Agric. Rev., **29** (2) : 89 - 98, 2008

BLACK PEPPER (*PIPER NIGRUM* L.) 'THE KING OF SPICES' - A REVIEW

T. Thangaselvabal, C. Gailce Leo Justin and M. Leelamathi

Horticultural Research Station,
Tamil Nadu Agricultural University, Pechiparai 629 161 Tamil Nadu, India.

ABSTRACT

Black pepper (*Piper nigrum* L.) the king of spices is originated in the Western Ghats of India and subsequently spread to other countries. It is the largest foreign exchange earner among spices and the average quantity exported from India accounts for more than 70 per cent of the total production. The demand for black pepper and its products is getting increased year by year in the world market but the production is not up to the level. At present the productivity in India is very low due to non adoption of good agricultural practices.

Black pepper (*Piper nigrum* L.) the king of spices is one of the important spice commodities of commerce and trade in India since pre-historic period. It originated in the tropical evergreen forests of the Western Ghats of India. India is the largest producer of black pepper, growing in about 2.15 lakh hectares with an annual production of 70,000 tonnes and the export has been 29,300 tonnes valued Rs. 427.63 crores (Spice Board,2008). In terms of total area, India ranks first and as for as productivity (315kg/ha) is concerned India is in the last position (Madan, 2000). The low productivity is mainly due to i)poor genetic potential of the vines, ii) high population of senile and unproductive vines, iii)losses caused due to biotic and abiotic stresses, iv)non-availability of quality planting material of improved varieties, v)non adoption of appropriate agronomic practices. Hence, as an effort towards this direction, the available information on various aspects like crop improvement, crop production and protection, post harvest management and value addition are reviewed.

Genetic resources

The first major study on the Indian *Piper* was done by Hooker (1886) in his Flora of British India. He reported 45 species of which 29 species are from India. Rama Rao (1914) in his 'Flowering Plants of Travancore' listed 14 species of *Piper* form Western Ghats. Fisher (1921) described six species from Annamalai hills. Fyson (1932) in his Flora of Nilgiris and Pulney hill-tops reported four species of *Piper* which includes *P. schmidtii* and *P. wightii*. Kanjilal *et al*., (1940) in their flora of Assam region reported three species. Duthie (1960) in his flora of Upper Gangetic plains and the adjacent Siwalic and Sub-Himalayan tracts included *P. longum, P. betle, P. mullesua, P. nepalense* and *P. nigrum*. Nirmal Babu *et al*. (1993) have reported five new taxa from Kerala. They are *P. silentvalleyensis, P. nigrum var. hirtellosum P. pseudonigrum* from Silent Valley biosphere reserve and *P. sugandhi, P.sugandhi var. brevipilis* from Sugandhagiri cardamom plantations, Wynad, Kerala.

Cytology

Cytology of *Piper* has been studied by various workers and most of them are confined to the determination of chromosome number (Rahiman and Nair, 1986 and Samuel, 1986). The reported chromosome numbers 2n = 24, 26, 36, 39, 40, 48, 52, 60, 64, 65, 68, 78, 80, 96, 104, 132 *etc*. point to the existence of a polyploid series in the genus *Piper*. All the species studied from South India and Sri Lanka could be traced to a common basic number x = 13 while the North Indian species seem to have a basic number x = 12. The haploid number n = 12 as seen in *P. cubeba* may represent comparatively a primitive number from which x = 13 might have evolved (Jose and Sharma, 1985).

Floral biology

Pepper is mostly dioecious in wild form (Krishnamurthi, 1969), but in the cultivated types, the plants are mostly gynomonoecious (*i.e.,* bearing female and bisexual flowers) or trimonoecious (*i.e.,* bearing female, male and bisexual flowers). Bisexual flowers are protogynous and stigmas are exerted 3-8 days before anther dehiscence (Martin and Gregory, 1962). Flowers open between 17.30 and 02.30 hrs with peak opening during 19.30-20.30 hrs (Kanakamany, 1982). Stigmas remain receptive for ten days with peak receptivity 3-5 days after exertion (Martin and Gregory, 1962). Nambiar *et al*., (1978) reported that distal flowers in inflorescence lost their receptivity in fewer days which is indicated by a viscous condition.

Mode of pollination

Since pepper is mostly dioecious in wild state, cross pollination is essential for sexual reproduction in such types. Cultivated pepper, however, has mostly bisexual flowers fertilized by self pollination. Cultivated plants have been selected for genetic constancy and reliable fertility since the beginning of domestication (Frankel and Galun, 1977). Kinds of pollination, which take place in pepper are, within the same flower, between flowers in an inflorescence, and between flowers in separate inflorescence (Ibrahim *et al*., 1985).

Varietal evaluation

Systematic research efforts in the last three decades resulted in the release of superior lines of black pepper varieties by hybridization/ open pollination/clonal selection from the popular cultivars. Seven varieties *viz*., Panniyur-1, 2, 3, 4, 5, 6 and 7 yielding between 1.27 and 2.57 tonnes/ha have been released by PRS (KAU) under AICRP on spices. IISR have released four varieties *viz*., Sreekara, Subhakara, Panchami and Pournami with an yield ranging from 2.3 to 2.8 tonnes/ha. The CPCRI, Regional station, Palode released a variety PLD-2 with a potential of 2.4 tonnes/ ha (Ravindran *et al*., 2000).

Crop ecology

Black pepper grows successfully between 20° North and 20° South of equator and from sea level upto 1500 m above MSL. It is a plant of humid tropics, requiring 2000-3000 mm of rainfall, tropical temperature and high relative humidity with little variation in day length throughout the year. Black pepper does not tolerate excessive heat and dryness. In India, black pepper growing areas receive 1500 mm to more than 4000 mm rainfall. Rainfall after stress induces profuse flowering (Pillay *et al.,* 1988). Growth of fruit bearing lateral shoots and photosynthetic rate are maximum during peak monsoon (June - July) in India (Mathai, 1983). A relative humidity of 60 - 95% is optimum at various stages of growth. The crop tolerates temperature between 10 and 40°C. The ideal temperature is 23 and 32°C with an average of 28°C. Optimum soil temperature for root growth is 26 and 28°C (Wahid and Sitepu, 1987).

Black pepper is a day neutral plant and the vines exposed to direct solar radiation developed physiological disorders even under favourable soil moisture conditions. According to Vijayakumar and Mammen, (1990) black pepper vines kept under shade (7 % incident light) remained green and healthy whereas those exposed to sunlight turned yellow and developed necrotic patches during summer. Fifty per cent shade boosted the growth of black pepper cuttings in the nursery (Senanayake and Kirthisinghe, 1983). Illumination above 50,000 lux (900 ì mol s^{-1} m^{-2}) decreased carbon fixation in a few varieties of black pepper (Mathai, 1983).

Black pepper grows well on 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 near neutral p^H, high organic matter and high base saturation with Ca and Mg enhanced the productivity (Sadanandan, 1993).

Crop production

Cultivation of black pepper varies from very intensive monoculture to extensive homestead gardens. It is propagated vegetatively as well as through seeds. As the crop is heterozygous in nature, seedlings raised from seeds will not breed true to type. Hence vegetative propagation is preferred for commercial cultivation. Though black pepper can be propagated through cuttings, grafting, layering and budding, rooted cuttings are preferred for commercial cultivation. Runner shoots are used for producing cuttings. The length of the cuttings varies from 30 - 60 cm and consists of a single node to seven nodes (Irulappan *et al*., 1981). Direct field planting of cuttings result in poor establishment hence, cuttings with 2 or 3 nodes have to be raised in the nursery initially and transplanted to the main field after attaining sufficient growth (Sasikumar and Johnson, 1992). A rapid multiplication technique through bamboo method for meeting the large scale demand of quality planting material has also been developed (Ravindran *et al*., 2000).

Standards

Black pepper vines require support for their establishment. Both living and non-living standards are used to black pepper. Some of the common living standards are *Erythrina indica* Lanmk., *E. lithosperma* Blume, *Garuga pinnata* Roxb., *Gliricidia sepium* (Jacq.) and *G. maculata* (B & K). Mathew *et al*., (1996) reported that *Ailanthus malabaricum* DC and *G. pinnata* are the best living standards.

The non-living standards used include, reinforced concrete posts, granite pillars and teak poles which require high initial investment compared to living standards. Dead wood standards are used in Malaysia, Brazil and in Indonesia facilitating closer spacing resulting in higher yields (George, 1981). Shade regulation of live standards is an important cultural practice during cloudy or rainy weather to allow sufficient light for crop growth, if not, the yield will be reduced to 50 per cent or more (Ramadasan, 1987). Spraying of reflectants (lime, china clay) over the leaf surface reduced stress during summer and enhanced the chlorophyll content (Vijayakumar and Mammen, 1990).

Spacing

As a monocrop, black pepper is planted normally at a spacing of 2.5 m x 2.5 m. According to Ravindran *et al*., (2000) the optimum spacing for planting pepper vine is 3 x 3 m or 3 x 2 m. Kurien *et al*., (1994) recorded the highest competition between living standards and black pepper at closer spacing of 2 m x 2 m.

Establishment of plantation

Living standards should be planted 3-4 years in advance so as to attain sufficient height at the time of planting black pepper. During establishment of living standards, the side branches are pruned to enable the standards to grow erect. Pruning is dependent on the growth of foliage and normally one or two pruning in a year is sufficient. Pruning of living standards before flowering enhances the yield of black pepper (Mathai and Sastry, 1988).

Training and pruning

Training is an essential step for establishment of black pepper vines. The vines have to be tied to the standards at the nodes by suitable materials for anchorage. The leaves are removed from vines after attaining a height of 1m and 10 days later they are brought down and ¾th of the basal portion is buried around the standard or round the base of the standard and covered with good top soil to induce a good root system and for production of more leader shoots from the nodes. Pruning is practiced to ensure leader shoot production and to induce the development of lateral shoots. Three rounds of pruning are enough to obtain necessary number of climbing shoots as well as appropriate bushiness (Kurien and Nair, 1998).

Irrigation

The feeder roots of black pepper is distributed in the top 50 - 60 cm depth of soil and therefore sensitive to moisture stress. During the dry period when there is no rain for 2-3 weeks, the soil moisture in the top 30 cm of soil is reduced to 50 per cent or less. Irrigating pepper vines from November / December upto the end of March and withholding irrigation till monsoon break increases pepper yield by 50 per cent. Application of 100 I of water at an interval of about 8-10 day is recommended (Raj, 1978). The water is to be applied in basins taken around the plants at a radius of 75 cm. Satheesan *et al*., (1998) reported that Evapo Transpiration (ETc) values of black pepper and *E. indica* (standard) obtained by Bowen Ratio-Energy Balance (BREB) method and Vapour Diffusion Model (VDM) ranged from 2.45 to 3.15 mm day^{-1} and 2.86 to 3.40 mm day^{-1}, respectively, during the period of moisture stress from January to March and the crop coefficient values for crop stand ranged from 0.53 to 0.78. These values will help in the estimation of water requirement of black pepper in different cropping systems.

Mulching

To protect the pepper vines from heat during summer and to avoid soil loss due to run off during rainy season mulching is essential. Digging twice a year and providing sod mulch is optimum to maintain the health and yield of black pepper vines (Nambiar *et al*., 1978). Cover crops such as *Calapagonium mucunoides* and *Desmodium trifolium* have also been suggested (Ahmad, 1993).

Weeding

Weeds are a major problem in black pepper plantations that are not maintained properly. Weed flora change with location, soil type and season. Abraham and Abraham (1998) recorded 55 weeds (41 dicots, 9 grasses, 3 ferns and 2 sedges) in black pepper gardens of Kerala. Use of glutosinate or paraquat or glyphosate or organic cover with coconut fibre resulted in significantly higher yield when compared with natural cover (Kuch *et al*., 1993). Clean weeding and use of herbicide led to occasional soil erosion. As an alternative, Ipor (1993) reported that cover crops like *D. trifolium* and *Centrosema pubescens* Benth. can be raised to smother the weeds. Maintenance of cover crop also reduced *Phytophthora* infections (Ramachandran *et al*., 1991).

Nutrient management

Farmers adopt application of inorganic fertilizers @ 362 - 549 kg N, 206 - 549 kg P_2O_5, 228 - 777 kg K_2O and 92 - 137 kg MgO ha^{-1} $year^{-1}$ (Sim, 1972). Yellowing of black pepper vines reduced and the crop yield improved considerably by the integrated application of organic manure and inorganic fertilizers @ 400 kg N, 180 kg P, 480 kg K, 425 kg Ca and 110 kg Mg ha^{-1} $year^{-1}$(De Waard 1979). Raj (1978) stated that fertilizer application advocated should contain 11-13% N, 5-7% P_2O_5, 6-18% K_2O, 4-5% MgO and trace elements. Organic farming can improve black pepper productivity and addition of organic matter enhanced the growth and biomass of the vines (Sivakumar and Wahid, 1994). Biofertilizers and vermicompost application also enhanced the growth, biomass, nutrient uptake, yield and quality of black pepper (Kandiannan *et al*., 1998; Kandasamy *et al*., 1998, Kannan and Thangaselvabai, 2006).

The critical stages of nutrient requirement are during initiation of flower primordia and flower emergence, berry formation and development. However, fertilizer application depends on soil moisture availability (Raj, 1978). NRCS (1989) recommended one third at first year, two third at second year and full dose from third year onwards in two splits. Fertilizer application is restricted to a lateral distance of 30 cm in full circle area around the vine. Fertilizer efficiency enhanced with slow release 'nimin' (nitrification inhibitor) coated urea (Sadanandan and Hamza, 1993) and mussoorie rock phosphate (Sadanandan, 1986).

Growth regulators

Spike shedding and berry drop are serious malady that affects the yield of pepper to an extent of 29.0 per cent and 40.0 per cent (Gawade, 1982). Geetha (1981) observed IAA and planofix at 50 ppm and 2, 4-D at 5 ppm reduced spike shedding and 80 ppm planofix reduced berry drop. Ponnusamy *et al*., (1980) reported that application of planofix (20 – 80 ppm) found to be promising in increasing the number of pepper berries per spike. Spraying planofix 40 ppm reduced the spike shedding by 20 per cent (Ravindran *et al*., 2000). Application of growth regulator *viz.,* NAA, 2, 4-D (10 ppm) seems to promote spike initiation. This gives better setting and development thus yielding bold berries (Salvi *et al*., 2000).

Harvest and yield

Generally, the first harvest of black pepper is done during the third year after planting. The symptom of maturity for harvest is when berries easily separate from the spikes upon rubbing between the hands (Govindarajan, 1977) or when one or more berries turn red on a spike. Plant characters like green berry yield, spike number, spike length and the angle of insertion of plagiotrophs has direct positive influence on yield (Sujatha and Namboothiri, 1995). Visual scoring for yield was found to be an easy method to estimate black pepper yield (Balakrishnan and Abraham, 1986).

Cropping systems with black pepper

Black pepper as a climbing vine is well adapted to grow as an under crop/mixed crop or intercrop with plantation crops. The humid rain forest ecosystem with tropical and sub-tropical climate provides appropriate environment for raising annual, biennial and perennial crops as inter and mixed crops in high density multi species cropping systems (Rethinam and Venugopal, 1994). Ginger, turmeric, coffee, arecanut, coconut, banana, cocoa, yam, cereals like upland paddy, pulses like redgram, vegetables, flowers, fodders and other annuals are intercropped with black pepper (Korikanthimath, 1994). Among different cultivars, Karimunda and Panniyur -1 were found to be ideal in coconut and arecanut plantations (Khader *et al*., 1990). Maximum return was achieved with the combination of coconut + black pepper + pineapple + cocoa and coconut + cocoa + cinnamon + black pepper + pineapple (Yufdy, 1993). Multistoried cropping involving pepper, cinnamon, and pineapple as component crops under forest agro ecosystem was found to be remunerative (Thangaselvabai *et al*., 2006).

Crop protection

Crop loss due to pest and disease incidence has been identified as one of the major production constraints. Control of these pests and diseases would be an effective short term strategy for increasing the productivity.

Insect pests

Though the crop is infested by 20 insect pests in India only four of them are serious *viz*, pollu beetle, top shoot borer and leaf gall thrips.

The pollu beetle *Longitarsus nigripennis* M. is the most destructive pest causing 30-40 per cent yield loss in endemic areas. During the flushing season (June-July) the adults feed on tender shoots, leaves and spikes by scraping the tissues leading to the formation of numerous holes in the leaves and black patches on the spikes. The infested berries turn yellow, finally black and crumble when pressed. Sometimes the grub damages the main spike resulting in the drying of berries. The beetles can be managed by regulation of shade of standards since the pest infestation is generally higher in shaded areas in the plantation (Devasahayam and Koya, 1993).

Three to four sprays of endosulfan 0.05% from July onwards at 21 days interval and neem based insecticides such as neemgold 0.6% during August-October was found to be effective (Nandakumar *et al*., 1987).

The top shoot borer *Cydia hemidoxa,* is a serious pest in younger plantations in all black pepper areas. The larvae bore into tender terminal shoots and feed on internal tissues resulting in blackening and decaying of affected shoots. The borer can be managed by spraying of monocrotophos or endosulfan on tender terminal shoots, during July-October (Premkumar and Devasahayam, 1989).

The leaf gall thrips *Liothrips karnyi,* induce the formation of marginal leaf galls and they are the most serious pest causing upto 23 per cent damage in the leaves. Apart from the formation of marginal leaf galls, the feeding activity of the thrips results in reduced size, crinkling and thickening of infested leaves (Devasahayam, 1990). It can be managed by application of monocrotophos 1.5ml/ litre at the time of flush initiation stage (Soundararajan and Gailce, 2001). The white tailed mealybug, *Ferrisia virgata* Cox. causes damage to the berries and vines and this can be managed by the application of monocrotophos 2ml/litre during spike formation stage (Gailce *et al*., 2005).

Diseases

Quick wilt or foot rot caused by *Phytophthora capsici,* and slow wilt associated with plant parasitic nematodes are the two major diseases which cause considerable crop losses. Leaf spot or hollow berry (fungal pollu) caused by *Colletotrichum gloeosporioides*, bacterial leaf spot caused by *Xanthomonas campestris pv. beticola*, little leaf and phyllody are some of the other diseases which are on increase in recent times. Quick wilt disease is known in India since 1902 and the crop loss due to this disease on global scale has been estimated to be about $ 4.5-7.5 million per annum. All parts of black pepper are prone to infection and as such both foliar, collar and root infections are known to cause varying degrees of damage. Collar rot is always fatal and the infected vine succumbs in 20-30 days and hence it is termed as quick wilt (Anandaraj *et al*., 1989).

An integrated disease management involving host resistance, cultural practices and chemical and biological control measures is an ideal strategy to combat the losses due to this scourge. Systematic removal and burning of dead and dried up vines from the plantation, providing good drainage and application of neem cake were found to reduce the fungal load in the soil (Sadanandan *et al*., 1990). Bordeaux paste application to the collar, spraying the foliage with 1% Bordeaux mixture and drenching the basins with 3 to 5 litres of 0.2% copper oxychloride, once as a pre monsoon treatment (May-June) and another as a post monsoon treatment (August-September) should be undertaken as a prophylactic measure (Sharma and Ramachandran, 1984). Spraying the foliage and drenching the soil with Ridomil-ziram (100 ppm) or metalaxyl reduced the infection to the minimum (Ramachandran, 1990).

Slow Decline is considered as fungal and nematode complex coupled with soil moisture stress and malnutrition. Foliar yellowing, defoliation and die back are the aerial symptoms of this disease. The affected vines show varying degrees of feeder root loss and the expression of symptoms on the aerial parts occur after considerable portions of the feeder roots are lost (Nambiar and Sharma, 1977).

Severely affected vines which are beyond recovery should be removed from the plantation and destroyed. The pits for planting should be treated with phorate @ 15 g or carbofuran @ 50 g at the time of planting. Nematode free rooted cuttings raised in fumigated or solarized nursery mixture should be used for planting in the field. Phorate @ 30g or carbofuran @ 100 g/vine should be applied during May/June (with the onset of south west monsoon) and September / October. Along with phorate the basins should be drenched with either copper oxychloride 0.2 % or metalaxyl 0.125 % (Ramachandran, 1990).

The fungal Pollu, *Colletotrichum gleosporioides* disease can be distinguished from the 'pollu' caused by the beetle by the presence of characteristic cracks on the infected berries. Bordeaux mixture (1%) spray was found to be effective in controlling the disease (Unnnikrishnan *et al*., 1987).

Post harvest management

Post harvest technology covers a gamut of several unit operations after harvesting of pepper, such as curing, drying, cleaning or garbling, quality evaluation, packaging, and storage.

Curing

For the preparation of good quality black pepper, a simple blanching process has been developed by CFTRI (1980). This involves despiking of the mature greenish yellow pepper spikes after harvest and cleaned by winnowing. Then transferred to perforated aluminium vessel or even bamboo basket and dipped in boiling water for a minute and spread out on a clean cement floor or mat for sun drying.

Drying

The berries are dried under sun for 4 to 7 days until the outer skin of the berries become black in colour with wrinkled appearance. The berries could be dried in the solar cabinet dryer for four days with spreading density of 18 kg / m^2 and the colour of the dried produce was black while the sun dried berries took 5 days to dry with a spreading density of 5 kg / m^2 and the colour was dull black (Patil, 1983).

Grading

After drying, the berries has to be garded. Ungraded pepper contains fractions, dust, stalk, pin heads and immature, over mature and large berries. The grading is done by a combination of size, sieving and weight classification by air blast (Mariwala, 1974). The major grade is the average sized black pepper known as Malabar Garbled (MG) which constitutes 95 per cent of India's export. Tellichery Garbled (TG) is another gold grade of black pepper (Mathew and Sankarikutty, 1978).

Packaging and storage

Whole black pepper properly cleaned and dried to a moisture level of 10-11 per cent, can be stored without growth of any mould in liners, 0.003 inch or more thick. New bags suitably treated with fungicides and insecticides should be used and stored properly in scientific warehouses or fumigated godowns with controlled ventillation (Mariwala, 1974).

Value added products

The products developed from pepper broadly fall into three groups namely Black pepper, White pepper and Green Pepper. Black and white pepper are widely used for culinary purposes, flavouring of processed foods and for perfume and medicinal use, while green pepper is produced and marketed to specific consumers and end-users.

Black Pepper

Black pepper, which is prepared by drying the mature green berries, is a major spice with varied applications in processing industries. It is employed in a very wide range of foodstuffs, particularly in meat products. Black pepper products include black pepper powder, pepper oil and pepper oleoresin. Pepper oil and oleoresin are produced in response towards the increased quality consciousness, preference for natural flavours and inconsistency in quality of raw materials (John Zacharriah, 1989).

White Pepper

White pepper is the white inner corn obtained after removing the outer skin or pericarp of the pepper berries. For white pepper the berries are harvested when ripe and prepared by retting, steaming /boiling and rolling or running water treatment (Gopalan *et al*., 1990). It is made from ripe pepper berries by keeping it in slow flowing water or dipping it in water for seven to nine days to soften the pericarp of the skin. The pericarp is then removed by scrubbing or macerated against a plastic wire mesh and the corns are washed and dried (Madusoodanan *et al*., 1990). The CFTRI, Mysore has developed a process of steam cooking and skin removal by pulping machine (Govindarajan, 1977). At National Research Centre for Spices, Calicut, a process of steaming, boiling the despiked pepper for 13 minutes and rolling it in a container in running water to remove the skin has been developed (John Zacharriah, 1989). The product developed from white pepper is white pepper powder. It is preferred over black pepper in light coloured preparations such as sauces, cream soups, *etc*., where dark coloured particles are undesirable. It imparts pungency and a modified natural flavour to the food stuff.

Green pepper

The green pepper is prepared from unripe developed pepper berries, which are artificially dried or preserved in the 'wet' form in brine, vinegar or citric acid. The buff coloured pepper is obtained by subjecting freshly harvested over-mature berries to heat treatment to prevent the blackening of the skin and dried to get a bleached finish. The colour is as white as that of white pepper and the percentage of dry matter yield is high (28-30 per cent) compared to white pepper as there is no loss of outer skin (John Zacharriah, 1989).

Pepper Oleoresin

It is prepared by solvent extraction of ground pepper. Production process uses a number of equipments like precleaners, pulverizers, extractors and solvent recovery units. Besides, for quality control measures, instruments like gas chromatography and ultraviolet spectrophotometer are used. Oleoresin of pepper can be prepared according to the customer requirement of quality

Other products

The other value added products include pepper sal, green pepper sauce, pepper perfume, pepper cookies, pepper tea and pepper sweets (Mathew, 1984). The oil of pepper is prepared by steam distillation of powdered pepper. The oil yield is about 2-3.5 per cent (Kirshnamoorthy *et al*., 1972).

CONCLUSION

The literature reviewed in this paper highlighted the improved pepper production technologies. Since, increasing productivity and extending area to non traditional regions are going to be the major thrust areas for the future, all these emerging positive developments provide strength to profitable pepper farming and to meet the challenges of global competition.

REFERENCES

Abraham, M and Abraham, C.T. (1998). *Spice India*, **11**: 11-13.
Ahmad, K. (1993). *The Pepper Industry – Problems and Prospects* Univ. Pertanian Malaysia, Bintulu Campus, Malaysia, p. 97 – 103.
Anandraj, M. *et al*. (1989). *Indian Phytopath.*, **42**: 473-476
Balakrishnan, R and Abraham, J. (1986). *J. Plantn. Crops.*, **14**: 115 – 118.
CFTRI, (1980). *Annual Report for 1978-79*. Central Food Technological Research Institute, Mysore. p.187
De Waard, P.W.F. (1979). *J. Plantn. Crops,* **7**: 43 – 50.
Devasahayam, S. (1990). *Entomon.*, **15**: 137-138
Devashayam. S and Abdulla Koya. K.M. (1993). *Indian Inst. Spice Research*, 19-22

Duthie, J.F. (1960). F*lora of the Upper Gangetic Plains and the Adjacent Siwalik and Sub Himalayan Tracts.* Vol. **II** , Botanical Survey of India, Calcutta, pp. 123-145.

Fisher, C.E.C. (1921). *Rec. Bot. Surv. Ind*., **9**: 151

Frankel, R. and Galun, E. (1977). *Pollination Mechanism, Reproduction and Plant Breeding* . Monographs on TAG. Springer Verlag, Berlin

Fyson,T. (1932) *The Flora of South Indian Hill Stations- Ootacamund, Coonur, Kotagiri, Kodaikanal, Yercaud and Country around.* Vol. **I**. Madras. pp.198-200.

Gailce Leo Justin, C. *et al*. (2005). *Second All India Conference of KAAS*, Kanyakumari. Sept. 2005, p.105-107

Gawdae, T.D. (1982), *M.Sc.,(Ag.) Thesis,* Konkan Krishi Vidyapeeth. Dapoli- Ratnagiri. p.128

Geetha, C.K. (1981). *M. Sc., (Hort.) Thesis,* Kerala Agricultural University, Vellanikara, Trichur.

George, C.K. (1981). *Souvenir, Workshop on Processing of Pepper and Pepper Products* Central Food Technology Research and Training Institute, Mysore. p. 3 - 5.

Gopalan, A. *et al*. (1990). *Indian Perfumer,* **34**: 152 – 156.

Govindarajan, V.S. (1977). *Critical Rev. Food Sci. Nutr.,* **9**: 115 – 225.

Hooker, J.D. (1886). *The Flora of British India.* Vol. **VI**. Reeve and Co., London. 78-95.

Ibrahim, K.K. *et al.* (1985). *Indian Spices.* **22**:21-25

Ipor, I.B. (1993). *The Pepper Industry - Problems and Prospects.* Univ. Pertanian Malaysia. Bintulu Campus. Malaysia. pp. 206 – 214.

Irulappan, I. *et al*., (1981). *PLACROSYM*-**IV** 87-93, CPCRI, Kasaragod.

John Zachariah, T. (1989). *Review Report.* National Research Centre for Spices, Calicut p.8

Jose, J and Sharma, A.K. (1985). *Cytologia*, **50**: 301-310.

Kanakamany, N.T. (1982). *M.Sc.(Ag) Thesis* Kerala Agricultural University, Trichur

Kandiannan, K, *et al.*, (1998). In: *First International Agronomy Congress on Agronomy. Environment and Food Security*. Indian Society of Agronomy. New Delhi, p. 206.

Kanjilal, U.N. *et al.* (1940). *Flora of Assam*. Vol. **IV**, Govt. of Shillong 31-38.

Kannan, J and Thangaselvabai,T.(2006). *J. Scott Research Forum* **3**:16-18

Kanthaswamy, V. *et al*. (1998). *South India Hort*., **44**: 85-89

Khader, K.B.A *et al*. (1990). *J. Plantn. Crops*, **20**: 19 – 24.

Korikanthimath. V.S. (1995). *J. Spices Aromatic crops,* **4**: 119-128

Krishnamurthi, A. (1969). *The Wealth of India*: Raw Materials, **8**: 350.

Krishnamurthy, N. *et al*. (1972). *Proc. Natl Symp. Plant. Crops* ISPC, KASARGOD. 181

Kuch, T.K. *et al.* (1993), In: *The Pepper Industry - Problems and Prospects* pp. 193 - 205. Univ. Pertanian Malaysia, Malaysia.

Kurien, S and Nair, P.C.S. (1998).*Agric. Res. J. Kerala,* **19**: 21-26

Kurien, S. *et al*. (1994). *Indian Cocoa Arecanut Spices J.,* **18**: 75 – 79.

Madan, M.S. (2000). *J. Spices Aromatic Crops,* 5 :225-232

Madhusoodanan,K.J. *et al.*(1990). *Spices India*, **3**:5-7

Mariwala, J.V. (1974). *Proc. Symp. Dev. Prospects for Spice Industries* p.17

Martin, F.W. and Gregory, L.E. (1962). *Crop Sci.*, **3**: 295-299

Mathai, C.K and Sastry, K.S.K. (1988). *Comp. Physiol. Eco.* **13**: 97 – 102.

Mathai, C.K. (1983). *Ph.D. Thesis*, University of Agricultural Sciences, Bangalore. p 220

Mathew, A.G. (1984). *J. Plantn. Crops*, **12**: 94-97

Mathew, A.G. and Sankarikutty, B. (1978). *Proc. Nat. Sem. on Pepper*, Central Plantation Crops Research Institute, Kasaragod. p.69.

Mathew, T, *et al*. (1996).. *J. Plantn. Crops*, **24**: 86 – 91.

Nambiar, K.K.N. and Sarma, Y.R. (1977). *J. Plant. Crops*, **5:** 92-103

Nambiar, P.K.V. *et al*. (1978). *J Plantn. Crops*, **6**: 4 – 11.

Nandhakumar, C. *et al.*(1987). *National Symp Integrated Pest Control- Progress and Perspectives.* 15-17 October 1987, Trivandrum. p 50.

NRCS (1989). *Annual Report* , National Research Centre for Spices, Calicut p.65.

Nirmal Babu, K *et al*. (1993). *J. Spices and Aromatic Crops,* **1**: 88-93

Patil, R.T. (1983). *Final Report*, CPCRI, Kasaragod. p.59.

Pillay, V.S. *et al*. (1988). *In*: *Agrometerology of Plantation Crops.* Kerala Agricultural Univ., Trichur. p.152 - 159

Ponnuswami, V. *et al.* (1980). *South Indian Hort*., **28**: 225 – 226.

Premkumar, T. and Devashayam, S. (1989). *J. Bombay Nat. His. Soc.,* **86**: 112-113

Rahiman, B.A. and Nair, M.K. (1986). *J. Plant. Crops,* **14**: 52-56

Raj, H.G. (1978). *In: Silver Jubilee Souvenir. Pepper Research Station, Panniyur*. Kerala Agricultural University. Trichur. pp. 65 – 74

Ramachandran N. (1990). *Ph.D. Thesis,* Univ. of Calicut, Calicut, p.138

Ramachandran, N. *et al*. (1991). *Annual Report National Research Centre for Spices*, Calicut. Kerala. pp. 158 - 174.

Ramadasan, A. (1987). *Indian Cocoa Arecanut Spices J.,* **10**: 43 – 44.

Rama Rao, M., (1914). *In: Flowering Plants of Travancore*, Govt. Press. Thiruvananthapuram. p. 336-338

Ravindran, P.N, *et al*. (2000). *Indian J. Arecanut Spices and Medicinal Plants*, **2**: 71– 78.

Rethinam, P and Venugopal, K. (1994). In: *Advances in Horticulture* Vol. **9**. Malhotra Publishing House, New Delhi. p. 605 - 620

Sadanandan, A.K and Hamza, S. (1993). *J. Plantn. Crops*., **21**: 58 – 66.

Sadanandan, A.K. *et al*. (1990). National Centre for Spices, Calicut, India. 6

Sadanandan, A.K. (1986). *In: First Workshop on the Role of Slow Release Fertilizers in Plantation Crops* pp.150

Sadanandan, A.K. (1993). *Proc. Nat. Sem. Potassium on Plant. Crops*. Potash Research Ins. of India, Gurgaon, Haryana, p.75-88.

Salvi, B.R. *et al.*, (2000). *South Indian Hort.*, **48**: 16 – 18.

Samuel, R. (1986). *Kew Bull*. **42**: 468-469

Sarma,Y.R. and Ramachandran N.(1998). *Central Plantation Crops Research Institute*, Kasaragod, Kerala, India.

Sasikumar, B and Johnson, K. (1992). *J. Plant. Crops*, **20**: 165-167

Satheesan, K.V. *et al*.(1998). In:Water and Nutrient Management for Sustainable Production and Quality of Spices. *Indian Society for Spices*. Calicut, pp. 123 -130.

Senanayake, Y.D.A and Krithisinghe, J.P. (1983). *J. Plantn. Crops*., **11**: 105 – 108.

Sim, E.S. (1972). *Malaysian Agric. J.*, **48**: 244 – 248.

Sivakumar, C and Wahid, P.A. (1994). *J. Spices Aromatic Crops*., **3**: 135 – 141.

Soundarajan, R.P and Gailce Leo Justin, C. (2001). *Proc. Second National Symp. IPM in Horticultural Crops: New Molecules, Biopesticides and Environment.* Oct. 17-19, Bangalore 129

Spice Board (2008). *Spice India*., **21**:25-27.

Sujatha, R and Namboodiri, K.M.N. (1995). *J. Trop. Agric*., **33**: 11 – 15.

Thangaselvabai, T. *et al.* (2006). *Proc. Nat. Sem. Emerging Trends in Production, Quality, Processing and Export of Spices*. 28-29

Unnikrishnan Nair, P.K. *et al*. (1987). *Agric. Res. J*., *Kerala*, **25**: 136-139

Vijayakumar, K.R and Mammen, G. (1990). In: *Proc. Intl. Cong.f Pl. Physiol.,* 15 – 20, February, 1988. Vol. **2**. Society of Plant Physiology and Biochemistry, New Delhi, pp. 935 – 938.

Wahid, P and Sitepu, D. (1987). *Current Status and Future Prospect of Pepper Development in Indonesia.* FAO, Regional Office for Asia and Pacific, Bangkok.

Yufdy, M.P. (1993). *Int. Pepper News Bull*., **17**: 13 – 19.