black pepper

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Black pepper (*Piper nigrum* L.) (Family: *Piperaceae*) is a perennial vine grown for its berries extensively used as spice and in medicine. India is one of the major producer, consumer and exporter of black pepper in the world. During 2013-14, 21250 tonnes of black pepper products worth Rs. 94,002 lakhs were exported to various countries. Black pepper is cultivated to a large extent in Kerala, Karnataka and Tamil Nadu and to a limited extent in Maharashtra, North eastern states and Andaman & Nicobar Islands. The crop is grown in about 201381 hectares with a production of 55000 tonnes annually (2012–13). Kerala and Karnataka account for a major portion of production of black pepper in the country.

Climate and soil

Black pepper is a plant of humid tropics requiring high rainfall and humidity. The hot and humid climate of sub mountainous tracts of Western Ghats is ideal for its cultivation. It grows successfully between 20° North and South latitudes, and, up to 1500 m above sea level. The crop tolerates temperatures between 10° and 40°C. The favourable temperature range is 23 - 32°C and the ideal temperature is around 28°C. Optimum soil temperature for root growth is 26 - 28°C. The ideal range of relative humidity for the crop is 75-80%. A well distributed annual rainfall of 1250-2000 mm is considered ideal for black pepper. Black pepper can be grown in a wide range of soils with a pH of 5.5 to 6.5, though in its natural habitat it thrives well in red laterite soils.

The black pepper growing tracts in the West Coast of India include (1) coastal areas where black pepper is grown in homesteads (2) midlands where black pepper is extensively cultivated on a plantation scale and (3) hills at an elevation of 800-1500 m above sea level, where the crop is mostly grown on shade trees in coffee, cardamom and tea plantations.

Varieties

A majority of the cultivated types are monoecious (male and female flowers found in the same spike) though variation in sex expression ranging from complete male to complete female is found. Over 75 cultivars of black pepper are being cultivated in India. Karimunda is the most popular cultivar in Kerala. The other important cultivars are Kottanadan (South Kerala), Narayakodi (Central Kerala), Aimpiriyan (Wayanad), Neelamundi (Idukki), Kuthiravally (Kozhikode and Iduk-

ki), Balancotta, Kalluvally (North Kerala), Malligesara and Uddagare (Karnataka). Kuthiravally and Balancotta exhibit alternate bearing habit. In terms of quality, Kottanadan has the highest oleoresin (17.8%) content followed by Aimpiriyan (15.7%).

Eighteen improved varieties of black pepper have been released for cultivation (Table 1). Panniyur-1, Panniyur-3 and Panniyur-8 are hybrids evolved at the Pepper Research Station, Panniyur (Kerala Agricultural University). IISR Girimunda and IISR Malabar Excel are the two hybrids released from ICAR-Indian Institute of Spices Research, Kozhikode, Kerala.

Propagation

Black pepper vines produce three types of shoot, namely (1) Primary climbing shoot with long internodes having adventitious roots at nodes which cling to the supports/ standards; (2) Runner shoots which originate from the base of the vine and creep on the ground, have long internodes which strike roots at each node and (3) Fruit bearing lateral shoots. Cuttings are raised mainly from runner shoots, though terminal shoots can also be used. Cuttings from lateral branches develop a bushy habit. Rooted lateral branches are used for raising bush pepper. Though seeds (berries) are fully viable, they are not generally used for raising plantations as seedlings will not be genetically uniform.

Production of rooted cuttings

Traditional method

Runner shoots from high yielding and healthy vines are kept coiled on wooden pegs fixed at the base of the vine to prevent the shoots from coming in contact with soil and striking roots. The runner shoots are separated from the vine during February-March, and after trimming the leaves, cuttings of 2-3 nodes are planted either in nursery beds or in polythene bags filled with potting mixture (soil, sand and farm yard manure in 2:1:1 ratio). Adequate shade has to be provided and the polythene bags are to be irrigated frequently. The cuttings become ready for planting during May-June.

Rapid multiplication method

A propagation technique developed in Sri Lanka has been modified for adoption in India for quick and easy multiplication of black pepper vines. In this method, a trench of 45 cm depth, 30 cm width and of conve-

Table 1. Improved varieties of black pepper and their characteristic features

Variety	Pedigree	Mean yield (dry) (kg/ha)	Dry recovery (%)	Quality attributes			Features
				Piperine (%)	Oleoresin (%)	Essential oil (%)	
	Kerala Agricultural University (KAU), PRS, Panniyur, Kerala						
Panniyur -1	Hybrid, Uthirankotta × Cheriyakaniakadan	1242	35.3	5.3	11.8	3.5	High yielding, not suited to heavily shaded areas
Panniyur -2	Selection (Cul. 141) from cv. Balancotta	2570	35.7	6.6	10.9	-	Shade tolerant
Panniyur -3	Hybrid (Cul. 331), Uthirankotta × Cheriyakaniakadan	1953	27.8	5.2	12.7	-	Late maturing
Panniyur -4	Selection from Kuthiravally type	1277	34.7	-	9.2	-	Stable yielder
Panniyur -5	Open pollinated progeny selection from Perumkodi	1098	-	5.5	12.3	3.8	Tolerant to shade
Panniyur -6	Clonal selection from Karimunda	2127	32.9	4.9	8.3	1.3	Suited to all black pepper tracts
Panniyur -7	Open pollinated progeny selection from Kuthiravally	1410	33.6	5.6	10.6	1.5	Suited to all black pepper tracts
Panniyur -8	Hybrid (HB 20052), Panniyur 6 × Panniyur 5	1365	39.0	5.7	12.2	1.2	High yielding, field tolerant to Phytophthora foot rot and drought
	ICAR-Indian Institute of Spices Research, Kozhikode, Kerala						
Subhakara	Selection from Karimunda (KS-27)	2352	35.5	4.0	10.0	6.0	Suited to all black pepper tracts
Sreekara	Selection from Karimunda (KS-14)	2677	35.0	4.2	13.0	4.0	Suited to all black pepper tracts
Panchami	Selection from Aimpiriyan (Coll. 856)	2828	34.0	4.7	12.5	3.4	Late maturing
Pournami	Selection from Ottaplackal (Coll. 812)	2333	31.0	4.1	13.8	3.4	Tolerant to root knot nematode
PLD -2	Clonal selection from Kottanadan	2475	-	3.3	15.5	3.5	Suited to Thiruvananthapuram and Kollam districts of Kerala
IISR Shakthi	Open pollinated progeny of Perambramundi	2253	43.0	3.3	10.2	3.7	Tolerant to Phytophthora foot rot.
IISR Thevam	Clonal selection of Thevamundi	2481	32.0	1.7	8.2	3.1	Tolerant to Phytophthora foot rot; suited to high altitudes and plains
IISR Girimunda	Hybrid, Narayakodi x Neelamundi	2880	32.0	2.2	9.7	3.4	Suited to high altitudes
IISR Malabar Excel	Hybrid, Cholamundi x Panniyur-1	1440	32.0	4.9	14.6	4.1	Suited to high altitudes; rich in oleoresin
ICAR-Indian Institute of Horticulture Research, CHES, Chettali and ICAR- Indian Institute of Spices Research, Regional Station, Appangala, Karnataka							
Arka Coorg Excel	Seedling selection	3267	37.8	2.1	6.9	1.6	High yielding, with long spikes and bold berries

nient length is made. The trench is filled with rooting medium comprising of forest soil, sand and farm yard manure in 1:1:1 ratio. Split halves of bamboo or split halves of PVC pipes are fixed at 45° angle by keeping split portion facing upward on a strong support on one side of the trench. Rooted cuttings are planted in the trench at the rate of one cutting for each bamboo split. The lower portions of the bamboo splits are filled with rooting medium (preferably weathered coir dust-farm yard manure mixture in 1:1 ratio) and the growing vine is tied to the bamboo split in such a way to keep the nodes pressed to the rooting medium. Each single nodded cutting with the bunch of roots intact is cut and planted in polythene bags filled with fumigated potting mixture. *Trichoderma* @ 1g and VAM @ 100 cc/kg of soil can be added to the potting mixture. The buds start developing in about three weeks and the poly bags can then be removed and kept in shade till main field planting. The advantages of this method of propagation are (i) rapid multiplication rate (1:40), (ii) well developed root system, (iii) higher field establishment and (iv) vigorous growth as a result of better root system.

Trench method

A simple, cheap and efficient technique for propagating black pepper from single nodes of runner shoots taken from field grown vines has been developed at the Institute. A pit of 2.0 m × 1.0 m × 0.5 m size is dug under a cool and shaded area. Single nodes of 8-10 cm length and with their leaf intact are, taken from runner shoots of field grown vines. They are planted in polythene bags (25 cm × 15 cm, 200 gauge) filled with a mixture of sand, soil, coir dust and cow dung in equal proportions with their leaf axil exposed above the potting mixture. After keeping the bags in the pit, the pit should be covered with a polythene sheet. The cuttings should be irrigated at least five times a day with a rose can. Cuttings in poly bag are drenched 2-3 times with copper oxychloride (2 g/litre).

After about 1 month, new shoots start emerging from the leaf axil. The cuttings can be taken out of the pit after two months of planting and kept in a shaded place and watered twice a day. These cuttings will be ready for field planting after about 2 ½ months. By this method 80-85% success rate can be obtained.

Serpentine method

Serpentine layering technique can be used for production of rooted cuttings of black pepper in a cheap and effective manner. In a nurs-

ery shed with roofing sheet or shade net, rooted black pepper cuttings are planted in polythene bags holding about 500 g potting mixture, which will serve as mother plants. As the plant grows and produces few nodes small polythene bags (20 ×10 cm) filled with potting mixture may be kept under each node. The node may be kept gently pressed in to the mixture assuring contact with the potting mixture with the help of a flexible twig such as mid rib of a coconut leaflet. Roots start growing from the nodes and the cuttings keep on growing further. The process of keeping potting mixture filled polythene bags at every node junction to induce rooting at each node is repeated. In three months the first 10 to 12 nodes (from the mother plants) would have rooted profusely and will be ready for harvest. Each node with the ploythene bag is cut just below the rooted node. The cut end is also buried into the mixture to induce more roots. Polythene bags used are filled with solarized potting mixture fortified with biocontrol agent. The Potting mixture is prepared by mixing two parts of fertile topsoil, one part of river sand/granite powder and one part of FYM (2:1:1). The rooted nodes will produce new sprouts in a week time and will be ready for field planting in 2-3 months. The growing vines are to be irrigated every day with a rose can or sprinklers. By this method, on an average, 60 cuttings can be harvested per mother plant in a year

Soil-less nursery mixture

Partially composted coir pith and vermicompost (75:25) enriched with *Trichoderma* (in talc formulation, 10^7 cfu/g at the rate of 10 g/kg) is an ideal potting medium for black pepper nursery for healthy planting material production using plug-trays compared to conventional multiplication.

The plug-tray nursery technique involves initial multiplication of black pepper runners in a modified serpentine method, ie. by allowing runners to strike roots in the partially decomposed coir pith and vermicompost (75:25) bed of convenient dimension (1.5 m width, 10 cm height and convenient length). The vines trail on rooting medium and strike roots at every node. After 45-60 days, leaving the terminal 5 nodes, about 15-20 node rooted runner is cut into single node rooted cuttings and transferred to plug-trays (cell dimension of 7.5 × 7.5 × 10.0 cm) filled with soil-less nursery mixture [composted coir pith and vermicompost (75:25) enriched with *Trichoderma*]. Better rooting and establishment is recorded under humidity controlled green house (27±2^{o}C)

with intermittent mist. The cuttings are retained in the trays for about 45-60 days (4-5 leaf stage) for initial establishment. The established cuttings are then transferred to shade net/ naturally ventilated green house for hardening (45-60 days). Healthy black pepper rooted cuttings are ready for field planting after 120-150 days.

Vertical column method

A novel method of intensifying quality planting material production has been standardized using vertical cloums with soil-less media. The technique involves growing orthotropes on vertical column (2 m height, 0.3 m diameter) made of half an inch plastic coated welded wire mesh. The column is filled with partially decomposed coirpith and vermicompost @ 3:1 ratio fortified with bio-control agent *Trichoderma harzianum*. Growing the vine on vertical column can be effectively utilized for the production of three types of planting material i.e., single node cuttings, top shoots with lateral branch (use of top shoots for field planting is having advantage of producing fruit bearing branch from the base and start yielding early) and laterals or plagiotropes which can be used for production of bush pepper.

The hi-tech poly house (temperature of 25-28°C and relative humidity 75-80% with intermittent misting) is advisable for the above production system. Eight to ten cuttings can be planted around each vertical column. The cuttings are allowed to trail on the column ensuring that each node comes in contact with the medium. It takes about four to five months for the cuttings to reach the top of the column. At this stage each vine will have around 20 nodes with few lateral branches (at 12^{th}-15^{th} node). The top 5-7 nodes with lateral branches can be used as orthotropic shoots for field planting.

In four to five months time, about 150 single node cuttings, 10 - 15 laterals and 10 top shoots can be produced in this method. Two hundred such columns can be accommodated in a poly house size of 320 m^2. In a year, three harvesting cycles can be made. These cuttings can be rooted further for field planting using pro-trays.

Nursery diseases

Phytophthora infection

Phytophthora infection is noticed on leaves, stems and roots of cuttings in the nursery. Dark spots with fimbriate margins appear on the leaves, which spread rapidly resulting in defoliation. The infection on the stem

is seen as black lesions which result in blight. The symptoms on the roots appear as rotting of the entire root system.

Spraying Bordeaux mixture (1%) on leaves and drenching soil with copper oxychloride (0.2%) at monthly intervals prevents the disease. Alternatively, metalaxyl-mancozeb (0.125%) or potassium phosphonate (0.3%) could also be used. The potting mixture may be sterilized through solarization. To the sterilized mixture, bio agents such as VAM @ 100 cc/kg of mixture and *Trichoderma harzianum* @ 1 g/kg of soil (*Trichoderma* population @ 10^{10} cfu/g) may be added at the time of filling of nursery mixture in polythene bags. Since the biocontrol agents mainly protect the root system, the aerial portion may be protected with chemicals. If Bordeaux mixture is used care must be taken to prevent dripping of fungicide to the soil. Alternatively, systemic fungicides such as metalaxyl-mancozeb (0.125%) and potassium phosphonate (0.3%) which are compatible with *Trichoderma* may be used.

Anthracnose

The disease is caused by the fungus *Colletotrichum gloeosporioides*. The fungus infects the leaves causing yellowish brown to dark brown irregular leaf spots with a chlorotic halo. Pre-planting treatment of two/three node cuttings by immersing in a solution of carbendazim + mancozeb (0.1%) for 30 minutes and spraying Bordeaux mixture (1%) alternating with carbendazim (0.1%) is effective against the disease.

Leaf rot and blight

The disease is caused by the fungus *Rhizoctonia solani* and is often serious in nurseries during April-May when warm humid conditions prevail. The fungus infects both leaves and stems. Grey sunken spots and mycelia threads appear on the leaves and the infected leaves are attached to one another with the mycelia threads. On stems, the infection occurs as dark brown lesions which spread upwards and downwards. The new flushes subtending the points of infection gradually droop and dry up. A prophylactic spray with Bordeaux mixture (1%) prevents both the diseases.

Basal wilt

The disease is mainly noticed in nurseries during June-September and is caused by the fungus *Sclerotium rolfsii*. Grey lesions appear on stems

and leaves. On the leaves white mycelia are seen at the advancing edges of the lesions. The mycelia threads later girdle the stem resulting in drooping of leaves beyond the point of infection and in advanced stages the rooted cuttings dry up. Small whitish to cream coloured grain like sclerotia bodies appear on the mature lesions. The disease can be controlled in the initial stages, by adopting phytosanitary measures. The affected cuttings along with defoliated leaves should be removed and destroyed. After periodic sanitation, the cuttings are to be drenched with carbendazim (0.2%) or Bordeaux mixture (1%).

Viral infections

Vein clearing, mosaic, yellow specks, mottling and small sized leaves are the most apparent symptoms for identifying viral infections in the nursery. As viruses are systemic in nature, primary spread occurs through planting material since black pepper is vegetatively propagated. When infected plants are used as source of planting material, the cuttings will also be infected. Hence, selection of virus free healthy mother plants is very important for producing disease free cuttings. Secondary spread of the disease occurs through insects such as aphids and mealy bugs. When the poly bag cuttings are placed close and crowded in the nursery, chances of spread through these insects are more. Hence, regular monitoring of the nursery for insects and spraying with insecticide like dimethoate (0.05%) should be resorted to whenever insect attack is noticed. Besides, inspection and removal of infected plants should also be done at regular intervals.

Nematode infestation

Root-knot nematodes (*Meloidogyne* spp.) and burrowing nematode, *Radopholus similis* are the two important nematode species infesting rooted cuttings in the nursery. The damage caused to roots by nematode infestations result in poor growth, foliar yellowing and sometimes interveinal chlorosis of leaves. The establishment of nematode infected cuttings will be poor when planted in the field and such cuttings develop slow decline symptoms at later stages.

Soil solarization or steam sterilization can be adopted for sterilizing the nursery mixture. The sterilized nursery mixture may be fortified with biocontrol agents such as *Pochonia chlamydosporia* or *Trichoderma harzianum* @ 1-2 g/kg of soil, the product containing 10^8 cfu fungus/g of substrate. A prophylactic application of nematicide is also necessary

to check the nematode infestation. For this, make three equidistant holes of 2-3 cm depth in the bag around the cuttings and place phorate* 10 G @ 1 g/bag or Carbofuran* 3 G @ 3 g/bag in these holes and cover with soil. Carbosulfan 0.1% @ 50 mL/bag can also be applied to control nematodes. A light irrigation may also be given to ensure adequate soil moisture after nematicide application. In rapid multiplication nurseries where the rooted cuttings are retained for longer durations nematicides may be applied at 45 day intervals as described above.

Establishment of plantations

Selection of site

For planting black pepper in slopes, the lower half of northern and north eastern slopes are preferred. This will save the vines from sun scorching from southern side during summer.

Preparation of land and planting standards

With the receipt of first rains in May-June, primary stem cuttings of standard trees such as *Erythrina* spp., *Garuga pinnata*, *Grevillea robusta* (silver oak), seedlings of *Alianthus malabarica* (Matti) are planted in pits of 50 cm × 50 cm × 50 cm size filled with cow dung and top soil. The planting is done at a spacing of 3 m × 3 m which would accommodate about 1110 standards per hectare. The black pepper vines can be trailed on the standards after three years when they attain sufficient height. Whenever *E. indica* is used as standard, application of phorate 10 G* @ 30 g may be done twice a year (May/June and September/October) to control nematodes and stem and root borer. When *E. indica* and *G. pinnata* are used, the primary stems are cut in March/April and stacked in shade till the stems start sprouting in May.

Planting

Pits of 50 cubic centimeters at a distance of 30 cm away from the base, on the north, eastern or north eastern side of supporting tree are taken with the onset of monsoon. The pits are filled with a mixture of top soil, farmyard manure @ 5 kg/pit and 150 g rock phosphate. Neem cake @ 1 kg, *Trichoderma harzianum* @ 50 g also may also be mixed with the mixture at the time of planting. With the onset of monsoon, 2-3 rooted cuttings of black pepper are planted individually in the pits.

Lowering of the vines is a practice followed in many pepper grow-

* banned in Kerala

ing regions. In this method, the vines are allowed to trail on support trees up to 1.5 m. Subsequently, the vines are carefully separated from the standard and buried in the soil around the base of the standard ensuring that the growing tip is of the vine is kept above the soil. This practice induces more leader shoots covering the entire standard and production of laterals from the base of the standard.

Cultural practices

As the plants grow, shoots are tied to the standard as often as required. The young vines should be protected from hot sun during summer by providing artificial shade. Regulation of shade by lopping the branches of standards is necessary not only for providing optimum light to the vines but also for enabling the standards to grow straight. Adequate mulch with green leaf or organic matter should be applied towards the end of north east monsoon. The base of the vines should not be disturbed to avoid root damage.

During the second year, the same cultural practices are repeated. However, lopping of standards should be done carefully from the fourth year onwards, not only to regulate height of the standards, but also to shade the black pepper vines optimally. Lopping may be done twice (during June and September) in a year. Excessive shading during flowering and fruiting encourages pest infestations.

Growing cover crops like *Calapogonium mucunoides* and *Mimosa invisa* are also recommended under West Coast conditions as an effective soil cover to prevent soil erosion during rainy season. During summer the cover crops dry up leaving thick organic mulch.

Manuring and fertilizer application

Manuring and fertilizer application is critical for proper establishment and growth of plants. Application of lime or dolomite @ 500 g/vine in April-May during alternate years is recommended under highly acid soil conditions. Organic manures in the form of cattle manure or compost can be given @ 10 kg/vine during May. Neem cake @ 1 kg/vine can also be applied.

Recommended blanket nutrient dosage for black pepper vines (3 years and above) are as follows:

NPK 50: 50: 150 g/vine/year (General recommendation)

NPK 50: 50: 200 g/vine/year (for Panniyur and Kannur district in Kerala)

NPK 140: 55: 270 g/vine/year (for Kozhikode district in Kerala)

Only one-third of this dosage should be applied during the first year which is increased to two-thirds in the second year. The full dose is given from the third year onwards. As the soil fertility will be varying with the agro ecological conditions or management systems, site specific nutrient management for yielding gardens based on their soil test results for major nutrient is advocated. The recommended dose of nutrients for varying soil test values of N, P and K is given in Table 2. The fertilizers are to be applied in two split doses, one in May-June and the other in August-September and sufficient soil moisture must be ensured. The fertilizers are applied at a distance of about 30 cm all around the vine and covered with a thick layer of soil. Care should be taken to avoid direct contact of fertilizers with roots of black pepper. When biofertilizer like *Azospirillum* is applied @ 50 g/vine, the recommended nitrogen dose may be reduced by half. In soils that are deficient in zinc or magnesium, foliar application of 0.25% zinc sulphate twice a year (May-June and September-October) and soil application of 200 g/vine magnesium sulphate, respectively is recommended. Foliar application of micronutrient mixture specific to black pepper is also recommended (dosage @ 5 g/L) twice, starting at flowering and followed at monthly intervals for higher yield.

Table 2. Soil test based fertilizer recommendations for dry yield target levels of 3 and 6 t/ha

Soil test value for available nutrients (kg/ha)		Fertilizer nutrient recommended (kg/ha) for yield targets	
		3.0 t/ha	6.0 t/ha
Nitrogen			
	< 150	50	100
	150-250	25	80
	250-400	10	55
	>400	-	20
Phosphorus (P_2O_5)			
	< 10	40	80
	10-30	30	70
	30-50	10	55
	>50	-	30
Potassium (K_2O)			
	< 110	150	310
	110-300	125	275
	300-500	80	250
	>500	35	110

Bush pepper

Rooted lateral branches grown as bushes are known as bush pepper. Bush pepper can be raised as potted bushes or field grown bushes. Bush pepper yields green pepper throughout the year and the fresh yield per bush can be up to 1 kg after 3 years of planting.

Microbial consortium

A talc based formulation (IISR Biomix) consisting of a consortium of Plant Growth Promoting Rhizobacteria [*Micrococcus luteus* (BRB 3)] + [*Enterobacter aerogenes* (BRB 13)] + [*Micrococcus sp.* (BRB 23)] is also applied to black pepper in the nursery and main field for enhanced growth and yield. During application, 20 g of talc formulation is mixed in one litre of water and is applied at the rate of 250 mL per vine in the field and at the rate of 100 mL per bag in the nursery. Alternatively, 1 kg of talc formulation can be mixed with 100 kg of farmyard manure (or well decomposed cow dung) and applied at the rate of 1 kg per vine in the basin i.e. around the root zone. It can be applied twice a year (during May-June and September-October).

Summer irrigation

Irrigating black pepper vines during summer (March 15th to May 15th) at fortnightly interval enhances productivity by 90 to 100% compared to unirrigated crop. Vines are irrigated at the basin through hose and 50 litres per vine is recommended (15 years and above). This can be reduced to 40 litres per vine for 11-15 years age group and 30 litres for vines aged between 5 - 10 years. The spiking will be uniform in the irrigated crop as most of the spikes (> 90%) emerge by July while in rain fed crop only around 60% of spikes emerge in July and may extend till September. Spike length will be comparatively more in irrigated crop.

Plant protection

Diseases

Foot rot disease

Foot rot (quick wilt) caused by *Phytophthora capsici* is the most destructive of all diseases and occurs mainly during the south west monsoon season. All parts of the vine are vulnerable to the disease and the expression of symptoms depend upon the site or plant part infected and the extent of damage.

Symptoms

- One or more black spots appear on the leaves which have characteristic fine fimbriate margins which rapidly enlarge and cause defoliation.
- The tender leaves and succulent shoot tips of freshly emerging runner shoots trailing on the soil turn black when infected. The disease spreads to the entire vine from these infected runner shoots and leaves during intermittent showers due to rain splash.
- If the main stem at the ground level or the collar is damaged, the entire vine wilts followed by shedding of leaves and spikes with or without black spots. The branches break up at nodes and the entire vine collapses within a month.
- If the damage is confined to the feeder roots, the expression of symptoms is delayed till the cessation of rain and the vine starts showing declining symptoms such as yellowing, wilting, defoliation and drying up of a part of the vine. This may occur during October-November onwards. These vines may recover later and survive for more than two seasons till the root infection culminates in collar rot and death of the vine.

Management

The disease can be controlled by adopting integrated disease management strategies.

Phytosanitation

- Removal and destruction of dead vines along with root system from the garden is essential as this reduces the buildup of inoculum (*Phytophthora* population).
- Planting material must be collected from disease free gardens and the nursery preferably raised in fumigated or solarized soil.

Cultural practices

- Adequate drainage should be provided to reduce water stagnation.
- Injury to the root system due to cultural practices such as digging should be avoided.
- The freshly emerging runner shoots should not be allowed to trail on the ground. They must either be tied back to the standard or pruned off.

- The branches of support trees must be pruned at the onset of monsoon to avoid build up of humidity and for better penetration of sunlight. Reduced humidity and presence of sunlight reduces the intensity of leaf infection.

Chemical control

Any one of the following chemical control measures can be adopted.

- After the receipt of a few monsoon showers (May-June), all the vines are to be drenched at a radius of 45-50 cm with copper oxychloride (0.2%) @ 5-10 litres/vine. A foliar spray with Bordeaux mixture (1%) is also to be given. Drenching and spraying are to be repeated during August-September. A third round of drenching may be given during October if the monsoon is prolonged.
- After the receipt of a few monsoon showers, all the vines are to be drenched with potassium phosphonate (0.3%) @ 5-10 litres/vine. A foliar spray with potassium phosphonate (0.3%) is also to be given. A second spraying with potassium phosphonate (0.3%) is to be repeated during August-September. If the monsoon is prolonged, a third round of drenching may also be given during October.
- After the receipt of a few monsoon showers, all the vines are to be drenched with metalaxyl mancozeb (0.125%) @ 5-10 litres/vine. A foliar spray with metalaxyl mancozeb (0.125%) may also be given. A second application can be given during August-September.
- At the onset of monsoon (May-June), apply *Trichoderma harzianum* around the base of the vine @ 50 g/vine (this quantity is recommended for a substrate containing *Trichoderma harzianum* @ 10^{10} cfu/g). A foliar spray with potassium phosphonate (0.3%) or Bordeaux mixture (1%) is also to be given. A second application of *Trichoderma harzianum* and foliar spray of Bordeaux mixture (1%) or potassium phosphonate (0.3%) are to be given during August-September.

Pollu disease (Anthracnose)

This disease is caused by *Colletotrichum gloeosporioides*. It can be distinguished from the pollu (hollow berry) caused by the beetle by the presence of characteristic cracks on the infected berries. The disease appears towards the end of the monsoon. The affected berries show brown

sunken patches during early stages and their further development is affected. In later stages, the discolouration gradually increases and the berries show the characteristic cross splitting. Finally, the berries turn black and dry. The fungus also causes angular to irregular brownish lesions with a chlorotic halo on the leaves. The disease can be managed by prophylactic spraying of Bordeaux mixture (1%) or carbendazim + mancozeb (0.1%).

Spike shedding

Spike shedding especially in varieties like Panniyur-1 at higher elevations like Kodagu and Idukki is one of the emerging problem. It is seen in serious condition when the pre-monsoon showers are delayed and flowering and spiking occur during June-July. These spikes predominantly produce female flowers instead of bisexual flowers. Heavy spike shedding may occur due to lack of pollination and anthracnose infection. Irrigation of vines from second fortnight of March (50-60 litres/vine at fortnightly intervals) coupled with prophylactic spraying with bordeaux mixture (1%) or carbendazim + mancozeb (0.1%) reduces the intensity of spike shedding.

Stunt disease

This disease caused by viruses is noticed in parts of Kannur, Kasaragod, Kozhikode, Wayanad and Idukki Districts of Kerala and Kodagu, Hassan and Uthara Kannada districts of Karnataka. The vines exhibit shortening of internodes to varying degrees. The leaves become small and narrow and appear leathery, puckered and crinkled. Chlorotic spots and streaks also appear on the leaves occasionally. The yield of the affected vines decreases gradually.

Two viruses namely *Cucumber mosaic virus* and a *Badnavirus* are associated with the disease. The major means of spread of the virus is through the use of infected stem cuttings. The disease can also be transmitted by insects like aphids and mealy bugs. The following strategies are recommended for the management of the disease.

- Use virus free healthy planting material
- Regular inspection and removal of infected plants; the removed plants may be burnt or buried deep in soil
- Aphids and mealy bugs should be controlled by spraying insecticide such as dimethoate (0.05%).

Phyllody disease

This disease caused by phytoplasma is noticed in parts of Waynad and Kozhikode districts of Kerala. The affected vines exhibit varying levels of malformation of spikes. Some of the floral buds are transformed into narrow leaf like structures, exhibiting phyllody symptoms. In advanced stages, the leaves become small and chlorotic, and the internodes are also shortened. The affected fruiting laterals give a witches broom appearance. Severely affected vines decline rapidly and become unproductive within 2 to 3 years. The infected vines are to be destroyed to prevent further spread of the disease.

Slow decline (slow wilt)

Slow decline is a debilitating disease of black pepper. Foliar yellowing, defoliation and die-back are the aerial symptoms of this disease. The foliar yellowing appears from October onwards coinciding with depletion of soil moisture. With the onset of south west monsoon during May/June, some of the affected vines recover and put forth fresh foliage. However, the symptoms reappear in subsequent seasons after the cessation of the monsoon and the vines gradually lose their vigour and productivity. The affected vines show varying degrees of feeder root loss due to nematode infestation and the expression of symptoms on the aerial parts occur after a considerable portion of the feeder roots are lost. Nematodes such as *Radopholus similis* and *Meloidogyne incognita* infestations lead to necrosis and development of galls on roots and rotting of feeder roots. The damage to feeder roots is caused by these nematodes and *P. capsici* either independently or combined. There is no spatial segregation of plant parasitic nematodes and *P. capsici* in the soil under field conditions. Hence, it is necessary to adopt a combination of fungicide and nematicide application for the management of the disease.

- Severely affected vines should be removed from the plantation and destroyed, as it is impossible to recover them whenever high population of nematode are noticed
- The pits for planting should be treated with phorate* 10 G @15 g or carbofuran* 3 G @ 50 g at the time of planting.
- Nematode free rooted cuttings raised in fumigated or steam sterilized nursery mixture should be used for planting in the field.
- Phorate* 10 G @ 30 g or carbofuran* 3 G @ 100 g/vine should

* banned in Kerala

be applied during May/June (with the onset of south west monsoon) and September/October. Along with nematicides the basins should be drenched with either copper oxychloride (0.2%) or potassium phosphonate (0.3%) or metalaxyl-mancozeb (0.125%).

In areas severely infested with root knot nematodes, cuttings of the resistant variety 'Pournami' may be planted. Biocontrol agents like *Pochonia chlamydosporia* or *Trichoderma harzianum* can be applied @ 50 g/vine twice a year (during April-May and September-October). The fungus load in the substrate should be 10^8 cfu/g.

While applying nematicides, the soil should be raked in the basin of the vine lightly without causing damage to the root system and the nematicide should be spread uniformly in the basin and covered with soil immediately. Sufficient soil moisture should be ensured at the time of nematicide application. The control measures should be taken up during early stages of the disease.

Insect pests

Pollu beetle

Pollu beetle (*Lanka ramakrishnai*) is the most destructive pest of black pepper and is more serious in plains and at altitudes below 300 m. The adult is a small black beetle measuring about 2.5 mm × 1.5 mm, the head and thorax being yellowish brown and the fore wings (elytra) black. Fully-grown grubs are creamy-white and measure about 5 mm in length.

The adult beetles feed and damage tender leaves and spikes. The females lay eggs on tender spikes and berries. The grubs bore into and feed on the internal tissues and the infested spikes turn black and decay. The infested berries also turn black and crumble when pressed. The term pollu denotes the hollow nature of the infested berries in Malayalam. The pest infestation is more serious in shaded areas in the plantation. The pest population is higher during September-October in the field.

Regulation of shade in the plantation reduces the population of the pest in the field. Spraying quinalphos (0.05%) during June-July and September-October or quinalphos (0.05%) during July and Neemgold (0.6%) (neem-based insecticide) during August, September and October is effective for the management of the pest. The underside of leaves (where adults are generally seen) and spikes are to be sprayed thoroughly.

Top shoot borer

The top shoot borer (*Cydia hemidoxa*) is a serious pest in younger plantations in all black pepper areas. The adult is a tiny moth with a wing span of 10-15 mm with crimson and yellow fore wings and grey hind wings. The larvae bore into tender terminal shoots and feed on internal tissues resulting in blackening and decaying of affected shoots. Fully-grown larvae are greyish green and measure 12-15 mm in length. When successive new shoots are attacked, the growth of the vine is affected. The pest infestation is higher during July to October when numerous succulent shoots are available in the vines. Spray quinalphos (0.05%) on tender terminal shoots; repeat spraying at monthly intervals (during July-October) to protect emerging new shoots.

Leaf gall thrips

Infestation by leaf gall thrips (*Liothrips karnyi*) is more serious at higher altitudes especially in younger vines and also in nurseries in the plains. The adults are black and measure 2.5 mm-3.0 mm in length. The larvae and pupae are creamy white. The feeding activity of thrips on leaves causes the leaf margins to curl downwards and inwards resulting in the formation of marginal leaf galls. Later the infested leaves become crinkled and malformed. In severe cases of infestation, the growth of younger vines and cuttings in the nursery is affected. Spray dimethoate (0.05%) during emergence of new flushes in young vines in the field and cuttings in the nursery.

Scale insects

Among the various scale insects recorded on black pepper, mussel scale (*Lepidosaphes piperis*) and coconut scale (*Aspidiotus destructor*) causes serious damage to black pepper vines at higher altitudes and also to older cuttings in nurseries in the plains. Females of mussel scales are elongated (about 1 mm length) and dark brown and that of coconut scales circular (about 1 mm in diameter) and yellowish brown. Scale insects are sedentary, remaining permanently fixed to plant parts and appear as encrustations on stems, leaves and berries. They feed on plant sap and cause yellowing and wilting of infested portions; in severe cases of infestation the affected portions of vines dry up. The pest infestation is more severe during the post monsoon and summer periods.

Clip off and destroy severely infested branches. Spray dimethoate (0.1%) on affected vines after harvest of produce; repeat spraying after

21 days to control the infestation completely. Initiate control measures during early stages of pest infestation. In nurseries spraying neem oil 0.3% or Neemgold 0.3% or fish oil rosin 3% is also effective in controlling the pest infestation.

Minor pests

Leaf feeding caterpillars, especially *Synegia* sp., damage leaves and spikes of younger vines and can be controlled by spraying quinalphos (0.05%). Mealybugs, gall midges and aphids infest tender shoots especially in nurseries. Spraying dimethoate (0.05%) may be undertaken if infestations are severe. Mealybug infestation on roots can be controlled by drenching with chlorphyriphos (0.075%) and undertaking control measures against *Phytophthora* and nematode infections.

Organic production

Conversion plan

For certified organic production of black pepper, at least 18 months the crop should be under organic management *ie* in the new plantations the first crop of pepper can be sold as organic, as the yielding starts from third year. To convert an existing plantation to organic, a conversion period of 36 months is set for the perennial crops. The conversion period may be relaxed if the organic farm is being established on a land where chemicals were not previously used, provided sufficient proof of history of the area is available. It is desirable that organic method of production is followed in the entire farm; but in the case of large extent of area, the transition can be done in a phased manner for which a conversion plan has to be prepared.

The entire pepper holding can be converted to organic production when pepper is grown as sole crop. When grown in a mixed cultivation system, it is essential that all the crops in the field are also subjected to organic methods of production. Black pepper as a best component crop in agri-horti and silvi-horti systems, recycling of farm waste can be effectively done when grown with coconut, arecanut, coffee etc. As a mixed crop it can also be intercropped with green manure/ legumes crops enabling effective nutrient built up.

In order to avoid contamination of organically cultivated plots from neighboring non-organic farms, a suitable buffer zone with definite border is to be maintained. In smallholder groups, where the pepper holdings are contiguous, the isolation belt is needed at the outer pe-

riphery of the entire group of holdings. Pepper grown on this isolation belt cannot be treated as organic. In sloppy lands adequate precaution should be taken to avoid the entry of run off water and chemical drift from the neighboring farms.

Management practices

For organic production, traditional varieties adapted to the local soil and climatic conditions that are resistant or tolerant to diseases, pests and nematode infection should be used. All crop residues and farm wastes like green loppings, crop residues, grasses, cow dung slurry, poultry droppings etc. available on the farm can be recycled through composting, including vermicomposting so that soil fertility is maintained at high level. No synthetic chemical fertilizers, pesticides or fungicides are allowed under organic system. Farmyard manure may be applied @ 5-10 kg/vine along with vermi/ leaf compost @ 5-10 kg/ vine based on the age of the vine. Further, supplementation of oil cakes like neem cake (1 kg/vine), composted coir pith (2.5 kg/vine) or composted coffee pulp rich in potassium and suitable microbial cultures of *Azospirillum* and phosphate solubilizing bacteria will improve the fertility. Based on soil test, application of lime/dolomite to correct the pH, rock phosphate/ bone meal and wood ash or sulphate of potash (mineral potassium) may be done to get required quantity of phosphorus and potassium. When the deficient conditions of trace elements become yield limiting, restricted use of mineral/chemical sources of micronutrients and magnesium sulphate are allowed as per the limits of standard setting or certifying organizations.

Use of biopesticides, biocontrol agents, cultural and phytosanitary measures for the management of insect pests and diseases forms the main strategy under organic system. Management of pollu beetle by shade regulation and Neemgold (0.6%) spray at 21 day intervals during July-October, and that of scale insects by removing severely infected branches and spraying Neemgold (0.6%) or fish oil rosin (3%) are recommended.

Application of bio control agents like *Trichoderma* or *Pseudomonas* multiplied in suitable carrier media such as coffee husk/ coir pith compost, well rotten cow dung or quality neem cake may be done regularly to keep the foot rot disease in check. To control fungal pollu and other foliar diseases spraying of 1% Bordeaux mixture may be done restricting the quantity to 8 kg copper per hectare per annum. Application of quality neem cake mentioned earlier along with the bio agents *Pocho-*

nia chlamydosporia will be useful to check the nematode population and thereby slow decline disease.

Certification

Certification and labeling is usually done by an independent body to provide a guarantee that the production standards are met. Govt. of India has taken steps to have indigenous certification system to help small and marginal growers and to issue valid organic certificates through certifying agencies accredited by APEDA. The inspectors appointed by the certification agencies will carry out inspection of the farm operations through records maintained and by periodic site inspections. The grower has to document all the details with respect to field map, field history sheet, activity register, input record, output record, harvest record, storage record, pest control records, movement record, equipments cleaning record and labelling records etc. Documentation of farm activities is must for acquiring certification especially when both conventional and organic crops are raised. Group certification programmes are also available for organized group of producers and processors with similar production systems located in geographical proximity.

Harvest and post harvest management

Harvesting

Black pepper takes about 7-8 months after flowering to reach full maturity. In India the crop is harvested during December –January in plains and January-April in the high ranges of Western Ghats. It is important to harvest pepper at the proper stage of maturity in order to achieve a dried product of good colour and appearance. Harvest starts when one or two berries turn yellow. The spikes are nipped of by hand and collected in bags. Normally, single pole bamboo ladder is used as a support for harvesting. If the berries are allowed to over ripe, there is heavy loss due to berry drop and damage by birds. Harvested spikes are generally collected in clean gunny bags. Spikes which are fallen on to the ground may be collected separately, cleaned and then pooled to the general lot.

Recent advances in product diversification have necessitated harvesting of the berries at different stages of maturity. The level of maturity required at harvest for processing into different pepper products is given below.

Product	Stage of maturity at harvest
Canned pepper	4-5 months
Dehydrated green pepper	10-15 days before maturity
Oleoresin and essential oil	15-20 days before maturity
Black pepper	Fully mature and 1-2 berries start turning from yellow to red in each spike
Pepper powder	Fully mature
White pepper	Fully ripe

Post harvest processing

Post harvest processing operations followed for black pepper involves threshing, blanching, drying, cleaning, grading and packaging. During processing care should be taken to maintain the quality at each step of operation.

Threshing

Threshers with capacities varying from 50 kg/h to 2500 kg/h are available which can thresh quickly and provide clean product.

Blanching

The quality of the black pepper can be improved by a simple treatment of dipping the mature berries taken in perforated vessel in boiling water for a minute before drying. This processing technique has several advantages:

- Uniform coloured black pepper is obtained after drying.
- Reduces the microbial load.
- Pepper can be dried in 3-4 days as against 5-6 days required when following the traditional practice
- Removes the extraneous impurities like dust from the berries.

Drying

Pepper has moisture content of 65% to 70% at harvest, which should be brought to safer levels of 10% by adequate drying. The green colour of matured pepper is due to the presence of chlorophyll pigment. During drying, enzymatic browning sets in and the phenolic compounds are oxidized by atmospheric oxygen under the catalytic influence of the enzyme phenolase and eventually turn black.

Sun drying is the conventional method followed for drying of black pepper. The despiked berries are spread on concrete floor and dried under sun for 3-5 days to bring the moisture content below 10%. Dried

black pepper with high moisture content (>12%) is susceptible to fungal attack. Mycotoxins produced by the fungal attack render the pepper unfit for human consumption. In order to achieve a quality dry product, pepper berries are spread on clean dry concrete floor / bamboo mats/ PVC sheets and dried in the sun for a period of 4 - 6 days. The average dry recovery varies between 33-37% depending on the varieties and cultivars.

Mechanical driers developed by various agencies are also used to dry black pepper. Models of varying capacities operated either electrically or by burning agricultural wastes are available for drying of black pepper by maintaining temperature below 55^0C.

Cleaning and grading

The threshed and dried black pepper has extraneous matter like spent spikes, pinheads, stones, soil particles etc. mixed with it. Cleaning and grading are basic operations that enhance the value of the produce and help to get higher returns. Cleaning on a small scale is done by winnowing and hand picking which removes most of the impurities. Such units consist of a fan/ blower and a feeding assembly. The fan is placed at the rear end of the hopper. Cleaning is achieved by feeding the material through the hopper into a stream of air blowing in perpendicular direction. The lighter fractions (dust, immature berries, pin heads and spent spikes) are blown away. Grading of black pepper is done by using sieves and shifting black pepper into different grades based on size. The major grades of black pepper are Tellicherry Garbled Special Extra Bold (TGSEB) (4.8 mm); Tellicherry Garbled Extra Bold (TGEB) (4.2 mm); Tellicherry Garbled (TG) (4.0 mm); Malabar Garbled (MG grades 1 and 2) and Malabar Ungarbled (MUG grades 1 and 2).

White pepper

It is generally prepared by retting (with frequently changing of water) fully ripened red berries for 7-8 days followed by removal of outer skin, washing and drying to a moisture level of 12%. White pepper is also prepared by fermentation using matured green bepper and black pepper.

Packaging

Organically grown black pepper should be packaged separately and labeled. Mixing different types of pepper is not good from a commercial

point of view. Eco friendly packaging materials such as clean gunny bags or paper bags may be adopted and the use of polythene bags may be minimized. Recyclable/ reusable packaging materials shall be used wherever possible.

Storage

Black pepper is hygroscopic in nature and absorption of moisture from air, during rainy season when there is high humidity may result in mould and insect infestation. Before storage it is to be dried to less than 10 per cent moisture. The graded produce is bulk packed separately in multi layer paper bags or woven polypropylene bags provided with food grade liners or in jute bags. The bags are arranged one over the other on wooden pallets after laying polypropylene sheets on the floor.

A state of the art spice processing unit adhering to latest quality standards is operational at ICAR- IISR experimental farm, Peruvannamuzhi., which caters to the training and processing requirements in the spice processing sector.

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