भाकृअनुप
ICAR

Good Agricultural Practices (GAP) for

BLACK PEPPER

(Piper nigrum L.*)*

A Practical Guide for Sustainable, Safe and Quality Black Pepper Production

ICAR – Indian Institute of Spices Research
ICAR – All India Coordinated Research Project on Spices
Kozhikode – 673012, Keralam, India
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Foreword

Black pepper (*Piper nigrum* L.), popularly known as the "King of Spices", is one of the most important spice crops cultivated in India and has played a significant role in the country's spice trade for centuries. The crop is valued for its characteristic pungency, aroma and wide applications in the food, pharmaceutical, nutraceutical and cosmetic industries. India is one of the major producers, consumers and exporters of black pepper, with cultivation concentrated mainly in Kerala, Karnataka and Tamil Nadu. The cultivation of black pepper has now expanded to several non-traditional areas including the North Eastern Region and the Andaman & Nicobar Islands.

The adoption of Good Agricultural Practices (GAP) is essential for ensuring sustainable production of high-quality black pepper while minimizing environmental impact. GAP emphasizes the use of healthy planting material, efficient nutrient and water management, integrated pest and disease management, conservation of natural resources, safe use of agrochemicals and hygienic post-harvest handling practices.

This publication has been prepared to provide farmers, extension personnel, farmer producer organizations, exporters and other stakeholders with scientifically validated recommendations on black pepper cultivation. The manual covers important aspects including propagation, field establishment, nutrient management, pest and disease management, harvesting, processing and quality assurance.

The manual is expected to serve as a practical guide for improving productivity, ensuring quality produce and promoting sustainable black pepper cultivation in India.

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Preface

Black pepper cultivation in India is undergoing significant transformation due to changing climatic conditions, emerging pests and diseases, increasing quality requirements and growing demand from domestic and international markets. The need for sustainable production systems that ensure productivity, product quality, traceability and compliance with food safety standards has highlighted the importance of adopting Good Agricultural Practices (GAP).

This manual presents Good Agricultural Practices (GAP) for black pepper cultivation, integrating recommendations developed through research and field experience from ICAR institutes, State Agricultural Universities and extension agencies.

The publication covers key aspects of black pepper cultivation, including:

- Selection of varieties and planting material
- Nursery management and propagation
- Field establishment and training of vines
- Nutrient, water and shade management
- Integrated pest, disease and nematode management
- Harvesting, processing and storage
- Safe use of agrochemicals and worker safety
- Quality standards and residue management

The objective of this manual is to support farmers in adopting improved cultivation practices that enhance productivity, ensure high-quality produce, facilitate market access and promote environmentally sustainable black pepper production.

Disclaimer

The crop production, plant protection and post-harvest management recommendations presented in this publication are based on research findings, field evaluations and technical expertise available at the time of publication. Certain products, molecules or management practices mentioned in this document may have been included based on their demonstrated efficacy under experimental or field conditions.

Farmers, extension personnel and other stakeholders are advised to use only those pesticides, fungicides, insecticides and other plant protection products that are approved and registered by the Central Insecticides Board and Registration Committee (CIB&RC), Government of India, for use in black pepper. Users should always follow the label claim, recommended dosage, waiting period, safety precautions and statutory regulations applicable at the time of use.

The inclusion of any product, active ingredient or trade name in this publication does not constitute endorsement by ICAR-Indian Institute of Spices Research. The Institute shall not be responsible for any consequences arising from the use of products or practices that are not approved by the competent regulatory authorities.

Readers are encouraged to consult the latest recommendations issued by ICAR, State Agricultural Universities, the Directorate of Plant Protection, Quarantine & Storage, and CIB&RC before adopting plant protection measures.

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1. Introduction

Black pepper *(Piper nigrum* L.), belonging to the family Piperaceae, is one of the oldest and most widely traded spices in the world. It is popularly known as the "King of Spices". The crop is cultivated for its berries, which are used extensively as a spice, flavouring agent and ingredient in traditional and modern medicine. The characteristic pungency of black pepper is attributed to the alkaloid piperine, while its aroma is derived from the volatile oils present in the berries.

India has a long history of black pepper cultivation and trade and is recognized as one of the centres of diversity of the crop. Black pepper is predominantly cultivated in Kerala, Karnataka and Tamil Nadu. It is also grown in other states like Maharashtra, North Eastern states and the Andaman & Nicobar Islands under diverse agro-climatic conditions.

Black pepper is a perennial climbing vine commonly grown on live standards or support trees. The crop plays an important role in the livelihood of farmers in the humid tropical regions of India and remains one of the country's most important export-oriented spice crops.

The increasing demand for high-quality, residue-safe pepper in domestic and international markets has emphasized the need for adoption of Good Agricultural Practices (GAP). Implementation of GAP helps improve productivity, maintain produce quality, ensure food safety, conserve natural resources and enhance the competitiveness of Indian black pepper in global markets.

2. Agro-climatic Requirements

Black pepper is a plant of the humid tropics requiring high rainfall and humidity. It grows successfully between 20° North and South latitudes and up to 1500 m above sea level. The favourable temperature range is 23-32°C and the ideal temperature is around 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.

3. Soil Requirements

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.

4. 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.

Other important cultivars are Kottanadan (South Kerala), Narayakodi (Central Kerala), Aimpiriyan (Wayanad), Neelamundi (Idukki), Kuthiravally (Kozhikode and Idukki), Balancotta, Kalluvally (North Kerala), Malligesara and Uddagare (Karnataka). The cultivars Kuthiravally and Balancotta exhibit the alternate bearing habit. In terms of quality, Kottanadan has the highest oleoresin (17.8%) content followed by Aimpiriyan (15.7%).

Twenty-one improved varieties of black pepper have been released for cultivation (Table 1). Panniyur-1, Panniyur-3, Panniyur-8 and Panniyur-10 are hybrids evolved at the Pepper Research Station, Panniyur (Kerala Agricultural University). IISR Girimunda, IISR Malabar Excel and IISR Chandra are the three hybrids released from ICAR–Indian Institute of Spices Research, Kozhikode, Keralam

Some popular varieties of black pepper:

SREEKARA

IISR SHAKTHI

IISR GIRIMUNDA

IISR MALABAR EXCEL

IISR THEVAM

PANNIYUR - 1

PANNIYUR 5

PANNIYUR 8

IISR CHANDRA

ARKA COORG EXCEL

PANCHAMI

PLD-2

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

Variety	Pedigree	Mean yield (dry) (kg/ha)	Dry recovery (%)	Quality attributes			Features
				Piperine (%)	Oleoresin (%)	Essential oil (%)	
	Kerala Agriculture University (KAU), PRS, Panniyur, Kerala						
Panniyur -1	Hybrid, Uthirankotta × Cheriyakaniakadan	3850	35.3	5.3	11.8	3.5	First hybrid, high yielding, suited for open areas
Panniyur -2	Open pollinated progeny selected from cv. Balancotta	2570	35.7	6.6	10.9	3.4	Shade tolerant
Panniyur -3	Hybrid Uthirankotta × Cheriyakaniakadan	1953	27.8	5.2	12.7	3.1	Late maturing, prefers open conditions
Panniyur -4	Selection from cv. Kuthiravally	1277	34.7	4.4	9.2	3.1	Stable yielder
Panniyur -5	Open pollinated progeny selection from Perumkodi	1107	35.7	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 Kalluvally	1410	33.6	5.6	10.6	1.5	Prefers partial shade
Panniyur -8	Hybrid, Panniyur 6 × Panniyur 5	2173	39	5.7	12.2	1.2	High yielding, field tolerant to Phytophthora foot rot and drought
Panniyur -9	Open pollinated progeny selection from Panniyur 3	3150	38	6.1	12.7	5	High yielding, field tolerant to Phytophthora foot rot and drought
Panniyur -10	Hybrid – Panniyur 1 x Cul.54	2700	36	5.3	10.3	3.3	Climate resilient, field tolerant to Phytophthora foot rot

	ICAR-Indian Institute of Spices Research, Kozhikode, Kerala						
Subhakara	Selection from Karimunda (KS-27)	2352	35.5	3.4	12.4	6	Suited to all black pepper tracts
Sreekara	Selection from Karimunda (KS-14)	2677	35	5.3	13	7	Suited to all black pepper tracts
Panchami	Selection from Aimpiriyan (Coll. 856)	2828	34	4.7	12.5	3.4	Late maturing
Pournami	Selection from Ottaplackal (Coll. 812)	2333	31	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	3.3	10.2	3.7	Tolerant to Phytophthora foot rot.
IISR Thevam	Clonal selection of Thevanmundi	2481	32	1.65	8.15	3.1	Tolerant to Phytophthora foot rot; Suited to high altitudes and plains
IISR Girimunda	Hybrid, Narayakodi x Neelamundi	2880	32	2.2	9.65	3.4	Suited to high altitudes
IISR Malabar Excel	Hybrid, Cholamundi x Panniyur-1	1440	32	4.95	14.6	4.1	Suited to high altitudes; Rich in oleoresin
IISR Chandra	Hybrid Progeny of HP 1117 x Thommankodi (HP 1117 is F1 of Cholamundi x Thommankodi)	2905	33.5	5.1	8.71	3.2	Regular bearer, early maturing high fruit set and long spike
Arka Coorg Excel	Seedling Selection (ICAR-IIHR & ICAR-IISR)	2850	37.8	4.5	7.32	2.4	High yielding, long spikes and bold berries

5. Propagation and Planting Material

Black pepper vines produce three types of shoots, namely: (i) primary climbing shoots with adventitious roots at the nodes that cling to the support; (ii) runner shoots arising from the base of the vine and creeping on the ground; and (iii) fruit-bearing lateral shoots. Black pepper is propagated mainly through vegetative means using rooted cuttings. Runner shoots are the most commonly used source of planting material, although terminal shoots may also be used. Cuttings from lateral branches develop a bushy growth habit and are used for the production of bush pepper. Although black pepper seeds (berries) are viable, they are generally not used for raising plantations because the resulting seedlings are not genetically uniform.

Production of Rooted Cuttings

Runner shoots from healthy and high-yielding vines are used for raising rooted cuttings. Cuttings of 2–3 nodes are planted in nursery beds or polythene bags filled with a potting mixture of soil, sand and farmyard manure (2:1:1) during February-March. Alternatively, partially composted coir pith and vermicompost (75:25) enriched with *Trichoderma* (talc formulation @ 10 g /kg medium) can be used as a nursery medium for the production of healthy black pepper planting material in plug-trays. Adequate shade and irrigation should be provided, and the rooted cuttings become ready for planting during May–June. Improved methods of multiplication such as the serpentine method, plug-tray nursery technique and vertical column method have also been standardized for rapid production of quality planting material. Details of these methods are provided in **Annexure I.**

Bush Pepper

Rooted lateral branches may be used for raising bush pepper plants. Bush pepper can be grown in pots, kitchen gardens, roof terraces, shade houses or in the field without support standards. A detailed protocol for bush pepper production is provided in Annexure II. Bush pepper plants produce green pepper throughout the year and may yield up to 1 kg of fresh pepper per bush after three years of planting. A detailed protocol for bush pepper production is provided in **Annexure II.**

6. Field Preparation and Planting

Preparation of Land and Planting Standards

For planting black pepper on slopes, the lower half of northern and north-eastern slopes are preferred to protect the vines from scorching sun during summer. With the receipt of first rains during May-June, stem cuttings of standard trees such as *Erythrina* spp., *Garuga pinnata*, *Grevillea robusta* (silver oak) and seedlings of *Ailanthus malabarica* (Malayalam- *Matti*) are planted in pits of 50 cm × 50 cm × 50 cm size filled with topsoil and cow dung.

The standards are planted at a spacing of 3 m × 3 m, accommodating about 1110 standards per hectare.

Black pepper vines are trailed on the standards after about three years when they attain sufficient height. When *Erythrina indica* and *Garuga pinnata* are used, the stems are cut during March-April and stacked under shade until sprouting commences in May.

Planting

Pits of 50 cm × 50 cm × 50 cm are taken at a distance of about 15-30 cm away from the base of the support tree on the northern, eastern or north-eastern side with the onset of monsoon. The pits are filled with a mixture of topsoil, farmyard manure @ 5 kg per pit and rock phosphate @ 150 g per pit. One kilogram of Neem cake enriched with 50 g *Trichoderma harzianum* talc formulation may also be incorporated at the time of planting. With the onset of monsoon, 2-3 rooted black pepper cuttings are planted individually in each pit.

7. Cultural Practices

As the vines grow, the shoots are tied to the standards as often as required. 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 for providing optimum light to the vines and for promoting straight growth of the standards. The base of the vines should not be disturbed to avoid root damage. Lopping may be carried out twice a year, during June and September.

Excessive shade during flowering and fruiting encourages pest infestation and should be avoided.

8. Nutrient Management

Application of lime or dolomite @ 500 g per vine during April-May in alternate years is recommended under highly acidic soil conditions. For mature vines, organic manures such as cattle manure or compost may be applied @ 10 kg per vine during May. Neem cake @ 1 kg per vine may also be applied. The general fertilizer recommendation for black pepper vines (three years and above) is NPK @ 50:50:150 g per vine per year. One-third of the recommended dose is applied during the first year, two-thirds during the second year and the full dose from the third year onwards.

As soil fertility varies with soil type, agro-ecological conditions and management practices, site-specific nutrient management based on soil test results is recommended. The recommended fertilizer doses for different soil test values and dry pepper yield targets are given in Table 2. Fertilizers should be applied in two split doses during May-June and August-September, ensuring adequate soil moisture at the time of application.

Fertilizers are applied at a distance of about 30 cm around the vine and covered with soil. Direct contact of fertilizers with roots should be avoided. When *Azospirillum* is applied @ 50 g per vine, the recommended nitrogen dose may be reduced by half. In zinc-deficient soils, foliar application of zinc sulphate (0.25%) is recommended twice a year during May-June and September-October. In magnesium-deficient soils, magnesium sulphate @ 200 g per vine may be applied. Foliar application of a black pepper-specific micronutrient mixture @ 5 g/L is recommended twice, with the first spray during spike initiation followed by a second spray after two to three months.

Table 2. Soil Test-Based Fertilizer Recommendations for Dry Pepper Yield Targets

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 (P2 O5)		
< 10	40	80
10-30	30	70
30-50	10	55
>50	-	30
Potassium (K2O)		
< 110	150	310
110-300	125	275
300-500	80	250
>500	35	110

Microbial Consortium (IISR Biomix)

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

9. Soil Testing

Soil testing is an important component of Good Agricultural Practices (GAP) as it provides information on the fertility status of the soil and helps in formulating appropriate fertilizer recommendations. Regular soil testing enables efficient nutrient management, improves fertilizer use efficiency and helps maintain soil health. It is recommended that soil testing be carried out once in three years. Soil samples should be analysed in accredited soil testing laboratories of the State Departments of Agriculture, State Agricultural Universities or other recognized laboratories. The procedure for collection of representative soil samples is given in **Annexure III.**

10. Water Management

Summer irrigation significantly improves black pepper productivity. Irrigation at fortnightly intervals from 15 March to 15 May has been found to enhance productivity by 90-100% compared to unirrigated vines. Irrigation is provided through basins around the vines. A quantity of 50 litres of water per vine is recommended for vines aged 15 years and above. This may be reduced to 40 litres per vine for vines aged 11-15 years and 30 litres per vine for vines aged 5-10 years. Summer irrigation promotes uniform spike emergence, with more than 90% of spikes emerging by July, whereas spike emergence in rainfed vines may extend up to September. Irrigated vines also produce comparatively longer spikes.

11. Integrated Pest and Disease Management (IPM)

Integrated Pest and Disease Management (IPM) involves the use of healthy planting material, field sanitation, proper drainage, balanced nutrition, biological control agents and need-based application of plant protection chemicals. Adoption of IPM helps reduce crop losses, minimize pesticide residues and promote sustainable black pepper production.

12. Disease Management

Foot Rot (Quick Wilt)

Foot rot (quick wilt) caused by *Phytophthora capsici* is the most destructive disease of black pepper and occurs mainly during the southwest monsoon season.

Symptoms

• One or more black spots with characteristic fine fimbriate margin appear on the leaves, enlarge rapidly and cause defoliation.
• Tender leaves and succulent shoot tips of freshly emerging runner shoots trailing on the soil turn black when infected.
• If the collar region or main stem at ground level is affected, the entire vine wilts followed by shedding of leaves and spikes. The branches break at the nodes and the vine collapses within a month.
• If the damage is confined to feeder roots, symptoms appear after the monsoon as yellowing, wilting, defoliation and gradual decline of the vine.

Foot rot disease symtoms on vines and leaves

Management

Phytosanitation

- Remove and destroy dead vines along with the root system.
- Use planting material from disease-free gardens.
- Raise nurseries in fumigated or solarized soil.

Cultural Practices

- Provide adequate drainage and avoid water stagnation.
- Avoid injury to roots during cultural operations.
- Prevent runner shoots from trailing on the ground by tying them to stakes or pruning them.
- Prune branches of support trees at the onset of monsoon to reduce humidity and improve sunlight penetration.

Chemical and Biological Control

- After the receipt of monsoon showers (May-June), drenching the soil around the base of vines with copper oxychloride (0.2%) @ 5–10 L per vine and a foliar spray of Bordeaux mixture (1%) was found effective. Repeat during August-September.
- On appearance of symptoms, drench and spray with metalaxyl–mancozeb (0.125%). Repeat during August-September.
- Alternatively, drench and spray with potassium phosphonate (0.3%) and repeat during August-September.
- If the monsoon is prolonged, a third application may be given during October.
- Apply *Trichoderma asperellum* @ 50 g per vine during May-June and again during August-September.

Anthracnose (Pollu Disease)

Anthracnose or pollu disease is caused by *Colletotrichum gloeosporioides*.

Symptoms

- Affected berries develop brown sunken patches during the initial stages
- The discolouration gradually increases, resulting in characteristic cross-splitting of berries
- The berries eventually turn black and dry
- On leaves, the pathogen causes angular to irregular brown lesions surrounded by a chlorotic halo

Disease symptom of Anthracnose/Pollu Disease on leaf and spike

Management

- Spray Bordeaux mixture (1%) twice, first application during June-July (before flowering) and then at August (berry formation stage)
- Drench and spray with *Pseudomonas fluorescens* P1 (2%) during May-June and October for the management of foot rot and anthracnose

Stunt Disease (viral disease)

Stunt disease is a viral disease of black pepper.

Symptoms

- Shortening of internodes.
- Small, narrow, leathery, puckered and crinkled leaves.
- Chlorotic spots and streaks on leaves.
- Progressive reduction in yield.

Damage symptom of stunt disease

Management

- Use virus-free healthy planting material.
- Regularly inspect fields and remove infected plants.
- Destroy infected plants by burning or deep burial.
- Control aphids and mealybugs by spraying suitable systemic insecticides.

Phyllody Disease

Symptoms

- Floral buds transform into narrow leaf-like structures.
- Leaves become small and chlorotic.
- Internodes become shortened.
- Fruiting laterals develop a witches'-broom appearance.
- Severely affected vines become unproductive within 2–3 years.

Phyllody disease

Management

• Remove and destroy infected vines to prevent further spread of the disease.

Table 3. Indicative Disease Management Schedule for Black Pepper

Crop stage / season	Operation	Purpose
Pre-monsoon (May-June)	Provide drainage, prune standards, remove diseased vines	Disease prevention
May-June	Drench basins with copper oxychloride (0.2%) and apply Bordeaux mixture (1%) as foliar spray	Foot rot management
May-June	Apply *Trichoderma asperellum* @ 50 g per vine	Foot rot management
August-September	On appearance of foot rot symptoms, drench and spray with Metalaxyl–mancozeb (0.125%).	Disease management
August-September	Second application of *T. asperellum*	Biological suppression
October (if monsoon continues)	Third drenching and spraying, if required	Foot rot management
Throughout season	Remove and destroy diseased vines and infected plant parts	Phytosanitation
May-June and October	Apply *Pseudomonas fluorescens* P1 (2%) solution both as a soil drench and as foliar spray	Anthracnose and foot rot management

***Note**: At present, fungicide Metalaxyl–mancozeb is approved by the Central Insecticides Board and Registration Committee (CIB&RC), Government of India, specifically for use in black pepper. The management measures described above are based on research findings and field observations.*

13. Insect Pest Management

Pollu Beetle

Pollu beetle (*Lanka ramakrishnai*) is the most destructive insect pest of black pepper and is more serious in plains and at altitudes below 300 m.

Symptoms

- Adult beetles feed on tender leaves and spikes

- Grubs bore into berries and feed on the internal tissues
- Infested spikes turn black and decay
- Infested berries turn black and crumble when pressed
- Pest incidence is generally more severe in heavily shaded plantations
- The pest population is usually high during September-October

Infested spike

Affected berries

Leaf damage

Management

- Regulate shade in the plantation to reduce pest incidence
- Spraying chlorantraniliprole (0.05%) during June-July and September-October has been found to be effective in managing the pest
- Spraying Neemgold (0.6%) during August, September and October has been found to be effective in managing the pest

Top Shoot Borer

Top shoot borer (*Cydia hemidoxa*) is a serious pest in young black pepper plantations.

Symptoms

- Larvae bore into tender terminal shoots and feed on internal tissues
- Affected shoots turn black and decay
- Severe infestation may result in drying of terminal shoots and loss of growth
- Pest incidence is generally high during July-October

Top shoot borer damage

Management

- Spraying systemic insecticides during July-October has been found to be effective in managing the pest.

Leaf Gall Thrips

Leaf gall thrips *(Liothrips karnyi*) is an important pest in high-altitude areas, particularly in young vines and nursery plants.

Symptoms

- Feeding by thrips causes leaf margins to curl downward and inward.
- Marginal leaf galls are formed.
- Infested leaves become crinkled and malformed.

Leaf gall thrips damage

Management

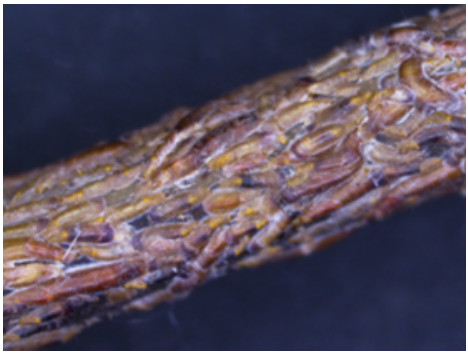
- Spraying systemic insecticides during the emergence of new flushes in young vines and nursery cuttings has been found to be effective in managing the pest.

Scale Insects

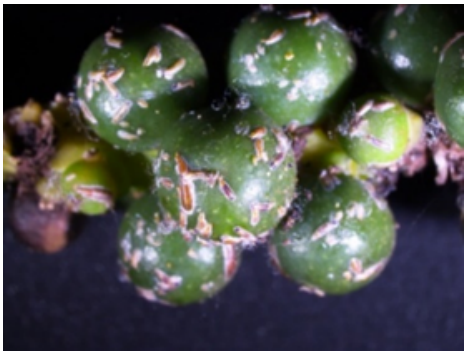
Among the various scale insects recorded on black pepper, mussel scale (*Lepidosaphes piperis*), coconut scale (*Aspidiotus destructor*), soft scales (*Protopulvinaria longivalvata*, *Marsipococcus marsupialis*) and snow scales (*Unaspis* spp.) cause serious damage to black pepper vines and in older nursery cuttings.

Symptoms

- Scale insects appear as encrustations on stems, leaves and berries
- They feed on plant sap, resulting in yellowing and wilting of affected portions
- Severe infestations may cause drying of affected portions of the vine
- Infestation is generally severe during the post-monsoon and summer periods

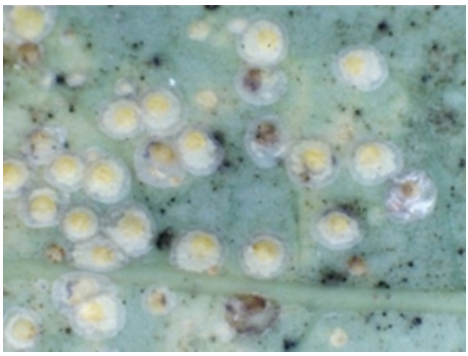


Twig



Berry

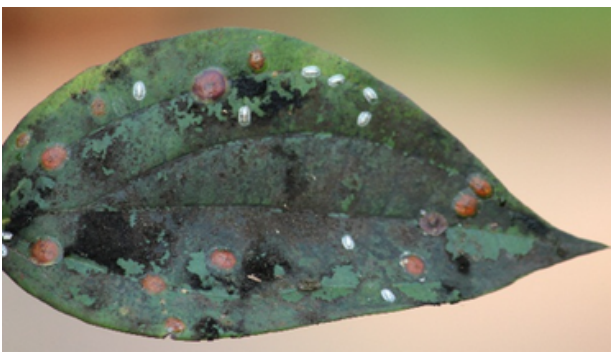
Mussel Scale infestation on twig and berries



Aspidiotus destructor

Protopulvinaria longivalvata

Unaspis spp



Marsipococcus marsupialis

Management

- Clip off and destroy heavily infested branches
- Spraying systemic insecticides after harvest and repeating the spray after 21 days has been found to be effective in managing the infestation
- In nurseries, spraying neem oil (0.3%) or Neemgold (0.3%) has been found to be effective in controlling the pest

Minor Pests

Leaf-feeding caterpillars, especially *Synegia* spp., damage leaves and spikes of young vines. Mealybugs, gall midges and aphids infest tender shoots, particularly in nurseries.

Tailed mealybug (*Ferrisia virgata*)

Root mealybug (*Planococcus* sp.)

Management

- Spraying systemic insecticides or neem-based botanical insecticides may be undertaken when infestations are severe.

Table 4. Indicative Insect Pest Management Schedule for Black Pepper

Crop stage / season	Pest	Management practice
Throughout the year	General pest management	Maintain field sanitation, regulate shade and monitor pest incidence regularly.
June–July	Pollu beetle	Regulate shade in the plantation. Spraying chlorantraniliprole (0.05%) has been reported to be effective in managing the pest.
August–October	Pollu beetle	Spraying neem-based insecticides such as Neemgold (0.6%) has been reported to be effective.
July–October	Top shoot borer	Regular monitoring of young vines. Spraying systemic insecticides has been reported to be effective in managing the pest.
During emergence of new flushes	Leaf gall thrips	Monitor young vines and nursery plants. Spraying systemic insecticides has been reported to be effective.
Post-monsoon and summer period	Scale insects	Clip and destroy heavily infested branches. Spraying systemic insecticides after harvest and repeating after 21 days has been reported to be effective.
Nursery stage	Scale insects	Spray neem oil (0.3%) or Neemgold (0.3%) when infestation is observed.
As and when required	Minor pests (leaf-feeding caterpillars, mealybugs, gall midges and aphids)	Monitor regularly and adopt appropriate management measures when infestations reach damaging levels.

Note: *At present, no insecticides are approved by the Central Insecticides Board and Registration Committee (CIB&RC), Government of India, specifically for use in black pepper. The management measures described above are based on research findings and field observations. Growers are advised to consult the latest CIB&RC-approved recommendations and use only products approved for black pepper, if any, at the time of application.*

14. Nematode and Slow Decline Complex

Slow Decline

Slow decline is a debilitating disease complex of black pepper associated with nematodes such as *Radopholus similis* and Root knot nematode, *Meloidogyne incognita* and infection by *Phytophthora capsici.*

Symptoms

- Foliar yellowing, defoliation and die-back
- Symptoms generally appear from October onwards with depletion of soil moisture
- Temporary recovery may occur during the southwest monsoon followed by recurrence of symptoms after the monsoon
- Infested roots show necrosis, gall formation and rotting of feeder roots
- Affected vines gradually lose vigour and productivity

Field symptom of slow decline

Root knot nematode affected roots

Lesion nematode affected roots

Management

- Remove and destroy severely affected vines
- Treat planting pits with carbosulfan (0.1%) at the time of planting was found effective
- Use nematode-free rooted cuttings raised in fumigated or steam-sterilized nursery media
- Application of fluopyram @ 0.5 ml/L (3-5 L per vine) was found effective for the management of R. *similis*
- Drenching basins with copper oxychloride (0.2%) or potassium phosphonate (0.3%) or metalaxyl-mancozeb (0.125%) is also found effective
- In areas severely infested with root-knot nematodes, plant the resistant variety '*Pournami*'
- Apply *Pochonia chlamydosporia* or *Trichoderma asperellum* @ 50 g per vine twice a year (April-May and September-October)

***Note*:** *At present, no nematicides are approved by the Central Insecticides Board and Registration Committee (CIB&RC), Government of India, specifically for use in black pepper. The fungicide metalaxyl–mancozeb is approved by CIB&RC, specifically for use in black pepper. The management measures described above are based on research findings and field observations. Growers are advised to consult the latest CIB&RC-approved recommendations and use only products approved for black pepper, if any, at the time of application.*

15. Physiological Disorders

Spike Shedding

Spike shedding is generally observed when pre-monsoon showers are delayed and flowering and spiking occur during June-July. Such spikes predominantly produce female flowers instead of bisexual flowers. Severe spike shedding may occur due to poor pollination and anthracnose infection.

Management

- Irrigate vines from the second fortnight of March at 50-60 L per vine at fortnightly intervals.
- Spray Bordeaux mixture (1%) prophylactically
- These practices help reduce the intensity of spike shedding

16. Harvesting

Black pepper takes about 7-8 months after flowering to reach full maturity. In India, harvesting is carried out during December-January in the plains and January-April in the high ranges. Harvesting is initiated when one or two berries in a spike turn yellow.

The spikes are harvested manually by nipping them off and collected in clean bags. Spikes that fall on the ground should be collected separately, cleaned and then pooled with the harvested produce.

The optimum stage of harvest varies depending on the end use of the produce (Table 5).

Table 5. Optimum Maturity Stage for Harvesting of Different Black Pepper Products

Product	**Stage of Maturity at Harvest**
Canned pepper	4–5 months after fruit set
Dehydrated green pepper	10–15 days before maturity
Oleoresin and essential oil	15–20 days before maturity
Black pepper	Fully mature; 1–2 berries in each spike start turning yellow to red
Pepper powder	Fully mature
Freeze-dried green pepper	Full maturity before ripening
White pepper	Fully mature or ripe berries
Freeze-dried red pepper	Fully ripe

17. Post-harvest Handling and Processing

Post-harvest processing of black pepper involves threshing, blanching, drying, cleaning, grading, packaging and storage. Care should be taken at each stage to maintain product quality and prevent contamination.

Threshing

Threshers of varying capacities are available for rapid and efficient separation of berries from spikes.

Black pepper thresher

Blanching

The quality of black pepper can be improved by dipping mature berries in boiling water for one minute before drying.

Benefits of blanching include:

- Uniform black colour after drying
- Reduction in microbial load
- Faster drying (3-4 days compared to 5-6 days under conventional drying)
- Removal of dust and other extraneous impurities

Drying

Freshly harvested pepper contains about 65-70% moisture, which should be reduced to about 10% for safe storage. Sun drying is the traditional method, wherein berries are spread on clean drying floors, bamboo mats or PVC sheets and dried for 4-6 days. The average dry recovery ranges from 33-37%, depending on the cultivar. Dried produce with moisture above the recommended level is susceptible to fungal infestation and mycotoxin contamination. Mechanical dryers may also be used, maintaining temperatures below 55°C.

Black pepper spiral separator

Cleaning and Grading

Cleaning removes spent spikes, pinheads, stones, soil particles and other foreign matter. Cleaning may be carried out by winnowing, hand picking, blower-assisted cleaning or spiral separation.

Grading is performed using sieves and is based on berry size and quality.

Major commercial grades include:

- 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)
- Malabar Ungarbled (MUG Grades 1 and 2)

Black pepper cleaner cum grader

Packaging and Storage

The dried produce should be packed in clean, dry and undamaged packaging materials. Multi-layer paper bags, woven polypropylene bags with food-grade liners or clean jute bags may be used. Black pepper is hygroscopic and readily absorbs moisture from the atmosphere. Therefore, the produce should be dried to below 10% moisture before storage. Bags should be stored on wooden pallets in clean, dry and well-ventilated storage areas protected from insects, rodents and moisture.

18. Identification and Traceability

Traceability is an important component of Good Agricultural Practices (GAP) and facilitates quality assurance, market compliance and product recall, if required.

- The final produce should be clearly and legibly labelled with the product name, month and year of harvest, and the name of the farmer or farming agency
- Where quality testing has been carried out, the produce may be labelled appropriately indicating compliance with the prescribed quality standards
- Records relating to cultivation practices, fertilizer application, and plant protection measures, harvesting, processing and storage should be maintained to facilitate traceability
- The produce should be traceable to the registered farm or production unit from which it originated

19. Quality Standards

The CODEX physical and chemical quality standards for the processed black and white pepper are given in Tables 6 & 7.

Table 6. Physical Characteristics of Black/ White pepper (CODEX Standards – CXS-326-2017)

Characteristic	Black Pepper			White Pepper		
	Grade I	Grade II	Grade III	Grade I	Grade II	Grade III
Bulk density, (g/l), min.	550	500	400	600	600	550
1 Light berries, % (m/m) max.	2.0	5.0	10.0	1.0	2.0	2.0
*2 Extraneous vegetable matter, % (m/m), max.	1.0	2.0	2.0	1.0	1.5	2.0
*3 Foreign matter, % (m/m), max.	1.0	0.5	0.5	1.0	0.5	0.5
Black berries/corns % (m/m), max.	NA	NA	NA	5.0	7.5	10.0
Broken berries, % (m/m), max.	NA	NA	NA	2.0	3.0	3.0
Mouldy Berries % (m/m), max.	1.0	2.0	3.0	1.0	2.0	3.0
Insect defiled berries / Corns, % (m/m), max.	1.0	1.0	2.0	1.0	1.0	2.0
Mammalian or/and other excreta, (mg/kg), max.	1.0	1.0	2.0	1.0	1.0	2.0
*4 Pinheads for black pepper, % (m/m), max.	1.0	2.0	4.0	NA	NA	NA

NA –NOT APPLICABLE

*1*Light berries*(in Black and White peppers only) -Generally immature berries without kernel with an apparent density lower than 0.30 g/mL or 300 g/L

*2*Extraneous vegetative matter*-Vegetative matter associated with the plant from which the product originates -but is not accepted as part of the final product". Light berries, pinheads or broken berries are not considered as extraneous matter.

*3Foreign matter-Any visible objectionable foreign detectable matter or material not usually associated with the natural components of the spice plant; such as sticks, stones, burlap bagging, metal

*4Pinheads–Developed from unfertilized flowers, berries with a diameter of less than 2 mm with more angularity than normal berries, they have soft texture (collapse under heavy pressure) and have less odour and flavour than pepper berries.

Table 7. Chemical characteristics of Black and White pepper (CODEX Standards – CXS-326-2017)

Characteristic	**Black Pepper**			**White Pepper**		
	Grade I	Grade II	Grade III	Grade I	Grade II	Grade III
Moisture content, % (m/m), max.	12.0	12.0	13.0	12.0	12.0	13.0
Total ash, % (m/m), max, on dry basis.	6.0	7.0	7.0	3.5	4.0	4.0
Non-volatile ether extract, % (m/m) min, on dry basis.	7.0	7.0	6.0	6.0	6.0	6.0
Volatile oils1, % (ml/100 g) min, on dry basis.	2.0	1.5	1.0	1.5	1.5	1.0
Piperine content, % (m/m), min, on dry basis.	3.5	3.0	2.0	4.0	3.5	3.0
Acid-insoluble ash, % (m/m) max, on dry basis.	1.5	1.5	1.5	0.3	0.3	0.3

[1]The volatile oil content should be determined immediately after grinding

20. GAP Checklist for Black Pepper Farmers

Before and during crop production, farmers should ensure compliance with the following Good Agricultural Practices (GAP):

- ✓ Select suitable sites with well-drained soils and avoid waterlogging.
- ✓ Maintain records of soil and irrigation water quality wherever applicable.
- ✓ Use healthy, disease-free and true-to-type planting material obtained from reliable sources.
- ✓ Raise nurseries using recommended nursery media and adopt appropriate nursery sanitation measures.
- ✓ Plant suitable support trees (standards) and maintain the recommended spacing.
- ✓ Apply organic manures, biofertilizers and fertilizers based on soil test recommendations.
- ✓ Conduct soil testing periodically and follow site-specific nutrient management practices.
- ✓ Apply lime or dolomite in acidic soils as recommended.
- ✓ Maintain proper drainage, especially during the monsoon season.
- ✓ Regulate shade by timely pruning of support trees to ensure optimum light penetration and reduce pest and disease incidence.
- ✓ Protect young vines from excessive heat and moisture stress.
- ✓ Adopt summer irrigation wherever feasible to improve flowering, spike emergence and yield.
- ✓ Practice timely weeding, mulching and other intercultural operations.
- ✓ Use biological control agents and biofertilizers wherever recommended.
- ✓ Adopt integrated pest, disease and nematode management practices.
- ✓ Use only approved pesticides and follow recommended dosages, waiting periods and safety precautions.
- ✓ Wear appropriate personal protective equipment (PPE) while handling agrochemicals.
- ✓ Maintain records of fertilizer application, plant protection measures, irrigation and harvesting operations.
- ✓ Harvest spikes at the appropriate stage of maturity based on the intended end use.
- ✓ Follow recommended threshing, blanching, drying, grading and storage practices.
- ✓ Ensure proper packaging, labelling and traceability of produce.
- ✓ Store dried pepper in clean, dry and hygienic conditions to prevent moisture absorption, mould growth and insect infestation.

Adoption of these Good Agricultural Practices helps improve productivity, enhance pepper quality, ensure food safety, reduce pesticide residues and promote sustainable black pepper cultivation.

Annexure I. Improved Propagation Techniques in Black Pepper

A. Serpentine Method of Propagation

The serpentine layering technique is a simple and efficient method for the large-scale production of rooted cuttings of black pepper.

Procedure

1. Plant healthy rooted black pepper cuttings in polythene bags filled with potting mixture and maintain them as mother plants under a nursery shed covered with roofing sheets or shade net.
2. As the mother plant grows and produces nodes, place small polythene bags (20 × 10 cm) filled with potting mixture beneath each node.
3. Gently press each node into the potting mixture using a flexible support such as the midrib of a coconut leaflet to ensure proper contact.
4. Roots develop from each node while the shoot continues to grow.
5. Continue placing filled polythene bags beneath newly formed nodes to induce rooting at every node.
6. After about three months, the first 10–12 rooted nodes from the mother plant become ready for harvest.
7. Separate each rooted node by cutting just below the rooted portion.
8. Bury the cut end into the potting mixture by gentle pressing to promote additional root formation.
9. The rooted nodes produce new shoots within a week and become ready for field planting within 2–3 months.

Advantages

- Rapid multiplication of planting material.
- Simple and low-cost technique.
- Production of approximately 60 rooted cuttings per mother plant per year.
- Suitable for decentralized nursery production.

Serpentine method of black pepper rooted cutting propagation

B. Plug-tray Nursery Technique

The plug-tray nursery technique enables the production of healthy and uniform planting material using a soil-less nursery medium.

Nursery Medium

Partially composted coir pith and vermicompost (75:25) enriched with *Trichoderma* (talc formulation @ 10 g /kg medium) is recommended as the nursery medium.

Procedure

1. Establish rooted black pepper vines using the modified serpentine method in beds prepared with the recommended nursery medium.
2. Allow the vines to trail over the rooting medium so that roots develop at each node.
3. After 45–60 days, retaining the terminal five nodes, cut the rooted runner into single-node rooted cuttings.
4. Transfer the rooted cuttings into plug-trays (cell size: 7.5 × 7.5 × 10 cm) filled with the soil-less nursery mixture.
5. Maintain the trays under a humidity-controlled greenhouse (27 ± 2°C) with intermittent misting for better rooting and establishment.
6. Retain the cuttings in plug-trays for 45–60 days until they reach the 4–5 leaf stage.
7. Transfer the established plants to a shade-net house or naturally ventilated greenhouse for hardening for another 45–60 days.
8. The rooted cuttings become ready for field planting within 120–150 days.

Advantages

• Production of healthy and uniform planting material.
• Better rooting and establishment.
• Efficient utilization of nursery space.
• Reduced mortality after transplanting.

Plug-tray method black pepper rooted cutting production technique

C. Vertical Column Method

The vertical column method is an intensive propagation technique for large-scale production of quality planting material.

Preparation of Vertical Column

1. Prepare vertical columns of about 2 m height and 0.3 m diameter using plastic-coated welded wire mesh. medium inside the column.

2. Fill the columns with partially decomposed coir pith and vermicompost (3:1) enriched with *Trichoderma harzianum* talc formulation @ 10 g /kg medium. Maintain the columns inside a polyhouse with a temperature of 25–28°C and relative humidity of 75–80% under intermittent misting.

Procedure

1. Plant 8–10 rooted cuttings around each column.
2. Train the vines so that each node comes in contact with the rooting medium inside the column.
3. Allow the vines to grow upward along the column.
4. After 4–5 months, the vines reach the top of the column and each vine develops about 20 nodes along with a few lateral branches.
5. Harvest the planting materials as follows:
    - Single-node cuttings
    - Top shoots with lateral branches
    - Lateral (plagiotropic) shoots for bush pepper production
6. Root the harvested cuttings further in pro-trays before field planting.

Advantages

- Large-scale multiplication of quality planting material
- Simultaneous production of multiple types of propagules
- Early-yielding top shoots can be produced for field planting
- Efficient utilization of protected cultivation structures

Expected Output

Under favourable conditions, one such column can produce approximately 150 single-node cuttings, 10–15 lateral shoots and 10 top shoots within 4 months, three harvesting cycles can be completed annually under polyhouse conditions.

Vertical column method for black pepper rooted cutting production

Annexure II. Bush Pepper Production Technology

(AI generated image)

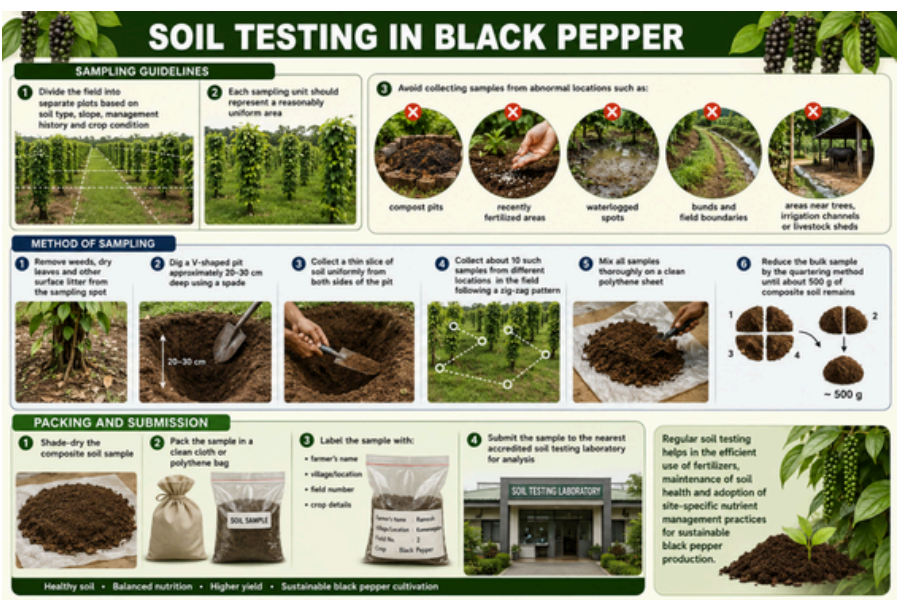
Nutrient Management of bush pepper

For potted plants, apply 100 g FYM or vermicompost per pot at six-month intervals and 3 g each of urea, single superphosphate and muriate of potash, or 5 g of NPK (18:18:18) mixture at bimonthly intervals. Alternatively, 10 g of groundnut cake or neem cake may be applied instead of NPK fertilizers at bimonthly intervals. In purely organic cultivation systems, *Pseudomonas fluorescens*, *Trichoderma*-enriched FYM/neem cake and neem-based pesticides may be used for pest and disease management. Depending on plant spread and management, yields of up to 1.5 kg green pepper pot^{-1} $year^{-1}$ may be obtained.

For field-grown mature bush pepper plants, apply 5 kg FYM or compost per plant per year along with 20 g urea, 25 g single superphosphate and 25 g muriate of potash at four-month intervals. To enhance growth, foliar spraying of vermiwash (2%) or a micronutrient mixture (0.5%) may be carried out at monthly intervals. For disease management, 25–50 g of biocontrol agents such as *Trichoderma* or *Pseudomonas* spp. may be applied along with FYM or compost at six-month intervals. Depending on plant growth and canopy spread, 2–3 kg green pepper per plant year may be obtained in a year.

Annexure III. Soil Sampling Procedure

Soil testing is an important component of Good Agricultural Practices (GAP) and helps in assessing soil fertility status, nutrient availability and soil health. Representative soil samples should be collected carefully, preferably before fertilizer application.alth and adoption of site-specific nutrient management practices for sustainable black pepper production.



(AI generated image)

Annexure IV. Preparation of Bordeaux Mixture and Mass Multiplication of *Trichoderma*

A. Preparation of Bordeaux Mixture (1%)

Bordeaux mixture is widely used in black pepper for the management of foot rot, anthracnose and other fungal diseases.

(AI generated image)

B. Mass Multiplication of *Trichoderma* (On-farm Method)

Procedure

1. Powder dry neem cake and well-decomposed cow dung separately.
2. Mix neem cake and cow dung in a 1:9 ratio.
3. Sprinkle water uniformly to obtain adequate moisture.
4. Add commercial *Trichoderma* formulation @ 1–2 kg per 100 kg of substrate mixture.
5. Mix thoroughly to ensure uniform distribution.
6. Cover the mixture with a perforated polyethylene sheet or newspaper and keep under shade.
7. Turn the mixture once after 7 days to facilitate aeration and uniform fungal growth.
8. The enriched bio-product becomes ready for use after about 15 days.

Use

The enriched *Trichoderma* formulation may be applied to nursery, planting pits or vine basins as part of an integrated disease management programme for suppression of soil-borne pathogens.

Annexure V. Worker Safety, Hygiene and Safe Use of Pesticides

Worker Safety and Hygiene

(AI generated image)

Annexure VI. Measures to Minimize Pesticide Residues in Black Pepper

To ensure residue-safe black pepper production and compliance with domestic and export market requirements, farmers should adopt the following practices:

- Follow Integrated Pest Management (IPM) principles and emphasize preventive, cultural and biological control measures
- Use only pesticides approved by the Central Insecticides Board and Registration Committee (CIB&RC) for use in black pepper
- Apply pesticides strictly at the recommended dosage, timing and method of application
- Avoid unnecessary and repeated pesticide applications
- Rotate pesticides with different modes of action whenever possible to prevent resistance development
- Observe the recommended waiting period between pesticide application and harvest
- Avoid pesticide application immediately before harvest
- Prefer spot treatment of affected plants rather than blanket application whenever feasible
- Maintain proper field sanitation and promptly remove diseased or pest-infested plant parts
- Calibrate spraying equipment regularly to ensure uniform application and prevent overdosing
- Use clean water for preparation of spray solutions
- Avoid contamination of irrigation water sources, drying yards, storage areas and harvested produce during pesticide application
- Maintain records of pesticide applications, including product name, active ingredient, dosage, date of application, target pest or disease and harvest date
- Train workers in the safe handling and application of pesticides and ensure the use of appropriate personal protective equipment (PPE)
- Store pesticides separately from harvested produce, packaging materials and food items
- Follow recommended harvesting, drying, grading, packaging and storage practices to prevent contamination during post-harvest handling
- Ensure traceability by maintaining records of cultivation practices, agrochemical use and post-harvest operations

Adoption of these practices helps minimize pesticide residues, improves food safety, enhances market acceptability and supports compliance with domestic and international quality standards for black pepper.

Annexure VII. Pesticides Approved for Use in Black Pepper

Recommended pesticide	Target disease	Recommended dosage	Waiting period from last application to harvest	Toxicity class
Metalaxyl 4% + Mancozeb 64% WP	Phytophthora foot rot	0.17% solution or 1700 g ha^{-1}	Not less than 21 weeks	Blue
Metalaxyl 18% + Mancozeb 64% WP	Phytophthora foot rot	1.8 g a.i. $vine^{-1}$ or 0.09% solution	Not less than 21 weeks	Blue

***Note**: The list is based on approved recommendations available at the time of publication. Farmers are advised to consult the latest notifications and registrations issued by the Central Insecticides Board and Registration Committee (CIB&RC), Government of India, before using any pesticide. Only products approved for use in black pepper should be applied, strictly following label claims, recommended dosages, waiting periods and safety precautions.*

Annexure VIII. Nutrient Deficiency Symptoms and Corrective Measures in Black Pepper

Nutrient	Deficiency Symptoms	Corrective Measures
Nitrogen (N)	General chlorosis and stunted growth. Yellowing of older leaves followed by younger leaves. Leaf tips and margins of older leaves become brown and necrotic.	Apply organic manures and fertilizers as per the recommended Package of Practices (POP). In severe cases, foliar application of urea (0.5 -1.0%) may be given
Phosphorus (P)	Bronzing of older leaves accompanied by necrosis of leaf tips and margins and stunted growth.	Apply organic manures and phosphorus fertilizers as per the recommended POP. In severe cases, foliar application of DAP (0.5%) may be given.
Potassium (K)	Browning and necrosis of leaf tips and margins of older leaves. Symptoms gradually spread to younger leaves.	Apply organic manures and potassium fertilizers as per the recommended POP. In severe cases, foliar application of sulphate of potash (SOP) at 0.5-1.0% may be given.
Calcium (Ca)	Young leaves develop small brown necrotic pinhead spots. Interveinal chlorosis may also occur. Symptoms gradually spread to older leaves.	Apply lime or dolomite (1-2 t ha^{-1}) in acidic soils. Where symptoms occur, foliar application of calcium nitrate (0.5-1.0%) may be given.

Magnesium (Mg)	Pale yellow discoloration of leaf margins and tips followed by necrosis and defoliation. Major veins remain green while the lamina turns yellow.	Apply dolomite (1-2 t ha^{-1}) or magnesium sulphate (20 kg ha^{-1}). In severe cases, foliar application of magnesium sulphate (0.5–1.0%) may be given.
Sulphur (S)	Chlorosis of younger leaves, progressing to bright yellow interveinal areas. Premature leaf fall and dieback of growing tips may occur.	Apply sulphur at 5-10 kg ha^{-1} through elemental sulphur, gypsum or sulphur-containing fertilizers such as ammonium sulphate or potassium sulphate.
Boron (B)	Stunted growth, interveinal chlorosis and necrosis. Necrotic lesions may develop along the main veins.	Apply borax or boric acid based on soil test recommendations. In general, borax may be applied at 2-5 kg ha^{-1}. Foliar application of boric acid (0.2%) at monthly intervals may be given after symptom appearance.
Iron (Fe)	Interveinal chlorosis of younger leaves. The youngest leaves may become completely chlorotic under severe deficiency.	Foliar application of ferrous sulphate (0.5%) may be given upon appearance of deficiency symptoms.
Manganese (Mn)	Interveinal chlorosis with veins remaining green. Chlorotic leaves later turn yellow or whitish and mature leaves may become necrotic.	Apply manganese-containing fertilizers such as manganese sulphate or Mn-EDTA at 2-10 kg ha^{-1}. In severe cases, foliar application of Mn-EDTA (0.1%) may be given.
Zinc (Zn)	Stunted growth and interveinal chlorosis of younger leaves. Leaf margins become puckered, and leaf size, petiole length and internodal distance are reduced.	Apply zinc sulphate at 5 kg ha^{-1}. Where symptoms occur, foliar application of zinc sulphate (0.5%) may be given to prevent further symptom development.

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