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# Nutrient management in spices


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ICAR-Indian Institute of Spices Research
Kozhikode – 673 012, Kerala

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# Nutrient management in Spices


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# Preface

Spices hold an important place in the cultural, culinary, and economic realm, particularly in India, which is recognized as the land of spices. These high-value crops not only contribute significantly to national and global trade but also support the livelihoods of farmers including millions of small and marginal farmers. However, the yield potential and quality of spice crops are often limited by suboptimal soil fertility and imbalanced nutrient management practices.

Efficient nutrient management is essential to harness the maximum productivity of spice crops while maintaining soil health and ensuring sustainability. With the increasing challenges of climate change, land degradation, and nutrient depletion, there is an urgent need to adopt scientifically validated and crop-specific nutrient management strategies.

This technical bulletin aims to provide a comprehensive overview of the nutrient requirements and best management practices for major spice crops such as black pepper, ginger, turmeric, cardamom, nutmeg, clove, and cinnamon. It covers the physiological basis of nutrient uptake, critical growth stages, recommended fertilizer schedules, foliar nutrition, and organic inputs, along with insights into emerging trends like site-specific nutrient management and integrated nutrient management (INM).

The information presented is based on the latest research findings, field-level experiences, and recommendations from leading institutions working in the domain of spices. We hope that this bulletin will serve as a practical guide for researchers, extension personnel, progressive farmers, and policymakers striving to enhance the productivity, quality, and sustainability of spice cultivation.

We gratefully acknowledge the contributions of fellow scientists, field staff, and farmers whose experiences and feedback have enriched the content of this publication. We welcome constructive suggestions and insights from readers to further improve future editions.

Authors

Date: 1st July 2025

Place: ICAR-IISR, Kozhikode

# NUTRIENT MANAGEMENT IN SPICES

## 1. Introduction

India is renowned for its diverse range of spices, which thrive in a variety of soil types and climatic conditions across the country. The country's topography, combined with its rich agricultural traditions, contributes to the cultivation of spices such as black pepper, cardamom, ginger, turmeric, and tree spices such as nutmeg and cinnamon. Soil fertility plays an important role in spice cultivation. Spices generally thrive in soils with good drainage and adequate organic matter content. The ideal pH for many spice crops ranges from 6.0 to 7.5, allowing for optimal nutrient availability. The major spice-growing regions in India include Kerala, Karnataka, Tamil Nadu, and Andhra Pradesh, each with unique soil properties and characteristics. For instance, the Western Ghats of Kerala and Karnataka are known for their rich, lateritic soils, which are well-drained and rich in organic matter, making them ideal for crops like pepper, ginger, turmeric and cardamom. In contrast, the alluvial soils of the Indo-Gangetic Plain provide fertile conditions for growing spices such as ginger, turmeric, coriander and cumin. Nutrients such as nitrogen, phosphorus, potassium, and essential micronutrients are crucial for healthy plant growth and development. Therefore, regular soil testing and nutrient management practices are essential to address any deficiencies and improve the soil health. Additionally, the impact of climate on soil conditions cannot be overlooked. Monsoonal rains can lead to leaching of nutrients, while dry spells may affect soil moisture levels and nutrient solubility and transport. Implementing sustainable practices, such as crop rotation, cover cropping, and organic amendments, can help maintain soil fertility and improve resilience to climate variability.

Nutrient management is a strategic approach to optimize the use of nutrients in agricultural systems to enhance crop production while minimizing the environmental impact. It involves careful planning and application of fertilizers, organic amendments, and soil amendments based on soil test results, crop needs, climatic and environmental conditions. Effective nutrient management practices aim to improve soil health, increase crop yields, and reduce nutrient runoff into water bodies, thereby mitigating issues like eutrophication. By integrating scientific knowledge, technology, and sustainable practices, nutrient management promotes economic viability for farmers while supporting ecosystem integrity and food security. This bulletin covers the nutrient management aspects of spice crops such as black pepper, ginger, turmeric, cardamom, nutmeg, and clove.

## 2. Soil health and nutrient constraints in spice growing soils

Soil is a vital component of agricultural ecosystems, acting as a medium for plant growth, a reservoir of nutrients, and a habitat for various organisms. The composition of soil comprising minerals, organic matter, water, and air, plays a crucial role in spice cultivation.

## 2.1. Soil Components

- **Mineral particles**: These include sand, silt, and clay, which influence soil texture, drainage, and nutrient retention. Sandy soils drain quickly but may lack nutrients, while clay soils retain moisture but can become compacted limiting root growth.
- **Organic matter**: Composed of decomposed plant and animal materials, organic matter enhances soil structure, fertility, and moisture retention. It also supports beneficial microbial activity, which is essential for nutrient cycling.
- **Soil water**: Adequate moisture is essential for spice crops. Water availability influences nutrient uptake and overall plant health.
- **Soil air**: The exchange of gases in the soil is crucial for root respiration and microbial activity. Poorly aerated soils can hinder growth and lead to root diseases.

## 2.2. Soil related constraints in spice cultivation

### Soil erosion

The main constraints faced in the potential zones for spices are steep sloping landform leading to excessive erosion, risk of water logging in down slope areas during heavy monsoon periods and acidic soils due to heavy leaching of bases from soil leading to low soil fertility status. The extent of soil erosion in spice growing tracts i.e. Western Ghats, Coastal and NEH region ranges from 20-80 t $ha^{-1}$ $yr^{-1}$, and it is rated to be very severe, affecting approximately 2.4 lakh $km^2$ area in these regions. Adopting soil and water conservation measures like terracing and bunding to reduce the degree and length of the slope and to reduce erosion is the primary measure. Soil erosion and associated nutrient losses is a serious issue in the humid tropics, more so in ginger and turmeric as the soil is constantly disturbed for cultural operations without much conservation measures where, substantial amount of soil and nutrients will be removed through the runoff water.

### Low fertility

The major reasons for low productivity of spices are low soil pH, high clay and low sand content, low CEC, low base saturation, low status of organic carbon, K, Ca, Mg and Zn. Use of low level of inputs like manures and fertilizers, crop protection chemicals and crop loss due to diseases add to the farmer's distress. Unlike most other spices, pepper and cardamom are perennial crops and the utilization pattern of nutrients over several years, could be uniquely different. Also, black pepper and cardamom are grown widely under coastal or moist humid tropics/forest eco systems where the rainfall is very high, and thus leaching of applied nutrients and bases is a major constraint. Except widely adapted



turmeric and seed spices, which are grown in wide range of pH varying from 5.0 to 7.5, all the other major spices are grown in slightly acidic soils which are being grouped under red loams or laterites. These soils are generally deficient in available P, Ca, Mg, Zn, B and with low CEC.

### Imbalanced/ No fertilizer application

Initial survey in spice growing areas of Kerala showed that 57% of the samples collected were low in P and 52% of soil collected from Karnataka and 9% sample collected from Kerala are deficient in K. Among micronutrients, deficiency of Zn is more predominant in acid soils of India with highest deficiency rate of 57% in acid soils of Meghalaya followed by Jharkhand, Odisha and West Bengal (23-54%). Studies at Kozhikode and Wayanad districts, the main spice growing areas of Kerala, showed an alarming trend of nutrient imbalances. Soils (representing 26 panchayats) were generally acidic with >70% of samples falling below pH 6.0. The mean available P level was 114.35 ± 83 kg $ha^{-1}$ and 9% of the samples had high (25-35 kg $ha^{-1}$), 30% had very high (36-100 kg $ha^{-1}$) and 25% of the soils recorded extremely high (> 100 kg $ha^{-1}$) available P. The exchangeable K levels were low to medium (69%) and 38% of samples were low in exchangeable Ca. A major percentage of the samples were low in exchangeable Mg (44% low and 13% very low), available S (29%), B (32%) and Zn (29%). Relatively excess/ indiscriminate and long-term use of N & P straight fertilizers, which are generally free from micronutrients, ignoring potential soil amelioration with liming materials, has raised concern about preferential building up of P and imbalance of other nutrients, and created wide spread deficiencies of secondary and micronutrients especially Mg, B and Zn in major spice growing soils. The alleviation of such deficiency by use of corrective soil amendments and micronutrient fertilizers is also limited due to non-availability of standard fertilizer materials and its awareness by farmers. Efforts to correct this imbalance have to be made through promotion of site-specific nutrient management taking into consideration the initial soil fertility status.

The major soils of cardamom growing tracts come under alfisols, derived from schists, granite and gneiss and are lateritic. Soils most suited for cardamom are red lateritic loam with layers of organic debris present in evergreen forests, although it grows on a variety of soils with only a shallow zone of humus accumulation. In general, cardamom-growing soils are fairly deep having good drainage. The clay fraction is predominantly kaolinitic and hence there is some fixation of potassium in these soils. The cardamom-growing soils of Karnataka are mostly clay loam.

Ginger adapts widely to different soils. Maximum ginger yield was realized in soils with moderate acidity (pH 5.7) and high organic matter (1.1%) content. Higher yield requires well drained and deep friable soils. In India, ginger is gown on sandy loams, clay loams and laterite soils, but virgin forest soils rich in fertility are ideal. Generally large-scale cultivation of ginger is practiced in high range laterites of Kerala and North Eastern states.

Turmeric can be cultivated in most areas of the tropics and subtropics provided the rainfall is adequate or facilities for irrigation are available. As it requires a hot and moist climate, it is usually grown in regions with an annual rainfall of 1000 to 2000 mm. Turmeric thrives best on loamy or alluvial, loose, friable, fertile soils and cannot stand water logging. Well-drained sandy or clayey loam or red loamy soils having acidic to slightly alkaline soil is ideal for its cultivation.

## 3. Nutrient assessment

Continuous nutrient uptake by crops leads to the gradual depletion of essential elements in the soil. Unlike living organisms, nutrient depletion in soil cannot be easily detected through visual examination. To assess the nutrient status of the soil, a representative soil sample is typically collected and sent to a laboratory for detailed analysis. While soil test kits are available for on-site testing, their results tend to be less precise due to their reliance on colorimetric observations, which can be subjective. Another method for evaluating soil fertility involves analyzing nutrient levels in index leaves of crops, which provide a good indication of the soil's nutrient supplying power. Additionally, the identification of deficiency symptoms on plant leaves can offer valuable clues about the nutrient status of the soil, though this method may be less reliable and specific than laboratory-based tests.

### 3.1. Soil testing

Soil testing is the most efficient method for assessing the soil fertility levels. It is used for suggesting fertiliser recommendation to the crops, predicting response of crops to applied nutrients and to assess the soil problems such as acidity, salinity and sodicity.

#### Soil sampling

Soil sampling is to be carriedout with proper planning. Since soil testing is done on a small fraction of soil, it is important to make sure that the soil collected is of representative to the area being sampled. Sampling for soil testing is to be undertaken to assess the suitability of land for spices before cultivation. Periodic assessment of soil fertility also required for judicious fertiliser application, by sampling in existing fields.

#### Selection of sampling unit

On reaching the site, conduct a visual survey by walking in the field and by observing variation with respect to slope, colour, texture, cropping pattern and management practices. If all these aspects are similar, one field can be considered as one sample unit. Separate samples are required for areas differing in each of these characteristics. However, in any case, one sample is required for every 1 to 2 hectares. Areas such as recently fertilised plots, bunds, channels, near wells and compost pits etc. are to be avoided while sampling. To increase the accuracy, large areas may be subdivided into more number of smaller units based on the availability of resources.



#### Depth and time of soil sampling for spices

The ideal depth for soil sampling varies depending on the root zone of the spice crop being grown, but generally, samples should be taken from the top 0-15 cm and 15-30 cm of soil for most spice crops like black pepper, cardamom, ginger and turmeric. For deep-rooted tree spices like nutmeg, clove and cinnamon, sampling might extend deeper, up to 45-60 cm.

The frequency of soil sampling depends on the crop's growth cycle and the management practices in place, but it is typically done at least once a year or before planting seasons to evaluate the nutrient status and make necessary adjustments to fertilizers or soil amendments. If significant changes in plant health or growth are noticed, additional sampling may be necessary to address nutrient imbalances.

#### How and where to sample

By traversing the area, decide the number of units to be sampled. For each uniform area, 10-15 sub-samples are to be collected, by traversing the field in a zigzag manner. These sub-samples can be mixed to make one composite sample per unit. While mixing care should be taken to mix the respective depths. Before taking samples, remove the debris and litter on the soil surface. The soil sampling can be performed using an auger which permits easy sampling from different depths, compared to the use of the spade. If the auger is not available a GI pipe can be used for sampling purpose.

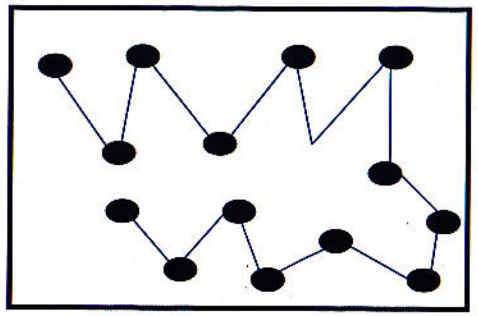

**Fig. 1.** Zigzag/crisscross pattern for soil sampling

If the farmer is interested in only surface soil sample analysis, a V-shaped cut is made in soil, and soil samples are drawn in a thin slice (1.5-2.5 cm) from top to bottom to the depth range desired (0-30 or 0-15 cm). Subsamples are drawn from all the sites marked to make a composite sample.

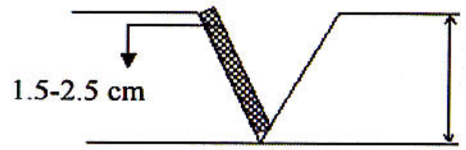


**Fig. 2.** Method of taking surface soil samples

For tree spices, the sampling is done at the drip line of the canopy, where fertilizer is applied. For black pepper, the sampling is to be drawn 30 cm away from the vine base. For crops like ginger and turmeric, sampling is done as per the methods suggested above, before the land preparation.

### Mixing, quartering and storage

The mixing of subsamples to make composite samples can be done by quartering method to reduce sample size to about 500 g. For this, thoroughly mix all the subsamples, taking care to mix respective depthwise spread on paper or cloth, remove large stones and pieces of roots, make four quarters and discard the opposite quarters. This process can be continued till getting a suitable quantity.

**Fig. 3.** Quartering method for sample size reduction

Transfer soil to a clean polythene or cloth bag. Place label indicating the name of the farmer, depth of sampling, field identification details, date of sampling both inside and outside the sample bag. Send these samples immediately to nearby soil testing laboratory, along with sample information, parameters to be tested, crops to be grown for which fertilizer recommendation is required and analysis fees. If samples are to be sent later, make sure to dry samples under shade by spreading on paper, for 2-3 days.

### Soil testing and soil health card

In the laboratory, soil samples are subjected to various analyses. The parameters tested are soil pH (as a measure of soil acidity/alkalinity), electrical conductivity (to know salinity status of soil), organic carbon, major nutrients such as available nitrogen, available phosphorus and available potassium, secondary nutrients such as calcium, magnesium, and sulphur, and micronutrients such as iron, manganese, zinc, copper, boron and molybdenum. If the soil pH is less than 5.5, it is better to test for lime requirement. The soil test laboratories provide the results in the form of report or soil health cards. The soil health cards contain the information such as nutrient content in soil and its rating. It may also contain the rate of fertiliser to be applied and application methods or guidelines for getting the fertiliser recommendations.

### 3.2. Nutrient deficiency symptoms

Nutrient deficiency symptoms in plants manifest as visible changes in growth and appearance, which help to identify specific nutrient deficiencies. For example, nitrogen deficiency typically results in yellowing of older leaves (chlorosis) due to reduced chlorophyll production, while phosphorus deficiency causes stunted growth and purpling of leaves. Potassium deficiency often leads to browning and yellowing at the leaf edges, particularly in older leaves, and can also cause weak stems. Micronutrient deficiencies, such as iron, manifest as interveinal chlorosis (yellowing between veins) in young leaves, while magnesium deficiency may show as yellowing between leaf veins with small necrotic spots. Calcium deficiency often results in distorted or dead tissue at the growing tips or root tips, while sulfur deficiency causes yellowing of younger leaves. Identifying these symptoms early allows for targeted interventions to correct nutrient imbalances and ensure healthy plant growth.

**Table 1. Deficiency symptoms of plant nutrients**

| Element | Deficiency symptoms |
|---|---|
| N | Uniform yellowing localized in older leaves followed by necrosis. Reduction in root shoots growth and leaf area. The older leaves first lose their green colour, becoming somewhat yellowish. |
| P | Purple to bronze yellowing with ash coloured necrotic areas. Reduction in root growth. |
| K | Marginal necrosis that progress to major distal portion of the lamina. Marked reduction in the foliar K content.A |
| Ca | Appearance of tiny brown necrotic pinhead spots over chlorotic area near leaf margins in young leaves. This is followed by interveinal chlorosis and die-back of shoot tips. The growing points of the plant become stunted. |
| Mg | Interveinal chlorosis of older leaves at first which gradually spreads towards the middle portion. Pale yellow discoloration of the leaf margins and tips occur at later stage. The major veins remain green and laterals turn yellow. Necrosis and defoliation also occur. |
| B | Death of growing points of shoot and root. Failure of flower buds to develop. Blackening and death of tissues, especially inner tissue of brassica plants. |
| Cl | Reduced leaf size, yellowing, bronzing and necrosis on leaves. Roots reduced in growth and without hairs |
| Cu | Yellowing of young leaves. Rolling and dieback of leaf tips. Leaves are small. Tillering is retarded. Growth is stunted. |
| Fe | Interveinal yellowing of younger leaves with distinct green veins. Entire leaves become dark yellow or white with severe deficiency, and leaf borders turn brown and die. |
| Mn | Interveinal tissue becomes light green with veins and surrounding tissue remaining green on dicots (Christmas tree design) and long interveinal leaf streaks on cereals. Develop necrosis in advanced stages. |
| Mo | Mottled pale appearance in young leaves. Bleaching and withering of leaves and sometimes tip death. Legumes suffering Mo deficiency have pale green to yellowish leaves. Growth stunted. Seed production is poor. |
| Zn | Deep yellowing of whorl leaves (cereals). Dwarfing (rosette) and yellowing of growing points of leaves and roots (dicots). Rusting in strip on older leaves with yellowing in mature leaves. Leaf size reduced. Main vein of leaf or vascular bundle tissue becomes silver-white, and marked stripes appear in middle of leaf. |

The deficiency symptoms in some of the spice crops are given below.

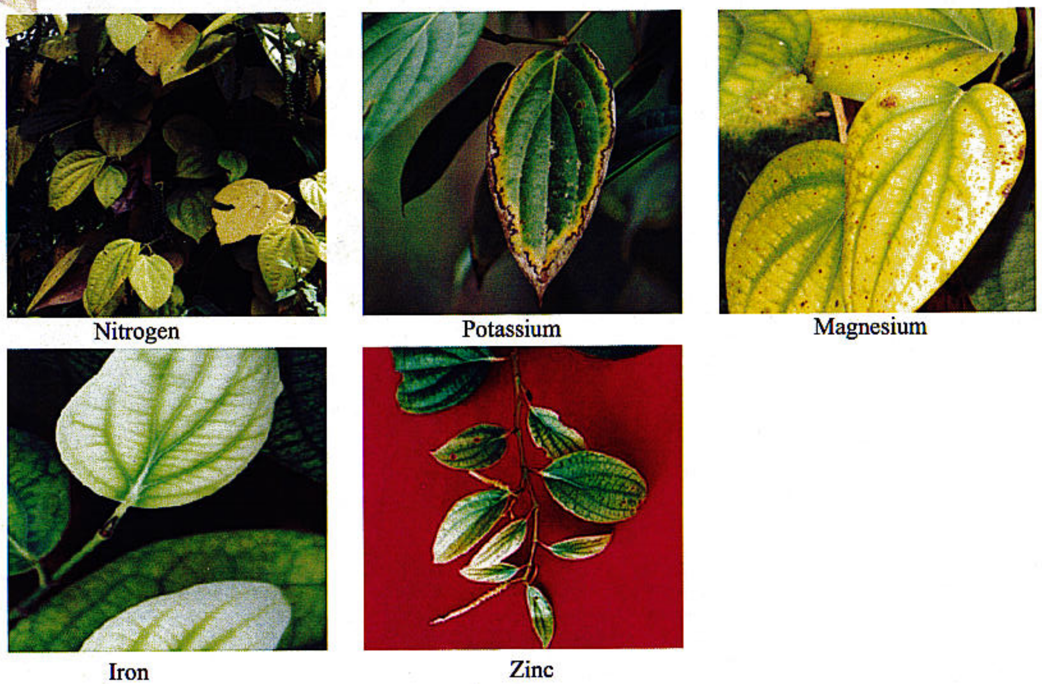


**Fig. 4. Symptoms of nutrient deficiency in Black pepper**

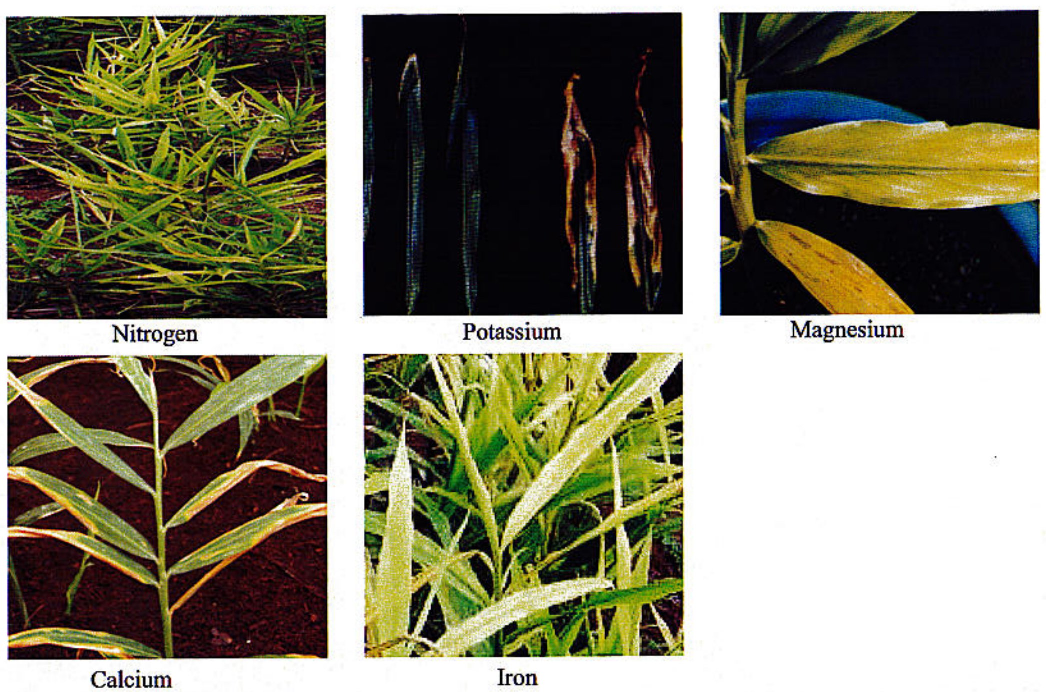


**Fig. 5. Symptoms of nutrient deficiency in Ginger**




**Fig. 6. Symptoms of nutrient deficiency in Turmeric**

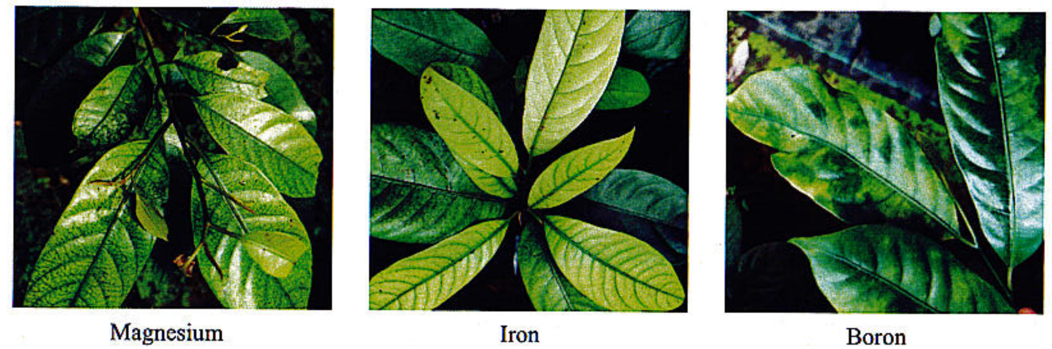


**Fig. 7. Symptoms of nutrient deficiency in Nutmeg**

### 3.3. Leaf sampling, analysis and interpretation

Leaf analysis is the quickest way to assess the nutrient supplying power of the soil. However, the usefulness of leaf analysis depends upon the correctness of leaf sampling. So utmost care should be exercised while collecting leaves for analysis. Leaf analysis offers to monitor the plant nutrition throughout the growing season and enables to modify the nutrient through soil, foliar application or through fertigation.

#### Stage of leaf and time of sampling in spices

The table given below indicates the stage of leaf and time of sampling in different spice crops.

Table 2. Leaf sampling guidelines for major spice crops

| Sl.No. | Crop | Sampling leaf and stage |
|---|---|---|
| 1 | Black pepper | Youngest mature leaf from fruiting lateral adjacent to the spike, from all around the pepper vines |
| 2 | Ginger | Fifth pair of leaf from top to bottom |
| 3 | Turmeric | Third leaf from top to bottom |
| 4 | Cardamom | Youngest mature leaf 5th pair from tillers at panicle initiation stage of growth |
| 5 | Nutmeg | Youngest mature leaf (leaves from the upper canopy, preferably those that are about 6 to 12 months old) |
| 6 | Clove | Youngest mature leaf |
| 7 | Cinnamon | Youngest mature leaf |
| 8 | Vanilla | Youngest mature, healthy leaves of the current season growth that are typically about 6 to 8 months old |
| 9 | Garcinia | Fully mature healthy leaves from the upper canopy, ideally those that are around 6 to 12 months old |
| 10 | Paprika | Youngest mature leaf that are about 6 to 8 weeks old after transplanting |

### Precautions in leaf sampling

- Do not sample, when the leaves are soiled or covered with dust.
- **Select healthy leaves**: Choose leaves that are green and free from signs of disease, pest damage, or stress.
- **Avoid young and old leaves**: Do not sample young, immature leaves or older leaves that may be yellowing or senescent, as these may not accurately reflect the nutrient status of the plant.
- **Take multiple samples**: For a comprehensive analysis, collect leaves from multiple plants within the same field to account for variability. Aim for about **10-15 leaves** from different plants in various locations.



- **Label the samples**: Clearly label each sample with the date, location, and any relevant details about the plants or field conditions.
- **Transport to the laboratory**: Keep the samples cool and dry during transport to the laboratory to prevent deterioration.

Enclose the collected leaves in paper bags and send immediately to soil and leaf analysis laboratory along with information such as the name of the farmer, location, the age of the tree, collection date, and the parameters to be tested etc. The sample have to be oven dried at 60 °C after washing with 0.2% detergent solution, 0.1 N HCl. Final washing is to be done with double distilled water before oven drying.

### Interpretation of plant analysis results

In the laboratory, plant samples are subjected to acid digestion and analysis for essential nutrient content. These contents are compared with critical nutrient concentration. The critical nutrient concentration is the level of nutrient in plant part below which yields are not satisfactory.

## 4. Nutrient management in spices

### 4.1. Nutrient removal

For sustainable production and yield of spice crops, the nutrient removal from soil need to be compensated through application of fertilisers. The nutrient removal by different spice crops is given in the table given below.

Table 3. Nutrient removal by different spices crops

| Crop* | Av. yield (dry) kg/ha | Uptake (kg/ha) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N | $P_2O_5$ | $K_2O$ | Ca | Mg | Fe | Mn | Zn | Cu |
| Pepper | 2000 | 42.0 | 7.0 | 40.0 | 6.4 | 3.9 | 0.09 | 0.10 | 0.04 | 0.03 |
| Cardamom | 450 | 6.0 | 2.1 | 16.8 | 3.4 | 1.2 | 0.10 | 0.16 | 0.03 | 0.006 |
| Ginger | 4800 | 170.0 | 30.0 | 132.0 | 8.6 | 9.1 | 1.8 | 0.5 | 0.13 | 0.04 |
| Turmeric | 5300 | 135.0 | 43.0 | 215.0 | 10.1 | 16.0 | 1.2 | 0.8 | 0.24 | 0.05 |
| Clove | 275 | 3.1 | 1.0 | 2.8 | 3.3 | 0.8 | 0.01 | 0.08 | 0.07 | 0.002 |
| Nutmeg | 750 | 7.8 | 1.9 | 3.7 | 4.4 | 1.2 | 0.21 | 0.02 | 0.01 | 0.01 |

* nutrient removal based on average economic produce yield

## 4.2. Soil Acidity management

Soil acidity is one of the major factors affecting spice production. Except widely adapted turmeric and seed spices all the spices are grown in slightly acidic soils. Optimum soil pH for major spice crops and lime recommendation are given below

Table 4. Optimum soil pH for major spice crops

| Crop | pH Range |
|---|---|
| Black pepper | 6.0-7.0 |
| Ginger | 5.5-6.5 |
| Turmeric | 6.0-7.5 |
| Cardamom | 5.5-6.0 |
| Tree spices | 4.5-6.0 |

Table 5. General recommendation of lime/ dolomite

| Soil pH | Lime/dolomite (kg/acre) |
|---|---|
| Up to 3.5 | 1000 |
| 3.5-4.4 | 850 |
| 4.5-5.0 | 600 |
| 5.1-5.5 | 350 |
| 5.6-6.0 | 250 |
| 6.0-6.5 | 100 |
| 6.6-7.3 | nil |

Application of lime/ dolomite @ 500 to 1000 gm per standard in alternate years depending upon the soil pH is recommended for black pepper and @250 to 500 g/ plant for cardamom when the soil is below pH 6.0. As most of the ginger and turmeric are grown in acidic soils (especially in NEH states) application of soil amendments like lime and dolomite @ 1-2 t/ acre at the time of land preparation will help to improve the productivity of the crop.

Application of gypsum + dolomite (1:1) also helpful in improving the soil pH and addition of gypsum found to bring improvement of subsoil acidity in black pepper and nutmeg thereby helping to improve the root activity in the sub soil.

## 4.3. Soil Test based nutrient management in spices

Based on the nutrient uptake pattern it is also observed that more than 50% of the nutrient uptake was mainly distributed during critical developmental stages. In order to sustain the growth and production, nutrient application should be split evenly between the stages of nutrient demand like new flush production, flowering and berry/fruit development. As the soil fertility will be varying with the agro ecological conditions or management systems, site specific nutrient management based on their soil test results for major nutrient is advocated



### Black pepper

Black pepper (*Piper nigrum*), a perennial climber and a highly valued spice derived from the dried fruit of the pepper plant, native to Western Ghats of Kerala. The plant climbs on to the support tree. Renowned for its distinct flavour and health benefits, black pepper is one of the most widely used spices globally and is known as king of spices and black gold.

Black pepper exhibits dimorphic growth pattern. The phenological stages of black pepper include germination, vegetative growth, flowering, fruit development and ripening. Germination occurs within 2 to 4 weeks after planting, followed by a vegetative phase where the plant establishes leaves and roots. Flowering typically happens 6 to 9 months post-planting, leading to the development of green berries over the next 5 to 6 months. These berries ripen and change color from green to red, signaling the appropriate time for harvesting.

Critical growth stages for black pepper include flowering, fruit development, and ripening. Successful pollination during flowering is vital for berry production, while adequate water and nutrients during fruit development are crucial for achieving optimal yield. Proper timing of the harvest ensures high-quality peppercorns, as premature or delayed harvesting can affect the flavor and market value. By managing these stages effectively, farmers can enhance the yield of this valuable spice.

Major nutrients (nitrogen, phosphorus, potassium), secondary nutrients (calcium and magnesium) and micro nutrients especially Zn are the most important nutrients essential for black pepper growth, development and yield. Studies on nutrient removal by black pepper plants showed that for the production of 100 kg of dried produce 2.05, 0.35 and 1.85 kg of N, $P_2O_5$ and $K_2O$, respectively is required. Among the major nutrients studied, uptake of N was highest followed by K and Ca and among micro nutrients iron uptake was the highest. The magnitude of the nutrients removed was in the order: N>K>Ca>Mg>P>S.

Manuring and fertilizer application is critical for proper establishment and growth of black pepper plants. Organic manures in the form of cattle manure or compost can be given @ 10 kg/ vine during May. Neem cake @ 1 kg/vine can also be applied. Application of lime or dolomite @500 g/vine in April – May during alternate years is beneficial under highly acid soil conditions. The general blanket recommendation for black pepper is 50-50-150 or 140-55-250 g N $P_2O_5$ $K_2O$ per vine per year for vines of age 3 years and above. In the first and second years one third and two-third of the dose is recommended.

The targeted yield based recommended dose of nutrients for varying soil test values of N, P and K is given in Table 6. The fertilizers are to be applied in two split doses, one in May-June and the other in August-September and sufficient soil moisture must be ensured. The fertilisers are to be applied at a distance of about 30 cm all around the vine and covered with a thick layer of soil. When biofertilizer like *Azospirillum* is applied @ 50 g/vine, the recommended N dose may be reduced by half.

Table 6. Soil test based fertilizer recommendations for dry yield target levels in Black Pepper

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

In soils that are deficient in zinc or magnesium, foliar application of 0.25% zinc sulphate twice a year during May-June and September – October and soil application of magnesium sulphate @200g/vine is recommended. Foliar application of micronutrient mixture specific to black pepper at the rate of 5g/L is also recommended twice, at flowering and berry formation stage or at monthly intervals for higher yield.

## *Small cardamom*

Cardamom is generally grown in the rich fertile soils of the forest eco-system. The nutrient analysis data obtained from cardamom-growing tracts in south India revealed that the limiting leaf nutrients were in the order Zn > K > P > Ca > Mg > Cu > Mo > Fe > Mn > N. Being a perennial crop, sucker production occurs throughout the year. Initiation of panicles and development of capsules are spread over a period of eight to nine months in a year. A steady absorption and utilization of plant nutrients take place throughout the life cycle of cardamom which warrants regular application of nutrients for higher yields.



Nutrient uptake studies in cardamom have indicated the uptake of N, P, K, Ca and Mg to be in the ratio of 6:12:3:0:8 respectively and for the production of one kg of cardamom capsules, 0.122 kg N, 0.014 kg P and 0.2 kg K are removed by the plant.

In cardamom plantation it was estimated that 5-8 tonnes of dry leaves from shade trees as mulch contribute approximately 100-160 kg N, 5-8 kg P, 100-160 kg K, 10-16 kg Ca, 25-49 kg Mg/ ha/ year. Organic manures like cow dung/compost @ 5 kg/plant may be applied during May/June along with rock phosphate and muriate of potash. Under irrigated condition, manuring can be done in two splits (May and September). Application of neem cake @ 1.0 kg + vermicompost @ 2 kg/plant improves plant growth and capsule yield. Apply agricultural lime @ 1 kg/plant/year for soils with pH below 5.0 in one or two splits during May and September. Fertilisers shall be applied only after 15-20 days of lime application.

As the soil fertility will be varying with the agro-ecological conditions or management systems, site specific nutrient management based on the soil test results for major nutrients are advocated. The recommendation for site specific nutrient management based on soil test report is given below. The general recommendation is 75:75:150 $NP_2O_5K_2O$ kg/ha for rainfed and 125:125:250 kg/ha for irrigated crop.

Table 7. Soil test based fertilizer recommendations for dry yield target levels in small cardamom

| Soil test value for available nutrients (kg/ha) | | Fertilizer nutrient recommended (kg/ha) for yield targets 6.5 q/ha | 11.00 q/ha |
|---|---|---|---|
| Nitrogen | <150 | 255 | 400 |
| | 150-250 | 200 | 370 |
| | 250-400 | 100 | 320 |
| | >400 | 50 | 150 |
| Phosphorus ($P_2O_5$) | <25 | 225 | 275 |
| | 25-50 | 175 | 225 |
| | >50 | 100 | 175 |
| Potassium ($K_2O$) | <250 | 350 | 550 |
| | 250-500 | 280 | 500 |
| | 500-800 | 180 | 450 |
| | >800 | 50 | 250 |

Foliar spray of zinc (Zinc sulphate @ 250 g/100 litres of water) during April/May and September/October enhance growth, yield and quality of the produce. Zinc should be applied alone and not to be mixed with any insecticide/fungicide. Soil application of boron in two splits along with NPK fertilizers (Borax @ 7.5 kg/ha) is also recommended. Foliar application of micro nutrient mixture developed by IISR specific to cardamom is also recommended at 5 g/L, 2-3 times, in May-June and September-October.

## Ginger

Ginger rhizomes are mainly N and K exhausting, intermediary in P and Mg removal and the least in Ca removal. The uptake of N, P and K in leaf and pseudostem increases up to 180 days and then decreases, whereas that of rhizome uptake steadily increases till the harvest. About 48.41% of the N absorbed from fertilizer applied at seedling stage is distributed to the shoots and leaves. While 65.43% of the N derived from fertilizer applied at vigorous growth of rhizome was distributed into rhizomes, and only 32.04% was distributed into shoots and leaves. An average dry yield of 4.0 t $ha^{-1}$ dry ginger rhizomes removes 180 kg N, 27 kg $P_2O_5$, 132 kg $K_2O$, 8.6 kg Ca, 9.1 kg Mg, 1.8 kg Fe, 500 g Mn, 130 g Zn and 40 g Cu $ha^{-1}$. For healthy growth of ginger, very low external Ca is required. A heavy ginger crop removes 35-50 kg P $ha^{-1}$. The leaves of healthy plants contained 1.1 to 1.3% of Ca and concentrations as low as 2 ppm is sufficient to achieve 90 per cent of maximum yield. An appropriate critical limit of 2.1 - 3.74 mg Zn $kg^{-1}$ for soil and 27.0-53.8 mg Zn $kg^{-1}$ for leaf was fixed for getting maximum ginger yield.

At the time of planting, well decomposed cattle manure or compost @ 25-30 tonnes/ha has to be applied over the beds prior to planting or applied in the pits at the time of planting. Application of neem cake @ 2 tonnes/ha at the time of planting helps in reducing the incidence of rhizome rot disease/ nematode and increasing the yield. The fertilizers are to be applied in 2-3 split doses. Full dose of phosphorus is applied as basal at the time of planting. Equal split doses of N and K is top dressed at 45, 90 and 120 DAP. The general fertiliser schedule for ginger in different states are given below.



Table 8. Fertiliser recommendation for ginger

| State | Recommendation |
|---|---|
| Kerala | FYM 30 t/ha; NPK 70-50-50 kg/ha. Full dose of P maybe applied as basal dose. Half of N & K applied at 45 DAP, and the remaining quantity of N & K applied at 90 DAP. |
| Karnataka | FYM / compost 25 t/ha; NPK 100-50-50 kg/ha. Apply entire dose of P & K at planting. Half of N applied at 30-40 DAP and the remaining at 60-70 DAP. |
| Odisha | FYM / compost 25 t/ha; NPK 125-100-100 kg/ha. Full P and half K applied as basal dose in furrows before planting. N & remaining K is applied in 2 splits at 45 and 90 DAP. |
| Meghalaya | FYM 10 t/ha; NPK @ 60-90-60 kg/ha |

As the soil fertility will be varying with the soil type, agro ecological conditions or management systems, site specific nutrient management based on the soil test results advocated as given in Table 9.

Table 9. Soil test based fertilizer recommendation for ginger

| Soil test value for available nutrients (kg/ha) | | Fertilizer nutrient recommended (kg/ha) for fresh yield targets | |
|---|---|---|---|
| | | 25 t/ha | 30 t/ha |
| Nitrogen | <150 | 250 | 340 |
| | 150-250 | 180 | 270 |
| | 250-400 | 90 | 175 |
| | >400 | - | 50 |
| Phosphorus ($P_2O_5$) | <10 | 55 | 75 |
| | 10-30 | 35 | 55 |
| | 30-50 | 15 | 25 |
| | >50 | - | 5-10 |
| Potassium ($K_2O$) | <110 | 100 | 130 |
| | 110-300 | 75 | 100 |
| | 300-500 | 35 | 50 |
| | >500 | 5 | 15 |

The fertilisers are to be applied in 2-3 split doses. Full dose of P is applied as basal at the time of planting. Equal split doses of N and K is top dressed at 45, 90 (and 120) DAP.

In zinc deficient soils, basal application of zinc fertiliser upto 6 kg zinc/ha (30 kg of zinc sulphate/ha) gives good yield. Foliar application of micronutrient mixture specific to ginger is also recommended at the rate of 5g/L twice during 60 and 90 DAP for higher yield

Muching the beds with green leaves / organic wastes is essential to prevent soil splashing, soil erosion and to add organic matter to the soil apart from controlling weeds and conserving moisture. The first mulching is done at the time of planting with green leaves @10-12 t/ha. Green leaf mulching is to be repeated @7.5 t/ha at 45 and 90 DAP, immediately after weeding, fertiliser application and earthing up.

## Turmeric

In turmeric the maximum uptake is observed in active vegetative growth phase. Higher uptake of K up to third, N up to fourth and P up to fifth months of development is observed with subsequent decrease in their uptake. Planting mother rhizomes enhances the uptake of N, P and K as compared to primary or secondary rhizomes. The uptake of nutrients by turmeric was in the order of K > N > Mg > Ca. Crop removal studies at IISR have showed that an average dry yield of 6.0 t $ha^{-1}$ rhizome removes 150 kg N, 48 kg $P_2O_5$, 245 kg $K_2O$.

At the time of planting, well decomposed cattle manure or compost @ 30-40 tonnes/ha has to be applied over the beds prior to planting or applied in the pits at the time of planting. Application of neem cake @ 2 tonnes/ha at the time of planting helps in reducing the incidence of rhizome rot disease/ nematode and increasing the yield. In such case the dosage of FYM can be reduced.

Table 10. The general fertiliser recommendation of turmeric

| State | Soil type | Fertiliser recommendation, $NP_2O_5K_2O$ (kg/ha) |
|---|---|---|
| Kerala | Lateritic soils (Ultisols) | 60-50-120 |
| Andhra Pradesh & Telengana | Sandy clay loam (Inceptisols), Red soils (Alfisols) and heavy clay soils (Vertisols | 300-125-200 |
| Tamil Nadu | Clay loams (Mollisols) and heavy clay soils (Vertisols | 125-60-90 |
| Odisha | Red soils (Alfisols) | 60-50-90 |
| Karnataka | Red soils (Alfisols) | 120-60-120 |



As the soil fertility will be varying with the soil type, agro ecological conditions or management systems, site specific nutrient management based on the soil test results advocated as given in Table 11. The fertilizers are to be applied in 2-3 split doses. Full dose of phosphorus is applied as basal at the time of planting. Equal split doses of N and K is top dressed at 45, 90 and 120 DAP

Table 11. Soil test based fertilizer recommendation for turmeric

| Soil test value for available nutrients (kg/ha) | | Fertilizer nutrient recommended (kg/ha) for fresh yield targets 25 t/ha | 30 t/ha |
|---|---|---|---|
| Nitrogen | <150 | 120 | 170 |
| | 150-250 | 95 | 125 |
| | 250-400 | 50 | 90 |
| | >400 | - | 25 |
| Phosphorus ($P_2O_5$) | <10 | 60 | 90 |
| | 10-30 | 18 | 50 |
| | 30-50 | - | - |
| | >50 | - | - |
| Potassium ($K_2O$) | <110 | 275 | 325 |
| | 110-300 | 230 | 300 |
| | 300-500 | 150 | 235 |
| | >500 | - | 140 |

The fertilisers are to be applied in 2-3 split doses. Full dose of phosphorus is applied as basal at the time of planting. Equal split doses of N and K is top dressed at 45, 90 (and 120) DAP.

Micronutrient application is imperative for enhanced yield. In zinc deficient soils, basal application of zinc fertilisers upto 5 kg zinc/ha (25 kg zinc sulphate/ha) can increase yield. Foliar application of micronutrient mixture specific to turmeric developed by IISR, Kozhikode @ 5g/L twice at 60 and 90 DAP ensures 15-20% higher rhizome yield. The mixtures are pH specific to soil.

The crop is to be mulched immediately after planting with green leaves @12-15 t/ha. The mulching maybe repeated @7.5 t/ha at 45 and 90 DAP after weeding, fertiliser application and earthingup.

## Manuring and fertilizer application for Tree spices

### Nutmeg

A humid topical climate is the best for nutmeg and it grows up to an elevation of 1000 m above MSL. Nutmeg grows well in clay loam, lateritic clays and loamy soils that are well drained. Recommended fertilizer schedule for a mature plant is 1 kg of ammonium sulphate, superphosphate and muriate of potash along with 50 kg of compost per year. The fertilisers are to be applied during May-June and September-October. The Kerala Agricultural University recommended a fertiliser schedule of 20:20:50 g or NPK along with 15 kg of compost per year during the first year of planting which is to be gradually increased to 500:250:1000 g $NP_2O_5K_2O$ and 50 kg compost per year from 15$^{th}$ year onwards. Trials under AICRPS revealed that 50 kg FYM+ 400, 350, 1200 g $NP_2O_5K_2O$ together with 50 g biofertilizer optimum for nutmeg.

### Cinnamon

Cinnamon is a high dry plant, which tolerates a wide range of climatic conditions and thrives well from 300 to 350 m above MSL. A hot and moist climate is highly suited for its cultivation. It flourishes in a wide range of soils, even in marginal soils with poor nutrient status. Sandy loam soil rich in organic matter is the best. For an adult plant, $NP_2O_5K_2O$ in the ratio of 100:18:100 g per year is recommended in Andaman condition. The Kerala Agricultural University recommended a fertiliser schedule of 20:20:25 g of $NP_2O_5K_2O$ along with 20 kg of compost per year during the first year of planting which is to be gradually increased to 200:180:200 g $NP_2O_5K_2O$ and 50 kg compost per year from 15$^{th}$ year onwards. Fertiliser may be applied in two splits during May-June and September-October.

### Clove

Clove requires a humid climate and grows at 600 m to 1000 m above MSL with a rainfall of 1500-2000 mm and a mean temperature of 20-30$^0$ C. Deep red loam, sandy soil and black soil with deep gravely sub soil are suitable without any water logging. Nutrient removal by adult clove tree is in the following trend: K>N>Ca>Mg>S>Mn >P>Fe>Cu>B>Zn. The Kerala Agricultural University recommended a fertilizer schedule of 200:180:200 g $NP_2O_5K_2O$ and 50 kg compost per year from 15$^{th}$ year onwards.

# 5. Other Management strategies

## 5.1. Contouring

The introduction of contour staggered trenches (CST) with cover crops like pine apple or french bean could reduce the soil loss and runoff to a marked extent in cardamom.



Experiments were conducted at IISR, Regional Station, Appangala, with soil and water conservation measures like contour staggered trenches (CST) in alternate rows, CST with cover crops viz. pineapple, ginger, french bean etc. in cardamom plantations. Average runoff and soil loss ranged from 2219.74 kg per hectare to 495.56 kg per hectare with a minimum runoff (31.82 mm) and soil loss (495.56 kg/ha) in CST with pine apple treatment. Small quantity of nutrients was removed through runoff water and addition of vegetative barrier like pine apple, french bean and ginger leads to better soil cover and additional income.

The use of plant covers on steep slopes is advisable for the recycling nutrients, and consequently for an efficient regulation of the flow of nutrients by runoff and sediments. Vegetation cover makes a nutrient pool available while moderating surface runoff and sediment movement, both of which are major nutrient carriers. In addition, having inter or cover crops improves the soil fertility that benefits both the main and component crops. Live mulches like sun hemp, green gram, horse gram, black gram, niger, sesbania, cluster bean, French bean, soybean, cowpea, daincha and red gram can also be grown as intercrop in ginger or turmeric and mulched *in situ* between 45-60 days after planting. It will also reduce weed growth and increase the yield. Green manure crops like daincha (*Sesbania aculeata*) can be raised successfully in inter-spaces of ginger beds in a row, which adds to 50 per cent of the green leaves required for mulching, suppresses weed growth and reduces cost of production. Also, proper land use with appropriate crop planning with perennial crops and recommended package of practices has to be followed to prevent soil degradation, to improve productivity and the environment.

Deficiency of micro nutrients like boron (B) in soil results in reduced accumulation of sugars, amino acids, and organic acids at all leaf positions and overall reduction in yield. Hence technologies to alleviate macro and micro nutrient deficiencies in location specific soil-crop systems have to be given priority. Fertigation is adopted under precision farming project of Tamil Nadu for augmenting turmeric yield. Identification of efficient location specific strains of bio fertilizers and developing INM through conjoint use of organics along with inorganic fertilisers, to meet the plant nutrient requirement may be thought of.

## 5.2. Soil rhizosphere management in spices

The nature and the characteristics of nutrient release of chemical, organic and biofertilizers are different, and each type of fertilizer has its advantages and disadvantages with regard to crop growth and soil fertility. The significance of the rhizosphere arises from the release of organic material from the root and the subsequent effect of increased microbial activity on nutrient cycling and plant growth. The association between organisms and roots can be beneficial for water uptake, soil stabilization, growth promotion, nutrient mobilization etc.

ICAR-IISR has developed easy and reliable technology of storing and delivering PGPR bioagents as biocapsule. It is a preparation of viable microbial agents in a capsule form that enhances nutrient mobilization and use efficiency, growth and yield and provides protection against diseases at a negligible cost. These capsules are ecologically safe and easily applied by drenching in spices rhizoshere after dilution in 200 to 1000 liters of water for better growth and disease suppression.

Care should be taken to avoid injuries to the roots while performing intercultural operations to prevent infection. For cardamom, mulching plant basins with dried leaf/weed materials need to be undertaken in summer. In areas where the roots are exposed due to soil erosion, earthing up the base with topsoil need to be undertaken followed by mulching. In ginger and turmeric, mulching to be done at the time of planting with green leaves @ 10-12 tonnes/ha. Application of dried coconut leaves after removing the midrib or paddy straw (2-3 kg/bed) as mulch in ginger is also recommended for effective weed control. Green leaf mulching is to be repeated @ 7.5 tonnes/ha at 45 and 90 days after planting after weeding, fertilizer application and earthing up.

## 6. Spices for effective land use planning

For efficient land use planning and management, it is essential to find out the relationship between soil characteristics, vegetation, climate and crop requirements and the process in which these requirements are compared with the essence of land evaluation. The basic objectives of the land use policy are, preventing any further deterioration of land resources by appropriate preventive measures, restoring productivity of the degraded land by appropriate production packages, promoting optimum use of land under agriculture by mixed farming systems and providing technological and extension support to farming community for obtaining maximum production through increased productivity. The recent advances in technologies such as satellite imagery, use of GPS and modern mapping techniques using GIS have greatly improved the understanding of the land use planning. Proper land use with appropriate crop planning with perennial crops and recommended package of practices has to be followed to prevent soil degradation, to improve productivity and the environment. The suitable management measures to improve the adaptability of spices in the potential agro eco regions are mentioned in Table 13.

The main constraints faced in hot moist sub/ per humid to humid eco sub regions including Bengal basin, Lower, Middle and Upper Brahmaputra valley, foot hills and subdued eastern Himalayas covering majority of North Eastern states, Sikkim, West Bengal, Himachal Pradesh and high elevations of Uttar Pradesh are steep sloping



landform leading to excessive erosion, risk of water logging in valleys during heavy monsoon periods, acidic soils due to heavy leaching of bases from soil leading to low soil fertility status. Adopting soil and water conservation measures like terracing and bunding to reduce the degree and length of the slope and to reduce erosion is the primary measure. In NE states where ginger and turmeric are grown on slopes, contour terracing and raised bed cultivation has to be promoted to minimize soil erosion and also to avoid water logging. Integrated nutrient management (INM) strategy has to be adopted to enhance spices production and its sustainability over long periods through balanced nutrition without affecting soil health.

NE hill regions possess a climate that is congenial for the expansion of spice growing areas. Spices like black pepper, ginger, turmeric and most of the tree spices like nutmeg, cinnamon, cassia and garcinia can be exploited for intensive agriculture under mixed farming systems along with other horticultural crops. GIS studies using the various temperature and precipitation variable indicated that based on the climatic variable, the best regions for cultivation of nutmeg is the entire West coast strip extending from Kanyakumari to Surat in Gujarat with certain areas in Dakshina Karnataka being not suitable. Besides, certain pockets of Maharashtra like Bhandara, Raj Nadgaon, Satara, Jand areas, parts of Chigmagalur and Belgaum (Karnataka). Sambalpur and Baleshwar, Balangir, and Cuttack in Odisha are also suitable. Ginger has wider adaptability with many areas in Maharashtra such as Raj nandgaon, Thane, Nasik, Satara and Pune; Surat in Gujarat, Belgaum in Karnataka, Bastar and Betul in MP, Koraput, Ganjam are best. Majority of the areas in Assam and other Northeastern states except parts of Sikkim and Arunachal Pradesh are ideal for ginger cultivation.

In states like Maharashtra, Madhya Pradesh, lower Gangetic plains of UP, Bihar and North and Central Sahyadri sub humid and semi arid sub regions, the productivity of ginger and turmeric could be improved if proper measures are followed to overcome slight alkalinity and drought occurrence during later period of the crops. Measures like organic recycling, crop rotation with legumes, water harvesting, improving drainage through sub surface drains, drip irrigation/ fertigation and adoption of integrated disease control will help in improving the productivity of such crops. Potentiality of growing tree spices like clove, cinnamon and nutmeg in the hilly lands of Andaman and Nicobar islands was reported in combination with Coffee (Robusta), Black pepper, Coconut and Arecanut cropping systems.

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landform leading to excessive erosion, risk of water logging in valleys during heavy monsoon periods, acidic soils due to heavy leaching of bases from soil leading to low soil fertility status. Adopting soil and water conservation measures like terracing and bunding to reduce the degree and length of the slope and to reduce erosion is the primary measure. In NE states where ginger and turmeric are grown on slopes, contour terracing and raised bed cultivation has to be promoted to minimize soil erosion and also to avoid water logging. Integrated nutrient management (INM) strategy has to be adopted to enhance spices production and its sustainability over long periods through balanced nutrition without affecting soil health.

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In states like Maharashtra, Madhya Pradesh, lower Gangetic plains of UP, Bihar and North and Central Sahyadri sub humid and semi arid sub regions, the productivity of ginger and turmeric could be improved if proper measures are followed to overcome slight alkalinity and drought occurrence during later period of the crops. Measures like organic recycling, crop rotation with legumes, water harvesting, improving drainage through sub surface drains, drip irrigation/ fertigation and adoption of integrated disease control will help in improving the productivity of such crops. Potentiality of growing tree spices like clove, cinnamon and nutmeg in the hilly lands of Andaman and Nicobar islands was reported in combination with Coffee (Robusta), Black pepper, Coconut and Arecanut cropping systems.

Table 13. Potential agro eco zones with strategies for spices productivity

| Zone | State | Strategy |
|---|---|---|
| Western Hill Region | Himachal Pradesh, Uttarakhand | o Percentage share of high yielding improved varieties should be increased in ginger<br>o Contour terracing and raised bed cultivation, mulching<br>o Integrated nutrient and disease management<br>Promoting extension education of technologies in the remote areas. |
| Eastern Hill Region | Assam, West Bengal, North Eastern states, Sikkim | o Crop diversification through promotion of tree spices like cinnamon, nutmeg, cassia<br>o Increasing percentage share of improved varieties of ginger and turmeric.<br>o Contour terracing, raised bed cultivation, mulching, optimum seed size and spacing<br>o Integrated nutrient and disease management<br>Technology dissemination |
| Lower, mid and upper Gangetic Plain | West Bengal, Uttar Pradesh, Bihar Uttarakhand | o Percentage share of improved varieties of ginger and turmeric<br>o Crop diversification through promotion of tree spices like cinnamon, nutmeg, cassia<br>o Raised bed cultivation, mulching, optimum seed size and spacing<br>o Green manuring, legume cover crops, organic recycling<br>o Integrated nutrient and disease management<br>Technology dissemination in the remote areas |
| Hot, sub humid - semi arid, Eastern Plateau Hills | Bihar, Madhya Pradesh, Maharashtra, Odisha | o Crop diversification through promotion of tree spices like cinnamon, tamarind, garcinia<br>o Increasing percentage share of improved varieties of ginger and turmeric.<br>o Raised bed/ ridges cultivation, mulching, optimum seed size and spacing, drip irrigation<br>o Integrated nutrient and disease management, soil solarization<br>o Green manuring, legume cover crops, organic recycling<br>Farm ponds and check dams |
| Hot moist semi arid Western Plateau Region | Madhya Pradesh, Maharashtra | o Crop diversification through promotion of tree spices like tamarind<br>o Increasing percentage share of improved varieties of turmeric<br>o Raised bed/ ridges cultivation, mulching, optimum seed size and spacing, drip irrigation<br>o Integrated nutrient and disease management, soil solarization |
| | | o Green manuring, legume cover crops, organic recycling<br>o Farm ponds and check dams and improving drainage |
| Southern Plateau | Andhra Pradesh, | o Crop diversification through promotion of tree spices like cinnamon, tamarind, curry leaf |

| Zone | State | Strategy |
|---|---|---|
| Region | Karnataka, Tamil Nadu | o Increasing percentage share of improved varieties of turmeric<br>o Raised bed/ ridges cultivation, mulching, optimum seed size and spacing, drip irrigation<br>o Integrated nutrient and disease management, soil solarization<br>o Green manuring, legume cover crops, organic recycling<br>Farm ponds and check dams and improving drainage |
| East Coastal Region | Andhra Pradesh, Odisha, Tamil Nadu, Puduchery | o Crop diversification through promotion of tree spices like cinnamon, tamarind<br>o Increasing percentage share of improved varieties of turmeric, cinnamon<br>o Raised bed/ ridges cultivation, mulching, optimum seed size and spacing, drip irrigation<br>o Integrated nutrient and disease management, soil solarization<br>o Green manuring, legume cover crops, organic recycling<br>Farm ponds and check dams and improving drainage |
| Western Coastal Region | Kerala, Maharashtra, Tamil Nadu, Karnataka | o Crop diversification through promotion of tree spices like cinnamon, nutmeg, clove, tamarind, garcinia<br>o Increasing percentage share of improved varieties of ginger and turmeric<br>o Contour terracing, raised bed cultivation, mulching, optimum seed size and spacing<br>o Integrated nutrient and disease management, soil solarization<br>o Green manuring, legume cover crops, organic recycling<br>Farm ponds and check dams and reducing run-off |

| | | |
|---|---|---|
| Indian Islands | Andaman & Nicobar, Lakshadweep | o Crop diversification through promotion of tree spices like cinnamon, nutmeg, clove, garcinia<br>o Increasing percentage share of improved varieties of ginger and turmeric<br>o Raised bed/ ridges cultivation, mulching, optimum seed size and spacing<br>o Integrated nutrient and disease management, soil solarization<br>o Green manuring, legume cover crops, organic recycling<br>Farm ponds and check dams and improving drainage |

## 7. Future strategies for soil health management in spices

- Better understanding of nutrient release behaviour of soils would be useful in adopting the suitable nutrient management practices under varying soil, spice crop environment situations.
- Possibility of analyzing micronutrients in the soil test and proper interpretation of fertilizer response data based on soil test values need to be emphasized for improving the use efficiency in site specific nutrient management.
- Need to formulate the fertilizer recommendations for cropping system as a whole, rather than for individual spice, considering the role of spices as a remunerative intercrop in coconut, arecanut, coffee, tea and other fruit crop based systems.
- Intensive research in relatively less investigated areas of nutrient enrichment of composts, microbial dissolution of nutrients, and development of nano-fertilizers would be of great help in ensuring judicious input to the crops.
- Opportunities exist to develop novel 'multifunctional' microbial strains as bio-inoculants such as P, Zn solubilizers, suitable strain identification, preparation of effective formulation and efficient agronomic delivery systems to ensure large scale adoption under organic cultivation.

## 8. Conclusions

In addition to major (N, P, K) nutrients, requirement of secondary (calcium and magnesium) and micro nutrients especially B and Zn have become most important for better growth, development and yield of many of the spice crops. In soils with low pH, liming based on lime requirement could enhance the yield. It is therefore necessary to develop sound soil fertility management programme that encompasses nutrient recommendations based on robust soil tests. Crop management programs that are location/ site specific should form the basis for manure and fertilizer management that optimizes economic return while protecting the environment. Overall, it is apparent that in majority of the soils the reasons for low productivity of these crops are low pH, low levels of organic carbon, low CEC, K, Ca, Mg, B and Zn. In high rainfall areas measures for conserving soil and water runoff should be given priority to arrest the fertility drain. Inorganic fertilizer schedules for different agro-ecological locations exits for these crops. Similarly organic nutrition schedules have also been devised. However, among the different nutrient management strategies, INM through judicious use of inorganic fertilizers, biofertilizers, biosolids, biological nitrogen fixation, and other nutrient cycling mechanisms that enhance nutrient use efficiency appears to be the best bet.



## Appendix

### List of Licensees producing crop specific micronutrient mixtures

| S. No | Technology | Licensee Name & Address |
|---|---|---|
| 1 | A micronutrient composition for ginger and a process for its preparation (for soils with pH above 7) | 1.Deputy Director of Horticulture, Centre of Excellence for Floriculture, Vidyanagara, Shivamogga, Karnataka-577203<br>Email; coeflorismg@gmail.com<br>Ph: 97414 89878 |
| | | 2.Ecophytocare India Pvt Ltd<br>Mysore, Karnataka<br>Email:9886165014, 9686641471<br>Email:ecophytocare@gmail.com<br>Ph: 96866 59285 |
| | | 3.AIRR Organics and Biofertilizers Private Limited., Rajajinagar, Industrial Town, Bengaluru, Karnataka- 560044, India<br>Email: airrbiofertilizers@gmail.com<br>Ph:9886165014, 9686641471 |

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|---|---|---|
| 2 | A micronutrient composition for ginger and a process for its preparation (for soils with pH below 7) | 1.Centre of Excellence for Precision Farming, Maddur, Karnataka<br>Email; coemadhur@gmail.com<br>Ph: 96635 91881 |
| | | 2. Natura Nursery &Agro Products<br>Pattorakkal, Iringath PO,<br>Kozhikode,Kerala -673523, India<br>Email; naturanursery1@gmail.com<br>Ph: 94950 83753 |
| 3 | A micronutrient composition for turmeric and a process for its preparation (for soils with pH below 7) | 1.Centre of Excellence for Precision Farming, Maddur, Karnataka<br>Email; coemadhur@gmail.com<br>Ph: 96635 91881 |
| 4 | A micronutrient composition for black pepper and a process for its preparation | 1.M/s Hi-7Agro Bio Solutions,<br>#832, Sapthagiri Nilaya, Vasanthnagar, Hessaraghatta,<br>Bengaluru, Karnataka-560088<br>Email; hi7agri@gmail.com<br>Ph: 87921 23827 |
| | | 2.M/s Linga Chemicals<br>Madurai, Tamilnadu<br>Ph: 99940 93178, 95009 82800<br>Email: lingachem@gmail.com |
| | | 3.M/s Natura Nursery &Agro Products, Pattorakkal (H),<br>Meppayur PO, Kozhikode, Kerala-673524<br>Email; naturanursery1@gmail.com<br>Ph: 94950 83753 |
| | | 4.Centre of Excellence for Precision Farming, Maddur,<br>Mandya District, Karnataka-571428<br>Email; coemadhur@gmail.com<br>Ph: 96635 91881 |
| | | 5.Deputy Director of Horticulture, Centre of Excellence for Floriculture, Vidyanagara, Shivamogga,<br>Karnataka-577203<br>Email; coeflorismg@gmail.com<br>Ph: 97414 89878 |
| | | 6.Senior Assistant Director of Horticulture<br>Zilla Panchayat Bantwala Taluka, Jodumarga Post,<br>Bantwala Muda Village, Dakshina Kannada (Dist),<br>Karnataka- 574219<br>Email; bantwaladh@gmail.com<br>Ph:9448206393 |



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| | | 7.Bhoomi Bio Industries, Magadi Main Road, 4,<br>Ashwathnagar, Srigandakaval, Yeswanthpura, Hobli,<br>Bengaluru Urban, Karnataka<br>Email; bhoomibioindustries@gmail.com<br>Ph: 98807 55074 |
| | | 8.Future Biotech, Dharwad, Karnataka<br>Email:manjunath@futurebiotech.in<br>Ph: 94802 91450 |
| 5 | A micronutrient composition for cardamom and a process for its preparation | 1.M/s Hi-7Agro Bio Solutions,<br>#832, Sapthagiri Nilaya, Vasanthnagar, Hessaraghatta,<br>Bengaluru, Karnataka-560088<br>Email; hi7agri@gmail.com<br>Ph: 87921 23827 |
| | | 2.M/s Linga Chemicals<br>Madurai, Tamilnadu<br>Ph: 99940 93178, 95009 82800<br>Email: lingachem@gmail.com |
| | | 3.M/s Natura Nursery &Agro Products, Pattorakkal (H),<br>Meppayur PO, Kozhikode, Kerala-673524<br>Email; naturanursery1@gmail.com<br>Ph: 94950 83753 |
| | | 4.M/s. Raja G. Enterprises,<br>Salem. Tamil Nadu<br>Email:rajagenter@gmail.com<br>Ph:8072 555 925 |
| | | 5. Mr. Nirmal Nelson<br>M/s A & N Traders<br>Idukki, Kerala<br>Email: nelsonnirmal89@gmail.com |
| | | 6.ESAF Swasraya Producers Company Ltd, Thrissur, Kerala<br>Email:induchoodan@esafcooperative.com<br>Ph: 92880 09866 |
| | | 7. ICAR Krishi Vigyan Kendra (ICAR KVK),<br>Bapooji Sevak Samaj, Idukki, Kerala<br>Email:mjincybkvk08@gmail.com<br>Ph: 94437 29789 |