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A Case Study :

Nutrient management in small cardamom (*Elettaria cardamomum*)

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Cardamom, the "Queen of Spices" is native to evergreen Western Ghats of India and one of the most valuable spices in the world. Indian cardamom is known for its luxuriant green colour with good aroma quality, which was internationally accepted. The cardamom oil is found to be anti microbial in nature and hence used in mouth fresheners and confectioneries. Currently it is being grown in Kerala, Karnataka, Tamil Nadu and parts of Sikkim in India. The production and productivity of cardamom is gradually declining in certain tracts of cardamom cultivation. The reasons are so many, yet, nutrient deficiency accounts to a greater extent.

Deficiencies of nutrients in plants have various visual symptoms. The most common deficiency symptom is reduced growth, which is difficult to detect and diagnose at a glance. Other visual symptoms usually involve changes in coloration following a specific pattern, such as from the leaf tip down the midrib towards the base of the leaf or from the leaf margin toward the midrib or between the veins of the leaf. Such symptoms may appear in new leaves or old leaves, indicating the phloem-mobility of the deficient nutrient and the ability of the plant to translocate existing stocks of the deficient nutrient. In many cases, internodal distances will shorten as well (Korikanthimath, 1994). Many nutrient deficiency symptoms are ambiguous unless they are well-developed, and a visual diagnosis can be regarded as an educated guess until tissue samples are gathered and chemical analyses are used to compare elemental composition with healthy leaf tissue. In fact, many types of environmental and management damage can masquerade as visual nutrient deficiency symptoms.

Role of different nutrient elements on growth, yield and quality of small cardamom :

Good plant growth, yield and capsule quality depend on an adequate supply of all the nutrients through out growth. A deficiency of any one of them will affect the cardamom yields detrimentally. As visual symptoms of deficiencies tend to mask one another, it is be difficult to diagnose the actual problem. The descriptions of the more common deficiency symptoms are given below which would assist in making the correct diagnosis and allow timely action to be taken (Khader and Sayed, 1977).

Major nutrients :

Nitrogen :

Nitrogen is involved in the protein synthesis mechanism of cardamom plant and highly essential for the vegetative growth, photosynthesis and also for the development of chlorophyll (green colour) pigment of cardamom capsules. 'N' is very much important for the new tiller production, vegetative growth of young tillers, initial capsule development and also for the luxuriant green colour development of the capsule. Nitrogen deficiency may be exhibited by general paling, chlorosis (yellowing) on new leaf, young tillers and also lead to poor green colour development of cardamom capsules. Mild N deficiency will restrict plant growth, but often in a subtle manner that can only be assessed by comparison to plants grown with an adequate N supply. Moderate N deficiency will cause leaves to be light green or yellowish. Severe symptoms include necrosis (tissue death) starting at the tips of older leaves, with the tissue death developing a V-pattern down the midrib toward the base of the leaf. An adequate supply of N is associated with vigorous vegetative growth and a deep green colour. An over-supply of N may cause excessive, succulent growth with large, soft, thick and floppy leaves and large, soft, poor-quality capsules, such plants tend to lodge and are more susceptible to disease and insect attack. Excess N (imbalance in the plant) can cause thin cell walls, allowing fungi to penetrate more rapidly, whereas balanced nutrition can increase vigour of the plant. High N content reduces the phosphorous availability.

Cardamom plants do not use nitrate and ammonium, directly but must reduce nitrate and assimilate them into organic compounds. Reduction of nitrate takes place in both the root and shoot. Particularly at high rates of nitrate supply increasing amounts of nitrate will be in the xylem flow, where it will be end up in shoots and ultimately be reduced in the leaves. Nitrate in the roots will be reduced first to nitrite by *nitrate reductase* and then to ammonium by *nitrite reductase*. Ammonium will undergo reaction with glutamate to form glutamine by the action of *glutamine synthase*. Glutamine may then undergo additional transformations before entering the xylem flow as reduced N. 'N' availability can be influenced by the soil pH (Ranganathan and Natesan, 1985). The ammoniacal forms of nitrogen sources are the best for acidic cardamom soil to enhance the nutrient use efficiency. Hence, complex fertilizers 20:20:15 or 10:26:26 or18:18:18 or DAP are much useful.

Phosphorous :

Phosphorus is predominantly required for rhizome development, root formation, new panicle emergence from the base of the one year old tillers. Further phosphorus is heavily demanded by cardamom plant for its panicle initiation, expansion, development which also determines the important yield attributes *viz.*, the number of flowers per raceme and number of racemes per panicle. Majority of the cardamom growing soils of south India are low to medium in available phosphorous status. Acidic nature of cardamom soils would enhance the phosphorus fixation by the combined reaction of excess iron and aluminum present in the acidic red lateritic and clay loam cardamom soils and thus the phosphorous is unavailable to the cardamom plants. To enhance the phosphorus availability in cardamom soils phosphorus solubilizing and mobilizing microbes *viz.*, phosphobacteria (*Bacillus megatherium and Bacillus sulphurea* etc.,) and VAM (Vesicular Arbuscular mycorrhizae fungus) should be used in association with bulky organic manures to favour easy multiplication and colony formation of these organism under enough moisture availability. Based on the soil, leaf test analysis and uptake pattern the needy phosphorus should be supplied in time to ensure the productivity of cardamom.

The deficiency of 'P' would lead to general stunting, yellowing, poor rhizome and root development, panicle initiation and flowering. Symptoms appeared on the plant as small patches of purplish spots and premature dropping of older leaves are seen. Overall growth of plant was stunted and reduced numbers of suckers were observed. Severe deficiency could lead to panicle stunting and pinkish violet discoloration developed near the raceme stalk and also on the panicle rachis. Acid soluble form of P either as Rock Phosphate or Bone meal is better for acidic soils. High N content in the soil might reduce the phosphorous availability. Mixture containing N: P: S association in the form of Ammonium Phosphate Sulphate enhances the efficiency of applied nutrients (eg. 20:20:0:13 Complex). Lower availability of sulphur content in the soil also indirectly reduces the phosphorous uptake by the cardamom plants. Spray of water soluble form of phosphorous *viz.*, Poly feed (13:40:13 – NPK), Mono Ammonium Phosphate (12:61:0 NPK), Mono Potassium Phosphate (0:52:34 NPK) is helpful for more flowering and yield.

Potassium :

Potassium is a key element necessary for the growth and development mechanism of cardamom plant. The functions of potassium in the plant are not fully understood. It does play an important role in the water economy of plants and reduces the tendency to wilt. It also hardens supporting tissues and thereby reduces lodging. K may reduce susceptibility to disease and it improves the quality of fruits and other storage organs like swollen roots and tubers. A balanced N to K ratio is particularly important in plant nutrition, as K tends to reduce the adverse effects of excessive N. Most plants can take up large quantities of K without severe adverse effects. However, an excess of K may upset nutrient balance and thus induce deficiencies of other elements such as magnesium. Potassium is very mobile within the plant, and deficiency symptoms consequently appear first in older tissue, as K is translocated to the newer tissue where it is most needed. Generally the cardamom soils are low to very low in the soil available potassium content. Potassium is important for enhancing the capsule size and capsule quality, in terms of seed weight and essential oil content. Potassium deficiency in cardamom could be measured indirectly by judging the plant health (*i.e.*, pest and disease attack- incidence of stem and capsule borer and also heavy foliar diseases). Severe lodging of tillers during the south west monsoon season (*i.e.*, heavy wind blown during the June and August month in the plantations) due to the poor tiller strength and improper height of the tiller due to excess nitrogen absorption in comparison with the rhizome developed (*i.e.*, easy bending of tillers). The deficiency also characterized by marginal yellowing on the leaves of 10 months old tillers to 2 year old yielding tillers on advancement of the potassium deficiency lead to marginal scorching and drying of leaf blade along the margin progressing towards the mid-rib portions. Poor attachment of leaf base (*i.e.*, distance between the two leaf base are close and also expose the petiolar sheath base out of the pseudostem) with the pseudostem of cardamom plant. Since cardamom is grown on the highly sloped hilly terrains, the potassium available on the top soil is easily washed out through run off. Hence, proper management strategies should be followed to improve the potassium availability for cardamom based on periodical soil and leaf test results. K is basic key element for regulating many physiological functions in cardamom. It imparts tolerance against water stress, pest and diseases. High Mg content reduces the potassium availability. Water soluble form of potassium *viz.*, potassium nitrate (KNO_3 – 13:0:45-NPK), sulphate of potash (SOP – 0:0:50:20 – NPKS) Poly feed (13:40:13 – NPK) and Mono Potassium Phosphate (0:52:34 NPK) getting bold capsules with high oil content.

Soil application of fertilizers in Cardamom (Natarajan and Srinivasan, 1989)

Age of Plants	Irrigated areas (Kg/ha)	
1st year of planting	Nitrogen	-25
	Phosphorus	-25
	Potassium	-50
(2 split applications)		
2ndyear of planting	Nitrogen	-60
	Phosphorus	-60
	Potassium	-80
(3 split applications)		
3rd year onwards	Nitrogen	-125
	Phosphorus	-125
	Potassium	-250

Secondary nutrients :

Calcium :

Calcium plays a vital role in the development of new tillers, rhizome and also imparts resistance to capsule rot to certain extent on developing capsules. Addition of calcium to the cardamom soils through liming practices could not only reduce the acidity but also enhances the nutrient availability. Calcium deficiency in cardamom plants leads to the poor tiller emergence, poor husk development on the capsules, weak rhizome formation and also frequent rot incidence in the base of the clump. Deficiency symptoms appeared on young leaves. Root and shoot growth was restricted with no new growth of aerial shoots. The stem was thickened giving a bulb like appearance. The leaf margin turned brown with a golden yellow band underneath. Scattered golden yellow spots appeared on the leaves. The functions of calcium within the plant are not clear, however, it is considered necessary for the formation of cell walls. As most soils contain sufficient Ca to satisfy plant requirements, and because of liming and the use of other fertilizers containing Ca as a secondary constituent, actual deficiencies of Ca are rare. Excess calcium does not appear to affect plant growth directly, but may affect the uptake of certain elements from the soil. The presence of adequate calcium in the soil has a suppressive effect on some seedling diseases. Calcium in plant tissues can reduce bacterial soft rot. Calcium is not very mobile in plants and under certain conditions, such as drought, deficiency symptoms may occur, even though there is an adequate supply of Ca in the soil. Due to this poor mobility, symptoms are usually seen in new growth or tips of leaves or fruit. The following symptoms are associated with Ca deficiency: Stems are thick and woody, terminal buds may die. Older leaves have normal colour but new leaves may be yellowed. New growth is not turgid. Root tips die, restricting root development. Ca deficiency is expected on acid, leached soils, or soils with high potassium levels, or plants with high nitrogen levels, compared with calcium.

Biological functions :

Calcium is present in the cytoplasm at levels that would indicate that it is a *micro*nutrient, ~0.1 µM, in order to prevent interference with the high levels of P. Nonetheless, small fluctuations in Ca levels in the cytoplasm are part of signaling mechanisms for environmental stress. Ca pumps are directed out of the cytoplasm, either to vacuoles, where it may be precipitated as calcium oxalate, or across the plasmalemma. The function of the majority of plant Ca is structural, in the cell walls of shoots and roots.

Magnesium :

Magnesium is involved in the chlorophyll synthesis and also on the enzyme transfer mechanism. Magnesium deficiency is characterized by the formation of parallel yellowing on both the side of leaf blade along the mid rib from the base towards the tip. This symptom was seen on one year old to 2 year old tillers in the sun exposed area where enough sunlight can surpass on the leaf canopy. Besides the deficiency on leaf it would also reduce the colour development of capsules. Generally one soil application of magnesium sulphate could be advocated besides foliar spray of magnesium based nutrients like magnesium sulphate / magnesium humate to correct the deficiency. In some places where the potassium availability is high (or) high potassium supplied along with less magnesium containing fertilizers either through soil or foliar application could also reduce the magnesium uptake. The most familiar function of Mg, as the central ion in chlorophyll molecule, accounts for <25% of total plant Mg. Mg in the cytoplasm is related to enzyme activation: for example, the substrate for ATPases is MgATP. "Excess" Mg is known almost only in soils derived from serpentine or olivene, both Mg-rich rocks, in which the exchangeable Ca/Mg ratio is ~1/5 instead of the more common 4/1 to 1/1;

Sulphur :

Sulphur is important for formation of proteins, enzymes amino acids and vitamins for photosynthesis. It involves in the process of essential oil synthesis in the cardamom seeds. It further activates proteolytic enzymes and formation of chlorophyll. It will enhance the uptake of phosphorus. Besides that it offers cold and drought resistance to cardamom plant.

Biological functions :

- Amino acids: cysteine, methionine. organic-N/ organic-S in plants typically has a 30-40:1 molar ratio
- coenzymes and prosthetic groups
- glutathionine: antioxidant and precursor to phytochelatins

Deficiency symptoms are as follows: Stems are elongated, spindly and woody. Lower leaves are thick and firm, developing chlorosis which may be confused with nitrogen deficiency. Roots system is extensively developed, but spindly roots. Sulphur deficiency could develop in sandy soils if no sulphur-containing fertilizers are applied. The increasing incidence of sulphur deficiency, has considerably increased the use of sulphur fertilizers. Water-soluble sulphates, e.g. potassium sulphate or magnesium sulphate (18 % S), are most effective for correcting the sulphur deficiency in the standing crop, as also is ammonium sulphate (24 % S) where its acidifying effect can provide an added benefit. Slower-acting types such as calcium sulphate (a by – product of super phosphate with14 % S) should be used if leaching poses a problem. Yellow elemental sulphur (100 % S) may be applied either in powdered form or as the coating in sulphur-coated urea (10-20 % S).

Micronutrients :

Zinc :

Zinc is an essential component of various enzyme systems for energy production, protein synthesis, and growth regulation. Zinc-deficient plants also exhibit delayed maturity. Zinc is not mobile in plants so zinc-deficiency symptoms occur mainly in new growth. Poor mobility in plants suggests the need for a constant supply of available zinc for optimum growth. The most visible zinc-deficiency symptoms are short internodes (rosetting) and a decrease in leaf size. Cardamom plant could exhibit the zinc deficiency very often, since the cardamom soils are very poor in zinc availability. It was documented that the zinc availability in cardamom soil is less than 2 ppm (Srinivasan, 1998 - Micronutrient status of cardamom soils in south India, ICRI Techincal Bulletein). Zinc is involved in the formation of new tillers, panicles and also for the capsule development. Zinc deficiency in cardamom could lead to the poor development of capsule by showing a characteristic yellowing symptom on immature capsule and forms a abscission layer near the base of the capsule stalk and thus finally lead to immature shedding of capsule. The symptom on leaf is highly characterized by interveinal chlorosis and reduced leaf lamina on the new tillers. Severe zinc deficiency would also causes reduction in the tiller growth, *i.e.*, the tillers would expand its height at 1-1.5feet from the base and these tillers will be unproductive. Zinc deficiency is also easily accompanied by the incidence of root knot nematode (*Meloidogyne incognita*) and the relationship between zinc deficiency and nematode on cardamom was well evident in the field.

Recommended rates of zinc generally range from 5-8kg / acre. Band placement for soil application and foliar spray also are effective. A circular placement of field grade zinc sulphate @ 20-30g per plant in two equal splits based on the soil test values should be practiced with starter fertilizers is a common practice. Foliar sprays of a 0.25% $ZnSO_4$ will supply sufficient zinc, but two or three applications may be necessary (Sivadasan *et al*, 1991).

Boron :

A primary function of boron is related to cell wall formation, so boron-deficient plants may be stunted. Sugar transport in plants, flower retention and pollen formation and germination also are affected by boron. Seed and grain production are reduced with low boron supply. Boron-deficiency symptoms first appear at the growing points as tip burn. This results in a stunted appearance (rosetting), ill filled capsules due to poor pollination, hollow stems and capsule (hollow heart) and brittle, discolored leaves and loss of fruiting bodies. Boron deficiencies are mainly found in acid, sandy soils in regions of high rainfall and those with low soil organic matter. Borate ions are mobile in soil and can be leached from the root zone. Boron deficiencies are more pronounced during drought periods when root activity is restricted. Boron needs vary widely. As a prophylactic treatment soil application of Borax (11 % or 22 % B) @10-20gram per plant can be done. A better distribution can be obtained by incorporating the boron in e.g. phosphate or multi nutrient fertilizers. Boric acid or water soluble form of di sodium tetra octa borate (Borax) may be used through foliar application.

Copper :

Copper is necessary for carbohydrate and nitrogen metabolism, so inadequate copper results in stunting of plants. Copper is also required for lignin synthesis, which is needed for cell wall strength and prevention of wilting. Deficiency symptoms of copper are dieback of stems and twigs, yellowing of leaves, stunted growth and pale green leaves that wither easily. Copper deficiencies are mainly reported on organic soils (peats and mucks), and on sandy soils, which are low in organic matter. Copper uptake decreases as soil pH increases. Increased phosphorus and iron availability in soils decreases copper uptake by plants. Copper deficiency may most easily be corrected for a longer period by soil application of 5 kg/ ha Cu as Cu sulphate or oxides, etc. Chelates or neutralized Cu sulphate (25 % Cu) are suitable for foliar spraying of deficient crops. The copper deficiency is not a common problem in cardamom soils, since in most of the cardamom estates copper oxy chloride, copper hydroxide and bordeuax mixture are applied as pre monsoon, mid monsoon and post spray for the control of capsule rot (azhukal), clump rot and leaf spot and blotch control. Residual effects of applied copper are very marked, with responses being noted up to eight years after application. Because of these residual effects, soil tests are essential to monitor possible copper accumulations to toxic levels in soils where copper fertilizers are being applied. Plant analyses also can be used to monitor copper levels in plant tissues. Copper applications should be decreased or discontinued when available levels increase beyond the deficiency range.

Molybdenum :

Molybdenum is involved in enzyme systems relating to nitrogen fixation by bacteria growing symbiotically with legumes. Nitrogen metabolism, protein synthesis and sulfur metabolism are also affected by molybdenum. Molybdenum has a significant effect on pollen formation, so fruit and capsule formation are affected in molybdenum-deficient plants. Because molybdenum requirement is very low, most plant species do not exhibit molybdenum-deficiency symptoms. Unlike the other micronutrients, molybdenum deficiency symptoms are not confined mainly to the youngest leaves because molybdenum is mobile in plants. Molybdenum deficiencies are found mainly on acid, sandy soils in humid regions. Molybdenum uptake by plants increases with increased soil pH. Generally molybdenum availability in the acidic soil is very poor. The molybdenum deficiency on cardamom plants could lead to poor seed development, pale brown colour formation and capsule weight. Molybdenum is required in only very small amounts for the plant growth and development. Water soluble form molybdenum sources either the sodium molybdate (45% Mo) or ammonium molybdate (40 - 50% Mo) should be used for foliar application. Broadcasting of molybdenized phosphate fertilizers prior to planting or to pastures has been used to correct molybdenum deficiencies. Soluble molybdenum sources also can be sprayed on the soil surface before tillage to obtain a uniform application. Excess Mo in plants can be harmful to animals that eat them as it can cause sterility, amongst other things. Solubility in H2O Per cent Element

Manganese :

Manganese becomes more soluble in acid soils and is thus more likely to cause toxicity than deficiencies. Toxicity may also be induced by water-logging. Toxic levels of manganese in acid soils can be corrected by liming. Symptoms of Mn toxicity vary among vegetable crops. There is slow growth and necrotic spots on young plants. Small black spots develop on stems and on the underside of mature leaves. Veinal chlorosis may be seen on leaves and their inter-veinal areas may have some yellowing.

Diagnosing micronutrient status :

It is important to diagnose the status of all micronutrients before undertaking corrective measures. As discussed, micronutrient disorders can involve one or more nutrients as well as combinations of toxicities and deficiencies. The presence of one micronutrient deficiency does not indicate that all other micronutrients are low. Application of a complete package of micronutrients in a situation where a deficiency / toxicity situation exists will increase the problem (Ratnavele, 1968 and Sadanandan *et al.*, 2000). There are three systems for diagnosing nutrient status. The best diagnostic tool for micronutrients is foliar analysis. Visual observation of symptoms works but requires that damage be present (Srivatsava *et al.*, 1968). Most damage cannot be corrected. Commercial soil tests do not generally identify levels of all micronutrients. On the other hand, accurate tests and standards have been established for foliar analysis of all micronutrients.

Foliar sprays :

Foliar sprays are widely used to apply micronutrients, especially iron and manganese, for many crops. Soluble inorganic salts generally are as effective as synthetic chelates in foliar sprays, so the inorganic salts usually are chosen because of lower costs. Suspected micronutrient deficiencies may be diagnosed with foliar spray trials with one or more micronutrients. Correction of deficiency symptoms usually occurs within the first several days and then the entire field could be sprayed with the appropriate micronutrient source. Inclusion of sticker-spreader agents in the spray is suggested to improve adherence of the micronutrient source to the foliage. Caution should be used because of leaf burn due to high salt concentrations.

Advantages of foliar sprays are:

- application rates are much lower than for soil application;
- a uniform application is easily obtained; and
- response to the applied nutrient is almost immediate so deficiencies can be corrected during the growing season.

Micronutrient application :

Prior to adding micronutrients to correct a deficiency, check the substrate pH and make sure it is in the recommended range. If not, take steps to correct the pH before adding extra micronutrients. If there is still a problem then consider additions of the deficient

Inorganic Sources:

Stages of Growth and Need of the nutrients

Age of cardamom plants and stage of growth	Nature of nutrients needed	Type of nutrient preferred / supplements needed
Planting to 45 days after planting	More Phosphorous and lesser Nitrogen	Rock Phosphate, Bone meal, Neem cake, Azospirillum, Phosphobacteria and Vesicular Arbuscular Mycorrhizae (VAM)
11/2 to 6 months after planting	More Nitrogen and Calcium and relatively lesser P and K	Vermi-compost / Ground nut cake / Farm yard manure, Azospirillum
6 MAP to 12 months after planting	More Nitrogen, Phosphorous and Calcium and relatively lesser Potassium	20:20:0:13 10:26:26 DAP, Bone meal, Rock Phosphate etc.,
12 MAP to 16 months after planting	More Nitrogen, Phosphorous and Calcium and relatively lesser Potassium	

Foliar spray schedule for water soluble fertilizers, micronutrients and growth regulators for cardamom in western Ghats of South India

Month / Time of application	Water soluble fertilizers / micronutrients / growth regulators (To be dissolved in 200 litre of water)
March - April (Pre Monsoon Spray during panicle initiation and development stage)	Mono Ammonium Phosphate (12:61:0 –NPK) @ 1000g + Zinc Sulphate @ 500 g or EDTA Chealted Zinc @ 200g + Napthalene Acetic Acid @ 8 g (40 ppm) + Di sodium octa tetra borate (Borox) @ 300g or Boric Acid @ 200g
August - September (Mid Monsoon Spray during capsule setting, development and maturation stage)	Potassium Nitrate @ 1000g + Zinc Sulphate @ 500 g or EDTA Chealted Zinc @ 200g + Di sodium octa borate tetra hydrate (Borox) @ 300g or Boric Acid @ 200g
October – November (During capsule development and maturation stage)	Sulphate of potash (SOP) @ 1000g (0:0:50:20 – NPKS) + Zinc Sulphate @ 500 g or Chealted EDTA Zinc @ 200g + Magnesium Sulphate @ 500 g + Di sodium octa borate tetra hydrate (Borox) @ 300g or Boric Acid @ 200g

Note : The spray should cover the under, upper surface of the leaf, the developing panicles and also on capsules to get better results and easy absorption of nutrients at a faster speed. Eight gram of NAA (Napthalene Acetic Acid) should be initially dissolved in 100ml of alcohol before mixing into the tank mix.

micronutrient. There are three alternative methods of application for micronutrients: dilute concentrations may be applied in combination with macronutrients during each fertilizer application throughout the crop cycle. Sources, rates, and the final elemental concentration of each micronutrient should be compatible. When all of the micronutrients are desired most commercially prepared fertilizers can be used since they contain all micronutrients. When fertilizers are self-formulated, commercial products containing all micronutrients can be added into the fertilizer. The second method of application calls for higher concentrations to be applied one time as a normal watering. The third method involves a single foliar application of micronutrients. Foliar sprays are very useful where root injury due to such factors as disease or a poorly drained substrate would reduce root uptake of nutrients. However, the greatest risk of plant injury exists with foliar application. Spraying should be avoided during the mid day heat. Early morning, after sunrise, is an effective time for application. Plant uptake is enhanced by the increased drying time which occurs during the moist conditions in the morning. Nutrient uptake through the leaves is also greater in the light period than at night, thus making morning applications more desirable than evening sprays. Incorporate a recommended non ionic spreader / sticker into micronutrient sprays for more effective coverage. Use rates similar to those employed when applying pesticides.

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REFERENCES

Korikanthimath, V.S. (1994). Nutrition of cardamom. In: *Advances in Horticulture*. Eds. K.L.Chadha, Malhotra Publishing House Ltd. *New Delhi*.

Khader, K.B.A. and Sayed, A.A.M. (1977). Fertilizing cardamom-its importance. *Cardamom*, **9** (1-2) : 13-14.

Natarajan, P. and Srnivasan, K. (1989). Effect of varying levels of N, P and K on yield attributes and yield of cardamom (*Elettaria cardmomum*). *South Indian Horticulture*, **37** : 97-100.

Ranganathan, V. and Natesan, S. (1985). Cardamom soils and manuring. *Planters chronicle*, **80** (7) : 233-236.

Ratnavele, M.V.S. (1968). Value of soil and plant analysis. *Cardamom News*, **2** (6) : 1-4.

Sadanandan, A.K., Hamza, S. and Srinivasan, V. (2000). Foliar nutrient diagnostic norms for optimizing cardamom production. In *Spices and Aromatic plants*, Ind., Soc., for Spices, IISR, Calicut, pp. 101-104.

Sivadasan, C.R., Nair, C.K., Srinivasan, K. and Mathews, K. (1991). Zinc requirement of cardamom. *J. Plantation Crops*, **18** : 171-173.

Srivatsava, K.C., Bopaiah, M.G. and Ganapathy, M.M. (1968). Soil and plant analysis as a guide to fertilization in cardamom. *Cardamom News*, **2** (3) : 4-6.

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