भाकृअनुप
ICAR

ICAR-AICRPS Technologies

भाकृअनुप-अखिल भारतीय समन्वित मसाला अनुसंधान परियोजना ए आई सी आर पी एस

ICAR-All India Coordinated Research Project on Spices

ICAR-Indian Institute of Spices Research
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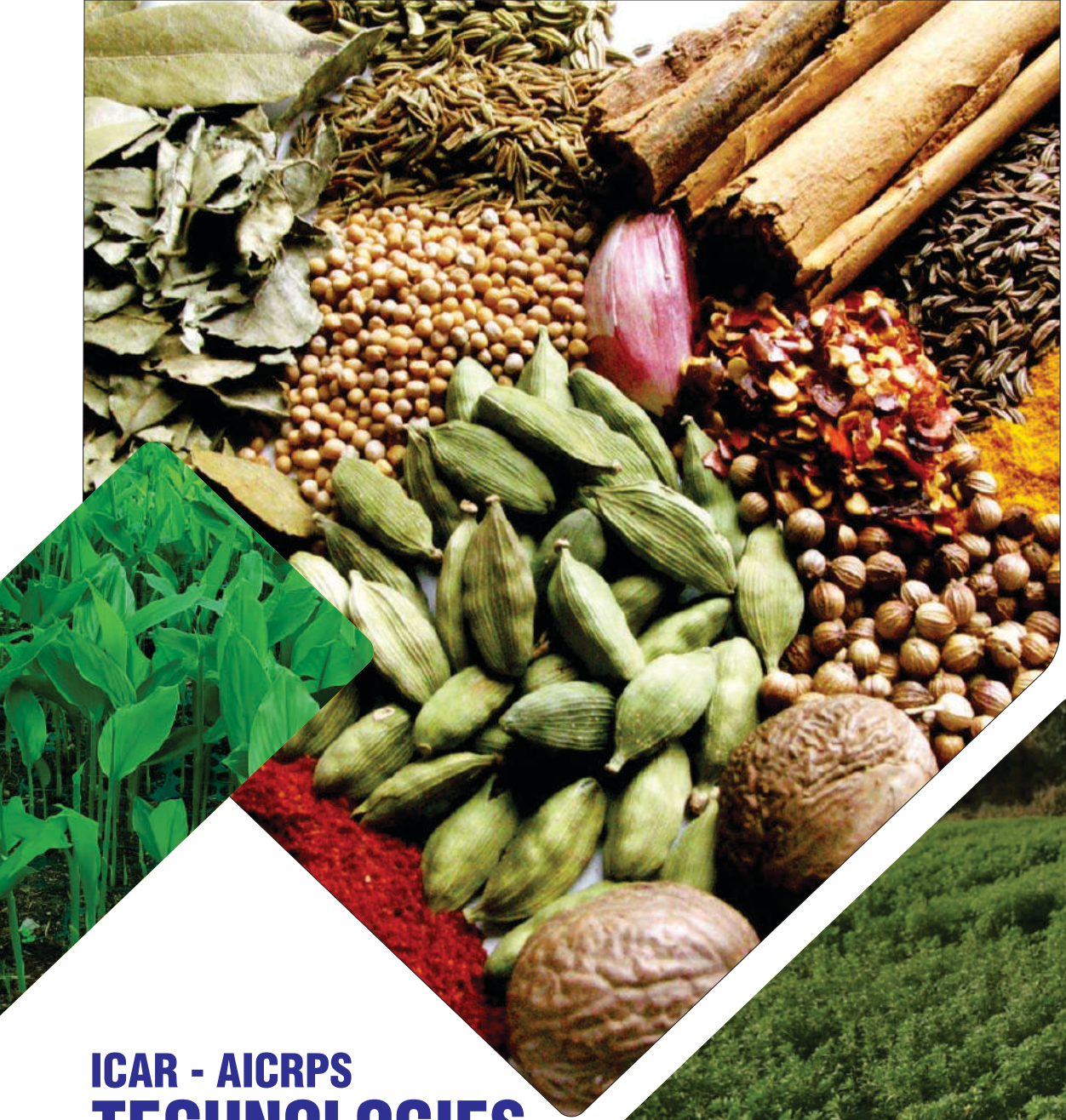

ICAR - AICRPS
TECHNOLOGIES

ICAR-All India Coordinated Research Project on Spices
(ICAR-AICRPS)
Indian Institute of Spices Research
Kozhikode – 673 012, Kerala, India.

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Prologue

ICAR-All India Coordinated Research Project on Spices (AICRPS), located at ICAR-Indian Institute of Spices Research, Kozhikode, Kerala has 38 centres (19 regular centres, 10 co-opting centres and 9 voluntary centres) representing 14 agro-climatic regions in 24 states including North Eastern states and tribal areas. ICAR-AICRPS plays a pivotal role in the development of varieties suitable to different agro climatic regions and addresses the problems faced by the farming community on crop diseases, crop management practices during adverse and aberrant weather conditions. ICAR-AICRPS has developed 176 crop wise technologies (summarized below in further Chapters) for varietal improvement, nutrient availability and plant health management in various spice crops. These technologies popularized through demonstrations are adopted by the concerned states and propagated through the state Agricultural departments.

The technology of rapid multiplication in ginger and turmeric through single node protray method which requires only 1/4th of the actual requirement of seed and saves huge amount of planting material is being adopted in major ginger and turmeric growing parts of the country. ICAR- AICRPS has developed micro irrigation technology for black pepper, cardamom, turmeric, coriander, fennel and fenugreek which provides 'More Crop Per Drop' of water. Organic production technologies, good agricultural practice (GAP) and sustainable agricultural practice (SAP) were developed for spices to cut down the use of pesticides, which minimises residues and preserves the ecosystem. Seed coating technology in seed spices using plant growth promoting rhizobacteria (PGPR) results in increased yield (10-30%), enhanced seed germination, improved quality and reduced storage pests of seed spices.

ICAR- AICRPS technologies have also percolated to the remote and inaccessible tribal lands of Chintapalli in Andhra Pradesh, Pottangi in Odisha, Raigarh in Chhattisgarh and NE states providing employment opportunities (especially women) and uplifting the economic status of farmers. These technologies helped in expanding the spices cultivation especially turmeric, ginger and black pepper in these nontraditional areas of cultivation.

Thus ICAR- AICRPS which coordinates spices research in the country has played its part in the contribution of technological interventions for increasing spice production, productivity, value addition and export of spices, making India the largest producer, consumer and exporter of spices. Owing to its significant contribution for the cause of spices, ICAR-AICRPS was awarded the prestigious Chaudhary Devi Lal outstanding Award for the best AICRP under ICAR in the year 2017.

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TECHNOLOGIES

Black Pepper

Crop production

Cropping system

Panniyur 5 is recommended for cultivation as a mixed crop in arecanut gardens.

Suitable standards

Silver oak is recommended as a suitable standard for black pepper in Andhra Pradesh. *Ailanthus malabarica* is recommended as the best standard for black pepper in drought prone areas.

Propagation

Middle 1/3rd portion of runner shoots of the vine is recommended for obtaining better rooting and establishment. Dipping the cut end of the vines in IBA (1000 ppm) for 45 seconds was also found to increase rooting.

Treating two node orthotropic cuttings devoid of leaves with powder formulation of *Pseudomonas fluorescens* or dipping in common sugar solution (2%) for one minute is recommended to enhance rooting.

Fig 1: View of black pepper nursery at Chintapalli

Irrigation

Providing basin irrigation at IW/CPE ratio of 0.25 (100 litres of water once in 8-10 days) during December-May for *Karimunda* variety is recommended for increased yield (72.2% increase over traditional method).

Providing drip irrigation @ 8 litres per day per vine and 50% RDF (half the Recommended Dose of Fertilizer as liquid fertilizer - 19:19:19 mixture) in 3 equal splits at weekly intervals during June, September and February was found beneficial than conventional method of irrigation and basal fertilizer application with the highest benefit cost ratio (2.07).

State-wise recommendation for fertilizers

Panniyur and similar areas: 50:50:200 NPK (kg/ha).
Medium fertile soil: 100:40:140 NPK (kg/ha).
Arecanut and black pepper mixed cropping system for heavy rainfall Sirsi region of Karnataka: 200:80:280 NPK (kg/ha).
Karnataka (under irrigated conditions): 150:60:210 NPK (kg/ha).
Andhra Pradesh (under rainfed conditions): 50:50:150 NPK (kg/ha).
Chintapalli area of Andhra Pradesh (high altitude): 100:60:160 NPK (kg/ha).
Laterite soils of Kerala, where soil N and K are low: 140:55:270 NPK (kg/ha).
Slow release fertilizers such as neem seed extract coated urea is recommended for nutrition management.

Foliar application of Zn (0.25%) twice during June and August is recommended for increasing the yield. Basal application of Zn (6 kg) and Mo (1 kg) is also recommended for increasing the yield and quality under deficient conditions.

Crop-specific micronutrient mixture application @ 5 g/L as foliar spray twice a year during April-May and August-September is recommended for increasing yield (15 to 25%) and improving the quality.

Application of FYM 10 kg, *Azospirillum* 50 g, Phosphobacteria 50 g, *Trichoderma* 50 g, *Pseudomonas fluorescens* 50 g, 50:50:200 g NPK vine^{-1} per year from 3rd year is recommended under Kerala conditions to enhance the yield.

Mulching

Mulching the basins of the vines with saw dust, coconut husk or dry leaves or polythene sheets is recommended as a measure to conserve moisture.

Crop protection

Management of *Phytophthora* foot rot (field)

Removing affected vines along with root system and burning, providing adequate drainage, growing grass cover and avoiding trailing of runner shoots on the ground, careful farm operations without injuring underground parts of the vine, improving microclimate by shade regulation, lopping off the branches of live standards to ensure better light penetration and to reduce humidity are recommended as non-chemical strategies to manage foot rot.

Application of neem cake @ 1 kg per vine, first round pre-monsoon spray with Bordeaux mixture followed by copper oxychloride drenching and second round Akomin (potassium phosphonate) spray followed by Akomin drenching during post-monsoon are recommended for Kerala. Wherever nematode incidence is high, *phorate @ 3 g a.i. can be applied during September-October besides adopting recommended phytosanitary measures.

Application of Akomin (3 to 5 ml per litre) as spray and drench twice, during pre-monsoon (first week of June) and post-monsoon (second week of August) along with the soil application of *Trichoderma harzianum* (10^7 cfu, @ 50 g /vine) with 1 kg of neem cake are recommended to manage foot rot.

Spraying Bordeaux mixture (1%) and drenching copper oxychloride (0.2%) @ 5-10 L/vine twice, during June and September, application of *T. viride* (50 g/vine) mixed with 1 kg neem cake followed by 0.2% Akomin spray in August or spraying 0.3% Akomin @ 3 L/vine and drenching @ 5 L/vine twice, before onset of monsoon and during second week of August are recommended to manage foot rot.

Adopting all cultural practices, neem cake application (@ 1 kg/vine), *phorate 3G (@ 30 g/vine), 1% Bordeaux mixture spray (@ 3 L/vine) and drenching (@ 5 L/vine) before onset of monsoon as first round (June), Akomin (0.4%) and Ridomil MZ-72 WP (100 ppm) as spray (@ 3 L/vine) and drench (@ 5 L/vine) separately as second (August) and third (September) rounds are recommended to manage foot rot in Uttara Kannada (Sirsi).

Application of antagonistic organisms like *Trichoderma viride* applied @ 150 g/vine along with 5 kg FYM to the basin of the vines during June is recommended to reduce *Phytophthora* foot rot.

A technique of grafting black pepper on *Phytophthora* resistant root stock, *Piper colubrinum* was developed which is an eco-friendly strategy to manage *Phytophthora* foot rot in water logged arecanut gardens thereby reducing excessive use of fungicides.

Management of *Phytophthora* foot rot (nursery)

Dipping the cuttings in culture suspension of *Trichoderma harzianum* and *T. viride* and fortnightly application of Bordeaux mixture (1%) or *captafol (1%) and solarization of nursery soil mixture (3.3 K lux) fortified with VAM and *Trichoderma* are recommended to reduce *Phytophthora* infection under nursery conditions.

Solarized potting mixture fortified with *Trichoderma harzianum* @ 1 g/kg and VAM (100 cc) was found effective for the management of *Phytophthora* infection in black pepper nursery.

Drenching Bordeaux mixture (1%) at 15 days interval is recommended to manage nursery diseases like *Phytophthora* foot rot, anthracnose and basal wilt.

Management of leaf rot and blight (nursery)

Removal of affected cuttings, spraying and drenching the cuttings with copper oxychloride (0.2%) or bavistin (0.2%) or Bordeaux mixture (1%) at bimonthly intervals is recommended for leaf rot and blight management.

Management of basal wilt (nursery)

Removal of affected cuttings, spraying Bordeaux mixture (1%) and drenching the cuttings with copper oxychloride (0.2%) at monthly intervals is recommended for basal wilt management.

Management of anthracnose

Apply carbendazim-mancozeb (0.1%) or carbendazim (2 g/L) followed by carbendazim-mancozeb (2 g/L). Alternatively, two sprays with propiconazole 25 EC (0.1%) @ 5 litres per vine during last week of May and August is also recommended to manage anthracnose under field conditions.

Management of scale insects

Two sprays either with *monocrotophos (0.05%) or dimethoate (0.05%) or quinalphos (0.05%) or fish oil and neem oil at fortnightly intervals after the harvesting of berries is recommended to manage mussel scale at high ranges of Idukki.

Management of leaf gall thrips

Application of carbofuran 3G or *phorate 10G @ 3 g a.i/vine during June-July and September-October and spray of 0.05% *monocrotophos or dimethoate or *phosphamidon (0.03%) on tender flushes controls leaf gall thrips.

Management of slow decline

Application of carbofuran 3G or phorate 10 G (30 g/vine) twice a year during May-June and September-October (covering with a thin layer of soil) along with Bordeaux mixture spraying and drenching copper oxychloride (0.2% @ 5-10 L/vine 2-3 times during monsoon) and soil application of neem cake @ 2 kg/vine are recommended to manage slow decline.

Management of pollu beetle

Spraying *endosulfan (0.05%) or quinalphos (0.025%) or dimethoate or *monocrotophos (0.05%) twice during June-July (21-30 days after setting of berries) and September-October is recommended to reduce pollu beetle infestation.

Management of top shoot borer

Spraying *endosulfan (0.05%) during the emergence of new flushes is recommended against top shoot borer.

Management of mealy bug

Drenching of *monocrotophos (0.1%) or dimethoate (0.05%) or quinalphos (0.05%) or fish oil and neem oil at 15 days interval controls mealy bug infestation.

Fig 2: Black pepper field view

Crop production

Scarification of seeds for 10 minutes with 25% nitric acid is recommended to increase germination.

Mulching nusery beds with polythene sheets soon after sowing when the sowing is done very late in the season (November-December) is recommended for enhancing seed germination.

Spacing

Kerala: 2 x 2 m for Malabar and *Vazhukka* types.
Karnataka: 1.8 x 1.8 m.
Tamil Nadu: 1.8 x 1.8 m (3025 plants/ha) and 2.7 x 2.7 m (1371 plants/ha for Malabar and Mysore types, respectively).
In clonal propagation, to increase proliferation of suckers planting at closer spacing of 0.9 x 0.9 m is recommended. A closer spacing of 0.3 x 0.9 m is also recommended for production of higher number of planting units *viz*., 8.8 suckers/m^2.

Trench system of planting is recommended to obtain higher yield (1294 kg dry capsules/ha) as compared to pit system (256.7 kg/ha).

Fertilizer recommendation

100% inorganic manure alone is recommended for Chikkamagaluru (Mudigere).

Application of boron as disodium tetraborate @ 20 kg/ha or molybdenum as sodium molybdate @ 0.25 kg/ha mixed with appropriate quantity of FYM @ 2 kg/plant with the onset of monsoon (May I or June I week) is recommended for enhancing the yield. In acidic loamy soils of Kerala, application of 2 kg dolomite for 3 years was found to improve the yield (2763 g $plant^{-1}$) with a B:C ratio of 2.42.

Spraying 25 ppm NAA or 2.5 ppm 2,4-D twice at monthly intervals soon after fruit set (June-July) is recommended to decrease fruit drop and increase fruit set. Application of etherel at 250 ppm under high light intensity (15 K lux) is also recommended for increasing the yield. Foliar application of urea (3%), single superphosphate (1%) and muriate of potash was also found to increase the yield.

Monthly application of Jeevamrutha (20 L $plant^{-1}$) along with 10 g each of biofertilizers (*Azospirillum* and PSB) and biocontrol agent (*Trichoderma viride*) along with 30 tonnes of compost is recommended as an organic production practice for Cardamom Hill Reserves, Kerala with a B:C ratio of 2.15.

Irrigation

Irrigation from January to August in low rainfall tracts @ 4 litres per clump per day through drip is recommended to increase the yield by 63% over control (no supplementary irrigation).

Irrigating cardamom @ 9 litres per clump per day along with 100% recommended dose of fertilizers through drip is recommended to realize highest capsule yield (316 kg ha^{-1}) with a B:C ratio of 3.37.

Weed management

The following herbicides are recommended for on-farm testing to manage weeds in cardamom plantations for a period of 90 days.

a) *Paraquat @ 0.4 kg a.i./ha with Atrazine 1 kg a.i./ha.
b) Glyphosate 0.8 kg a.i/ha with Diuron 1 kg a.i./ha.
c) Diuron or Atrazine 1 kg a.i./ha.

Fig 3: Yielding small cardamom

Crop protection

Management of rhizome rot/*Azhukal*/capsule rot

Adopting phytosanitation, regulating excess shade, thrashing to remove senile parts, spraying and drenching with Bordeaux mixture (1%) or copper oxychloride (0.2%) before the onset of monsoon (May/June) and after the end of monsoon (August) are recommended to manage the disease.

Management of seedling rot, damping off and leaf spot

Soil solarization, incorporating VAM in the nursery stage, treating seeds with carbendazim + captan @ 2 g/kg of seed for 60 minutes, spraying mancozeb (0.3%), providing good drainage, drenching with Bordeaux mixture are recommended to manage seedling rot disease. Two sprays

with *captafol (0.3%) or copper oxychloride or carbendazim (0.1%) at 10 days interval were found effective against leaf spot.

Management of pseudostem rot

Drenching carbendazim @ 2 g/L (5 L/plant) at monthly intervals from February-May or biological control by combined application of *Trichoderma harzianum* (50 g with 1 kg neem cake) + *Pseudomonas fluorescens* (2% spray) are recommended to manage pseudostem rot in Kerala.

Management of thrips, shoot and capsule borer

Spraying of Poneem 2 ml L^{-1} reduces shoot borer infestation by 50% and spraying of imidacloprid 200 SL (0.5 ml L^{-1}) reduces thrips infestation by 90%.

Spraying of *monocrotophos (0.05%) or quinalphos/*endosulfan/*fenthion (0.075%) twice during January/February and September/October controls thrips, shoot borer and capsule borer.

Spraying of *monocrotophos (0.05%) and phosalone (0.05%) alternatively at bimonthly intervals also controls these pests.

Management of shoot fly

Spraying quinalphos (0.03%) or phosalone (0.05%) or *monocrotophos (0.05%) or application of carbofuran (0.3 kg a.i/ha) is recommended to manage shoot fly infestation.

Management of root grub

Soil drenching with imidacloprid (0.015% @ 5 litres/plant) or chlorpyriphos (0.07% @ 5 L/plant) or carbofuran (@ 3 g a.i./clump) (10-15 cm around the plant) is recommended against root grub. Removal of mulch/weed cover and forking of soil prior to application of insecticides produce better results.

Management of root knot nematode

Application of *phorate 10 G @ 2.5 g a.i./clump during May/June and November/December or *aldicarb or carbofuran @ 5-10 kg a.i/ha is recommended to reduce root knot infestation.

Crop production

Propagation

Single bud pro-tray method in which rhizome bits of 5-6 g with a bud planted in pro-tray required 1/4th of planting material compared to conventional propagation which saves 60% cost incurred on seed rhizomes and ensures 98-100% field establishment with production of disease-free planting material. It is also suitable for early/delayed planting.

Pro tray technology in ginger

Tribal women preparing pro trays

Fig 4: Rapid multiplication of planting materials of ginger

State-wise recommendation for fertilizers

Kerala: 30 t FYM/ha, 70:50:50 kg NPK/ha, full dose of phosphorus and 50% K as basal dose, half the quantity of N at 60 DAS, remaining quantity of N and K at 60 DAS.

Karnataka: 25 t FYM/compost/ha, 100:50:50 kg NPK/ha, entire dose of P and K at planting, half quantity of N at 30-40 DAP and other half at 60-70 DAP.

Odisha: 25 t FYM/ha, 125:100:100 kg NPK/ha, full P and half K as basal in furrows before planting, N and K in 2 splits at 45th and 90th day.

Himachal Pradesh: 20-30 t FYM/ha, CAN @ 400 kg/ha, 100:50:60 kg NPK/ha and 15 kg superphosphate/ha. Apply super phosphate and potash at the time of planting and N in 3 equal doses first at the time of planting and subsequent 2 doses at 1 month interval and apply K_2O in splits, half at sowing and another half dose at rhizome initiation.

Bihar: 20-30 t FYM/ha and NPK @ 60:60:120 kg/ha or 80:50:50 kg/ha.

Andhra Pradesh: 20-30 t FYM/ha, 75:50:50 kg NPK/ha.

Chhattisgarh: 20-30 t FYM/ha, NPK @ 150:120:120 kg/ha.
Sikkim: 40-60 tonnes manure/ha.
Meghalaya: 10 t FYM/ha and 60:90:60 kg NPK/ha.

Integrated nutrient management package including FYM @ 30 t ha^{-1}, 80:50:50 kg NPK ha^{-1}, neem cake @ 2 t ha^{-1} together with inorganic fertilizers is recommended to increase the availability of nutrients in soil, increase yield and to reduce incidence of rhizome rot in Bihar.
Application of 125:100:100 kg of NPK/ha is also recommended to increase the yield in ginger. Application of N (125), P (100) and K (100) kg/ha resulted in fresh rhizome yield of 14.65 t/ha with the maximum net profit of Rs. 53000/- in Odisha (Pottangi).
Soil application of borax @ 5 kg/ha is recommended for increased yield in West Bengal.
Crop-specific micronutrient mixture @ 5g/L water applied as foliar spray at 60 and 90 days after planting is recommended to increase the yield (15 to 25% increase in yield).

Fig 5: Ginger field at Pottangi

Weed management

Application of oxyflurofen as pre-emergent herbicide @ 500 ml per ha at second day after sowing followed by application of quazilophop ethyl as post-emergent herbicide @1 litre per ha at 30 days of crop stage followed by hand weeding at 90 days of crop stage which reduced 3-4 manual hand weeding with a B:C ratio of 2.96 and yield of 22.79 t/ ha is recommended in Andhra Pradesh (Chintapalli).

Intercrops/companion/mixed cropping

A compatible crop combination of ginger + soybean is recommended for maximizing the returns from unit area. Soybean and red gram are also recommended as companion crops in Odisha.

Crop protection

Management of rhizome rot

Seed treatment with mancozeb (Indofil M-45 @ 0.25%) + carbendazim (0.1%) for 60 minutes, drying under shade for 24 hours before sowing/storage and dipping seed rhizomes in copper oxychloride (Blitox-50 @ 0.3%) before storage are recommended to manage rhizome rot.

Solarization of ginger rhizomes under polyethylene sheet (200 microns) at 47°C for 30 minutes, treating the solarized rhizomes with bioagents in combination i.e. *Trichoderma harzianum* (MTCC 5179) and bacterial consortium IISR 51 and GEB 17 at 10^8 CFU (for growth, nematode and *Pythium* suppression) for 30 minutes, treating the beds with respective bioagents as drenching at the time of planting of rhizomes and application of bacterial consortium after planting of rhizomes are recommended to manage the disease in Uttara Kannada (Sirsi). Alternatively, treating the solarized rhizomes with mancozeb (0.25%) for 30 minutes before planting and application of fungicides two times after sowing of rhizomes was also found effective in reducing the rhizome rot disease.

Solarization and seed rhizome treatment with mancozeb (0.3%), soil drenching with Dithane M-45 (0.3%) in Chikkamagaluru (Mudigere) and pre-sowing dipping of seed rhizomes in Blitox-50 (0.3%) for 30 minutes (Himachal Pradesh) are recommended to manage seed-borne infection due to rhizome rot pathogen.

Pre-sowing seed treatment with bavistin (0.1%) and combination of Dithane M-45 (0.25%) + bavistin (0.1%) followed by captan (0.25%) for 60 minutes is recommended for increasing the germination and to reduce post-emergence rot.

Crop residues of mustard and cabbage incorporation in soil (biofumigation) and rhizome treatment with metalaxyl + mancozeb (1.25 g^{-1} L of water) for 15-20 minutes are recommended to reduce soil-borne diseases under field conditions.

Management of bacterial wilt

For organic system of cultivation, adopt soil solarization along with the biocontrol agent, *Bacillus licheniformis* (GAP107 MTCC12725) launched as *Bacillich* is recommended to manage bacterial wilt with a B:C ratio of 3.23. For inorganic system of cultivation, $CaCl_2$ along with soil solarization manages the disease with a B:C ratio of 2.88 when both the treatments are imposed at the time of planting and at 30, 45, 60 and 90 days after planting.

Treating seed rhizomes with streptocycline (200 ppm) for 30 minutes and shade drying before planting and further, drenching of the beds with Bordeaux mixture (1%) or copper oxychloride (0.2%) is recommended for bacterial wilt control.

Fig 6: View of trial on bacterial wilt management in ginger at Kozhikode

Management of *Phyllosticta* leaf spot

Solan: Spraying hexaconazole two times at 20 DI (0.1%) resulting in 78.72% reduction of Phyllosticta leaf spot with a B:C ratio of 1.1 is recommended.

Dholi: Spray of carbendazim (0.1%) + mancozeb (0.1%) first at disease appearance and subsequently two sprays at 20 days interval after 1st spray or foliar spray with propiconazole (0.1%) first at disease appearance and then 2 times at 20 days interval or foliar spray with tricyclazole (0.1%) first at disease appearance and then 2 times at 20 days interval controls the disease.

Raigarh: Foliar spray with carbendazim-mancozeb (1:1) (0.1%) first at disease appearance followed by with two times at 20 days interval manages Phyllosticta leaf spot with a disease

intensity of 14.52% and C:B ratio of 1:2.6.

Pundibari: Spray of hexaconazole (0.1%) or propiconazole (0.1%) first at disease appearance and then two times at 20 days interval is recommended to reduce the disease up to 60% with a C:B ratio of 1:2.07.
Spraying mancozeb (0.2%) or Bordeaux mixture (1%) is also recommended to manage leaf spot disease.

Management of shoot borer

Spraying of dimethoate (0.1%) or quinalphos (0.1%) at bimonthly intervals or malathion (0.1%) or *monocrotophos (0.075%) during July-October at monthly intervals is recommended.

Management of rhizome scale (storage/field)

Dipping seed rhizomes in quinalphos (0.025%) or *fenthion (0.05%) before storage and foliar spray with *phosphamidon (0.05%) in the field at 6th and 7th months after planting is recommended against rhizome scale.

Management of rhizome fly

Spray of quinalphos (0.02%) at 60 DAP followed by soil application of furadan 10 kg/ha is recommended to manage shoot fly under field conditions.

Management of nematodes

Applying *Thimet (phorate) @ 10-15 kg/ha at the time of field preparation, treating infected rhizomes with hot water (50°C) for 10 minutes, using nematode-free seed rhizomes and solarizing ginger beds for 40 days are recommended for reducing nematode infestation.

Fig 7:Tribal farmers in their organic ginger (Suprabha) plot

Crop production

Propagation

Single bud pro-tray method in which rhizome bits of 5-6 g with a bud planted in pro-tray required 1/4th of planting material compared to conventional propagation which saves 60% cost incurred on seed rhizomes and ensures 98-100% field establishment with production of disease-free planting material. It is also suitable for early/delayed planting.

Fig 8: Turmeric protray plants at Kammarpally

Spacing

Karnataka/Maharashtra: 30 x 30 cm or 45 x 30 cm.
Odisha: 25 x 25 cm or 20 x 25 cm.
Tamil Nadu: 25 x 25 cm in ridge, furrow and flatbed system.
Uttar Pradesh: 30 x 20 cm.
Bihar and Andhra Pradesh: 30 x 20 cm or 45 x 15 cm.
Kerala: 25 x 25 cm.
Dholi: 30 x 30 cm.

State-wise recommendation for fertilizers

Andhra Pradesh: 200-300 kg N, 125-150 kg P, 100-150 kg K in 3 splits *viz*., 60 N, 60 P and 60 K kg/ha as basal dose, 60 N, 65 K kg/ha at 60 DAP and 60 kg N/ha at 120 DAP.
Tamil Nadu: 200:200:200 kg NPK/ha as basal and top dressing with 25 kg N/ha, 18 kg K/ha at 30, 60, 90 and 120 DAP.

Odisha: 60:30:90 kg NPK/ha in 2 split doses as basal, whole FYM and half K on furrows before planting (7.2 kg/m^2 and green mulch 2.5 kg/m^2), half N at 45 DAS, half N and half K at 90 DAP.
Kerala: 30:30:60 kg NPK/ha, full and half K applied as basal dose, 2/3rd after 30 days and rest N at 60 DAP.
Chhattisgarh: 150:125:125 kg NPK/ha, in 3 split doses i.e. 30, 60 and 90 days after planting.
West Bengal: 60:60:20 kg NPK /ha and 20-25 q FYM/ha.

Application of 100% RDF with urea and potash as straight fertilizers and P as water soluble fertilizer weekly once resulted in an yield of 49 t/ha which saved labour and 40% water requirement with B:C ratio of 2.94 and is recommended for turmeric growing areas of Tamil Nadu.

For iron deficient soils of Bihar (1.73ppm), foliar application of ferrous sulphate @ 0.5% at 60 and 90 days after planting is recommended for yield enhancement with C:B ratio of 1:2.54.

Crop-specific micronutrient mixture @ 5g/L water applied as foliar spray at 60 and 90 days after planting is recommended to increase the yield (15 to 25% increase in yield).

Organic nutrient management

Soil application of FYM @30 t ha^{-1} + vermicompost @ 20 q ha^{-1} + neem oil cake @ 8 q ha^{-1} resulted in 68% increase in yield over control with C:B ratio of 1:3.64. Also, soil application of inorganic N @150 kg ha^{-1} + *Azospirillum* @ 1.5 kg ha^{-1} + FYM @ 5 t ha^{-1} resulted in 35% increase in yield over control with C:B ratio of 1:5.27.

Fig 9: Organic farming plot of turmeric at Odisha

Drip irrigation

Application of water through drip system at 80% pan evaporation (once in a day for 45 minutes) with a total quantity of 538.40 ha mm increased yield by 10-15%.

Fig 10: Drip irrigation in turmeric

Intercropping

Intercropping with soybean maximises rhizome yield (17t/ha) and results in highest profit of Rs. 34000/- per ha and is recommended for Odisha (Pottangi).

Mixed cropping and border crops

Mixed cropping with chilli, colocasia, brinjal and cereals (maize and ragi) for Andhra Pradesh and chilli as a border crop in Tamil Nadu are recommended. A high return crop combination of turmeric + maize or turmeric + chilli or turmeric + castor was found beneficial.

Crop rotation

Rotating turmeric with maize (Tamil Nadu), maize or paddy (Andhra Pradesh and Odisha) and radish (Maharashtra) and sequential cropping i.e. turmeric-banana- sugarcane-turmeric, turmeric-banana-paddy-turmeric (Tamil Nadu) are recommended for increasing net returns per hectare.

Processing and production of quality dry turmeric

Drying of turmeric to reduce moisture up to 8-10% is recommended for storage.

Turmeric with papaya

Turmeric with maize

Turmeric with citrus

Turmeric with banana

Fig 11: Turmeric intercropping

Crop protection

Management of leaf blotch and leaf spot

Seed treatment as well as spraying with mancozeb + carbendazim (0.2% each) is recommended to manage both leaf blotch and leaf spot diseases.

Treating seed rhizomes with carbendazim, mancozeb and carbendazim (0.2%) for 60 minutes and shade drying before planting, spraying Bordeaux mixture (1%) or copper oxychloride or carbendazim (0.1%) or mancozeb (2.5 g/L) at 500 L/ha or captan (0.2 ml) at monthly intervals or foliar application of mancozeb-carbendazim (0.1%) are recommended to manage leaf blotch.

Treating seed rhizomes with azoxystrobin (0.1%) and spraying at 45, 75 and 105 DAP are recommended to manage leaf blotch with a low disease intensity of 15.48% and C:B ratio of 1:2.8. Also, treating rhizomes with carbendazim-mancozeb (1:1) (0.1%) and foliar sprays with carbendazim-mancozeb (0.1%) at 45 and 90 DAP managed leaf spot with a disease intensity of 13.64 % and C:B ratio of 1:2.8 in Chhattisgarh.

Treating rhizomes with mancozeb-carbendazim (0.1%) followed by foliar application of propiconazole (0.1%) at 40 days after planting and spraying mancozeb (2.5 g/L) at 15-20 days interval or copper oxychloride (0.25%) or bavistin (0.1%) or chlorothalonil (0.2%) or zineb (0.3%) or Bordeaux mixture (1%) are recommended to manage leaf spot.

Pre-planting treatment of rhizomes and foliar sprays of standing crop at 90, 105, 120 DAP with propiconazole (0.1%) are recommended for both leaf spot and leaf blotch control in Bihar.

Management of rhizome rot and wilt

Treating seed rhizomes with mancozeb (0.25%) or carbendazim (1%) for 30 minutes prior to storage and at the time planting and drenching infected plants/beds with copper oxychloride (0.3%) or mancozeb (0.3%) or Bordeaux mixture (1%) are recommended to reduce both rhizome rot and wilt.

Treating seed rhizomes as well as soil application of *Trichoderma viride* and *Pseudomonas fluorescens* @ 12.5 kg/ha and 25 kg/ha basal and top dressing, respectively along with application of recommended NPK and FYM are recommended to manage rhizome rot.

Management of storage rot

Treating the seed rhizomes with mancozeb (0.25%) or carbendazim (1%) reduces storage rot.

Management of rhizome scale

Seed dressing with quinalphos (0.075%) for 30 minutes before storage and also before sowing and spraying with *phosphamidon (0.05%) in field are recommended to reduce rhizome scale infestation.

Management of shoot borer

Spraying malathion (0.1%) or *monocrotophos (0.075%) or dimethoate or quinalphos during July to October at monthly intervals is recommended for shoot borer control.

Management of thrips

Spray of dimethoate (0.05%) or methyl dimethion (750 ml/ha) controls thrips.

Management of rhizome fly and maggot

Spraying quinalphos (0.02%) at 60 DAP is recommended to manage rhizome fly and maggot infestation.

Management of nematodes

Use of healthy nematode-free planting material, soil application of *aldicarb at 1 kg/ha twice (3rd and 5th month after planting) followed by irrigation and application @ 10-15 kg/ha at the time of field preparation are recommended to reduce nematode infestation.

Fig 12: A bumper harvest of turmeric

NUTMEG

Crop production

Application of 50 g each *of Azospirillum* (10^6 cfu) and Phosphobacteria (10^5 cfu) along with 400 g N, 350g P and 1200 g K/tree/year in two equal splits *viz*., May-June and October-November is recommended to maximise the yield. The recommended dose of biofertilizers need to be applied one month before the application of NPK when there is sufficient soil moisture.

Fig 13: View of nutmeg

CLOVE

Crop production

Application of 50g each *Azospirillum* (10^6 cfu) and Phosphobacteria (10^5 cfu) along with100 kg farmyard manure, 400 g N, 350g P and 1200 g K/tree/year in two equal splits during May-June and October-November is recommended to maximise green bud yield. The recommended dose of biofertilizer are to be applied one month before the application of NPK when there is sufficient moisture.

Providing drip irrigation @ 8 litres per day per plant is recommended to overcome moisture stress during summer months.

Crop production

Recommendations for sowing season and seed rate

Sowing the crop during October-November in North India for *Rabi* season is recommended. In Southern regions as summer crop, sowing may be undertaken during May and for *Rabi* crop, during October. The recommended seed rate is 14-16 kg/ha (RCr 41 and RCr 20), 12 kg/ha (RCr 436) for Rajasthan and 12-15 kg/ha for Andhra Pradesh. The optimum time of sowing recommended for Guntur is on 15th September.

State-wise recommendation for spacing

Gujarat: 40 x 15 cm or broadcasting.
Tamil Nadu: 15 x 15 cm.
Andhra Pradesh: 25 x 15 cm.
Uttar Pradesh: 30 x 10 cm.
Rajasthan: 30 x 10 cm.

Fig 14: Field view of coriander germplasm at Coimbatore

State-wise recommendation for fertilizers

Rajasthan: 10-20 t of well decomposed FYM, 60:30:40 kg NPK/ha and neem cake. FYM has to be applied at the time of field preparation and 20 kg N, 30 kg P and 20 kg K/ha at the time of sowing and the rest in two equal splits, one at the time of irrigation and second at flowering stage.

Application of N @ 60 kg/ha, in three equal splits i.e. basal, 30 and 60 days after sowing under irrigated conditions is also recommended.

Gujarat: 20 t FYM and 60:60:30 kg NPK/ha. N should be applied in two split doses as basal and at flower initiation stage and P as well as K as single basal dose during last ploughing.

Tamil Nadu: 10-15 t FYM and 20:40:40 kg NPK/ha.

Andhra Pradesh: 10-15 t FYM and 30:40:20 kg NPK/ha in single dose during last ploughing.

Bihar: 60:40:20 kg NPK/ha under irrigation in which, N to be applied in two equal splits at sowing and 60 DAS.

Uttar Pradesh: 60:30:30 kg NPK/ha.

Haryana: 60 kg N and 37.5 kg P/ha.

Foliar application of $MnSO_4$, $ZnSO_4$ and $CuSO_4$ each @ 0.50% and soil application of $FeSO_4$ @ 5 kg/ha or foliar application @ 0.125% is recommended to obtain higher seed yield in micronutrient deficient sandy loam soils. Foliar application should be done at pre-flowering stage. Soil application of $MnSO_4$ @ 25 kg/ha and $CuSO_4$ @ 0.5% and soil + foliar application of $FeSO_4$ @ 5 kg/ha + 0.125%, $MnSO_4$ @ 12.5 kg/ha and $CuSO_4$ @ 12.5 kg/ha +0.25% are also recommended.

Off-season leafy coriander

Planting coriander variety CS 11 during March-April under 50% agro-shade net is recommended to realize higher yield (4824 kg ha^{-1} with a yield increase of 25% over control) of physiologically matured leaf at 45 days after sowing. Application of 30:40:20 kg NPK per ha combined with spraying of GA (15 ppm) at 20 DAS is recommended.

Fig 15: Offseason production of coriander under shade net

Multi-cut coriander

Application of NPK as 60:30:00 kg ha^{-1} as full dose of phosphorus and half dose of nitrogen as basal as well as remaining half dose of nitrogen after first cut i.e. 40-45 DAS is recommended for obtaining maximum yield (18 q ha^{-1}) and C:B ratio (1:2.5).

For saline soils deficient in zinc (< 2 ppm), 0.5% zinc sulphate (2 sprays at 45 and 60 days after sowing) may be sprayed.

Treating the seeds with *Azotobacter* along with 50% of the recommended dose of nitrogen, application of FYM (50%) and vermicompost (50%) (Andhra Pradesh and Tamil Nadu) and soil application of inorganic N @ 33 kg/ha, *Azospirillum* @ 1.5 kg/ha and FYM @ 5 t/ha (Dholi) is recommended under organic package.

Soil application of Phosphate Solubilizing Bacteria (PSB) @ 15 kg ha^{-1} or *Azospirillum* @ 15 kg ha^{-1} along with NPK @ 60:40:30 kg ha^{-1} is recommended for improving productivity with yield enhancement of 47.6% and B:C ratio of 2.20 in Bihar.

Soil application of inorganic N @ 33 kg ha^{-1}, *Azospirillum* @ 1.5 kg ha^{-1} and FYM @ 5 t ha^{-1} is also recommended to realize higher yield (56% increase in yield over control) and C:B ratio of 1:1.77.

Weed management

Maintaining the crop free of weeds (manual weeding) up to the harvest stage is recommended to realize higher seed yield (9.14 q/ha) and higher net profit with a C:B ratio of 1:3.09.

Irrigation

In water deficit situation, only one irrigation with rain gun/sprinkler at flower initiation or two irrigations i.e. at flower initiation and grain filling stages are recommended to increase the yield by 20% compared to rainfed conditions.

Fertigation with water equal to 80% of actual evaporation (0.8 IW/CPE ratio) at an interval of 2-3 days with recommended dose of fertilizers through soluble fertilizers at different growth stages (20, 40, 60 and 80 DAS) are recommended for improving the yield and WUE in light textured soils. By adoption of this method, 18.7% water can be saved along with 45% increase in yield compared to conventional practice with a B:C ratio of 3.62.

Fig 16: Fertigation trial in coriander at Jobner

Harvesting

Plucking 50% of foliage when the crop is 60-75 days old was found economical in varieties PS 360, GAU 1, UD 354 as well as UD 3 and recommended for Rajasthan (Jobner).

In Gujarat, harvesting when 100% fruits turn to yellow colour in the whole plant is recommended to get significantly higher yield.

Crop protection

Management of wilt complex

Sowing in the first and second week of November, seed treatment with *Trichoderma viride* (formulation with CFU 10^6 @ 4 g/kg seed) and neem cake application @ 150 kg/ha following foliar spray of hexaconazole (0.05%), application of *T. viride* in combination with foliar spray of either hexaconazole or thiophanate methyl on 25, 40 and 55 DAS, cultivating resistant varieties *viz*., Co 3, Sadhana and Surabhi, adopting crop rotation, deep summer ploughing, using disease-free seeds, seed dressing as well as soil drenching with carbendazim (0.2%), seed dressing with 1.5 g carbendazim + 1.5 g thiram/kg seed and spraying twice with carbendazim (0.1%) and application of *Pseudomonas fluorescens* @ 10 kg/ha are recommended to manage wilt complex.

Management of stem gall

Selection of disease-free seeds, collection and destruction of affected plants, growing coriander variety RCr 41, seed treatment with *Agrosan GN/thiram (2.5 g/kg) or carbendazim (1 g/kg of seed), spraying Bayleton (0.4 ml/L of water) and repeating after 20 days, seed treatment with hexaconazole (0.2%) and propiconazole (0.2%) at 45, 60 and 75 days after sowing, seed

treatment with IISR *Pseudomonas* talc formulation @ 0.4% followed by its foliar sprays @ 0.4% at 40, 60 and 75 days after sowing are recommended for effective management of stem gall.

Fig 17: Stem gall infestation & Stem gall tolerant variety Hisar Bhumith

Management of powdery mildew

Two sprays with karathane 48 EC/carbendazim (0.01%) @ 250 liters at disease initiation and 10 days after with carbendazim (0.1%), two sprays with wettable sulphur (@ 2.5 g/L), once at the time of flower initiation and second spray 15 days later, dusting sulphur @ 25 kg/ha thrice, three foliar sprays with 5% onion leaf extract, spraying neem seed kernel extract (NSKE) @ 5% thrice, first spray immediately after the appearance of disease and the subsequent two sprays at 15 days interval and foliar spray of hexaconazole 5% SC (1 ml litre^{-1} of water) at the time of initial appearance of disease and second spray after 15 days interval (B:C ratio of 1:4.75) are recommended to manage powdery mildew.

Management of grain mould

Spraying carbendazim (0.2%) 20 days after flowering (grain formation stage and again at grain hardening stage) or captan (0.2%) twice, one at grain set and second at 15 days after first application is recommended for grain mould management.

Management of root rot

Drenching carbendazim (0.1%) twice, one at rot initiation stage and second at 20 days after first application is recommended.

Management of red mites

Foliar application of sulfex 3 g or dicofol 3 ml/L of water, 2-3 times at 10 days interval or spraying *monocrotophos/quinalphos (0.1%) at 15 days interval is recommended to manage red mite infestation.

Management of frost

Providing light irrigation in irrigated areas and spraying H_2SO_4 (0.1%) in rainfed areas as well as generating smoking around borders of the field manages frost damage.

Technology for application of PGPR

An eco friendly, seed coating technology in coriander, cumin, fennel and fenugreek using PGPR (FK 14 14 [*Pseudomonas putida*] & FL 18 *Microbacterium paraoxydans*] or combination of both) isolates was developed for increased yield (10-30%), enhanced seed germination, reduced storage pest incidence and suitable for mechanical sowing. It is a low cost technology which enhances seed quality and viability during storage. The farmers who adopted this technique are very much satisfied.

Coriander	Cumin	Fennel	Fenugreek

Fig 18: Encapsulation technology in seed spices

Fig 19: Nucleus seed production plot of coriander at Raigarh

Crop production

State-wise recommendation for sowing season

Gujarat: First week of November.
Rajasthan: 15 to 30th November.
Tamil Nadu: First fortnight of October.

State-wise recommendation for seed rate

Gujarat: 16-20 kg/ha.
Rajasthan: 12-15 kg/ha.
Tamil Nadu: 8-10 kg/ha.

State-wise recommendation for fertilizers

Gujarat: 30 kg N and 15 kg P/ha. Apply half N and full P and 10 t compost/FYM as basal dose and the balance N, a month after sowing as top dressing. NPK @ 25:20:20 kg/ha is also recommended.
Rajasthan: 30 kg N and 20 kg P/ha. Apply N in two splits at 30 and 60 DAS and full P as basal and10 t compost/FYM at the time of sowing.
Tamil Nadu: 70:60:40 kg NPK/ha. Apply 30 kg N, P and K as basal and the remaining N in two equal splits at 30 and 60 DAS.

Basal application of P @ 20 kg/ha and application of N as urea @ 30 kg per ha immediately after weeding when the crop is 30 days old is recommended for Jobner region. Application of 100% inorganic nitrogen and *Azospirillum* @ 1.5 kg/ha as seed treatment and 5 t FYM/ha resulted in highest seed yield (320 kg/ha) at Jobner.

Sulphur @ 45 kg/ha and foliar application of TGA, ascorbic acid and salicylic acid @ 100 ppm during vegetative and flowering stages is recommended for better yield.

Fertigation with water equal to 60% of actual evaporation (0.6 IW/CPE ratio) at an interval of 4 days and providing 80% recommended dose of fertilizers through soluble fertilizers at different growth stages (10, 20, 40, 50, 70 and 80 DAS) is recommended for improving the yield and WUE in light textured soils with 20% water saving and a B:C ratio of 1:1.5.

Fig 20: Dr. T. Janakiram, ADG (Hort. Sci.) with other seed spices scientists visiting fertigation trial of cumin at Jobner

Weed management

Planting distance of 15 cm, adopting seed rate of 8 kg/ha, application of 30 kg N/ha through broadcasting (in addition of 10 t/ha of FYM or compost/ha) in two equal splits at 30 and 60 days of crop growth and use of herbicides, terbutryn at 0.5 kg a.i./h or oxadizone at 0.5 kg a.i./ha or fluchloralin or pendimethalin at l kg a.i./ha to control the weeds are recommended.

Irrigation

Providing light irrigation after sowing and second irrigation at 8-10 days after germination and thereafter 3-5 times at 15-25 days interval is recommended.

Thinning

Plants must be thinned out to obtain a spacing of 12-15 cm in broadcast crop and 5 cm in line-sown crop during first weeding.

Crop rotation

Crop rotation for three years i.e., cluster bean-cumin-cluster bean-wheat-cluster bean - mustard is recommended to obtain high yield (257.59 q/ha) and to reduce wilt incidence.

Crop protection

Management of wilt

Use of healthy and disease free seeds, seed treatment with a mixture of carbendazim + captan (1:1) @ 4 g/kg of seed, carbendazim (0.1%) and *Trichoderma harzianum*, soaking the seeds

before sowing in water for 24 hours and pre-treatment with *Captaf/*Agrosan/*Difolatan/ bavistin/thiram @ 3 g/kg of seed, soil solarization during summer months and dry summer ploughing, organic amendments with neem cake @ 1 t/ha and soil application along with spraying of topsin (0.07%) or mancozeb (0.3%) and neem oil, growing wilt resistant variety *viz*., Gujarat Cumin 4 are recommended to manage wilt disease.

Soil application of vermi compost (2 t ha^{-1}), seed treatment with *Trichoderma* (6 g kg^{-1}) and spray of neem seed kernel extract (5%) are recommended for organic production and management of diseases like blight and wilt of cumin with C:B ratio of 1:2.29.

Fig 21: Field view of GC 4, wilt resistant variety of cumin

Management of blight disease

Prophylactic measures like seed dressing with carbendazim or captan (0.1%) as well as foliar application of mancozeb (0.2%)/carbendazim (0.1%) or copper oxychloride (0.1%) at the time of flowering followed by fortnightly intervals if there is rain or heavy dew are recommended to manage blight disease. Seed dressing with captan or thiram @ 2.5 g/kg seed followed by spraying with mancozeb @ 0.2% thrice at an interval of 15 days from 45 DAS is also recommended. Alternatively, spraying kresoxim methyl 44.3 SC (@ 1 ml L^{-1}), mancozeb 75% WP (@ 3.7 g L^{-1}) and difenaconazole 25 EC (@ 0.5 ml L^{-1}) at 40, 50 and 60 days after germination is also recommended for effective management of blight in cumin growing regions of Gujarat (21.32% PDI).

Management of powdery mildew

Adopting control measures at the initial stage of appearance of disease symptoms, such as dusting of sulphur @ 25 kg/ha or spray of 400-500 L/ha of wettable sulphur or Dinocap (0.25%) or karathane LC or *Calixin (0.05 to 0.1%) and repeating after 15-20 days commencing from 45 days after germination is recommended to manage powdery mildew.

Adopting line sowing @ 30 x 10 cm and application of potash @ 20 kg/ha along with recommended dose of fertilizers reduces the incidence of blight (PDI-17.3%) and powdery mildew (PDI-5.7%) with maximum yield (363 kg/ha) and C:B ratio of 1:2.41 in Gujarat.

Management of cumin aphid

Foliar spray with thiamethoxam 25WG (25 g a.i. ha^{-1}; 2.5 g 10 L^{-1} water) at 10% umbels infestation by aphids followed by spray of thiacloprid 21.7SC (25g a.i ha^{-1}; 2.88 g 10 L^{-1} water) after 10 days is recommended for aphid management in Gujarat.

PGPR technology

PGPR (FK 14 and FL 18) application is recommended for increasing the yield (10-30%), enhancing seed germination, seed quality and viability as well as reducing storage pest incidence which is also suitable for mechanical sowing.

Fig 22 : Field view of FLD cumin at Rajasthan

Crop production

State-wise recommendation for sowing season

Rajasthan: Depending upon prevailing climatic conditions, from 1st fortnight of October to mid-November for direct sowing. For transplanted crop, nursery should be raised during June and transplanting may be done during August/September.

Gujarat: For transplanted crop, nursery should be raised during first week of September and transplanting should be done during 2nd half of October and first fortnight of October for direct sowing.

Bihar: For *Rabi* crop (November), raise nursery during 1st week of September and transplant during first week of October.

Haryana: During first fortnight of October.

Sowing of HP 33 should be undertaken during first fortnight of October and PF 35 during third week of October at 30 X 20 cm spacing.

Nursery sowing:

Nursery should be raised during June-July for transplanting during August-September and September-October for transplanting in November.

Rabi: May-June (direct sowing), *Kharif:* October-November (transplanting) and rainfed (June-August).

Fig 23: Transplantation in fennel

State-wise recommendation for spacing

Rajasthan: 60 x 30 cm between the rows and 20 cm within the row.
Gujarat: *Rabi*: 45 x 10 cm and *Kharif*: 60 x 40 cm.
Haryana: 30 x 20 cm or 90 x 60 cm or 100 x 60 cm for transplanting seedlings.

State-wise recommendation for seed rate

Rajasthan: Direct sowing: 10-12 kg/ha, Transplanting: 3-4 kg/ha.
Gujarat: Direct sowing: 9-12 kg/ha, Transplanting: 3-5 kg/ha.
Haryana: Direct sowing: 9-12 kg/ha, Transplanting: 3-5 kg/ha.

State-wise recommendation for fertilizers

Gujarat: For *Rabi* crop, 90 kg N, 45 kg P, 20 kg K/ha and 25 t FYM (as basal dressing). N in 3 splits i.e. 50% N and P as basal, 25% N at 30 DAS and balance 25% at 60 DAS. 45 kg N and 30 kg P/ha as basal dose and 22.5 kg N and P/ha as second split at 30 DAS. After completion of weeding and thinning operations, 22.5 kg N and P/ha as second split at 60 DAS.
Rajasthan: For soils of poor fertility status, 40 kg P (as basal) and 90 kg N per ha. N should be applied in three equal split doses, at the time of sowing, 45 DAS and 120 DAS (flowering time).
Haryana: 50 kg N and 30 kg P/ha. N is applied in 3 splits, 50% as basal and at 30 and 60 DAS with irrigation.
Bihar: 60 kg N, 40 kg P and 20 kg K.
Uttar Pradesh: 60:50:10 kg NPK/ha. 15 kg N, 50 kg P/ha as basal dose followed by 15-30 kg N/ha as top dressing.

Application of RDF of 90 kg N and 30 kg P/ha along with 200 kg FYM enriched with 3 kg Fe + 1.5 kg Zn/ha as basal dose in furrow for light textured soils deficient in iron and zinc to obtain maximum yield (14.27 q/ha) with a B:C ratio of 2.11.

Fertigation with water equal to 80% of actual evaporation (0.8 IW/CPE ratio) at an interval of 2-3 days with 75% recommended dose of fertilizers through soluble fertilizers at different growth stages (20, 40, 60, 80 and 100 DAS) are recommended for improving the yield and WUE in light textured soils. By adopting this method, 25% fertilizer and 18.9% water can be saved along with 51% increase in yield as compared to conventional practice with a B:C ratio of 3.73.

Application of $ZnSO_4$ as foliar spray @ 0.50% or soil + foliar application @ 10 kg/ha + 0.25%, $FeSO_4$ as foliar application @ 0.25% or soil + foliar application @ 5 kg/ha + 0.125, $MnSO_4$ as foliar application @ 0.50% or soil + foliar application @ 12.5 kg/ha + 0.25% and $CuSO_4$ as foliar application @ 0.50% to realize higher seed yield in micronutrient deficient sandy loam soils. Foliar application should be done at flowering stage.
Picking of umbels at fully matured green stage i.e. before turning yellow is ideal to obtain optimum returns.

Weed management

Keeping the field weed free up to harvest stage is recommended to obtain maximum yield with higher net profit and a C:B ratio of 1:3.35.

Pre-emergent weedicide pendimethalin @ 1 kg/ha and adoption of one hand weeding at 50 DAS is recommended for effective management of weeds.

Intercropping

Cultivation of potato, tomato and cauliflower as intercrops is recommended for highest net returns from unit area.

Micro irrigation

Apply irrigation water by drip at 0.8% IW/CPE ratio on alternate days with paired row planting for increased seed yield and along with 19% saving irrigation water in comparison to surface irrigation.

Crop protection

Management of powdery mildew

Spraying of karathane (0.1%) or wettable sulphur (0.25%) once at flower initiation stage and another after 15 days (500-800 L) and also dusting with sulphur 300 mesh (20-25 kg/ha) are recommended to manage the disease.

Management of sugary disease

Spraying of *phosphamidon (0.2%) or dimethoate (Rogor) (0.33%) or quinalphos/*DDVP @ 0.05% at 15 days interval (3 sprays) commencing from 50% emergence of flowering is recommended to check aphids that spread the disease.

Management of *Ramularia* and *Alternaria*

Spraying of carbendazim (0.1%) or mancozeb (0.2%) or any copper fungicides (500-800 L/ha) twice at 60 and 90 DAS (500-800 L/ha) is recommended.

Management of stem and root rot

Treating the seeds with carbendazim @ 2g/kg of seed is recommended.

Management of frost

Spraying 0.1% solution of sulphuric acid and irrigating the crop prior to the incidence of frost and creating smoke cover at early morning before sunshine are recommended.

Management of seed midge of fennel

Two foliar sprays with acetamiprid 0.004% (2 g/10 L water; 20 g a.i. /ha) or thiamethoxam 0.0084% (3.36 g/10 L water; 42 g a.i. /ha) is recommended. First foliar spray should be done at

appearance of seed midge damage and subsequent sprays should be carried out 10 days after first spray.

PGPR technology

Seed pelletizing with IISR PGPR strains either FK 14 [*Pseudomonas putida*] or FL18 [*Macrobacterium paraoxydans*] or combination of both for better growth and yield.

Fig 24: Fennel flowering at Haryana

Crop production

State-wise recommendation for seed rate

Rajasthan, Gujarat, Bihar: 20-25 kg/ha.
Uttar Pradesh: 15-20 kg/ha.
Andhra Pradesh: 30 kg/ha.

State-wise recommendation for sowing season

Rajasthan: 1st week of October to last week of November.
Gujarat: Last week of September to 1st week of October.
Bihar: Middle of October.
Uttar Pradesh: October to November.
Tamil Nadu: First week of October.
Haryana: Middle of October to November.
Andhra Pradesh: First week of October.

State-wise recommendation for spacing

Rajasthan: 25 x 10 cm.
Gujarat: 15 x 10 or 30 x 10 cm.
Bihar: 20 x 10 cm.
Uttar Pradesh: 30 x 10 cm.
Tamil Nadu: 15 x 10 cm or 22.5 x 10 cm.
Haryana: 30 x 10 cm.

An optimum sowing period of first fortnight of November, a row spacing of 20 or 30 cm, a water requirement at IW/CPE ratio of 1:0 and application of 65 kg P/ha are recommended for high yields under Rajasthan conditions. Sowing by 15th October at a spacing 30 X 30cm was found economical at Dholi. Sowing the variety, Hisar Sonali during first week of November at a spacing of 30 x 10 cm is recommended for seed production under Hisar conditions. Irrigation should be given immediately after sowing. The crop requires 6-7 irrigations in light soil and 4-5 irrigations in heavy soil and the irrigation should be given at 30, 70, 90 and 110 DAS.

Irrigation

Application of irrigation water by drip at 0.6% IW/CPE ratio on alternative days with paired row planting resulted in saving 35% irrigation water in comparison to surface irrigation and resulted in higher seed yield.

Weed management

Application of fluchloralin @ 0.75 kg/ha, supplemented with one hand weeding is recommended for higher seed yield (1.65 t/ha), with a C:B ratio of 1:3.79.

Fig 25: Fertigation in fenugreek

State-wise recommendation for fertilizer

Rajasthan: 10 t FYM at the time of field preparation. 40 kg N, 40 kg P (20 kg N and 40 kg P/ha at the time of sowing).
Gujarat: 40 kg N, 40 kg P and 25 kg S/ha in two equal splits as basal and top dressing.
Bihar: 40 kg N, 60 kg P and 20 kg K.
Uttar Pradesh: 60:50:10 kg NPK/ha.
Tamil Nadu: 50 kg N, 25 kg P and 40 kg K/ha.
Andhra Pradesh: 10 t FYM, 30 kg N, 40 kg P and 20 kg K/ha as basal dose.

Application of 40 kg N and 40 kg P/ha and seed treatment with *Rhizobium meliloti* are recommended for general adoption at Jobner. Sowing the variety, RMt 1 by last week of October and UM 305 up to 15th November at 25-30cm row spacing is recommended to realize higher seed yield in semi-arid region like Jobner.

Integrated nutrient management methods including soil application of inorganic N @ 13 kg/ha + *Azospirillum* @ 1.5 kg/ha + FYM @ 5 t/ha, seed treatment with IISR rhizobacterial strain (FL 18) @ 20 g/kg seed and seed pelletizing with IISR PGPR strains either FK 14 [*Pseudomonas putida*] or FL 18 [*Macrobacterium paraoxydans*] or combination of both are recommended for increasing germination percentage and subsequent nutrient mobilization.

Crop protection

Management of root rot

Soaking the seeds in water for 6-8 hours and treating with bavistin or *Agrosan GN or thiram @ 3 g/kg seed before sowing is helpful in reducing root rot.

Seed treatment with thiram or captan @ 2 to 3 g/kg seed, application of neem cake @ 150 kg/ha combined with seed pelleting with *Trichoderma viride* and *T. harzianum* (CFU 10^6, talc formulation 4 g/kg of seed) followed by soil application of neem cake 150 kg/ha, drenching carbendazim (0.1%) once at initial appearance and after one month and deep summer ploughing of field and adoption of crop notation are recommended to manage root rot.

Management of powdery mildew

Dusting 300 mesh sulphur (25 kg/ha) or by two spraying with wettable sulphur @ 3 g/L or Dinocap (0.25%) or karathane L.C. (0.1%) twice at flowering stage and 15 days interval commencing from 40 DAS or spraying Dinocap or karathane (0.1%) @ 400-500 L/ha is recommended to manage powdery mildew.

Management of downy mildew

Spraying 400-500 litres Blitox/*Difolatan/Phytolan (0.25%) and repeating spray after 10 days (if needed) or spraying (@ 3 g/L) at 15 days interval is recommended for effective management of downy mildew.

Fig 26: Screening for disease tolerance in fenugreek germplasm at Gujarat

Management of damping off

Spraying carbendazim (@ 1 g/L) and cultural operations like crop rotation and removal of diseased plants is recommended to reduce damping off incidence. Seed treatment with *benomyl (@ 3 g/kg seed) or carbendazim (@ 3 g/kg seed) is also recommended for reducing seedling mortality.

Management of rust disease

Adopting good cultural operations, field sanitation and spray of mancozeb (0.2%) and Bayleton (0.05%) are recommended to manage rust under field conditions.

Management of aphids

Spraying dimethoate (0.3%) or *phosphamidon (0.33%) or malathion (1%) @ 400-500 L per ha is recommended to control aphids.

Management of leaf eating caterpillar and pod borers

Spraying with quinalphos (0.05%) or *monocrotophos (0.04%) is recommended to manage leaf eating caterpillar and pod borers.

* Agrosan, aldicarb, benomyl, calixin, Captaf, captafol, DDVP, difolatan, endosulfan, fenthion, monocrotophos, paraquat, phorate and phosphamidon.

These chemicals fall under the categories of pesticides which are banned or refused registration or to be phased out and restricted for use in India.

Fig 27: Demonstration of fenugreek disease tolerant variety HM 257 at Hisar

Epilogue

Spices are the most valuable group of horticultural crops, providing livelihood to millions of people in the country. India is the largest producer, consumer and exporter of spices. The ICAR-AICRP (Spices) centres were entrusted with a mandate to conduct research on the crop improvement, crop production, and crop protection aspects of mandate spice crops. The research effort has resulted in the generation of appropriate technologies for different agro-climatic regions. These technologies have been effectively disseminated to stakeholders by the transfer of technology network of the State Agricultural Universities and State Departments of Horticulture and Agriculture. ICAR- AICRPS technologies have also percolated to the remote and inaccessible tribal lands of Chintapalli in Andhra Pradesh, Pottangi in Odisha, Raigarh in Chhattisgarh and NE states providing employment opportunities (especially women) and uplifting the economic status of farmers. Also, expanded the production of spices especially turmeric, ginger and black pepper in these non-traditional areas of cultivation. Thus, ICAR-AICRP on Spices is achieving the goal of improving crop productivity and thus helping all the stakeholders involved in the growth of spice industry in the country.

Media plays an important role to disseminate information about new technologies and varieties to the farmers and other industrial beneficiaries. The centres of ICAR-AICRPS covering 24 states are undertaking many farmer-friendly training programmes, frontline demonstrations and other extension activities. Wide coverage is being given by the media for all the programmes and activities undertaken by the centres.

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Certificate

CHAUDHARY DEVI LAL OUTSTANDING ALL INDIA COORDINATED RESEARCH PROJECT AWARD-2017

(For Best All India Coordinated Research Project)

is presented to

All India Coordinated Research Project on Spices

Kozhikode, Kerala

16 July, 2018
New Delhi

(T. Mohapatra)
Secretary (DARE) &
Director General (ICAR)

(Radha Mohan Singh)
Minister of Agriculture & Farmers Welfare
Govt. of India

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