DIAGNOSIS OF NUTRITIONAL DISORDERS AND MANAGEMENT IN GRAPEVINE

NATIONAL RESEARCH CENTRE FOR GRAPES

(Indian Council of Agricultural Research)

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PREFACE

The deficiencies and excess of nutrients are not good for plants and this leads to drastic reduction in the yield and quality of grapes. Improper fertilization not only results in wasteful expenditure but it also has potential for a detrimental effect on vine growth and crop quality, apart from its effects on the soil health. Pollution of groundwater and environment are other issues associated with this. Considering the importance of timely diagnosis of deficiencies and toxicities of nutrients in crop productivity and efficient use of fertilizers, an attempt has been made to compile all the research and technical information, generated so far by the centre and the elsewhere in the form of bulletin entitled 'Diagnosis of Nutritional Disorders and Management in Grapevine'.

The information given in the bulletin will serve as guidelines for diagnosis and remedies of different nutritional disorders. Further, this bulletin will be handy information not only to the grape growers but also for students and researchers engaged in this line of work. Contribution made by Dr. J. Sharma, Scientist at this institute is therefore highly appreciated. I also take this opportunity to acknowledge the help of all the concerned staff of the centre in the preparation of this bulletin.

Place : Manjri, Pune
Date: August 2005

P. G. ADSULE
Director

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On the Cover: Vines suffering from potassium deficiency in saline soil.

1. Introduction

In most of the grape growing regions of India, rainfall has become scanty and therefore salinity related hazards are increasing due to lack of availability of good quality irrigation water. Because of adverse soil and climatic conditions and lack of location specific fertilizer and irrigation recommendations, more nutritional problems are being encountered in the major grape growing areas of the country. Improper fertilization of grapevines not only results in wasteful expense, but also has potential for a detrimental effect on vine growth and crop quality. Apart from this, it also degrades the soil health and causes environmental pollution.

Out of sixteen elements known to be essential for plant growth, carbon, hydrogen and oxygen are primarily obtained from air and water. The role and importance of carbon, hydrogen and oxygen will not be discussed here as these are primarily obtained from air and water. The other thirteen elements are absorbed mainly from soil and are commonly divided into two groups based on the relative amounts required for plant growth- macronutrients and micronutrients. Macronutrients are needed in plants in relatively higher amounts than micronutrients. Based on the element content in plant material, the following elements may be defined as macronutrients: Carbon, hydrogen oxygen, nitrogen, phosphorus potassium, calcium, magnesium and sulphur. The micronutrients are: zinc, iron copper, manganese, boron, molybdenum and chlorine are called micronutrients. All of these elements are indispensable for normal plant growth regardless of the amount required.

This publication discusses in brief the importance, occurrence, diagnosis and management of common nutrient deficiencies and toxicities observed in grapevines in majority of grape growing regions of the country. The information is based upon the surveys, farm visits and research undertaken by the centre in different parts of the country. A lot has also been contributed by growers experience and feedback in managing the different disorders. The most common and economic sources of different nutrients have been mentioned in this publication but this does not mean that other sources are not good. The choice is determined by the cost as well as soil conditions.

1.1 Nutrient Deficiencies observed in Indian vineyards

Common	*Less Common*	*Not observed*
Potassium	Manganese	Chlorine
Magnesium	Phosphorous	Copper
Iron	Nitrogen	Sulphur
Zinc	Calcium	Molybdenum
	Boron	

1.2 Nutrient Excesses observed in Indian vineyards

Common	*Less Common*
Sodium	Boron
Chlorides	Potassium
Nitrogen	
Copper	

2. Factors affecting vine growth, nutrient uptake and deficiency symptoms

For complete diagnosis, one must know and understand the field conditions that have impact on vine growth. Such knowledge may help in identifying the exact cause that is inducing or magnifying the apparent nutrient shortages. All the factors that influence vine growth, response to fertilization, and the final yield must be looked into. Some of the important factors are discussed below:

2.1 Soil pH and soil salinity - Soil pH gives the first hand information regarding probable nutrient deficiencies or excess and regulates the availability of the nutrient. In alkaline soils the micronutrients like Zn, Fe, Cu and Mn are likely to be in deficient range. The uptake rate of various plant nutrients is also pH dependent. The uptake rate for cations seems to be highest in more neutral range. Soil pH also influences the occurrence and the activity of soil microorganisms. Generally in low pH range (<5.50) fungi dominate in the soil and in rhizosphere, whereas at higher pH bacteria are more abundant. The nitrification of NH^{+}_{4}-N and

HNO_2 brought by *Nitrosomanas* and *Nitrobacter* depends considerably on soil pH, because these bacteria prefer more neutral soil conditions. Vines are sensitive to salinity. Excess soluble salts reduce the water and nutrient uptake and affect the overall development of the vines. Use of salt tolerant rootstocks is one of the solutions for the saline soils

2.2 Root zone - Examine the root zone soil for compactness and root development. Soil compaction and poor soil aeration affects the root development and applied fertilizers are not efficiently utilized. Soil compaction not only reduces total pore volume but also reduces the average size of soil pores. This affects water and air movement in soil. The vines raised on black cotton soils often suffer from compaction since these soils have poor structure. These soils swell when wet and shrink and become rock-hard and crack when dry (Fig.1). To improve aeration the root zone should be loosened and organic materials should be added regularly. When 40-50 percent of the soil volume consists of pore space it is considered as a good structure for plant growth. Such a soil is able to store water and can readily be penetrated by roots. Soil structure influences the soil aeration. The respiration of plant roots depends to a large extent on the oxygen supply in the soil air. Lack of oxygen directly affects the carbohydrate metabolism of roots. The oxygen supply to roots also depends on total volume of air present in soil. Poor structure occurs when sodium is dominant ion in the exchange complex, as it has a dispersing effect and prevents aggregation. Calcium plays an important role in soil structure. Calcium in combination with humic acids and clay minerals forms very stable organo-mineral complexes. Regular use of organic materials in soil such

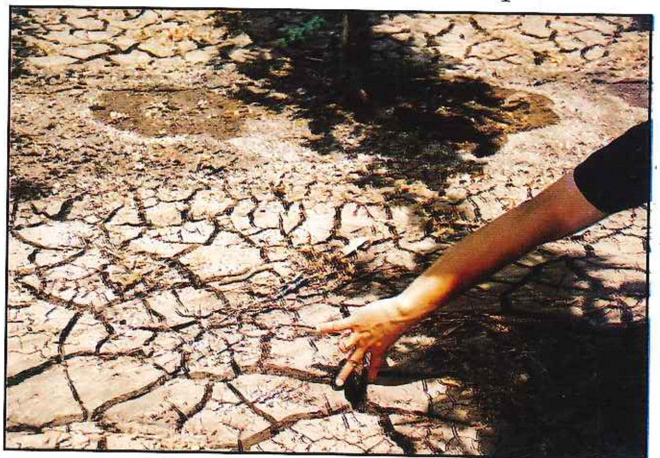

Fig.1. Heavy clay soils showing swelling and shrinkage behaviour

as FYM, composts and green manures etc. improves the structure. High organic matter and earthworms contribute considerably into the formation of stable aggregates. Wet soils are easily compacted than dry soils and sandy soils are more easily compacted than fine textured soils.

2.3 Temperature - Cool soil temperature slows down the rate of organic matter decomposition. This limits the release of nutrients like nitrogen, sulphur and other nutrients. Nutrients diffuse more slowly in cool soils. Mulching can regulate soil temperature. In winters, to increase the soil temperature both plastic and organic materials can be used for mulching. The choice of the mulching material is also determined by the climate, soil salinity and method of fertilizer application etc.

2.4 Soil moisture - Dry soil conditions may create nutrient deficiencies. Drought slows movement of nutrients to roots. Excessive moisture interferes with root development and respiration as a result of which nutrient uptake is impaired. This has a detrimental effect on vine growth (Fig.2). For proper root development adequate drainage should be provided.

Fig.2. Vines suffering from poor soil aeration as a result of excessive moisture after flood irrigation in heavy soil

2.5 Insects - Insect damage should not be mistaken for a nutrient deficiency. The roots, leaves and stems should be examined for insect damage that may cause similar symptoms. Nematode infested vines remain stunted and may show multiple deficiency symptoms.

2.6 Diseases - Sometimes the disease symptoms may be confused with the nutrient deficiencies. Close observation will show the difference between the plant diseases and nutrient deficiencies. The disease symptoms can often be detected with a small hand lens.

2.7 Cultural practices and variety - Under similar conditions one variety may show symptoms of deficiency while another variety may not show the symptom at all. The growth is affected by the climatic conditions, hence date of pruning will affect rate of growth and plant appearance, as well as final yield potential. Weeds rob vines of water, air, light, and nutrients. Hence the herbicides and mechanical controls have become more important today than ever before. There are always possibilities of herbicide drift from adjacent fields. It becomes therefore, important to know the symptoms of herbicide damage and the interactions of herbicides with soil conditions.

2.8 Nutrient Balance - This whole science of relationship of one element with another is complex. Understanding the relationship among the different elements is very important in diagnosing the deficiency/toxicity. When more of one nutrient is added or present in soil there is need for more of other. For example, when more N is added, the yield potential may increase and the need for K will also increase. A high quantity of P in the soil or in the plant may result in a deficiency of Zn. A high amount of available K in soil may result in deficiency of Mg. The imbalance can be identified by analysis.

3. Importance of tissue and soil analysis in diagnosing nutrient deficiency/toxicity

To identify the disorders, soil tests or plant analysis or both are used to find out the causes. Often a plant may border on deficiency of a nutrient and yet not show any symptoms. This condition is called 'hidden hunger'. Here, there are no visual symptoms, but the plant is not producing to its potential. This is one of the disadvantages of relying on symptoms alone. When plants reach the deficiency level where symptoms appear, yield has already been reduced. In most of the areas vines are grown in the hidden hunger zone. Sometimes one or more nutrients may be deficient simultaneously. Under such conditions it becomes difficult to find out the cause of the symptom visually and tissue and/ or soil testing becomes important.

The nutritional status of the vine should be monitored regularly. The recommended stages for petiole analysis are 45 days after foundation pruning (bud differentiation stage) and full bloom stage (Fig.3) after fruit pruning under double pruning and single cropping system in case of Thompson Seedless grapes. Sample consisting of 150-200 petioles should be collected from shoots, which are well exposed to the sunlight from all sides (cordons) of the vines. The petiole nutrient norms for Thompson Seedless vines are given in annexure I and II.

Fig.3. Petiole opposite the cluster is sampled at full bloom stage

Note: Petiole should be separated immediately from the leaf blade.

Soil analysis can reveal what is potentially available to the vine, but does not give good indication of soil-plant interactions. Often, little or no relationship is observed between soil and vine's nutritional status. Soil testing is, however, quite helpful in understanding fertilization approaches when a need is identified. Soil analysis is used to know the vineyard problems due to pH, salinity and certain toxicities. Soils should be analyzed for pH, a measure of acidity or alkalinity; electrical conductivity, a measure of salinity; exchangeable sodium percentage (ESP) to evaluate the sodium toxicity and soil permeability hazards; cation exchange capacity (CEC) to estimate relative excess or deficiency of cations, and for probable toxicity of boron and chloride. Soil samples should also be analyzed for texture, water holding capacity, bulk density besides the fertility status.

4. Macronutrients

4.1 Nitrogen (N)

Nitrogen is a constituent of amino acids, lecithin and chlorophyll. Grapevines absorb most of the nitrogen as nitrate and transport it to leaves where it is transformed into protein and other nitrogen compounds.

Grapevines rarely express visual symptom of N deficiency. Nitrogen deficient vines grow with poor canopies. Unless the deficiency is severe, symptoms are not easy to identify. Deficiency is indicated by uniform pale green to yellowish colour of leaves (Fig.4). Nitrogen deficiency during foundation pruning also reduces the number of fruitful canes.

Fig. 4. Nitrogen deficient vines with pale yellow leaves

More damage has been observed because of excess of nitrogen than too less of it. Excess nitrogen symptoms are more clearly defined than deficiency symptoms. Excess N also reduces the carbohydrate accumulation. Shoots tend to have long internodes and become flat. Excess nitrogen causes excessive shoot growth and delays cane and fruit maturity. Excess N also aggravates K

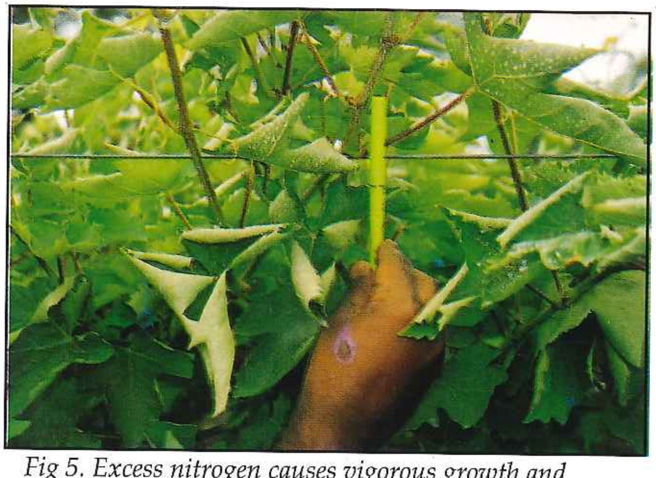

Fig 5. Excess nitrogen causes vigorous growth and induces potassium deficiency

deficiency as a result of excess vigour (Fig.5). Nitrogen promotes vegetative growth and excess N adversely affects the fruitfulness and yields particularly in vigorous varieties like Thompson Seedless, Tas-A-Ganesh, Manik Chaman, Sonaka, Flame Seedless, which are commonly grown in India. Nitrogen toxicity is not commonly observed. However, temporary NH^{+}_{4}-N toxicity has been observed in April - June (hot weather) where high amounts of neem cake have been added. In severe cases, the leaf burn may occur.

Nitrogen management:

Nitrogen is the third most needed and often neglected nutrient particularly during foundation pruning in the Indian viticulture. In high pH soils conversion of NH^{+}_{4}-N to NO^{-}_{3}--N is reduced and volatization losses are increased thereby decreasing N availability to vines. Too much nitrogen on the other hand results in excessive vine vigour and occasionally reduces the fruit set and quality. Nitrogen need is most critical during the stages of rapid shoot growth and berry development. The need is less during other growth stages. For direct soil application as high as 660 kg N/ha has been recommended under Madhya Maharashtra conditions. In light textured soils (sandy soils) leaching losses are high, hence more number of splits result in better use efficiency. For greater efficiency N should be applied through irrigation systems in the form of urea, calcium ammonium nitrate, ammonium sulphate or ammonium nitrate. Trials conducted in black cotton calcareous soils have shown that fertigation results in 60 percent savings compared to direct soil application method. Thirty percent of the total N required/year should be applied during first 30 days after foundation pruning, 30 percent during first 40 days after fruit pruning and 30 percent during berry growth and upto veraison stage. Fertilizer application during rest period is very important and 10 percent of the total annual N dose should be applied during rest period. Both manures as well as inorganic fertilizer should be immediately incorporated into soil after their application to reduce N losses. Most of the ground waters in Maharashtra are rich in nitrates, hence contribution of N from irrigation water, applied organic manures, etc. should also be taken into account while deciding the fertilizer doses.

4.2 Phosphorus (P):

The major role of P is in energy transformation in plants. Phosphorus is important in fruit bud differentiation and formation of roots. Phosphorus deficiency is detrimental to inflorescence formation. The deficiency results in more tendril formations instead of clusters (Fig.6). Phosphorus accumulates in fruitful buds. Phosphorus also increases the bunch weight. Recent research results indicate that downy mildew incidence is less in vines well supplied with phosphorus. Excess of phosphorus causes symptoms resembling to Fe deficiency. Excessive phosphorus also causes Zn deficiency.

Fig.6. Phosphorus deficiency reduces fruitfulness and only tendrils are formed.

Phosphorus management:

Phosphorus is one of the major nutrients and readily fixed in soils. As a result of this, it is often applied in excess in most of the vineyards. Poor fruitfulness has been observed in many vineyards in Sangli region under moisture stress despite high levels of available P in soil. New root development, bud differentiation and bunch development are the critical stages for this element. Hence continuous supply of phosphorus to grapevines should be ensured during all these stages. The efficiency of P fertilizers is very low due to fixation of applied P in the soil. The recommended phosphorus rates are as high as 880 kg P_2O_5/ha for direct soil application in calcareous soils of Madhya Maharashtra region. Application of the half of the recommended dose along with FYM at the time of each pruning for direct soil application under the drippers generally meets the requirements of the vines for the entire pruning season. The P fertilizers should be placed between two layers of FYM to minimise the fixation. Phosphatic fertilizers can be applied through irrigation systems. In case of hard water and lime rich soils low pH of phosphatic fertilizers is not a problem. Fertigation results in greater P use efficiency. Fertigation has been found to reduce the P application rates by 60 percent in calcareous soils at Pune. through fertigation 10 percent of the annual dose should be applied before foundation pruning (during rest period) and 60 percent dose during the bud differentiation stage (30 - 60 days after foundation pruning). The remaining 30 percent of the annual dose should be applied during the bloom, set and shatter stages (40 - 70 days after fruit pruning). For high calcium containing soils, P fertilizers without Ca are more effective. The most common inorganic fertilizers are SSP, DAP, phosphoric acid, mono and di- potassium phosphate and ammonium polyphosphate etc. Application of water insoluble sources is not useful in calcareous and alkaline soils. Due to introduction of drip irrigation system the fertilizers are placed in a pocket below the dripper. This practice minimises the fixation of phosphorus in the soil. Continuous use of fertilizers in the same place results in considerable build up. This should be monitored regularly to adjust the P fertilization. Some river waters may also contain considerable quantities of phosphates. This should be taken into account for deciding P application rates.

4.3 Potassium (K):

Fig 7. Inward leaf curling caused by K deficiency

Like all other plants, vines need potassium for sugar formation, protein synthesis and cell division. Potassium neutralizes the organic acids in the plants and also regulates activity of other mineral nutrients. It plays an important role in opening and closing of stomata and hence regulates water relations in plants. Potassium makes the buds fruitful. Potassium imparts disease resistance to the vines. Grapevines with insufficient K supply are more susceptible to powdery mildew.

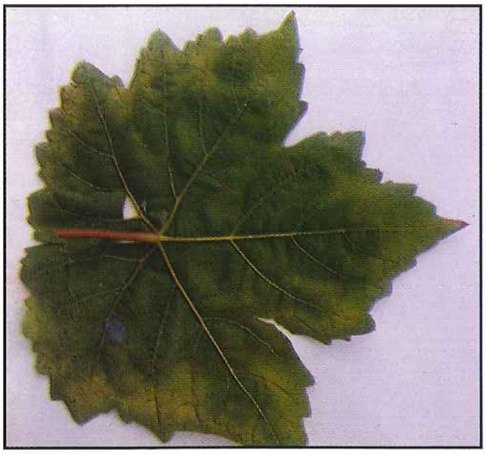

Fig 8. Marginal chlorosis caused by potassium deficiency

Deficiency symptoms on leaves are more obvious during foundation-pruning season particularly after rainfall, during grand growth period, veraison and ripening stage. The deficiency symptoms appear first on mature leaves. Inward leaf curling, a potassium deficiency symptom (Fig.7) is often observed in vigorously growing vines. Water berry formation is commonly associated with K deficiency. The yellowing or chlorosis starts from the margins of leaves then progresses inwards (Fig.8). Gradual fading or yellowing pattern is characteristic of potassium deficiency. In case of extreme deficiency the leaves show marginal burning (Fig.9)

Fig 9. Marginal leaf burning caused by K deficiency

Potassium management:

This nutrient ranks number one among the most deficient nutrients in Indian vineyards particularly in heavy calcareous and sandy soils. When potassium is deficient the yield losses are dramatic (Fig.9). Potassium needs of the grapevines are high and are comparable to the demand for nitrogen. The reasons are, in part, heavy/sandy texture, greater potassium fixation in heavy soils, soil salinity and sodicity and high calcium carbonate ($CaCO_3$) content in soil (Fig.10). Soil compaction reduces the potassium availability. This is the one of the reasons for low K use efficiency in vineyards raised on heavy black cotton soils.

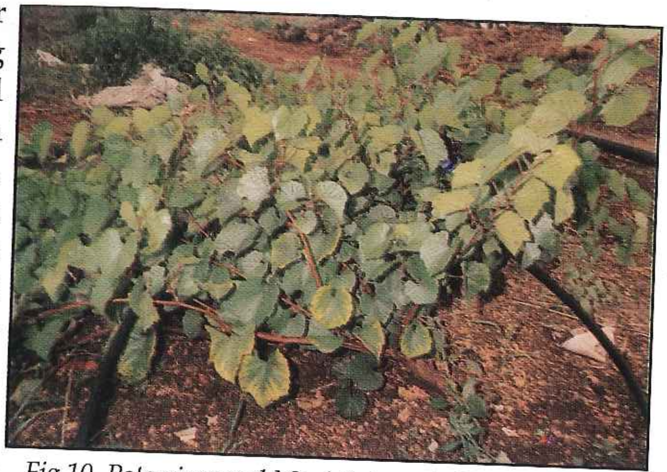

Fig.10. Potassium and Mg deficiency in Dog Ridge rootstock in high lime containing soil

The demand for potassium is high during cane maturity, bud development, veraison and ripening stage. Therefore, potassium application should be done in the beginning of these stages in case the direct soil application method is followed or should be applied through fertigation during these growth stage periods. For heavy black cotton type soils in Madhya Maharashtra conditions 660 kg K_2O /ha/year is recommended. Since grapevines are sensitive to chloride, either K_2SO_4 or KNO_3 and other chloride free K fertilizers are recommended under Indian conditions as most of the soils are saline/alkaline and receive low rainfall. Under deficient conditions single large application is more beneficial in overcoming the deficiency. For regular fertilization programme, fertigation or split application of potassium is more efficient than single large application to avoid fixation and leaching losses. Ten percent of the annual dose through fertigation should be applied before foundation pruning (during rest period). Thirty percent dose should be applied during post bud differentiation stage (60 - 120 days after foundation pruning) and remaining sixty percent between berry growth and crop maturity stage. Immediately after the inward leaf curling symptoms appear, spraying with 0.5 percent solution of potassium fertilizers like K_2SO_4 or KNO_3 depending upon the vigour of the vine provides immediate but temporary cures for deficiency. Higher concentrations e.g. 1 percent KNO_3 in spray solution may result in leaf burning. The spraying should be followed by bulk soil application of potassium fertilizers for quick recovery of the vines. The quick response is obtained by a single heavy soil application than split application.

4.4 Magnesium (Mg):

Magnesium is the constituent of the chlorophyll and therefore is essential for photosynthesis. Magnesium activates many plant enzymes required in growth process.

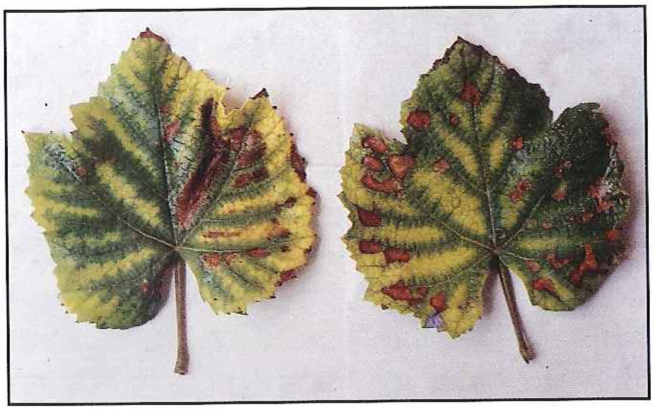

Fig.11. Mg deficiency symptoms in Bangolore blue grapes

Magnesium deficiency symptoms first appear on old leaves, as it is mobile within the plant system. The deficiency symptoms begin with yellowing of basal leaves and progresses to upper leaves. The chlorosis begins at or near leaf edge and moves inwards between primary and

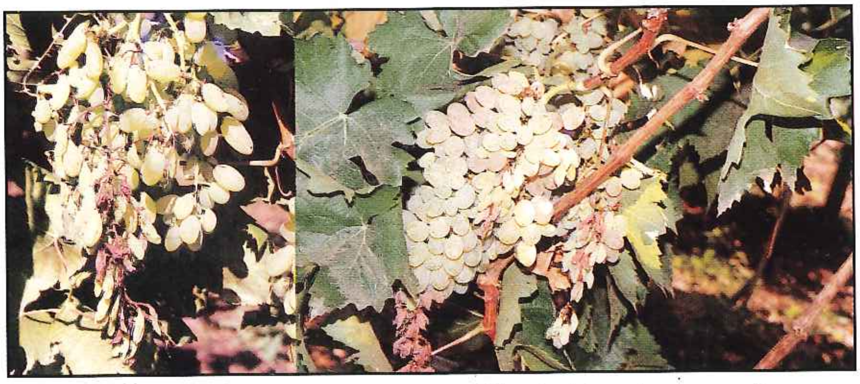

Fig 12. Bunch stem necrosis (mummification) in calcareous soils

secondary veins (Fig.11). Chlorosis also starts first between the veins. Mummification or bunch stem necrosis a commonly observed disorder in calcareous soils of Maharashtra is mainly due to Mg deficiency (Fig 12).

Magnesium management:

This is the most neglected secondary nutrient in majority of the Indian vineyards. Magnesium deficiency is common in vines growing on calcareous, sodic and sandy soils. The deficiency is commonly observed in vines grafted on rootstocks e.g. Dog Ridge mostly due to higher potassium accumulation by rootstocks. Hence under identical soil conditions varietal differences may be significant in this respect.

The demand for Mg is more during veraison and ripening period. Sometimes deficiency symptoms can be confused with potassium deficiency hence should be verified by petiole/leaf analysis. Higher NH^{+}_{4}-N rates also aggravate the Mg deficiency. For immediate correction of leaf symptoms foliar sprays with magnesium nitrate or magnesium sulphate @ 0.5 percent are quite effective. Higher rates may cause leaf burn. Magnesium sulphate ($MgSO_4$) sprays should be avoided after the fruit set to prevent scars etc. on berries. Since sprays give only temporary correction, therefore, soil application should be followed. There are no specific recommended rates. However, application of up to 180 kg $MgSO_4$/ha/year has been found sufficient in most vineyards grown on calcareous heavy soils in Maharashtra.

4.5 Calcium (Ca):

Calcium has an important role in structure and permeability of cell membranes. Calcium is essential for cell division and elongation. Calcium is immobile in the phloem, hence, in case of deficiency the terminal buds of the shoots and apical tips of the roots fail to develop. A healthy cation exchange promoted by Ca and water in soil contributes to grape health and disease resistance. Some times deficiency has also been noticed in clusters/bunches even in calcareous soils, particularly during cold season. The growing clusters dry up starting from the tip, which is similar to severe stem necrosis (Fig.12). Blossom end rot in sandy soils of Hyderabad region has been attributed to calcium deficiency.

Calcium management:

Calcium deficiency is common in light textured (sandy soils) acid soils and is less common in vines growing on black cotton soils as they are rich in lime and super phosphate is commonly used as a source of phosphorus in these soils. The deficiency is mostly due to restricted internal supply. Conditions impairing the growth of new roots reduce the access of vine roots. Hence poor root growth in heavy calcareous soils as observed in Nasik area reduces calcium uptake. Calcium application improves the shelf life of the berries and growers commonly use calcium nitrate and /or calcium chloride @ 0.2 percent to 0.5 percent during the berry development stage. Calcium chloride sprays sometimes result in leaf scorching or may leave white deposit on the berries. Calcium is immobile in the plant system hence bunch dipping with calcium salts @ 2-3 g per liter of water before and during veraison stage is most effective method to supply calcium. Calcium sprayed on leaves is of little use for bunch. Sufficient calcium is applied through super phosphate, a commonly used phosphatic fertilizer in Indian vineyards. The other commonly used sources of Ca are calcium ammonium nitrate and gypsum.

4.6 Sulfur (S):

Sulfur is needed for the synthesis of the sulfur containing amino acids cytine, cystëine and methionine, which are essential components of protein. Although not a constituent of chlorophyll it is also required for the synthesis of chlorophyll. Sulfur deficiency has not been reported in Indian vineyards.

Sulphur management:

Sulfur is commonly used fungicide and insecticide in viticulture. Sulfur deficiency in field has not been observed so far. However, it is highly needed as amendment in alkali soils and the vineyards being irrigated with sodium rich waters. Sulfur containing mineral fertilizers e.g. super phosphate, potassium sulphate and sulphate salts of micronutrients as well as fungicides/ insecticides add enough sulfur to vineyard soil. However, recent trend of use of sulfur free high analysis fertilizers has aggravated the sodium toxicity in vineyards irrigated with sodium rich water.

5. Micronutrients

5.1 Iron (Fe):

Iron (Fe) is transported as Fe^{++} (ferrous) form and combines with proteins to form complex organic compounds. It helps in chlorophyll formation. It is also a metal activator of several enzymes.

Fig.13. Fe deficiency on new leaves (see fine network of green veins)

In case of deficiency, initially a pale yellow with green network of veins is observed on the leaves (Fig.13). As the deficiency becomes severe, the leaves become yellow or even white. Severely chlorotic areas on leaves often turn brown and necrotic. Shoot growth is reduced only in severe deficiency.

Iron management

Iron deficiency is most common in calcareous soils and the symptoms can appear at any growth stage. The deficiency is primarily related to the soil conditions such as heavy texture, cold temperatures, and poor drainage, which limit root uptake. Lime induced chlorosis is a common term used to describe Fe deficiency in calcium carbonate containing soils. During rainy weather, when soil moisture is high and soil aeration is poor, bicarbonate (HCO_3^-) accumulates in soil medium and the chlorosis is likely to occur. It is supposed that HCO_3^- in root medium results in Fe immobilization in the plant. Improving soil structure is one of the most important measures in controlling Fe chlorosis. Vigorous shoot growth also induces in Fe deficiency. Iron deficiency can be easily corrected with the near neutral 0.2 percent ferrous sulphate ($FeSO_4$) sprays. However, sprays offer only temporary solution and benefits only existing foliage. Lower concentrations of salts are better for effective absorption. The pH of the spray should be checked to avoid toxicity. Iron moves very little from one tissue to another and only sprayed leaf areas recover. Depending upon the extent of deficiency, the sprays may be repeated every fortnight. Since Fe is immobile in phloem, soil application of preferably chelated sources is the best method for long lasting correction of deficiency. Application of 40-50 kg $FeSO_4$ /ha /year in pockets below drippers is generally sufficient in soils containing up to 10 percent free $CaCO_3$ content. Ferrous sulphate application either by mixing in FYM or digesting for 8-10 days in dung slurry is the most popular method to supply iron in Maharashtra. The Fe is easily fixed in the soil hence chelated sources are more effective on application rate per unit area basis. Among chelated sources Fe-EDDHA is the best in high lime containing and alkaline soils because of its wide range of stability constant.

5.2 Zinc (Zn):

Zinc is needed for auxin formation, inter-node elongation and chloroplast and strands formation. Zinc is essential for normal leaf development; shoot elongation, pollen development and fruit set.

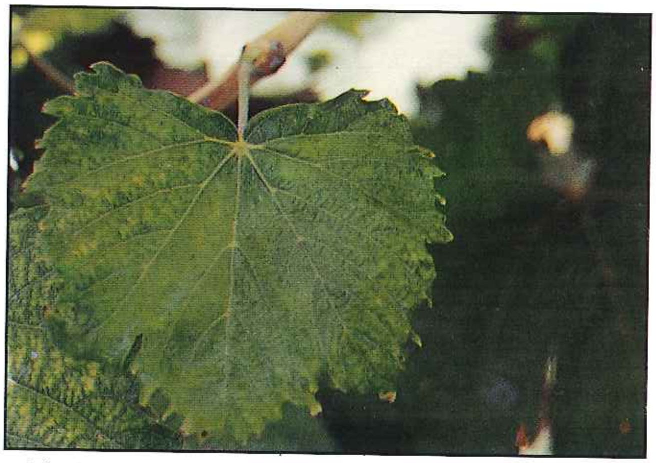

Fig.14. Zinc deficiency reduces leaf size wider petiolar sinus

The deficiency symptom may vary depending upon the extent of deficiency. The deficiency symptoms usually appear on new growth on both primary and secondary shoots. The leaves become chlorotic and distorted. In severely affected leaves the petiolar sinus becomes wider and leaves remain small compared to normal leaf (Fig.14) and the internodes become smaller. Zinc deficiency seriously affects the fruit set and development (Fig.15). Shot berries are formed which often fail to ripen. The shot berries may also be due to wrong application of GA_3 therefore, one must look at leaf symptoms also. For questionable symptoms like fan leaf, 2, 4-D injury, laboratory analysis should be followed to avoid confusion. High zinc can induce Fe deficiency.

Fig.15 Poor fruit set and shot berries caused by zinc deficiency

Zinc management:

Zinc deficiency is the second most wide spread deficiency in Indian vineyards. The deficiency is mainly encountered in sandy soils and soils containing high lime. Calcium carbonate content is the principal factor contributing to zinc adsorption in calcareous soils. Zinc deficiency is greater in high soil pH and in poorly aerated soils such as heavy black cotton soils of Maharashtra, calcareous soils and sandy soils found in Hyderabad and other grape growing regions. Among other nutrients phosphorus interferes with zinc metabolism as well as its uptake through roots. Since zinc is involved in fruit set, its application should be done well before berry setting. Soil application at pruning time or in the first week after fruit pruning is recommended. Zinc can be either applied in chelated form e.g. Zn- EDTA on label recommended rates or as zinc sulphate in 3-4 splits @ 20-30 kg/ha/year after digesting in cow dung slurry for 8-10 days. In Maharashtra state, application of micronutrients through cow dung slurry is most common. The slurry should be applied two to three times in a pruning season. For immediate correction of deficiency foliar sprays of zinc sulphate at the rate of 0.20 percent is recommended depending upon the extent of deficiency. A dilute spray solution concentration (0.20 percent) will be more effective than spraying with less amount of more concentrated solution. About 1000-litre spray solution/ha should be used for better absorption and if the symptoms persist the spray should be repeated after a fortnight. Zinc should be sprayed at least two weeks before bloom for improved berry set. The pH of the spray solution should be neutral or mildly acidic otherwise it may result in scorching. Zinc is phytotoxic and foliar applications should be avoided after the fruit set to avoid scarring of fruits. Since zinc is comparatively more mobile than iron in grape vines, foliar sprays are quite effective in correcting the deficiency.

5.3 Manganese (Mn):

Manganese is an activator for enzymes in growth processes. It helps in chlorophyll formation; thus under deficient conditions leaf chlorosis is observed. Sometimes the symptoms begin as chlorosis on basal leaves. The network of green veins on yellowing tissue is not as fine as in the case of Fe deficiency. Also, leaf malformation is not observed in manganese deficient leaves. The deficiency symptoms are extensive between primary and secondary veins (Fig.16). The manganese deficiency symptoms on lime rich soils are easily concealed under the more severe lime induced chlorosis.

Fig.16. Manganese deficiency on older leaves in Thompson Seedless

Manganese management:

Manganese deficiency is not commonly observed in Indian vineyards. This is partly due to use of manganese containing fungicides. The deficiency is observed in soils containing free calcium carbonates. High soil pH precipitates Mn as MnO_2 thereby reducing the Mn availability. The deficiency is frequently observed in cold wet season. Dry weather also aggravates Mn deficiency. The Manganese deficiency can be easily corrected with manganese sulphate ($MnSO_4$) sprays at the rate of 0.2 percent. Manganese sulphate at the rate of 20-25 kg /ha/year applied either through digested dung slurry or mixed with FYM as pocket placement below drippers is sufficient to ensure Mn supply to grapevines in most of the soils whenever deficiency is encountered. The entire dose is applied in 3- 4 splits. For soil application method, chelated sources are more effective on application rate per unit area basis. Lime or high pH-induced manganese deficiency can be rectified by acidification resulting from use of sulphur or other acid forming materials.

5.4 Boron (B):

Boron is the only essential micronutrient not specifically associated with either photosynthesis or enzyme functions, but is associated with carbohydrate chemistry and reproductive systems of the grapevines. It is believed to be important in the synthesis of one of the bases for RNA formation and in cellular activities like cell division, bud differentiation, maturation, respiration growth etc. Boron is associated with pollen germination and the stability of pollen tubes and is required for good fruit set. In case of deficiency the expanding leaves wrinkle. Necrotic spots may also develop along leaf margins. The deficiency symptoms occur primarily on younger leaves. Younger internodes swell slightly and pith becomes necrotic. Boron deficiency affects the development of berries. The berries develop a symptoms commonly called as hen and chicken or pumpkin and pea disorder (Fig.17).

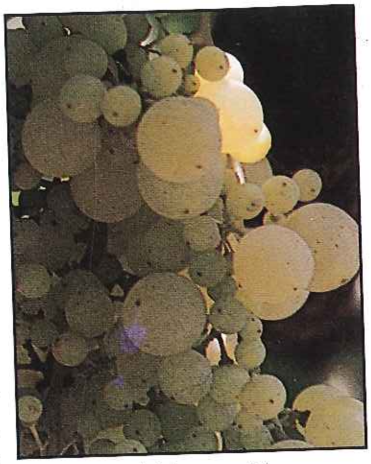

Fig.17. Chicken and hen disorder caused by boron deficiency

Boron management:

Coarse-textured, well-drained, sandy soils are generally deficient in boron. Boron deficiency is not common in heavy soils and soils well supplied with organic matter. Fine textured soils retain added boron for longer periods than sandy soils. Boron deficiency is often associated with low soil moisture conditions. The presence of calcium in alkaline soils also restricts the boron availability. The deficiency can be easily corrected with boron salt sprays at the rate of 0.1 to 0.2 percent. Sprays should be given at least two weeks before bloom for improved berry set. In general soil application is more beneficial than foliar sprays since B is relatively immobile in the plant system and sprays benefit only existing foliage. Soil application at the rate of 5 kg boric acid per ha/year in black cotton alkaline soils is generally sufficient to supply enough boron to grapevines. Grapevines are sensitive to boron excess. However, there are considerable differences among varieties in tolerance to excess of boron. Irrigation water containing 1 ppm or more boron may cause its toxicity in poorly drained soils e.g. heavy black cotton type soils. The boron toxicity symptoms appear as dark brown to black spots or necrosis at the edges at the tip of the serrations. In case of toxicity excess irrigation will help in leaching out the boron from soil.

5.5 Copper (Cu):

Copper is a constituent of photosynthetic enzymes like phenolase, superoxide dismutase. Copper is bound in plastocyanin, which is a component of electron transport chain of photosynthesis. Use of Cu fungicides in disease control is very well known. Copper deposits on stigma will prevent the germination of pollen and thus will inhibit fertilization. In hermaphrodite cultivars, this leads to development of shot berries and poor fruit set. Copper may also interfere with enzymatic reduction of nitrates. Excess of copper may produce Fe deficiency symptoms, as it interferes with Fe metabolism.

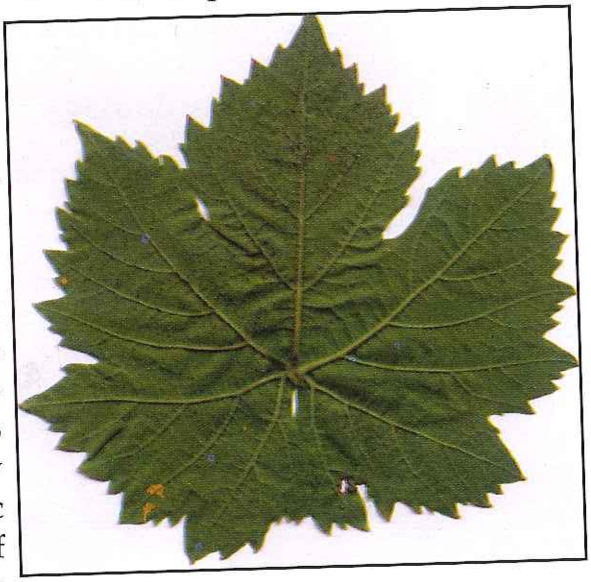

Fig.18. Copper toxicity

Copper deficiency has not been observed in field as lots of copper fungicides are used frequently for disease control. Toxicity symptoms as a result of excessive copper fungicides are frequently observed (Fig.18).

5.6 Molybdenum (Mo):

It is a component of two important enzymes; nitrogenase and nitrate reductase. Nitrate reductase is involved in conversion of nitrate -N to ammonical -N. Although molybdenum deficiency has not been observed in Indian vineyards, however, a deficiency will result in yellowing and necrosis of leaf blades. Phosphorus and Mg enhance the uptake of Mo while sulphate reduces the uptake. Molybdenum excess in literature has been reported to develop a chlorosis that is difficult to differentiate visually from the symptoms of Fe-deficiency.

5.7 Chlorine (Cl):

Chlorine is associated with the evolution of oxygen in photosystem II in photosynthetic process. It raises the cell osmotic pressure, affects stomatal regulation and increases hydration. In practice deficiency of chlorine seldom occurs because of its presence in atmosphere and has not been reported in Indian vineyards. Excess of chlorides is more serious problem in most Indian vineyards in Deccan plateau.

6. Salinity and sodicity damage to grapevines:

Soil salinity is the major cause for declining productivity particularly in Sangli and Solapur areas. In these areas rainfall is not sufficient for adequate leaching of salts. Saline groundwater is the major source of irrigation and proper drainage facilities have not been provided in the vineyards. Salt buildup is potential danger on almost all irrigated soils in arid and semiarid regions. Excessive concentration of soluble salts in soil solution is harmful in saline soils. Primary effect of excess salts is to retard the growth of plants by limiting the absorption of water. In sever cases the vines may die. Apart from total salt concentration, presence of specific ions such as chlorides, sodium and boron etc, in the soil solution is also important. These ions may either cause direct toxicity to grapevines or may cause nutritional imbalance. Experimental evidences suggest that soils having up to 10 milliequivalent chlorides per liter and EC up to 2.5 mmhos/cm in saturation extract are suitable for grape cultivation and more than 10 percent yield loss is not expected in these soils. The reduction on yield due to high salinity is mediated through the following physiological manifestations:

- Increased internal water deficit due to impaired water absorption
- Reduction in photosynthetic area due to leaf burn
- Loss of chlorophyll
- Reduced rate of photosynthesis
- Increased respiration and
- Hormonal disturbances

Factors contributing to salt accumulation in soil

- Use of saline irrigation water
- Improper drainage
- Low rainfall
- Faulty irrigation practices

Maintaining the soil near field capacity with frequent watering dilutes salts. During dry periods calcium and Mg may precipitate as $CaSO_4.2H_2O$ and $CaCO_3$ or $MgCO_3$ and will not react as soluble salts. This will increase the proportion of sodium in soil solution will increase. Periodic leaching will move the salts out of root zone.

6.1 Chloride toxicity:

Excess chlorides are the major cause of poor vine growth in saline soils of Solapur, Sangli, Pune and some parts in Nasik receiving very low rainfall. Chloride continues to be accumulated during the growing season mainly in petioles even though the toxicity symptoms appear in blades. Levels above 1.5 percent in petioles or 2.0 percent in blades are considered to be toxic (Robinson et al. 1984). Chloride toxicity causes leaf burn and usually the symptoms first appear on younger leaves (Fig.19). Leaf burning starts from margins

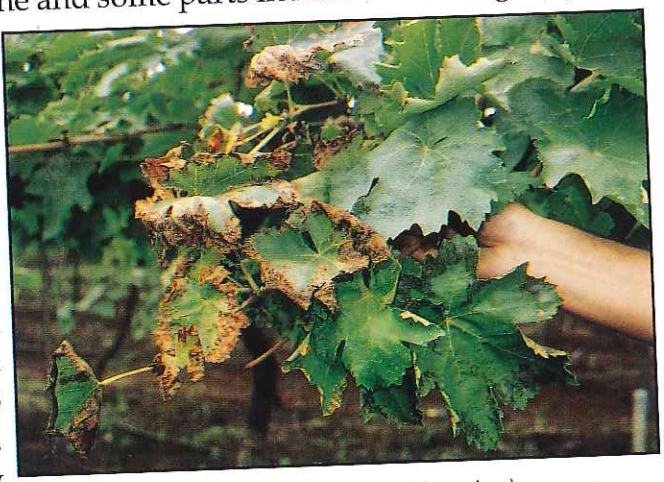

Fig.19. Chloride toxicity (marginal burning) on new leaves

and dead leaves fall off, stimulating the development of lateral shoots. Excess chloride causes death of vines. This is frequently observed in heavy soils particularly during hot climate where vines are irrigated with high chloride containing irrigation water. If adequate leaching/rainfall does not take place then the chloride can also cause a problem/toxicity even on light textured soils. Chloride toxicity has been commonly observed in sandy loam soils of Hyderabad region where muriate of potash has been applied. Saline soils contain enough salts to reduce vine growth largely due to osmotic effect, which makes water uptake by the roots more difficult. The threshold level for grapes is 10-25 meq/1 of chlorides in saturation extract, depending upon the variety and rootstock used as per the present information generated in various parts of the world. Rootstock like Dog Ridge (Fig. 20), 110 R, Ramsey and 1613 C are more tolerant to chlorides than own rooted vines of Thompson

Fig. 20. Own rooted vines of Tas-A- Ganesh (left) showing leaf burning whereas the leaves of the same variety grafted on Dog Ridge rootstock (right) showed no leaf burning when irrigated with saline water

seedless and its mutants. Leaching the excess salts from the root zone is the most effective method for correcting the soluble salt toxicities like chlorides. The water used for this purpose should be low in sodium. Rainwater may be effectively utilized for this purpose. If the soil is not free draining, proper drainage arrangements should be made to help wash out the salts.

6.2 Sodium toxicity:

Sodium is particularly detrimental, both because of its toxic effects on vines and its effects on soil structure. The direct effects of excess

Fig. 21. Excess sodium resulted in K deficiency in Thompson Seedless vines grafted on Dog Ridge rootstock

sodium are usually not clear, as excess Na is most commonly associated with excess chloride uptake. Since sodium and chloride problems are usually encountered simultaneously, it is often very difficult to identify visually. Generally more than 0.5 percent Na in petioles is considered harmful for grapevines. Symptoms of sodium excess are normally observed on mature leaves (Fig.21). The leaf burn progress from margin as an abrupt browning. There is no accompanying chlorosis, as with deficiencies of K and Mg. Hence soil petiole and leaf analysis should be carried out. The effect of sodium on uptake of K is well documented. The Na/K antagonism is quite strong in grapevines. When the amounts of exchangeable sodium becomes excessive in proportion to calcium and magnesium, the soils are called sodic or alkali. Sodicity causes dispersion of soil particles and reduces permeability to water and air. Green manuring helps in improving soil structure and reduces the sodicity hazards. The sodium hazard is estimated by determining the exchangeable sodium percentage (ESP) in the soil. Sodic soils are reclaimed usually by adding soluble Ca sources, usually gypsum (calcium sulphate) followed by leaching. While removing exchangeable sodium, presence or absence of calcium carbonate has to be taken into consideration. If the soil has no reserve of calcium carbonate addition of calcium sulphate or gypsum is necessary. In case of alkali soils that contain free calcium carbonate, the addition of substances that produce acidity reclaims the soil very effectively. Substances like farmyard manure, green manure, sulphur, sulphuric acid and mollasses even have been found to be effective reclaiming agents. The quantity of amendments required is determined by laboratory analysis and depend on the soil type and the severity of the problem. The amount of amendment required to displace the same amount of sodium will be more in case of clay soil than in sandy soil. Sodium sulphate formed as a result of gypsum or sulphur application should be leached out of root zone.

7. Suggested readings:

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Annexure-I

Petiole nutrient norms for Thompson Seedless grapes -bud differentiation stage for yield forecast

Nutrient	Norms				
	Deficient	Low	Optimum	High	Excessive
Nitrogen (%)	< 0.87	0.87 - 1.31	1.32 - 2.21	2.22 - 2.66	> 2.66
Phosphorus (%)	< 0.19	0.19 - 0.37	0.38 - 0.75	0.76 - 0.95	> 0.95
Potassium (%)	< 0.60	0.60 - 1.13	1.14 - 2.20	2.21 - 2.73	> 5.00
Calcium (%)	< 0.50	0.50 - 0.73	0.74 - 1.14	1.15 - 1.35	> 1.35
Magnesium (%)	< 0.20	0.20 - 0.49	0.50 - 0.80	0.81 - 1.00	> 1.00
Sulphur (%)	< 0.07	0.08 - 0.13	0.14 - 0.27	0.28 - 0.34	> 0.35
Iron (ppm)	< 10	10 - 29	30 - 80	81 - 200	> 200
Manganese (ppm)	< 25	26 - 75	76 - 174	175 - 225	> 225
Zinc (ppm)	< 12	13 - 50	51 - 130	131 - 170	> 200
Copper (ppm)	< 2.0	2.1 - 4.9	5.0 - 10.0	11.0 - 100.0	> 100

(Source: Bhargava and Chadha, 1993)

Annexure-II

Petiole nutrient norms for Thompson Seedless grapes -full bloom stage for yield forecast

Nutrient	Norms				
	Deficient	Low	Optimum	High	Excessive
Nitrogen (%)	< 0.50	0.51 - 0.86	0.87 - 1.61	1.62 - 1.98	> 2.00
Phosphorus (%)	< 0.11	0.12 - 0.28	0.29 - 0.65	0.66 - 0.83	> 1.00
Potassium (%)	< 1.49	1.50 - 1.99	2.00 - 3.02	3.03 - 3.54	> 4.00
Calcium (%)	< 0.79	0.79 - 0.97	0.98 - 1.36	1.37 - 1.56	> 2.00
Magnesium (%)	< 0.40	0.40 - 0.62	0.63 - 1.10	1.11 - 1.34	1.34
Sulphur (%)	< 0.07	0.07 - 0.08	0.09 - 0.13	0.14 - 0.16	> 0.20
Iron (ppm)	< 40	40 - 53	54 - 80	81 - 94	> 100
Manganese (ppm)	< 10	10 - 40	42 - 209	210 - 293	> 300
Zinc (ppm)	< 10	10 - 25	30 - 88	89 - 109	> 110
Copper (ppm)	< 2	2 - 5	5 - 10	100 - 240	> 250

(Source: Bhargava and Chadha, 1993)

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