total sugars. The correlation between the browning and the total sugar content of the fruit pulp vividly indicated a highly positive and significant influence in all the months of storage. The reducing sugars were negatively correlated and the influence was almost non-significant. However, the influence of non-reducing sugars and amino acids was highly significant but, exerted negative impact on the browning. Stadtman (1948) reported slight decrease in the sugars in orange juice concentrate as browning occurred which supports the present study. The decrease in free amino acids during the storage period with the progress in browning reaction could be accounted due to sugar – amine condensation as suggested by Ingles & Reynolds (1958) in apricot, with 95 per cent loss in free amino acids. The total carbohydrates of the pulp were not related to the browning that took place in tamarind pulp during the period of storage. It is evident that higher quantities of free amino acids were present in the pulp and the protein content of the pulp was found to increase gradually with the period of storage and was positively correlated with browning. The protein content was higher in the darker samples than the light coloured pulp. The present findings fall in line with the theory of Lewis & Neelakantan (1964), who reported on the darkening of the fruit pulp of tamarind during storage due to the Maillard reaction which is non-enzymatic support the present finding. In spite of protecting the pulp from light and atmospheric oxygen and storage of tamarind pulp under low temperature, the browning reaction could not be prevented. The rate of browning could only be delayed. The presence of high amino acids and protein in the pulp of tamarind and their highly positive significant correlation with the browning throughout the period of the current study is in accordance to the hypothesis of Roig *et al.* (1999) who observed the enhanced browning of antioxidant treated citrus juice aseptically filled in tetrabrik cartons might be due to the presence of amino acids and possibly other amino compounds.

The presence of high amounts of carbohydrates, soluble proteins and free amino acids in the tamarind pulp, might have caused the browning of pulp, which intensified with the period of storage during which the protein and amino acid contents also increased. He also suggested that phenolases present in fruit tissues are not always identical and that the substrates they affect may well be quite different in different plant tissues. The substrates identified for the phenolase complex were a number of anthocyanins and flavanoids. In the present study, the presence of higher quantity of anthocyanin in the pulp that were darker falls in line with the hypothesis of Meyer (2000). Anthocyanin present in the pulp might have triggered the reaction inducing the oxidation of phenols leading to browning. The addition of additives to tamarind pulp decreased the rate of browning which could be attributed to the antioxidant properties of the additives.

Anthocyanins are glycosides, which are ethers of monosaccharides sometimes with one monosaccharide moeity and sometime with two. The anthocyanin pigments when hydrolysed form anthocyanidine and carbohydrate (Monose). It could be inferred that the anthocyanin present in the pulp of tamarind during the storage period might have got hydrolysed to form anthocyanidin and monose. Anthocyanidine, at low pH are reddish and the accumulation of this might have caused the darkening of the pulp as the reaction progressed. The release of the monose entity might have led to the increase of the reducing sugar content of the pulp (Meyer 2000).

Table 1. Correlation matrix indicating the influence of various biochemical parameters on browning of tamarind pulp on 360th day of storage

	Browning	Acidity	Total soluble solids	Moisture	Phenols	Total sugars	Reducing sugars	Non-reducing sugars	Free amino acids	Total Carbo-hydrate	Pigment	Protein
Browning	1.000	0.749**	0.246ns	0.796**	-0.032ns	0.713**	0.848**	-0.586*	0.625**	0.495*	-0.405ns	0.206ns
Acidity		1.000	0.526*	0.859**	0.161ns	0.982**	0.825**	-0.795***	0.487*	0.431ns	-0.003ns	-0.021ns
Total Soluble solids			1.000	0.286ns	0.266ns	0.473*	0.485*	-0.512*	-0.202ns	-0.06ns	0.125ns	-0.029ns
Moisture				1.000	0.066ns	0.827**	0.648**	-0.482*	0.631**	0.553*	-0.293ns	0.031ns
Phenols					1.000	0.164ns	-0.026ns	-0.138ns	0.019ns	0.308ns	0.552*	0.174ns
Total sugars						1.000	0.814**	-0.819**	0.508*	0.431ns	0.054ns	-0.066ns
Reducing sugars							1.000	-0.810**	0.469*	0.210ns	-0.097ns	0.147ns
Non-reducing sugars								1.000	-0.318ns	-0.364ns	-0.194ns	-0.134ns
Free amino acids									1.000	0.392ns	-0.129ns	0.412ns
Total-carbohydrate										1.000	-0.225	0.075ns
Pigment											1.000	0.225
Protein												1.000

Table 2. Prediction of browning through biochemical constituents of tamarind pulp

Period of storage	Regression Equation	R^2	R^2 adjusted
30	Y= 0.044 + 0.002A + 0.001B + 1C – 0.0002 D – 0.004E + 0.01F – 0.002G + 0.00002 H + 0.001I – 0.003 J – 0.001 K	0.32NS	-0.94 NS
60	Y = -23.51 – 0.05 A + 8B+ 34C -0.1D + 0.01E + 0.1F + 1.8G + 0.1H - 0.002I + 0.6J - 0.4K	0.68 NS	0.10 NS
90	Y= 3.761 - 0.01A - 2B- 0.1C + 0.001D + 0.01E + 0.1F + 0.1G - 0.1H - 0.1I + 0.01J + 0.4K -0.4L	0.92*	0.77**
120	Y= -0.588 + 0.0003A - 1B - 0.02C -0.002D + 0.002E + 0.1F- 0.04G + 0.003H + 0.004I + 0.1J -0.001K	0.96**	0.87**
150	Y= -1.148 - 0.01A + 0.1B + 0.03C -0.004D + 0.01E + 0.04F + 0.04G + 0.01H + 0.0003I + 0.02J + 0.001K	0.88**	0.66*
180	Y = 0.068 – 0.003A + 0.1B + 0.03C + 0.003D + 0.005E + 0.03F – 0.02G – 0.001H – 0.002I + 0.01J - 0.0001K	0.89*	0.68*
210	Y = 0.610 – 0.01A + 0.02B + 0.1C – 0.002D + 0.01E + 0.01F – 0.04G + 0.001H + 0.001I + 0.01J-0.0001K	0.97**	0.90**
240	Y = 1.436 + 0.01A + 1B + 0.1C + 0.01D – 0.01E – 0.02F + 0.04G – 0.04H + 0.001I + 0.04J -0.002K	0.99**	0.96**
270	Y = -1.895+ 0.03A + 1B –0.1C+ 0.03D – 0.01E + 0.04F + 0.1G – 0.02H + 0.001I-0.2J + 0.01K	0.98**	0.94**
300	Y = -5.331 + 0.02A – 1B – 0.1C + 0.02D - 0.0004E + 0.1F + 0.01G – 0.02H + 0.002I + 0.3J + 0.0002K	0.95**	0.85**
330	Y = -6.765 + 0.1A – 3B – 0.1C + 0.02D + 0.01E + 0.002F + 0.2G – 0.01H + 0.05I+0.1J+0.01K	0.98**	0.95**
360	Y = -1.261 – 0.03A + 4B - 0.02C + 0.03D – 0.001E + 0.02F + 0.02G + 0.003H + 0.02I-0.2J+0.2K	0.95**	0.86**

A=Total soluble solids; B = Phenols; C = Amino acids; D = Reducing sugars; E = Total sugars; F = Moisture; G = Acidity; H = Non-reducing sugars; I = Total carbohydrates; J = Anthocyanin content; K = Protein content .

An increase in the free amino acid content was observed with the period of storage which exhibited a linear relationship with the browning of pulp. The inference obtained by Giribert and Ribas (2000) lend support to the present work, who have reported increased browning reactions in aqueous glucose systems at increased temperatures. They attributed the increased browning activity to the accumulation of aspargine, the most reactive amino-acid. The total free amino acids quantified in the present study might have had a higher fraction of aspargine, which ought to have led to the increased browning reaction.

References

George C K & Y S Rao 1997 Export of tamarind from India. Proceedings of National Symposium on Tamarindus indica L, Tirupathi (A.P.) Organised by Forest Dept. of A.P. 27-28 June 1997. Pp 156-161.

Giribet C. M & A I Ribas. 2000 Kinetics of colour development in aqueous glucose systems at high temperatures. J. Food Engineering, 44(3):181-189.

Hendel C E, H K Burr & M M Boggs. 1955 Non-enzymatic browning and sulfite flavour in dehydrated white potato. Effects of sulfite level and method of sulfite application. Food.Technol. 9, 627-630

Coulate T P 1984 Food. The chemistry of its components. Published by the royal society of chemistry, London pp23

Ingles D L & Reynolds T M 1958 Chemistry of Non-enzymatic browning IV. Determination of Amino Acids and Amino acid –Deoxyfructose in Browned Freeze dried Apricots. Australian J. of Chem., 11:575-580.

Lewis Y S & S Neelakantan 1964 The chemistry, Biochemistry and Technology of Tamarind. J. Sci. Industr. Res., 23(5): 204-206.

Meyer L H 2000 Food Chemistry – CBS Publishers and Distributors.

Molaison L J, J J Spadaro, M T Roby & F H Lee 1962 Dehydrated diced sweet potatoes in a pilot plant process and production evaluation. Food Technol., 16(1): 101.

Roig M G, J F Bello, Z S Rivera & J F Kennedy 1999 Studies on the occurrence of non-enzymatic browning during storage of citrus juice. J. Food Res. Int., 32(9):609-619.

Stadtman E R, 1948 Non enzymatic browning in fruit products. Adv. Food. Res., 1: 325.

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