Production of quality planting material in vegetatively propagated annual spice crops - ginger and turmeric

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Introduction

Ginger and turmeric belonging to the family *Zingiberaceae*, are two annual spice crops contributing to the national economy of India. Ginger (*Zingiber officinale* Rosc.) is one of the oldest known spices, esteemed for its aroma, pungency and medicinal properties. It is a tropical spice crop adapted for cultivation even in regions of subtropical climate. Being a shade loving crop with shallow root system, it is suitable for intercropping in coconut and arecanut gardens and in homesteads. Ginger is grown mainly as a rainfed crop in Kerala. In North Central India, it is grown as an irrigated crop. India is the largest producer of ginger. The crop occupies the largest area in Assam followed by Gujarat, Meghalaya, Arunachal Pradesh, Sikkim and Karnataka (www.indianspices.com).

Turmeric (*Curcuma longa* L.) is an ancient and sacred spice of India. The crop can be grown in diverse tropical condition from mean sea level to 1500m above MSL and is adapted to different soil types. India is the world's largest producer of turmeric. It is a major annual spice, grown as a rainfed crop in Kerala adapted to the coconut based cropping system. The crop occupies major share of area in Tamil Nadu, Telengana, Andhra Pradesh, Karnataka and Gujarat (www.indianspices.com).

Knowledge about the cultivars and high yielding varieties, planting materials available in the crops and method of producing good quality planting materials are important in the scenario of production of quality planting materials. Several traditional cultivars are available in both the crops which differ in yield and quality attributes. Similarly, high yielding varieties have been released from Central institutes and State Agricultural Universities. Both the spices are propagated vegetativly using rhizome bits. Seed rhizome bits of 15-25g weight with one or two viable buds are generally used for planting. The protocols for micropropagation were also standardized in both the crops. Tissue culture derived plantlets are not used for commercial planting as time taken for rhizome formation and to get normal size as that of conventional production is more. However, microrhizomes induced *in vitro* could be used for production of disease free nucleus planting materials. Pro-tray raised bud transplants being popularized now-a-days for planting in both the spice crops have helped to reduce seed rate considerably, suitable for mitigating the climate change and the propagules are suitable for high tech precision farming both under open and poly house conditions.

A. Production of quality planting material in ginger

1. Traditional cultivars and high yielding varieties

Several traditional cultivars of ginger are recognized in India which differ in yield and quality attributes . These cultivars grown in different ginger growing areas are generally named after the localities where they are grown. Some of the prominent indigenous cultivars are Maran, Himachal , Kuruppampadi, Ernad, Wayanad and Nadia. The exotic cultivar Rio-de-Janeiro has become highly popular in India.

Adoption of high yielding, disease free seed rhizomes is of paramount importance for the success of seed production programmes. Adoption of HYV helped to bring considerable increase in yield and quality of the produce. Kerala Agricultural University has released three high yielding high quality ginger varieties with high content of *gingerols* and *zingiberene* (Shylaja et al.2010 and Shylaja et al.2014) . There are eleven high yielding varieties of ginger released from various research stations (Table-1).

Table 1. High Yielding Varieties of ginger

Variety	Freshmean yield (t/ha)	Maturity (days)	Dry recovery(%)	Crude fibre(%)	Oleoresin(%)	Essential oil(%)
Indian Institute of Spices Research, Kozhikode – 673 012, Kerala						
IISR Varada	22.6	200	20.7	4.5	6.7	1.8
IISR Mahima	23.2	200	23.0	3.3	4.5	1.7
IISR Rejatha	22.4	200	19.0	4.0	6.3	2.4
High Altitude Research Station, Orissa University of Agriculture and Technology, Pottangi, 764 039, Orissa						
Suprabha	16.6	229	20.5	4.4	8.9	1.9
Suruchi	11.6	218	23.5	3.8	10.0	2.0
Suravi	17.5	225	23.5	4.0	10.2	2.1
Subhada	18.0	210	22.4	3.4	10.4	2.0
Y.S. Parmar University of Horticulture and Forestry, solan, Himachal Pradesh – 173 230						
Himagiri	13.5	230	20.6	6.4	4.3	1.6
Kerala Agricultural University, Thrissur – 680 656, Kerala						
Athira	21.0	220-240	22.6	3.4	6.8	3.1
Karthika	19.0	220-240	21.6	3.7	7.2	3.2
Aswathy	23.0	220-240	19.7	3.5	7.5	3.3

(Jayashree et al. 2015a)

2. Planting materials

2.1 Seed rhizomes

Seed rhizomes account for about 40 per cent of total cost of production in ginger. Carefully preserved seed rhizomes are cut into small pieces of 2.5-5.0 cm length weighing 15-20 g with one or two viable buds. The seed rate varies from region to region and with the method of cultivation adopted. In Kerala, the seed rate varies from 1500 to 1800 kg/ha. At higher altitudes the seed rate may vary from 2000 to 2500 kg/ha. (Aiyadurai 1966; KAU, 2011 ; Jayashree et al. 2015a). Size of planting material has direct relationship with yield (Timo 1982). The size of the seed rhizomes varies from place to place and cultivar to cultivar. Trials with rhizome bits of different weights namely, 15g (Kannan and Nair 1965), 20 – 30 g (CSIR 1976), 15 – 19 g (Mohanty et al. 1990), 20 – 25 g (AICRPS 1992) were reported/adopted.

Seed rhizome extraction (i.e., removal of seed planted after establishment of crop) has been practiced by local farmers for many years in the Hills of Sikkim and Darjeeling, India. By extracting the seed rhizome, farmers get back their investment on seed. But the wound created while detaching seed rhizome may serve as an entry point for pathogens (Rai and Gurung, 1997).

2.2 Bud transplants

Detached sprouts from mother rhizomes were tried as planting material in late 70s . Nair (1977) reported the use of detached sprouts of 4-6 cm height as planting material in ginger. The separated mother rhizome could be used as vegetable ginger. He reported the average yield of 1.16 kg green ginger per plant under Ambalavayal conditions of Kerala from detached sprouts.

Mahesh and Karla (1998) reported the effect of growth regulators and mulching on growth and yield of detached sprouts. Five-gram pieces of ginger cv. SG-713, planted in nursery beds, were transplanted in the field after 30, 60 and 90 days of sowing and treated with mulches and Ethrel (ethephon) in Solan, Himachal Pradesh. There was a significant increase in the yield with an increase in age of transplants. The highest yield among the age treatments (1.08 kg) was recorded from 90-day-old transplants and the lowest yield (0.48 kg) was recorded from 30-day-old transplants. Highest yields among mulch treatments (0.79 kg) and Ethrel treatments (0.82 kg) were recorded from the black polyethylene and the 200 ppm Ethrel treatment. The maximum yield per plot (1.27 kg) was observed in 90-day-old transplants treated with farmyard manure (FYM). Oleoresin contents were high with FYM, 100 ppm Ethrel and from 30-day-old transplants.

The effect of plant growth regulators on the growth and yield of ginger sprouts (cv. *Himgiri*) was studied in Solan, Himachal Pradesh, India, during 1997 and 1998 by Nath and Korla (2001). NAA, IAA, and IBA were applied to detached sprouts for 2 h only before planting in trays (1 ppm) or before transplanting in the field as well (0.5+0.5 ppm). The highest sprout survival rates (89.85 and 97.28%) were obtained with NAA and IAA at 0.5+0.5 ppm. IBA at 1 ppm gave the tallest plants (46.83 cm) with the highest number of leaves (31.45). All growth regulator treatments, except IBA at 0.5+0.5 ppm, were on a par with regard to the number of tillers. The heaviest rhizomes (49.62 g) and the highest yield (27.13 q/ha), net return (Rs. 15 333), and cost benefit ratio (1:0.039) were obtained with 1 ppm IBA. Ramana et al. (2003) has also reported the favourable effect of IBA. Transplants raised from seed rhizomes (about 5 g bits) in the nursery and planted in the field after 60 days with the onset of monsoon after treating with NAA or IBA (1 ppm) produced higher rhizome yield in Himachal Pradesh.

Though transplanting in ginger is not conventional, it is found profitable. A transplanting technique in ginger by using single bud sprouts (about 5 g) has been standardized to produce good quality planting material with reduced cost. The yield level of ginger transplants is on-par with conventional planting system. The technique involves raising transplants from single sprout seed rhizomes in the pro-tray and planted in the field after 30-40 days. The advantages of this technology are production of healthy planting materials and reduction in seed rhizome quantity and eventually reduced cost on seeds (Prasath et al. 2014).

Technology

- Select healthy ginger rhizomes for seed purpose
- Treat the selected rhizomes with mancozeb (0.3%) and quinalphos (0.075%) for 30 min and store in well ventilated place
- One month before planting, the seed rhizomes are cut into single buds with small piece of rhizomes weighing 4-6 g.

- Treat the single bud sprouts (mancozeb 0.3%) for 30 min before planting
- Fill the pro-trays (98% well) with nursery medium containing partially decomposed coir pith and vermicompost (75:25), enriched with PGPR/*Trichoderma* 10g/kg of mixture
- Plant the ginger bud sprouts in pro-trays
- Maintain the pro-trays under shade net house
- Adopt need based irrigation with rose cane or by using suitable sprinklers
- Seedlings will be ready within 30-40 days for transplanting

2.3 *In vitro* microrhizomes

In vitro microrhizomes are very useful for production of disease free planting materials. Among the various factors tested for rhizome induction, only sucrose (9% or 12%) was found to significantly influence rhizome formation in cultures . Experiments involving substitution of sucrose with other sugars and varying the volume of the culture medium indicated that the greater availability of carbon energy source rather than the osmotic effect of sucrose was responsible for rhizome formation. The highest germination rates of rhizomes upon transfer to soil resulted from rhizomes produced on medium containing 12% sucrose (Bhat et al. 1994). Maximum yield of rhizomes has been reported under continuous light (Sharma and Singh 1995). Temperature was also reported to be the most important factor in determining rhizome formation during the growth period. A 16/8 h (day/night) photoperiod, light intensity of 40% of full sunlight and air temperature of 22-30°C resulted in optimum rhizome growth and photosynthetic ability (Hyun et al. 1997).

Microrhizomes were successfully produced from tissue-culture derived shoots by transferring them to liquid MS medium supplemented (per liter) with 1mg BA, 2 mg calcium pantothenate, 0.2 mg GA3 and 0.05 mg NAA/ for shoot proliferation (Sharma and Singh 1995). After 4 weeks of incubation, the medium was replaced with microrhizome induction medium, consisting of MS salts supplemented with 8 mg BA and 75 g sucrose. Microrhizome formation started after 20 days of incubation in stationary cultures at 25±1°C in the dark. Microrhizomes with 1–4 buds and each weighing 73.8–459 mg were harvested after 50–60 days. After storage for 2 months in moist sand at room temperature, 80 per cent of the microrhizomes sprouted, producing roots and shoots. Another protocol perfected by Rout et al. (2001) involves shoot multiplication of ginger by meristem culture on a MS basal medium supplemented with 26.6 µM BA, 8.57 µM IAA, and 1111.1 µM adenine sulfate and 3% (w/v) sucrose. *In vitro* rhizome formation from *in vitro*-raised shoots was achieved on MS medium supplemented with 4.44 µM BA, 5.71 µM IAA, and 3–8% (w/v) sucrose after 8 weeks of culture. The microrhizomes sprouted in a soil mixture within 2 weeks of planting. The sprouted plantlets survived under field conditions with normal growth . *In vitro*-grown rhizomes of ginger grew well, when grown on the carbonized rice husk: peat medium (5:1 ratio) (Cho et al. 1997). Plant acclimatization has been reported to be successful with laboratory hardening under 85 ìE m^{-1} s^{-1} light for seven days then plants were transplanted. The percentage of established plants and sanitary conditions tended to be better in the presence of sand only or sand in combination with other media. It is possible to obtain a multiplication rate of 70,000 plants/ rhizome/year . *In vitro* production of micro rhizomes in ginger was also reported by Babu *et al.*(2005) and Zheng *et.al* (2008), Abbas *et al.*(2014) and Singh *et al.*(2014).

Among the three ginger cultivars taken for the study (cvs. Mahima, Rejatha and Varada), cv. Rejatha showed superiority in two trials and cv. Mahima responded more in the field condition. The pathogen free nature of the in vitro microrhizome was confirmed using disc culture method. The microrhizome and minirhizome technology developed in this study holds better promises for

large scale production of pathogen free seed rhizomes in ginger (Archana *et.al* (2013 a and 2013 b).

3. Production of quality seed rhizomes

3.1 Selection of site

Ginger is not cultivated continuously in the same field due to the exhaustive nature of the crop and incidence of diseases caused by soil borne pathogens. A gap of two years may be given for cultivating ginger in the same piece of land. It is a shade loving crop and 25 per cent shade is found ideal for better growth and yield (Sreekala and Jayachandran, 2002). Virgin forest soil rich in humus is the best soil for its cultivation. It prefers medium loam soil with high humus and good drainage. The depth of soil should be least 30cm. The optimum pH range of the soil is 6 to 7 (Purseglove *et al.*1981).

3.2 Preparation of land

Clear the field during April - May and burn the weeds, stubbles, roots etc. *in situ*. Prepare the land by ploughing three or four times or by digging. Prepare raised beds of convenient length (across the slope where the land is undulating), 1 m width and 25 cm height with 40 cm spacing between beds. Provide drainage channels after every 25 beds on flat lands (Nybe and Miniraj, 2005).

3.3 Season and method of planting

The best time for planting ginger is during first fortnight of April, after the receipt of pre-monsoon showers. Due to late pre monsoon showers and prevalence of very high temperature during April-May due to climate change, it is advantageous to take up planting of ginger in the second fortnight of May. Adjust planting time in ginger so as to get moderate showers at the time of planting, plenty of rainfall during growth period and a dry period of one month prior to harvest. Plant rhizome bits with viable healthy buds facing upward in small shallow pits of 4-5 cm deep at a spacing of 25 x 25 cm. In general, planting depth varies with size of planting unit, soil type, and soil moisture content (Kandiannan *et al.*, 1996). The seed rate varies from region to region and method of cultivation. In Kerala, the seed rate adopted is 1500-1800 kg/ha.

3.4 Manuring

Ginger is an exhaustive crop and requires heavy manuring and mulching to obtain high yield. Requirement of nitrogen (N) is the most critical among the major nutrients. For quick growing crop like ginger, fertilizer containing a high proportion of water-soluble P_2O_5 is needed for better yield (Sushama and Jose, 1994). Only under high rates of K application the crop can be grown successfully under shaded conditions (Jayaraj, 1990). Secondary nutrients are also essential for the healthy growth of ginger. However, deficiency of secondary nutrients is less since very large quantities of FYM and leaf mulch are applied. Need based application of micronutrients is recommended for ginger.

Cattle manure or compost is applied to beds and planting pits. Apply *Trichoderma* amended cowdung- neemcake mixture to planting pits to control soil borne pathogens (Vilasini, 1996) .

Apply FYM 30t/ha and N:P_2O_5:K_2O 75:50:50: kg/ha/year. Full dose of P_2O_5 and 50 per cent of K_2O is applied as basal. Half the quantity of N is applied 60 days after planting. The remaining quantity of N and K_2O is applied 120 days after planting (KAU, 2011).

The growth of ginger can be classified into three distinct periods: a phase of active vegetative growth (90-120 days after planting), a phase of slow vegetative growth (120 to 180 days after

planting), and a phase of senescence (180 days to harvest). The pattern of rhizome development also followed the same trend except that the development of rhizome continued up to harvest (Johnson, 1978). According to Johnson, the total uptake of N, P and K progressively increased with advancing periods of crop growth, and the uptake by the leaf and pseudostem progressively increased up to 180 days after planting and decreased thereafter. However, the uptake by rhizome steadily increased till harvest.

3.5 Mulching

Immediately after planting, mulch the beds thickly with green leaves @ 15 t/ha. Repeat mulching with green leaves twice @ 7.5 t/ha, first 45-60 days and second 90-120 days after planting. Grow green manure crops like daincha and sunn hemp in the interspaces of beds and use them for second mulching of ginger (Valsala et al. 1990).

3.6 After cultivation

Remove weeds by hand-weeding before each top dressing of fertilisers and mulching. Repeat weeding according to weed growth during the fifth and sixth month after planting. Earth up the crop after each top dressing and avoid water stagnation in the plot.

3.7 Plant protection

3.7.1 Pests

a. Shoot borer

Shoot borer (*Conogethes punctiferalis*) is the most serious pest of ginger. The larvae bore into pseudostems and feed on internal tissues resulting in yellowing and drying of leaves of infested pseudostems. The prescence of bore hole on the pseudostem through which frass is extruded and the withered yellow central shoot are characteristic symptoms of pest infestation. The shoot borer could be controlled by spraying dimethoate or quinalphos at 0.05% and by mechanical control (removing dead heart and burning). Shoot borer infestation if not controlled effectively, the plants will succumb to the attack of soft rot and bacterial wilt pathogens.

b. Rhizome scale

Rhizome scale (*Aspidiotus hartii*) infests rhizomes in the field at later stages of development and also in storage. Adult scales are circular, light brown to grey and appear as encrustations on the rhizomes. They feed on sap, attack dormant buds, rhizomes become shrivelled and desiccated affecting its germination. The pest can be controlled by treating seed material with quinalphos 0.05 % for 30 minutes before storage and before planting.

3.7.2 Diseases

a. Soft rot

Soft rot is the most destructive disease of ginger which results in total loss of the crop. The disease is soil and seed borne and is caused by *Pythium* spp. The collar region of the affected pseudostem becomes water soaked. Rotting spreads to the rhizome resulting in soft rot. Foliar symptoms first appear as yellowing of lower leaves. Yellowing of leaves proceeds upwards followed by drooping, withering and drying of pseudostems. For control of rhizome rot, select sites with proper drainage, select seed rhizomes from disease free areas, treat seed rhizomes with 0.3 per cent mancozeb. When incidence of rhizome rot is noted in the field, dig out the affected plants and drench the beds with 0.3 per cent mancozeb. Inoculation with native arbuscular mycorrhiza,

Trichoderma sp. and *Pseudomonas fluorescens* at the time of planting is recommended as biocontrol methods.

b. Bacterial wilt

Bacterial wilt caused by *Ralstonia solanacearum* is also a soil and seed borne disease. Water soaked spots appear at the collar region of the pseudostem and progress upwards and downwards. The disease symptom first appears as loss of turgidity of leaves, curling of leaf margins and plants wilt. The leaves of the infected plants become orange yellow at the margins with a band of green area on either side of the mid rib. Shoots of diseased plants show vascular discolouration. The affected pseudostem and rhizome when pressed gently extrudes a milky ooze from the vascular strands. Selection of sites with proper drainage, collection of seed rhizomes from disease free areas and seed treatment with streptocycline 200ppm for 30 minutes are the precautions to be adopted for the control of the disease. If disease is noticed in the field, dig out the affected plants and drench the beds with 0.2 per cent copper oxy chloride.

In a trial to find out alternatives for banned pesticides, soil drenching with flusilazole 2ml/l, rhizome treatment with 2% Pseudomonas fluorescens and soil drenching copper hydroxide 2g/l and rhizome treatment with mancozeb and combined soil application of bleaching powder (15g/bed) + lime 250g/bed and the organic treatment -rhizome treatment and soil drenching with *Pseudomonas fluorescens* 2% + cowdung slurry 2% and Bioconsortium are effective against all three ginger diseases viz. soft rot, rhizome rot and bacterial wilt (KAU,2015).

c. Leaf spot

The incidence of leaf spot caused by *Phyllosticta zingiberi* appears as chlorotic specks. Spots of various sizes with whitish centre, dark brown margin and yellow halo around the spot are seen. In advanced stages, leaf turns brown and dries up. The disease spreads through rain splashes during intermittent showers. The incidence is severe when grown in open condition. The disease can be controlled by spraying 1per cent Bordeaux mixture or 0.3 per cent mancozeb.

3.8 Harvesting, seed preparation and storage

For seed purpose, the crop can be harvested at 7½ to 8 months maturity, when the pseudostem dries off completely. Harvesting should be done without injuring the seed rhizomes. Removal of pest and disease affected rhizomes completely from the plot at the time of harvest will help to reduce the inoculum for succeeding crop.

After harvest, trim off the fibrous roots attached to the rhizomes, remove soil from the clump and select seed rhizomes. Soak selected seed rhizomes for 30 minutes in a solution of mancozeb and quinalphos to give terminal concentration of 0.3 per cent of the former and 0.05 per cent of the latter. Dry the treated rhizomes in shade by spreading on the floor and store the rhizomes in pits (1 × 1 × 1 m) dug under shade on a layer of sand or saw dust spread on the bottom. It is advisable to spread layers of leaves of *Glycosmis pentaphylla* (*panal*). Cover the pits with coconut fronds. Examine the stored rhizomes at monthly intervals and remove the rhizomes that show signs of rotting. Provide one or two holes for better aeration. Treat seed rhizomes once again with the above fungicide and insecticide before planting also (KAU, 2011)

In order to obtain good germination, proper storage of seed rhizomes is essential. The seed rhizomes should be stored properly so that rotting, shriveling, dehydration and sprouting can be avoided until the next planting season. Maintaining a storage temperature of 22 – 25°C make the growing buds fat and strong and temperature higher than 28°C in the long run make the buds thin

and weak. If the storage humidity is too low, rhizome epidermis may loose water and wrinkle thus affecting the sprouting speed and bud quality.

Zero energy cool chamber (ZECC), is found ideal for storing fresh ginger. Studies on storage of "seed pieces" of ginger showed that, the number of days to germination decreased with length of storage period while percentage germination and yield increased from 0 to 42 days storage. However, germination and yield were consistently lower after 35 days storage. This anomalous behaviour may be due to secondary dormancy during which the seed pieces lost their dormancy up to 21 days of storage but regained or entered into secondary dormancy at 35 days and again lost dormancy after 42 days (Timpo and Oduro 1977).

Ginger seed rhizomes were subjected to 15 different storage treatments in 1994. Storage in 100-gauge polyethylene bags with 3% ventilation covered with dry sand was the most effective treatment, recording the lowest weight loss (26.9%), sprouting percentage (12.32%) and disease incidence (9.07%) during storage. This method also gave the highest values for recovery of healthy rhizomes after 3 months of storage (90.92%) and sprouting when planted in the field (88.34%) (Chandrappa et al. 1977). Rai and Hossain (1998) compared the three traditional methods of storage of seed rhizomes at Sikkim and Darjeeling hills and reported that storage in soil pits was the best method for small scale growers.

3.9 Economics of seed rhizome production

The average fresh yield of rhizomes from high yielding varieties is around 20 t/ha. The selected seed rhizomes (after removing cut and damaged rhizomes) available for storage after first seed selection will be around 17t /ha. The recovery of seed rhizomes after storage of 3-3½ months will be around 70 per cent. The quantity of seed rhizomes available after storage and second seed selection (done after storage) will be thus 12t /ha. At the sale price of Rs.100/ kg of seed, an amount of Rs.12,00,000/- could be expected from one hectare of seed production plot. Deducting the costs towards cultivation and storage of seed rhizomes, a net profit of Rs.5, 00, 000/- could be expected from one hectare of seed production plot.

Practical tips on production of quality seed rhizomes in ginger

- Select soils with high organic matter content and good drainage with a soil depth of 30cm and pH of 6-7. Virgin forest soil rich in humus is the best soil.
- Do not cultivate ginger continuously in the same piece of land, a gap of two years may be given for cultivation.
- Adjust planting time in ginger so as to get moderate showers at the time of planting, plenty of rainfall during growth period and a dry period of one month prior to harvest.
- Take raised beds of 25 cm height and ensure proper drainage in the field.
- Mark healthy and disease free beds in the field when the crop is six months old and still green for collection of seed rhizomes.
- Use good quality seeds free from pests and diseases and treated with a fungicide and an insecticide.
- Use bio control agents like *Trichoderma* and *Pseudomonas* for the control of soil borne pathogens
- Grow green manure crops like daincha and sun hemp in the inter spaces for use in second mulching

- Adopt chemical and mechanical methods for the control of shoot borer
- Take all precautions for the control of soft rot and bacterial wilt diseases
- Do clean harvesting by removing small rhizome bits, pest and disease affected rhizomes completely from the plot.

B. Production of quality planting material in turmeric

1. Traditional cultivars and high yielding varieties

A number of cultivars are available in the country and are known mostly by the name of locality where they are cultivated. Cultivars can be grouped into three based on maturity period as short, medium and long duration. Some of the popular cultivars are Duggirala, Tekkurpet, Sugandham, Amalapuram, Erode local, Salem, Alleppey, Moovattupuzha and Lakdong. The improved varieties of turmeric released from ICAR-Indian Institute of Spices Research, Kozhikode and their salient features are given in Table 2.

Table 2. High yielding turmeric varieties

Variety	Mean yield (fresh) (t/ha)	Crop duration (days)	Dry recovery (%)	Curcumin (%)	Oleoresin (%)	Essential oil (%)
ICAR-Indian Institute of Spices Research, Kozhikode						
Suvarna	17.4	200	20.0	4.3	13.5	7.0
Suguna	29.3	190	12.0	7.3	13.5	6.0
Sudarsana	28.8	190	12.0	5.3	15.0	7.0
IISR Prabha	37.5	195	19.5	6.5	15.0	6.5
IISR Prathibha	39.1	188	18.5	6.2	16.2	6.2
IISRAlleppey Supreme	35.4	210	19.3	6.0	16.0	4.0
IISR Kedaram	34.5	210	18.9	5.5	13.6	3.0
Tamil Nadu Agricultural University, Coimbatore						
Co 1	30.0	285	19.5	3.2	6.7	3.2
BSR 1	30.7	285	20.5	4.2	4.0	3.7
BSR 2	32.7	245	20.0	3.8		
High Altitude Research Station, OUAT, Pottangi, Odhisa						
Roma	20.7	250	31.0	6.1	13.2	4.2
Suroma	20.0	255	26.0	6.1	13.1	4.4
Ranga	29.0	250	24.8	6.3	13.5	4.4
Rasmi	31.3	240	23.0	6.4	13.4	4.4
Surangi	23.4	180-200	28.0	4.5-6.5	12.7	4.6
Tirhut College of Agriculture, RAU, Dholi, Bihar						
Rajendra Sonia	42.0	225	18.0	8.4	10.0	5.0

ICAR Research Complex for NEH Region, Shillong, Meghalaya						
Mega Turmeric 1	23.0	310	16.4	6.8	-	-
Kerala Agricultural University, Thrissur						
Kanti	36.5	240-270	20.0	7.2	12.1	5.2
Sohba	33.7	240-270	19.3	7.4	15.9	4.2
Sona	37.5	240-270	18.9	7.1	18.0	4.4
Varna	33.4	240-270	19.1	7.9	13.9	4.6
Sardarkrushinagar Dantiwada Agricultural University, Jagudan						
Sugandham		15.0	210	23.3	3.1	11.0 2.7

(Jayashree et al. 2015b)

2. Planting materials

2.1 Seed rhizomes

Turmeric is propagated through vegetative rhizome for commercial production. Rhizome (also denoted as 'clump', 'bulb', 'corms' 'set', 'tuber' in the literature) is of two types viz., mother rhizome and finger rhizome also known as daughter rhizome (developed from mother rhizome). The fingers are primary, secondary or tertiary depending on their position, primary finger constitute a major share in the clump, the secondary and tertiary are less in quantity. Both mother and finger are used for propagation. However, primary fingers are commonly used for planting due to its large availability. In India, mother rhizome are used for planting in Krishna and Guntur districts, and finger alone is used in Cuddapah district of Andhra Pradesh whereas both mother and fingers are used separately in Tamil Nadu . Mother rhizomes are found better than finger rhizomes (Aiyadurai 1966). The highest yield was obtained from whole mother rhizomes followed by the primary rhizomes with 5-6 internodes and the half-cut mother rhizomes. Whole mother rhizomes produced rapid growth and development of plants. The primary, secondary and tertiary rhizomes with 3-4 internodes did not differ from one another in terms of growth and yield. The combined effect of half cut mother rhizome with $N:P_2O_5:K_2O$ at 120-60-120 kg ha^{-1} produced the highest yield (94.26 t/ha). Dhatt *et al.* (2008) recorded that mother rhizome and primary fingers were significantly superior than secondary fingers in respect of plant growth characteristics, yield $plant^{-1}$, size of mother rhizome, primary and secondary fingers production. Although, mother rhizome and primary finger were at par in terms of plant growth, yield and size of secondary fingers, but former was a better planting material in terms of size of mother rhizome and primary finger. It is therefore the growers should use either mother rhizome or primary finger as planting material to raise the turmeric crop for higher yield .

2.1.1 Seed size

Mothers split longitudinally into two halves and fingers are broken into pieces of 5 to 10 cm length weighing approximately 50 to 100 g with one or two buds are used for planting (Aiyadurai 1966). Philip (1983) reported that the highest yields could be obtained from seed rhizome pieces with 2 to 3 eyes, and primary rhizome of 30-40 g with a larger diameter or mother rhizome weighing 25-34 g. Singh *et al.* (2000) noted that whole mother rhizomes (70-80 g) planted at 50x20 cm gave highest yield in Haryana. Planting of full mother rhizome of 80-100 g resulted in minimum leaf blotch incidence caused by *Colletotrichum capsici* and maximum rhizome yield

(22 t/ha) followed by half mother rhizome of 50-80 g (Archana et al. 2000). It was observed that plants from 30 g, 40 g and 50 g of daughter rhizomes had a significantly larger shoot biomass and higher yield than those from smaller daughter rhizomes in both the greenhouse and field experiments. The shoot biomass and yield are highest in the plants grown directly from mother rhizomes when compared to the plants from daughter rhizomes attached to that of mother rhizomes. This study further indicated that the turmeric seed rhizome should be 30-40 g with a larger diameter, and seed mother rhizome should be free from daughter rhizomes. Randhawa & Mishra (1974) while studying the effect of seed size in turmeric reported that large sized rhizome weighing approximately 100 g gave significantly higher yield (61 q ha^{-1}) than small sized rhizomes (53.3 q ha^{-1}) of 50 g weight.

2.1.2 Seed rate

Seed rate of turmeric generally varies based on type of rhizome and spacing adopted. When mother rhizome was used, rate reported was 1800 kg ha^{-1} while it was 1200 kg/ha for finger. Different seed rates were suggested by several workers (Rao et al.2006). Seed rate recommended for planting one hectare is 2500 kg (KAU,2011).

2.1.3 Preservation of seed rhizomes

Rhizomes for seed purpose are generally stored by heaping in well ventilated rooms and covered with turmeric leaves. The seed rhizomes can also be stored in pits with saw dust, sand along with leaves of *Stychnos nux-vomica* (*kanjiram*). The pits are to be covered with wooden planks with one or two openings for aeration. The rhizomes are to be dipped in quinalphos (0.075%) solution for 20-30 minutes if scale infestations are observed and in mancozeb (0.3%) to avoid storage losses due to fungi.

2.2 Bud transplants

Single bud transplants in turmeric as a technique for accelerated production of quality planting material with reduced cost was reported by Chitra and Jansirani (2014). An experiment was laid out at Tamil Nadu Agricultural University, Coimbatore to standardize the rapid multiplication technique in turmeric with four different treatments. Among the various treatments, the treatment finger rhizome with one bud recorded significantly the highest shoot length (24.96 cm), root length (12.08 cm), vigorous index (2334.84) and crop establishment (88.96 %) when compared to other treatments.

2.2.1 Standardization of potting media for protray budling production of turmeric

A trial was laid out to standardize the potting media for protray budling production of turmeric with eight different treatments. The finger rhizome pieces treated with Carbendazim 2g/l for 10 minutes. The rhizome pieces were then spread over the polythene sheet under the tree shade and covered with the medium. The medium was irrigated with rose-can before covering it with another polythene sheet and kept aside for 4 days. The rhizome pieces with buds were picked out and then placed in protrays containing the medium. Approximately 1.2 kg of medium is required for filling one protray. The rhizome pieces were covered with respective medium, irrigated sufficiently with rosecane and the trays were kept one above the other such that 10 trays in one set under the shade net and covered with a polythene sheet until germination. After 7 days, the protrays with sprouted rhizomes were placed individually inside the shade net. Watering was done at regular intervals and Humic acid (0.5%) was sprayed after the emergence of first leaf. After 10 days of the emergence of first leaf, drenching with 19:19:19 mixture @ 0.2% was done. The seedlings attain the transplantable stage after 30 – 35 days of sowing of rhizomes.

All the treatments exhibited significant difference for the various growth parameters of the seedlings. Among the treatment, the treatment Cocopeat + *Pseudomonas fluorescens* was found to show conspicuous effect on the sprouting percentage (95.27), stem length (25.72 cm), root length (12.62 cm), vigorous index (2463.05) and crop establishment (95.40%). The treatment Cocopeat was found to exhibit least performance for all the parameters except sprouting percentage (84.73) and crop establishment (76.60%).

2.2.2 Standardization of suitable planting season for turmeric transplants

An experiment was laid out to standardize the suitable planting season for turmeric transplants with seven different treatments.

Growth parameters: Among the various treatments, the treatment June 15th planting recorded prominent plant height (116.19 cm) and number of leaves (13.13). However the treatment July month planting registered the highest number of tillers per plant (4.60).

Pest and disease incidence: The field experiments conducted during the 2011-12 season showed the incidence of shoot borer comparatively lower in the planting season June 15th (0.84%) followed by July 15th (1.13%) and August 15th (1.16%). Similar trend was found with respect to incidence of rhizome scale in the planting seasons June 15th (0.54%) and July 15th (0.86%). In the case of rhizome rot, all the treatments with single bud derived plants found to exhibit lesser incidence percentage than the June month planted rhizome derived plants (24.50%) and least incidence was recorded in June 15th planting (4.60%) and July 15th planting (5.25%).

Yield parameters: The treatment June 15th planting recorded the highest fresh rhizome weight per plant (1.176 kg), dry rhizome weight per plant (0.242 kg), fresh rhizome yield per hectare (47.18 t) and dry rhizome yield per hectare (9.70 t).

Economics: The treatment June 15th planting recorded the highest gross returns (Rs. 2,68,800/ ha), net returns (Rs. 1,86,750/ha) and B:C ratio (2.28:1). It was followed by July15th planting.

2.2.3 Studies on the effect of rhizome size and nursery on growth and yield of turmeric

A trial to standardize the size of the planting material and to study the effect of the seedling on growth and yield parameters was laid out with nine different treatments. Among the different treatments, the treatment single node (5 g) planting in portray (1 month) recorded the highest yield (67.94 kg) compared to control primary full length rhizome (25-30 g) planting directly in the field (43.77 kg). Enhanced growth and less rhizome maturation phase were observed in bud transplants (Table 3). Transplants from single bud recorded double the yield in turmeric (Table4).

Table 3. Growth comparison of Direct planting vs. single bud transplants in turmeric

Growing Phase	Direct planting method	Transplanting method
1. Sprouting phase	20 DAP	Seedlings having 3-4 leaves (1 month old)
2. Vegetative phase		
(i) One month after planting	2-3 leaves/plant	6-7 leaves/plant
(ii) Tillering stage	3 MAP	1½ – 2 MAP
3. Rhizome development phase	Starts 5 MAP	Starts 3 MAP
4. Rhizome maturation phase	7 – 9 months	6 – 7 months

Table 4. Comparison of direct planting vs. single bud transplants in turmeric

Characters	Direct planting method	Transplanting method
Propagation through	Whole Rhizome	Rhizome single bud
Seed rate	1000 kg/ac	300 kg/ac
Cost of planting material	Rs. 12,000	Rs. 3,600
Crop establishment	75 - 80%	95 -100 %
Rhizome development	Starts 5 months after planting	Starts 2 months after planting
Productivity	10 - 12 tons/ac	20 - 22 tons/ac

2.3 *In vitro* micro rhizomes

The induction of microrhizomes in four varieties of turmeric viz. Ranga, Rasmi, Roma and Suroma were reported by Nayak (2000). Microrhizomes were produced from tissue culture derived shoots of four cultivars by transferring them to Murashige and Skoog (MS) liquid medium supplemented with 6-benzyladenine (BA) (1-5 mg/litre), enhanced concentration of sucrose (50-100 g/ litre) and with reduced photoperiod (0-8 h). BA (3 mg/litre), sucrose (60 g/litre) and photoperiod (4 h) was found to be most effective for induction of microrhizome in all four varieties of turmeric. Microrhizomes were formed at the base of the shoots r and the weight varied from 40 to 700 mg. Interactions of different factors such as BA, sucrose and photoperiod had a significant effect in the induction of microrhizome. Concentration of sucrose was most effective in rhizome formation followed by photoperiod and BA in the medium. Microrhizomes were harvested after 120 days of culture. These microrhizomes could be stored in MS media with low concentration of BA (0.01 mg/litre) and in moist sand at room temperature. Microrhizomes were produced in vitro independent of seasonal fluctuation and sprouted with roots and shoots in potted soil during planting seasons which were then transferred to the field. These microrhizomes, since produced *in vitro* can be used as disease free seed rhizomes. Storage of microrhizome *in vitro* would facilitate continental and intercontinental germplasm exchange programmes

Efficient procedure for *in vitro* micro rhizome production in turmeric was also reported by Shirgurkar et.al (2001) , Islam et.al (2004) and Cousins et.al. (2008). *In vitro* microrhizome and minirhizome production in turmeric cultivar Alleppey supreme and its comparative anatomical and histochemical analysis were reported by Archana et al.(2014). The variety showed highest response in liquid MS medium with 80 gl-1 sucrose in Planton culture vessels. The microrhizome technology developed during the present study can be used for large scale production of planting materials in turmeric within a short period of time without compromising the quality and quantity.

Conclusion

The method of production of quality seed rhizomes in turmeric is the same as that of ginger. The difference exists only in seed rate and nutrient management. The high seed rate and long period of storage of seed rhizomes in hot summer period are the major problems faced in seed production of ginger and turmeric. The microrhizome technology / bud transplant technology together with open precision / high tech precision farming technologies will help to overcome these problems and aid in production of high quality seed rhizomes of ginger and turmeric in large scale.

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