Black pepper (*Piper nigrum*) (Family: *Piperaceae*) is a perennial climbing vine grown for its berries extensively used as spice and in medicine. India is a leading pr oducer, consumer and exporter of black pepper in the world. During 2005-06, 16,700 tonnes of black pepper products worth Rs. 14,050 lakhs wer e exported to various countries accounting for 6.0 % of export earnings among spices. Black pepper is cultivated to a lar ge extent in Kerala and Karnataka and to a limited extent in Tamil Nadu and other states. The crop is grown in about 2,46,000 hectares with a production of 69,000 tonnes annually. Kerala and Karnataka account for a major portion (92 %) of production of black pepper in the country .

Climate and soil

Black pepper is a plant of humid tropics r equiring adequate 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 latitude, and from sea level up to 1500 m above sea level. The crop tolerates temperatures between 10° and 40° C. A well distributed annual rainfall of 125-200 cm is consider ed ideal for black pepper. Black pepper can be grown in a wide range of soils with a pH of 4.5 to 6.5, though in its natural habitat it thrives well in red laterite soils.

The black pepper gr owing areas in the W est Coast of India include (i) coastal areas wher e black pepper is gr own in homesteads (ii) midlands and where black pepper is extensively cultivated on a plantation scale and (iii) hills at an elevation of 800-1500 m above sea level, wher e the crop is mostly gr own on shade trees in coffee, cardamom and tea plantations.

Varieties

A majority of the cultivated types ar e monoecious (male and female flowers found in the same spike) though variation in sex expression ranging fr om complete male to complete female is found. Over 75 cultivars of black pepper ar e being cultivated in India. Karimunda is the most popular of all cultivars in Kerala. The other important cultivars ar e Kottanadan (South Kerala), Narayakodi (Central Kerala), Aimpiriyan (Wynad), Neelamundi (Idukki), Kuthiravally (Kozhikode and Idukki), Balancotta,

Kalluvally (North Kerala), Malligesara and Uddagare (Karnataka). Kuthiravally and Balancotta exhibit alternate bearing habit. A few important cultivars and their salient features are given in Table 1. In terms of quality, Kottanadan has the highest oleoresin (17.8%) content followed by Aimpiriyan (15.7%).

Sixteen improved varieties of black pepper have been released for cultivation (Table 2). Panniyur-1 and Panniyur-3 are hybrids evolved at the Pepper Research Station, Panniyur (Kerala) and have Uthirankotta and Cheriyakaniakadan as their female and male parents, respectively. IISR Girimunda and IISR Malabar Excel are the two hybrids released from Indian Institute of Spices Research, Calicut.

Table1. Important cultivars of black pepper and their characteristic features

Cultivar	Fresh mean yield (kg/vine)	Quality attributes				Features
		Oleoresin (%)	Piperine (%)	Essential oil (%)	Dry recovery (%)	
Aimpirian	4-5	15.0	4.7	2.6	34	Good for higher elevations, good in quality, late maturing
Arakulamunda	2	9.8	4.4	4.7	33	Moderate and regular bearer
Balankotta	1-2	9.3	4.2	5.1	35	Moderate and irregular bearing
Karimunda	2-3	11.0	4.4	4.0	35	Suitable for all pepper growing areas, high yielder, shade tolerant.
Kalluvally	1-2	8.4-11.8	2.5-5.4	3.0	35-38	Good yielder with high dry recovery, drought tolerant
Kottanadan	5	17.8	6.6	2.5	34-35	High yielding, drought tolerant
Kuthiravally	3	15.0	6.0	4.5	35	High yield, good quality
Narayakodi	1-2	11.0	5.4	4.0	36	Moderate yielder with medium quality
Neelamundi	2	13.9	4.6	3.3	33-34	Good yielder, Tolerant to *Phytophthora* infection
Vadakkan	3	10.8	4.2	3.2	-	Medium quality and yield

Table 2. 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 (%)	
Panniyur -1(KAU)	Hybrid between Uthirankotta x Cheriyakaniakadan	1242	35.3	5.3	11.8	3.5	Not suited to heavily shaded areas
Panniyur -2 (KAU)	Selection (Cul. 141) from cv. Balancotta	2570	35.7	6.6	10.9	-	Shade tolerant
Panniyur -3 (KAU)	Hybrid (Cul. 331) Uthirankotta x Cheriyakaniakadan	1953	27.8	5.2	12.7	-	Late maturing
Panniyur -4 (KAU)	Selection from Kuthiravally Type	1277	34.7	-	9.2	-	Stable yielder
Panniyur -5 (KAU)	Open pollinated progeny selection from Perumkodi	1098	-	5.5	12.3	3.8	Tolerant to shade
Panniyur -6 (KAU)	Clonal selection from Karimunda	2127	32.9	4.9	8.3	1.3	Suited to all black pepper tracts
Panniyur -7 (KAU)	Open pollinated progeny selection from Kuthiravally	1410	33.6	5.6	10.6	1.5	Suited to all black pepper tracts
Subhakara (IISR)	Selection from Karimunda (KS-27)	2352	35.5	3.4	12.4	6.0	Suited to all black pepper tracts
Sreekara (IISR)	Selection from Karimunda (KS-14)	2677	35.0	5.3	13.0	7.0	Suited to all black pepper tracts

Panchami (IISR)	Selection from Aimpiriyan (Coll. 856)	2828	34.0	4.7	12.5	3.4	Late maturing
Pournami (IISR)	Selection from Ottaplackal (Coll. 812)	2333	31.0	4.1	13.8	3.4	Tolerant to root knot nematode
PLD -2 (IISR, CPCRI, Palode)	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	1.65	8.15	3.1	Tolerant to *Phytophthora* foot rot; Suited to high altitude and plains
IISR Girimunda	Hybrid between Narayakodi x Neelamundi	2880	32.0	2.2	9.65	3.4	Suited to high altitude
IISR Malabar Excel	Hybrid between Cholamundi x Panniyur-1	1440	32.0	4.95	14.6	4.1	Suited to high altitude; Rich in oleoresin

Propagation

Black pepper vines develop three types of aerial shoots, namely (a) primary stem with long internodes, with adventitious roots which cling to the standards (b) runner shoots which originate from the base of the vine and have long internodes which strike roots at each node and (c) fruit bearing lateral branches.

Cuttings are raised mainly from runner shoots, though terminal shoots can also be used. Cuttings from lateral branches are seldom used since they develop a bushy habit. However, rooted lateral branches are useful for raising bush pepper.

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 each are planted either in nursery beds or in polythene bags filled with fertile soil. 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

An efficient propagation technique developed at 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 convenient 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 with septa or split halves of PVC pipes of 1.25-1.50 m length and 8-10 cm diameter provided with plastic septa at 30 cm intervals are fixed at 45° angle on a strong support. 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 so as to keep the nodes pressed to the rooting medium. The tying can be done with dried banana leaf sheath fibers or coir rope. The cuttings are irrigated regularly. As the cuttings grow, the bamboo splits are filled with rooting medium and each node is pressed down to the rooting medium and tied. For rapid growth, a nutrient solution of urea (1 kg), super phosphate (0.75 kg), muriate of potash (0.5 kg) and magnesium sulphate (0.25 kg) in 250 litres of water is to be applied @ 0.25 litre per vine at monthly intervals.

When the vine reaches the top (3-4 months after planting of the cutting) the terminal bud is nipped off and the vine is crushed at about three nodes above the base, in order to activate the axillary buds. After about 10 days, the vine is cut at the crushed point and removed from the rooting medium and cut between each node. Each cutting with the bunch of roots intact is 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. Care should be taken to keep the leaf axil above the soil. The polythene bags should be kept in a cool and humid place, or should be covered with thin polythene (200 gauge) sheet to retain humidity. The buds start developing in about 3 weeks and the polybags can then be removed and kept in shade.

The advantages of this method of propagation are rapid multiplication (1:40), well developed root system, higher field establishment and 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 x 1.0 m x 0.5 m size is dug under a cool and shaded area. Single nodes of 8-10 cm length and with their leaf intact, taken from runner shoots of field grown vines are planted in polythene bags (25 cm x 15 cm, 200 gauge) filled at the lower half with a mixture of sand, soil, coir dust and cow dung in equal proportion. The single nodes are to be planted in the bags in such a way that their leaf axil is

above the potting mixture. The polythene bags with the planted single nodes are arranged in the pit. After keeping the bags in the pit, the pit should be covered with a polythene sheet. This sheet may be secured in position by placing weights on the corners. The cuttings should be watered at least five times a day with a rose can and the pit should be covered with the polythene sheet immediately after watering. It is advisable to drench the cuttings 2-3 times with copper oxychloride (2g/litre).

After 2-3 weeks of planting, the cuttings will start producing roots which are visible through the polythene bags. After the initiation of roots the frequency of watering may be reduced to 3-4 times a day. After about 1 month, new shoots start emerging from the leaf axil. At this stage it is advisable to keep the pit open for about 1 hour per day so that the cuttings would harden and will not dry when they are taken out of the pit. The cuttings can be taken out of the pit after 2 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 can be obtained. Foliar application of nutrient solution will also enhance the growth of the cuttings.

Serpentine method

Cheaper propagation technique for production of rooted cuttings of black pepper is serpentine layering. In a nursery 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 (20x10 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 to enable rooting at that junction. 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 to induce rooting at each node is repeated. In 3 months the first 10 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 and the cut end is

also buried into the mixture to induce more roots. Polythene bags filled with solarized potting mixture or soil, granite powder and farmyard manure in 2:1:1 proportion is recommended for producing disease free rooted cuttings. The rooted nodes will produce new sprouts in a week time and will be ready for field planting in 2-3 months time. Daily irrigation can be given with a rose can. On an average, 60 cuttings can be harvested per mother plant in a year by this method.

Nursery diseases

Phytophthora infections

Phytophthora infections are 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 infections on the stem are 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% and drenching with copper oxychloride 0.2 % at monthly intervals prevents the disease. Alternatively, metalaxyl 0.01% (1.25 g/litre water) or potassium phosphonate 0.3% could also be used. The potting mixture may be sterilized through solarization. To the sterilized mixture, biocontrol agents such as VAM @ 100 cc/kg of mixture and *Trichoderma* @ 1g/kg of soil (*Trichoderma* population @ 10^{10} cfu/g) may be added at the time of filling of nursery mixture in polythene bags and at regular intervals. *Pseudomonas fluorescens* (IISR-6) may be added to the potting mixture @ 1 g of product containing 10^{10} cfu/g to enhance growth and to suppress root pathogens. Application of *Trichoderma* and IISR-6 in the potting mixture at the time of planting and drenching IISR-6 at 1st and 2nd months after planting is recommended for producing disease free cuttings. 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 (1.25 g/L) and potassium phosphonate (3 ml/L) which are compatible with *Trichoderma* may be used.

Anthracnose

The disease is caused by *Colletotrichum gloeosporioides*. The fungus infects the leaves causing yellowish brown to dark brown irregular leaf spots with a chlorotic halo. Spraying Bordeaux mixture 1% alternating with carbendazim 0.1% is effective against the disease.

Leaf rot and blight

The disease is caused by *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 both upwards and downwards. The new flushes subtending the points of infection gradually droop and dry up. Leaf spots caused by *Colletotrichum* sp. are characterized by yellow halo surrounding the necrotic spots. 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 *Sclerotium rolfsii*. Grey lesions appear on stems and leaves. On the leaves white mycelium 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, if noticed early, by adopting phytosanitary measures. The affected cuttings along with defoliated leaves should be removed and destroyed. Later all the cuttings should be sprayed with carbendazim 0.2% or Bordeaux mixture 1%.

Viral infections

Vein clearing, mosaic, yellow specks, mottling and small leaf are the most obvious symptoms for identifying viral infections in the nursery. As viruses are systematic 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. Secondary spread of the disease occurs thr ough insects such as aphids and mealybugs. Because of closed placing of seedlings 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 r esorted to whenever they ar e seen. Besides, regular inspection and removal of infected plants should also be done.

Nematode infestation

Root-knot nematodes (*Meloidogyne* spp.) and the 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 some times interveinal chlor osis of leaves. The establishment of nematode infected cuttings will be poor when planted in the field and such cuttings develop slow decline symptoms at a later date. Nematode infestations tend to be mor e in rapid multiplication nurseries.

Soil solarization can be done for sterilizing the nursery mixtur e. The solarized nursery mixtur e may be fortified with biocontr ol agents such as *Pochonia chlamydosporia* or *Trichoderma harzianum* @ 1-2 g/kg of soil, the pr oduct containing 10^6 cfu fungus/gm of substrate. Alternately, rhizobacteria like IISR 853 can be applied @ 1 g/bag (formulations containing $10^8 – 10^{10}$ cfu/g) at monthly intervals. 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 ar ound the cuttings and place phorate* 10 G @ 1g/bag or carbofuran* 3 G @ 3g/bag in these holes and cover with soil. A light irrigation may also be given to ensure adequate soil moistur e. In rapid multiplication nurseries where the rooted cuttings are r etained for a longer duration nematicides may be applied at 45 days intervals as described above.

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Establishment of plantations

Selection of site

When black pepper is grown in slopes, the slopes facing south should be avoided and the lower half of northern and north eastern slopes preferred for planting so that the vines are not subjected to the scorching effect of the southern sun during summer.

Preparation of land and planting standards

With the receipt of the first rain in May-June, primary stem cuttings of *Erythina* sp.(Murukku) or *Garuga pinnata* (kilinjil) or *Grevillea robusta* (silver oak) are planted in pits of 50 cm x 50 cm x 50 cm size filled with cow dung and top soil, at a spacing of 3 m x 3 m which would accommodate about 1110 standards per hectare. Seedlings of *Alianthus malabarica* (Matti) can also be planted and the black pepper vines can be trailed on it after 3 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 in groups. The stacked stems start sprouting in May. The stems are planted in the edge of the pits dug for planting black pepper vines.

Planting

Pits of 50 cm^3 at a distance of 30 cm away from the base, on the northern 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 and *Trichoderma harzianum* @ 50 g also may 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 on the northern side of each standard. At least one node of the cutting should be kept below the soil for better anchorage.

Cultural practices

As the cuttings grow, the shoots are tied to the standards as often as required. The young vines should be protected from hot sun during summer by providing artificial shade. Regulation of

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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 so as 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.

From the fourth year, two diggings are usually given in the inter species one during May-June, and the other towards the end of south-west monsoon in October -November. 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. Further, they dry during summer, leaving thick organic mulch.

Manuring and fertilizer application

Manuring and fertilizer application for pepper vines is to be done for proper establishment and growth of plants. Recommended 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 similar areas)

NPK 140:55: 270 g/vine/year (for Kozhikode and similar areas)

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. It is better to apply the fertilizers in two split doses, one in May-June and the other in August-September. 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. Organic manures in the form of cattle manure or compost can be given @ 10 kg/vine during MayNeem cake @ 1 kg/vine can also be applied. Application of lime @ 500 g/vine in April-May during alternate years is also recommended. When biofertilizer like *Azospirillum* is applied @ 100 g/vine, the recommended nitrogen dose may be r educed by half to 70 g/ vine. In soils that ar e deficient in zinc or magnesium, foliar application of 0.25% zinc sulphate twice a year (May-June and September-October) and soil application of 150 g/vine magnesium sulphate, respectively is recommended.

Plant protection

Diseases

Foot rot disease

Foot rot (quick wilt disease) 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 ar e 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 a characteristic fine fibr e like pr ojections at the advancing margins which rapidly enlar ge 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 entir e vine, fr om 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 after the rains 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 build up of inoculum (fungal 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 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 once again 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 drenching and spraying with potassium phosphonate 0.3% is to be repeated during August-September. If the monsoon is prolonged, a third round of drenching may be given during October.
- After the receipt of a few monsoon showers, all the vines are to be drenched with 0.125% metalaxyl mancozeb @ 5-10 litres/vine. A foliar spray with metalaxyl mancozeb 0.125% may also be given.
- At the onset of monsoon (May-June), apply *Trichoderma* around the base of the vine @ 50g/vine (this quantity is recommended for a substrate containing *Trichoderma* @ 10^{10} cfu). A foliar spray with potassium phosphonate 0.3% or Bordeaux mixture 1% is also to be given. A second application of *Trichoderma* 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 controlled by spraying Bordeaux mixture 1%.

Spike shedding

Spike shedding especially in varieties like Panniyur-1 at higher elevations like Kodagu and Idukki is one of the emerging diseases.

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. Irrigation of vines from second fortnight of March coupled with prophylactic spraying with Bordeaux mixture 1% or carbendazim 0.2% reduces the intensity of spike shedding.

Stunt disease

This disease which is 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 with varying degrees of deformation 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 through 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
- Insects such as aphids and mealy bugs on the plant or standards should be controlled with insecticide spray such as dimethoate @ 0.05%.

Phyllody disease

This disease which is caused by phytoplasma is noticed in parts of Waynad and Kozhikode districts of Kerala. The affected vines exhibit varying stages of malformation of spikes. Some of the floral buds are transformed into narrow leaf like structures. Such malformed spikes show leafy structures instead of floral buds, 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 become unproductive. In severely affected vines the entire spike is converted into small branches which appear chlorotic and the vines decline rapidly. The infected vine becomes unproductive within 2 to 3 years. The infected vines are to be destroyed to prevent the 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 affected vines exhibit varying degrees of root degeneration due to infestation by plant parasitic nematodes. The diseased vines exhibit foliar yellowing 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 diseased vines gradually lose their vigour and productivity. The affected vines show varying degrees of feeder root loss and the expression of symptoms on the aerial parts occur after a considerable portion of the feeder roots are lost. The root system of diseased vines show varying degrees of necrosis and presence of root galls due to infestation by plant parasitic nematodes such as *Radopholus similis* and *Meloidogyne incognita* leading to rotting of feeder roots. The damage to feeder roots is caused by these nematodes and *P. capsici* either independently or together in combination. 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 which are beyond recovery should be removed from the plantation and destroyed.
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- Nematode free rooted cuttings raised in fumigated or solarized nursery mixture should be used for planting in the field.

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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 @ 50g/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

The pollu beetle (*Longitarsus nigripennis*) 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 x 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 grayish 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 2.5-3.0 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*) cause 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; 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 of 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, rubber etc. As a mixed crop it can also be inter cropped 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 periphery 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. Based on soil test, application of lime/dolomite, rock phosphate/ bone meal and wood ash may be done to get required quantity of phosphorus and potassium supplementation. 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. 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.

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 Neemgold (0.6%) spray at 21 day intervals during July-October, shade regulation and that of scale insects by removing severely infected branches and spraying Neemgold (0.6%) or fish oil rosin (3%) are recommended.

Application of biocontrol 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 Bordeaux mixture 1% may be done restricting the quantity to 8 kg copper per hectare per annum. Application of quality neem cake mentioned earlier along with the bioagents *Pochonia chlamydosporia* will be useful to check the nematode population and thereby slow decline disease.

Certification

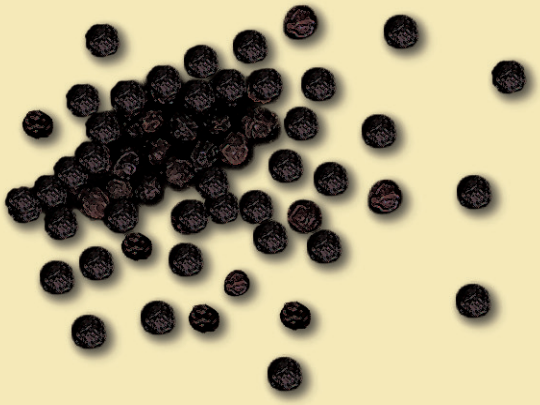
Certification and labeling is usually done by an independent body to provide a guarantee that the production standards are met. Govt. of India has taken steps to have indigenous certification system to help small and marginal growers and to issue valid organic certificates through certifying agencies 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.

Harvesting and processing

In Kerala, black pepper flowers during May-June. The crop is ready for harvest in 6-8 months from flowering. The harvest season extends from November to January in the plains and January to March in the hills. During harvesting the whole spike is hand picked when one or two berries in the spike turn bright orange. The berries are separated from the spikes and dried in the sun for 7-10 days. The optimum moisture content in dried pepper to prevent mould attack is 8-10%. The berries can be separated manually or mechanically using threshers. Threshers with capacities varying between 0.5 to 1.5 tons per hour are available. This enhances speedy and hygienic separation of black pepper berries. When dried, the berries retain the characteristic wrinkled appearance of black pepper of commerce. The fresh berries are dipped in hot water for a minute before drying in the sun which results in an attractive black colour and also reduces the drying time. The recommended drying surfaces are bamboo mat coated with fenugreek paste, cement floor and high density black polythene which gives better appearance and cleanliness to the dried product. Mechanical driers such as copra drier, convection drier and cascade type driers can also be employed for drying. The optimum temperature to be maintained in mechanical driers should be around 60ºC.

The white pepper of commerce is prepared either from freshly harvested berries or dried black pepper using special techniques such as retting, steaming and decortication. The recovery of white pepper from ripe pepper berries is about 25%. Water steeping is the most popular technique for preparing white pepper in which ripe pepper berries are soaked in water for 8-10 days and the outer skin is removed, washed and sun dried. The berries of Panniyur-1 are ideal to prepare white pepper.

Black pepper



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Black pepper (Extension Pamphlet)

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