STATUS OF CURRENT RESEARCH TOWARDS INCREASED PRODUCTION AND PRODUCTIVITY IN BLACK PEPPER IN INDIA

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INTRODUCTION

Black pepper (*Piper nigrum L*), the "King of Spices", originated in the Western Ghats of India and has been domesticated and spread to Southeast Asia, Africa and South America. Currently black pepper is cultivated in over eight countries. India accounts for about 26 percent of the world production and about 18 percent of export.

However, about 48 percent of the total area under black pepper in the world is in India. Global production during 2004 is estimated to be around 326,500 tons and the export is estimated to be about 225,300 tons.

In India, the pepper growing area is estimated to be about 257,770 ha (Source: DC & SD, Calicut). The average annual growth rate of pepper area and production are 8.80 and 9.06 percent respectively (base year 1996-97). The world demand for pepper for 2004 is projected to be about 250,000 tons.

The major weaknesses of the pepper industry in the country are low productivity, high cost of production, non-availability of sufficient healthy planting materials for replanting or fresh planting and crop loss due to biotic (diseases & pests) and abiotic stresses (drought).

Pepper productivity in India is very low, about 375 kg/ha, compared to other producing countries. Black pepper is mainly grown in India as a mixed crop. This system optimises production per unit area and sustains production through periods of low price. A monocrop of pepper may not be as viable with the high fluctuations in the

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J. pepper Industry

price of the commodity. Yield levels of pepper however, are generally affected in a mixed crop system due to nutrient competition and thus result in low productivity where nutrient supplements are neglected. *Phytophthora* foot rot and slow decline diseases continue to cripple pepper production in the country in spite of excellent IDM (Integrated Disease Management) technologies that have been developed, which are yet to percolate down to the farming community. Eco-friendly biocontrol technology developed for these maladies has been found to be effective in field demonstrations. Lack of awareness among producers and processors about the ideal post harvest technology (PHT) to produce "clean" products is another major weakness of the pepper industry in India. However the scenario is changing and pepper farmers are realising that these technologies are beneficial for them.

India has now a clear lead over other producing countries in organic spices. It is forecasted that by the year 2006 there would be a 5-6 fold increase in the demand for organic products all over the world. India's capability in the organic pepper sector can be geared to capture a lion's share of this global market.

Research on black pepper is carried out primarily under the Indian Council of Agricultural Research, through the Indian Institute of Spices Research (IISR), Calicut, the All India Coordinated Research Project on Spices (AICRPS), the Pepper Research Station, Panniyur, of Kerala Agricultural University and several State Agricultural Universities (SAUs) in South India. These multi-disciplinary research efforts are geared to address the basic issues outlined above, especially with respect to the changing global scenario of increasing demand for "clean" products.

CROP IMPROVEMENT AND BIOTECHNOLOGY

Conservation of black pepper genetic resources

Black pepper (*Piper nigrum* L.) originated from the Western Ghats of Peninsular India and this area is considered to be a centre of genetic diversity for pepper. Major efforts with respect to conservation of genetic resources are being undertaken to check the rapid gene erosion that is taking place due to biotic, abiotic, socio, political and economic factors. At the IISR, a large collection of about 3000 accessions of black pepper, of which 18 belong to different *Piper* species, are maintained. The germplasm of black pepper is conserved in clonal field repositories and also in *in vitro* gene banks, since black pepper is vegetativeley propagated and seed progenies are not true to type. Most of these collections are systematically evaluated and many promising lines have been identified (Ravindran and Nirmal Babu, 1994). Besides these, black pepper germplasm is conserved under the All India Coordinated Research Project on Spices (AICRPS) and also at the National Bureau of Plant Genetic Resources, New Delhi (NBPGR).

Varietal improvement

Varietal improvement is mainly through clonal selection of existing cultivars, open pollinated seedling progenies and through hybridization. Breeding methodologies have been standardized (Sasikumar *et al* 1992,1996) and specific strategies have been formulated. The major focus was to break the yield barriers, and this has resulted in the development of some high yielding varieties. Incidentally, some of these were also found to have high intrinsic quality characteristics.

In total there are 16 new varieties, of which 12 have been released and 4 have been recommended for release. Coll. 1041 is a clonal selection of the landrace "Thevanmudi", approved for release by IISR recently after collaborative trials with Tata Tea at the hot spot area of disease. This selection has good tolerance to foot rot and is a good yielder with above 5 kg. of fresh berries per vine. HP 813 (a hybrid rich in oleoresin, above 12%) and HP 105, a high yielding hybrid (above 6 kg per vine) are two other black pepper hybrids that have been recently approved for release by IISR, Calicut. They are suited to high altitude areas (above 3000 ft) as well as the plains. (Table I) (Anon, 2004).

Released varieties of black pepper from IISR:

Sreekara,

Subhakara

Panchami

Pournami

Table 1. Improved Black pepper varieties and their quality attributes

Variety	Avg yield - dry pepper (Kg/ha)	Driage (%)	Quality attributes (%)			Pedigree/Parentage	Institution Responsible
			Piperine	Oleoresin	Essential oil		
Panniyur-1	1242	35.3	5.3	11.8	3.5	Hybrid, Uthirankotta X Cheriyakaniyakadan	KAU *)
Panniyur-2	2570	35.7	6.6	10.9	3.4	Open pollinated progeny of Balankotta	-do-
Panniyur-3	1953	27.8	5.2	12.7	3.1	Hybrid, Uthirankotta X Cheriyankaniyakadan	-do-
Panniyur-4	1227	34.7	4.4	9.2	2.1	Clonal selection from Kuthiravally	-do-
Panniyur-5	1098	35.7	5.3	12.3	3.8	Open pollinated progeny of Perumkodi	-do-
Panniyur-6	2127	33.0	4.9	8.3	1.3	Clonal selection from Karimunda	-do-
Panniyur-7	1410	33.6	5.6	10.6	1.5	Open pollinated progeny of Kalluvally	-do-
Panchami	2828	34.0	4.7	12.5	3.4	Clonal selection from Aimpiriyan	IISR, Calicut
Pournami*	2333	31.0	4.1	13.8	3.4	Clonal selection from Ottaplackal	-do-
Subhakara	2352	35.5	3.4	12.4	6.0	Clonal selection from Karimunda	-do-
Sreekara	2677	35.0	5.1	13.0	7.0	Clonal selection from Karimunda	-do-
PLD-2	2475	-	3.3	15.5	3.5	Clonal selection from Kottanadan	CPCRI,RC Palode
IISR Girimunda (HP-105)	6.40@	32.0	2.2	9.6	3.4	Hybrid, Narayakodi X Neelamundi	IISR, Calicut
IISR Malabar Excel (HP 813))	3.0 @	32.3	2.9	13.5	3.2	Hybrid, Cholamudi X Panniyur 1	-do-
IISR Thevan (Coll 1041)	5.17@	32.5	1.6	8.5	3.1	Clonal selection from Thevanmudi	-do-
IISR Sakthi** (P24)	5.24@	43.0	3.3	10.2	3.7	Open pollinated progeny of Perambramundi	-do-

@ Kg fresh/vine *Resistant to root knot nematode ** Tolerant *P.capsici* (foot rot)

Development of host resistance against biotic and abiotic stress

In view of the serious disease problems encountered, especially foot rot and slow decline, focus has shifted to development of varieties resistant to or tolerant of these diseases. Efforts are also being made towards development of tolerance to drought.

Biotic: In order to exploit the inherent heterozygosity in vegetatively propagated black pepper cultivars, seedling progenies were raised on a large scale and mass screened with zoospore suspension of *P.capsici* for their reaction. P24, a seedling progeny of cultivar Perambramundi was found to be field tolerant with good yield potential. This variety has been recommended for release as IISR-Sakthi (Anon, 2004). Large scale screening of cultivars and hybrids using stem inoculation techniques did not yield a high degree of resistant material but tolerant lines (ACC 1047, ACC1095, ACC 847, ACC 971, HP 780, HP 104) have been identified. (Sarma *et al* 1994) These can be utilized in future breeding programs. High degrees of resistance or immunity for *P.capsici*, *R.similis* and *M.incognita* were identified in a wild type of *P.colubrinam. P.arboreum* was also found to be resistant to *P.capsici.* Breeding efforts to incorporate the multiple resistance of *P.colubrinam* on to black pepper did not yield results. However *P.colubrinum*, as a root stock under field conditions, was found productive where soil moisture levels are good (Kalloo *et al* 2001). Resistance to *R.similis* could not be identified in black pepper cultivars but resistance to *M.incognita* was identified and the variety was released as Pournami (Ramana and Mohandas 1986). The strategy is to discourage the monoculture of susceptible cultivars, even though they may be productive, and to encourage adoption of multiple line selections (Sarma and Anandaraj, 1996)

Abiotic: Since many black pepper areas have become drought prone in recent years, major emphasis has been given to developing drought resistant lines in black pepper. Among the 44 cultivars/varieties evaluated for drought tolerance, Panniyur-5 possessed the best morphological, physiological, biochemical and anatomical adaptations to tolerate water stress while Paniyur-1 had poor adaptation. Hence, in drought prone areas, Panniyur-5 may be preferred over Panniyur-1. More than 350 black pepper germplasm accessions were screened for drought tolerance, using morphological, physiological and biochemical parameters. The preliminary screening indicated that Acc. Nos. 1228, 1343, 1368, 4216 and 4226 were promising. These are being further screened under field conditions. (Krishna Moorthy, unpublished).

Biotechnology: In Black pepper, the role of biotechnology is manifold. Micropropagation is an important technology for large scale production of disease free planting material of elite genotypes and for *in vitro* conservation of the crop's genetic resources by slow growth as well as storage in liquid nitrogen. Genetic transformation and development of disease resistant transgenics is an important area that remains unexplored. Fingerprinting of these valuable genetic resources using molecular markers is another priority area. Development of resistant varieties and transfer of resistance from specific species like *P.colubrenum* to *P.nigrum* are the major thrust areas in improvement of black pepper. Biotechnology offers an efficient means to address these objectives. Broome and Zimmerman (1978) were the first to micropropagate black pepper.

MICROPROPAGATION

Methods of *in vitro* culture for cloning of black pepper have been using shoot tips, nodal segments and apical meristems from both mature and juvenile tissues have been reported (Mathew and Rao 1984; Philip *et al.* 1992; Nazeem *et al.* 1993; Nirmal Babu *et al.* 1997). Field evaluation of tissue cultured black pepper showed that tissue cultured plants are on par with vegetatively propagated plants.

Black pepper can be successfully regenerated from callus cultures. Nirmal Babu *et al.* (1997), and Joseph *et al* (1997), reported *in vitro* somatic embryogenesis from zygotic embryos indirectly at the callus phase, while Nair and Gupta (2003) reported high frequency direct somatic embryogenesis from integument (meternal) tissues.

Shylaja et al. (1994) and Nazeem et al. (1996) reported attempts at induction of variability on somaclones for tolerance or resistance to Phytophthora foot rot. They reported that *in vitro* selection of calli as well as somaclones using crude culture filtrate and toxic metabolite 8 isolated from *Phytophthora capsici* resulted in identification of tolerant somaclones among the regenerated plantlets. However these studies did not yield consistant results and were not of practical importance.

Shaji *et al.* (1996) reported high frequency isolation of viable protoplasts from *in vitro* derived leaves of both *P.nigrum* and *P.colubrinum*. This protoplast technology would be an ideal system for manipulation at cellular level to induce host resistance.

Only preliminary reports are available on *Agrobacterium* mediated gene transfer systems in *P.nigrum* (Sasikumar and Veluthambi 1996a,b). They have also obtained primary transformants for kanamycin resistance in the cotyledons using *Agrobacterium tumefaciens* binary vector strains LBA 4404 and EHA 105.

In vitro conservation of germplasm: Conservation of pepper germplasm in *in vitro* gene banks by slow growth has been reported. This is done by maintaining cultures at reduced temperatures, in the presence of osmotic inhibitors, at reduced nutrient levels, or by minimizing evaporation loss by using closed containers (Nirmal Babu *et al*, 1997). Black pepper cultures could be maintained in half strength WPM supplemented with 15 gl^{-1} each of sucrose and mannitol for one year with 85% survival. They

developed into normal plants without any deformities and were morphologically similar to mother plants. Choudhary and Chandel (1994) reported successful cryopreservation of black pepper seeds.

Molecular (RAPD) profiling of black pepper cultivars was studied by Pradeepkumar et al (2001) and they also developed diagnostic markers for many of the cultivars. Babu *et al* (2003) studied RAPD and AFLP profiling of related species of black pepper and studied the species inter-relation ships. Studies are also in progress at IISR to tag important agronomic characters with molecular markers.

CROP PRODUCTION

Planting material production, Integrated Plant Nutrient Management (IPNM) and water management are some of the thrust areas in crop production.

Planting Material Production

In India, runner shoots arising from the base of the vine are generally used as source of planting material. In the conventional method, bits with 2 to 3 nodes are planted in poly bags from February to March, under conditions of high humidity in nurseries. The rapid method of multiplication (Bavappa and Gurusinge 1978) involves allowing shoots to train on an inclined split bamboo filled with nursery mixture and the roots strike at each node. The rooted shoots are cut into single node bits and planted in poly bags. The cuttings will then be ready in June or July for field planting (Sivaraman 1992). As there may be soil contamination and possibly root infection by *P.capsici*, *R.similis* and *M.incognita*, the nursery soil should be fortified with VAM (Vesicular arbuscular mycorrhiza) *Trichoderma harzianum* and also PGPRs (Plant Growth Promoting Rhizobacteria), especially *Psedomonas flourescens* (Sarma & Anandaraj 1998b, Anandaraj *et al* 1996, Anandaraj *et al 2003*, Thankamani *et al 2003*). This approach ensures healthy, robust, rooted cuttings and the field establishment of nodes was as high as 90-95% (Sarma and Anandraj 1998a)

Nutrient Management

Soils: Though grown on a wide variety of soils, well drained virgin red, lateritic and aluvial soils rich in humus are most suitable for black pepper. In India pepper is grown mainly on the west coast tract where the soils are acidic and poor with respect to P, K, and secondary micronutrients, especially zinc. The major pepper growing soils of India can be broadly classified viz., Red loam (Alfisol), Forest loam (Mollisol) and Laterite (Oxisol).

Nutrient Uptake: Nutrient deficiency and toxicity symptoms of major and secondary micronutrients in black pepper were reported by many workers. An adult pepper vine requires 233.4g of N, 16.8g of P, 171.9g of K, 18.3g of Mg, 75.0g of Ca, 365mg of Fe, 281mg of Mn, 104mg of Zn, 89mg Cu and 60mg of B. These major nutrients must be applied in sufficient amounts to meet the uptake by the plant, in addition to the allowance made for nutrient losses through leaching. The quantities of macro and micronutrients removed through harvesting of produce are directly proportional to the yield. The amount of nutrients removed by harvesting of the crop follows a decreasing order, N>K>Ca>Mg>P>S>Fe>Mn>Zn. Pepper yields were significantly correlated with organic matter (r=0.63**) by Bray, P (r=0.816**) by Olsen, P (r=0.811**), Soil Zn (r=0.318**), leaf P (r=629**), Leaf Zn (r=0.306**) and berries P (r=0.576**). (Sadanandan and Hamza, 2002).

Inorganic fertilizers: Agro-ecological conditions, soil nutrient status, physical properties of the soil, cropping systems, incidence of disease etc., should be considered when fertilizer is applied. Studies on sources of phosphate for pepper showed that application of Mussoorie Rock Phosphate (MRP) @ 80 kg/ha/year was comparable with super phosphate in respect of soil availability, yield response and relative agronomic effectiveness and economics (Sadanandan and Hamza 1995).

Yield response functions and DRIS norms for black pepper growing soils and leaf nutrient concentrations for optimum yield have been developed. An optimum yield ranging from 561 to 4526 g per vine can be achieved if the index leaf (recently matured leaf) contains 1.65 to 2.79% N, 0.11 to 0.26% P, 1.18 to 2.84% K, 1.42 to 3.33% Ca, 0.4 to 0.6% Mg, 0.09 to 0.29% S, 126 to 1145ppm Fe, 109 to 721ppm Mn, 21 to 67pp Zn and 16 to 120ppm Cu. (Sadanandan *et al.*, 1996).

The response of black pepper (*Piper nigrum* L) to zinc was seen both under greenhouse and field conditions. In zinc deficient black pepper growing soils, application of Zn at 5mg/kg for potted bushes and Zn at 6.2 kg/ha for field conditions were found to be optimum for increasing the yield and improving the quality of black pepper (Hamza and Sadanandan, 2002). Correction of soil pH by lime application at 0.5 tons per ha^{-1} or application of molybdenum at 0.5kg per ha^{-1} met the Mo requirements of black pepper and increased berry yield by 14% (Hamza and Sadanandan, 2003). Use of Neem coated prilled urea at 100kg/ha increased the by yield 51%.

Integrated Plant Nutrient Management (IPNM): Application of N, P_2O_5, and K_2O at 140:55:270 kg/ha per year was found to be optimal in monocrops on laterite soils. Basal application of P with the onset of the monsoon and N and K in equal parts during June and September are recommended. Adoption of IPNM (FYM 5 tons/ha, + NPK 100:40:140 kg/ha + lime, Neem cake, Bone meal each at 500 Kg/ha) in mono- and mixed-cropping system resulted in yield increases of 222% and 170% respectively. The studies on the use of bio-fertilizers viz. N.fixers like Azorpirilum and

P. solubilising bacteria have been initiated and their potential for organic black pepper production remains to be explored (Srinivasalu *et al* 2000).

Studies on water requirements of black pepper indicated that irrigation at 7 liters/day per vine during October to May resulted in maximum yields (3.06 Kg/vine) in cv. Karimunda trailed on *Erythrina indica* standards.

Bush pepper: Bush pepper is an ideal under-storey crop in coconut plantations and agro-forestry systems and is also suitable for terrace gardens in urban and rural areas as it can be grown in pots. Bush pepper cultivation in oil palm plantations was also found to be successful. The growth and yield of bush pepper was superior under 50% shade. Application of NPK at 1.0, 0.5, 2.0 gms/pot (10 kg. of soil) at bimonthly intervals, increased the yield by 239%. The chemical source of N can be substituted with Neem cake (30g) or Groundnut cake (14 g). Bush pepper can be grown in the field at a spacing of 2m x 2m (2500 plants/ha). Application of FYM at 5 kg. per bush and NPK at 10:5:20 gms. per bush at quarterly intervals gave maximum yields of up to 1960 kg/ha during the fourth year of planting. Potassium sulphate was a better source of K than potassium chloride, as it increased the yield and quality of black pepper berries. Potassium sulphate application registered 4.1% content of essential oil, 13.5% oleoresin and 6.1% piperine, compared to 3.3%, 10.7% and 4.7% respectively for potassium chloride.

CROP PROTECTION

Crop protection still remains a major component of strategies for boosting crop production of black pepper. Foot rot and slow decline continue to be the major production constraints (Sarma *et al* 1991, Ramana 1991). Besides these, incidences of two important viral diseases, Cucumber mosaic (Sarma *et al* 2001) and badna virus (Bhat *et al* 2002) are on the increase. Damage due to root mealy bug is becoming increasingly serious. Even though chemical controls were given a greater thrust earlier (Sarma *et al* 1991, Ramachandran *et al* 1991) for disease management, an integrated approach involving nursery hygiene, phytosasnitation, cultural and chemical methods, with a greater thrust on biocontrol (Sarma and Anandaraj 1996) is the present strategy.

Integrated disease management of foot rot and slow decline: An ideal package of control practices for foot rot (*P.capsici*) and slow decline (*R.similis, M.incognita*) has been evolved, with a greater thrust on biocontrol. In the absence of multiple host resistance to these biotic stresses, biocontrol technology using biocontrol agents (BCA's) with multiple modes of action is the rational approach. However nursery hygiene, phytosanitation and strict adherence to cultural practices are the key factors for the success of biocontrol (Sarma and Anandaraj 1996, 1998).

The ideal package for foot rot management, which consisted of adoption of phytosanitary cultural practices, combined with aerial spraying of the vines with bordeaux mixture and drenching the soil with copperoxychloride, was demonstrated in an area covering 87,650 ha. over a period of three years, at a cost of US$ 6.3 million and the package was clearly seen to be successful, with a cost benefit ratio of 2.3 confirming the economic viability of the technology (Anon 1999). The earlier findings relating to the bioefficacy of systemic fungicides like metalaxyl (ridomil) and Fosetyle Al (Alliette) still holds good (Ramachandran and Sarma 1999). The disease suppressive role of potassium phosphonate has been established and incidentally, it has been found to be compatible with *T.harzianum* (Veena and Sarma 2000, Rajan and Sarma 1997).

Biological control

VAM (Vesicular arbuscular mycorrhiza): Among several VAM fungi tested, *Glomus fasiculatum* was found to be effective in suppressing root rot caused by all the three pathogens (*P.capsici, R. Similis, M.incognita*) and increased plant growth and yields (Anandraj *et al* 1996). Incorporation of VAM in the nursery mixture of black pepper was found to be ideal. In addition, *Verticillium chlamydosporium, Paecilomycis lilacinus, T.harzianum* and *Pasteuria penetrans* were found to be effective in suppressing plant parasitic nematodal infections in black pepper (Ramana and Eapen 2000). Technology for large-scale production of *Trichoderma* has been transferred to 15 entrepreneurs to meet the demands of the farming community.

***Trichoderma*:** The important role played by PGPRs in plantation crops and spices has been highlighted previously (Sarma *et al* 2003). Among several *Trichoderma spp* tested for their efficacy in suppressing root rot, *T.harzianum* (P26) was found to be highly suppressive to *P.capsici* and relatively stable in soil. The technology for large-scale inoculum production has been developed. Incorporation of *T.harzianum* along with VAM into the nursery mixture was found to be effective in promoting growth and suppression of root rot. Soil application of inoculum along with FYM or Neem cake resulted in the gradual reduction of *P.capsici* inoculum and consequent reduction in disease incidence and death of vines. The technology was demonstrated on farmers' fields on 2000 ha. over a period of 3 years and the impact analysis showed that 80% of the farmers accepted the technology (Sarma and Anandaraj 1998 a & b, Rajan, Sarma and Anandaraj 2002, Saju, Anandaraj, Sarma 2002)

PGPRs (Plant Growth Promoting Rhizobacteria): Efficient strains of PGPRs have been developed that have growth promoting and disease suppressive activity in black pepper (Sarma *et al* 2000, Diby Paul *et al* 2001). PGPRs, especially *Psedomonas*

flourescens, was found to be highly effective in suppressing root rot caused by *P.capsici*, and *R.similis* in black pepper, through growth promotion and induced systemic resistance (ISR). These were found to be compatible with *T.harzianum* and VAM (Thankamani *et al* 2003, Diby Paul *et al* 2003). PGPR isolates IISR522, IISR528, IISR853, and IISR859 showed dual suppression of *R.similis* and *M.incognita*. Currently, field evaluation trials with *T.harazianum, V.chlamydosporium* and *Pasteuria penetrans* for suppression of nematode damage in black pepper are in progress (Anon 2004).

Consortium approach: In order to provide better protection from soil borne pathogens, a consortium approach with a mixture of compatible *Trichoderma* and bacterial strains with multiple modes of action to suppress *P.capsici* and nematodes has been developed. This needs large-scale field evaluation. Incidentally *T.harzianum* was found to be compatible with potassium phosphonate, a systemic molecule effective against *P.capsici* and also with chlorpyriphos, which was found to be effective in reducing mealy bug damage to roots. As such these treatments will fit in well into IDM / IPM programs (Sarma and Anandaraj, 1998, Anandaraj *et al* 2003).

Anthracnose and spike shedding: Anthracnose caused by *Colletotrichum necator* and *C.gleosporioides* is becoming serious in high altitude areas, causing spike shedding as well as leaf infection. Detailed investigations are in progress. However pre-monsoon spraying with Bordeaux mixture does manage to check the disease. Cultural practices, like shade regulation and irrigation, need to be looked into for disease management (Sarma *et al* 1991).

Virus diseases: A strain of Cucumber mosaic virus (CMV) and a strain of badna associated with stunting diseases and pepper mottle mosaic have been identified (Sarma *et al* 2000, Bhat *et al* 2002). Yield reduction in the affected plants in considerable. The severity of the disease varies from place to place. It has been established that transmission of badna is through *Ferrisia virgata*, a mealy bug. Even though insect vectors are involved, it is likely that the spread of the disease is mainly through planting materials because of vegetative propagation. As such, diagnostics (ELISA) for detection of viruses in the nursery stock need to be developed to eliminate contaminated nursery stock. Since both diseases are sap transmissible, it is essential to avoid the use of the same farm implements to prune infected vines as well as healthy vines in other areas, without first disinfecting by dipping in hot water. Farmers and nurserymen should be appraised of the disease symptoms so that they can avoid using planting material from infected vines. Basic studies are necessary on the virus-vector relationships and to locate alternate hosts to eliminate those plants that harbour virus inoculum.

Insect Pest Management: Pollu beetle (*Longitarsus nigripennis*), Scale insects (*Aspidiotus destructor, Lepidosaphes piperis*) and top shoot borer (*Cydiahemidoxa*) have been identified as the main pests affecting pepper. Pollu beetles cause 'hollow berries' and scales damage the leaves and stems of vines, resulting in the drying up of affected branches (Devasahayam 2000a). The incidence of root mealy bug infestation is becoming serious but its role remains still obscure. As a component of IPM, cultural practices like shade regulation to check pollu beetle damage have been adopted. Even though endosulfan was found to be effective in checking pollu beetles, botanicals like neem products, specifically Neem gold (0.6%) or Neem azal (0.05%) or Neem mark (1%) were found to be as effective. Even though the latter are costly, they are preferred as they are safe.

In recent times, studies have been intensified to locate and identify parasites and predators of insect pests found on spices (Devasahayam 1996). Studies on parasites and predators to control scale insects led to the identification of the efficient natural enemies, *Chilochoris cirumdatus* and *C.nigrita*. Inundated release in the field was highly effective to control pest damage (Devasahayam 2000).

The research efforts on the varietal development, planting material production, nutrients, water management and effective biocontrol technology for disease and pest management have had profound impact on the production of black pepper. In order to improve yields, it is imperative to implement all the packages judiciously, taking advantage of all available technology. Post harvest handling and value addition should receive greatest priority. Greater efforts are needed too, in transfer of technology (TOT) in order to ultimately benefit the farming community. In recent years several NGO's (Non Governmental Organisations) have been getting involved in the TOT process and this may further help in increasing production and productivity. The present coordinated efforts of ICAR in strengthening production strategies should also be of benefit to pepper farmers.

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