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Soil Fertility Status of Grape (*Vitis vinifera* L.) Orchard Soils - A Review

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ABSTRACT

Grape production occupies significance in the context that it is the third most widely cultivated fruit crop after citrus and banana. Globally grape production contributes to about 16 per cent of the total fruit production. Grapevines require adequate supplies of nutrients for growth and fruiting. Nutrient deficiencies affect the quantity and quality of grape. Nutritional surveys carried out in different grape growing regions India have revealed that the growers are applying as high as 600 to 800 kg each of N, P_2O_5 and K_2O per ha every year accounting for 30 to 40 per cent of an annual recurring costs. So it is very important to know the nutrient status of soils for efficient utilization of resources for sustainable and ecofriendly production of grapes.

Key words: *Nutrients, Soil fertility, Grape orchards*

INTRODUCTION

Grape cultivation is believed to have originated in Armenia near the Caspian Sea in Russia from where it seems to have spread westward to Europe and eastward to Iran and Afghanistan. It is basically a temperate fruit crop, but has acclimatized to sub-tropical and tropical agro climatic conditions prevailing in the Indian sub-continent. Historically, it is grown mostly for wine making in the world over. In India on the contrary remarkable success has been achieved in table grape production and yield levels of fresh grapes are among the highest in the world. There has been large growth and import substitution in case of raisin (dried grapes) and is upcoming as a sector with good potentials for further growth. Total area of grapes in world is 7.50 lakh ha with a production of 66 million tonnes[16]. In India grapes are cultivated on an area of 0.12 lakh hectares with an annual production of 24.83 lakh tonnes with a productivity of 21.1 t ha^{-1}[28] and the main grape producing states are Maharashtra, Karnataka, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, Haryana and Punjab. Maharashtra ranks as number one state with an area of 90,000 hectares followed by Karnataka having 19,700 hectares with an annual production of 2.05 and 3.20 lakh tonnes, respectively[28] and the area under grape is on an increase due to its excellent returns obtained under present agro-climate conditions.

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The contribution of different states like Maharashtra, Karnataka, Andhra Pradesh, Mizoram and Tamil Nadu is 82.6, 12.9, 1.3, 0.8 and 1.7 per cent, respectively and the contribution of other states is 0.7 per cent. Among many varieties grown, Thompson Seedless occupies the prime place in Western and Southern parts of India in states like Maharashtra, Karnataka and Andhra Pradesh. It is multi-purpose variety good for both table purpose and raisin making. It is pertinent to mention that bulk of the production is used for table purpose, so India is mostly growing table varieties suiting to the taste of the local consumers. In Jammu and Kashmir it is cultivated on an area of 329 ha producing 803 M tonnes and the cultivation is mainly confined to district Ganderbal having an area of 128 ha with an annual production of 231 M tonnes. In J&K the main varieties grown are Anab-e-Shahi, Sahibi, Himrod, Hussaini and Thomson seedless.

Soil fertility influences both yield and quality of grapes through vine growth and ultimately the production. Grapevines require adequate supplies of nutrients for growth and fruiting. Nutrient deficiencies affect the quantity and quality of grape. Grapes grown under sandy soil conditions have a problem of low productivity due to poor fertility. It is the grower's objective to increase the availability of naturally occurring soil nutrients and to supplement deficient nutrients when needed, thus, it is highly needed to use the appropriate methods that lead to proper evaluation of the nutritional status of the crop. Nutrient management is one of the largest shares of cost with its impact on potential yield and crop quality. Optimum status of nutrients and their relationship with the components of yield according to "Bhargava's Physiological Stage Concept" hold the key of potential yield determination for next season crop. These involved the identification of yield components, recognition of phases of development at which they are initiated and differentiated and their relative contribution to the final yield and crop quality. Modern nutrient management strategy has shifted its focus towards the concept of practical sustainability with the components of eco-friendly approach to growers and to the crops. Research work and nutritional survey conducted by the scientists of Indian Institute of Horticultural Research, Bangalore have shown that the pollution to soil and water in the vineyards of peninsular India on account of heavy fertilization[6] is enormous, whereas crops like mango and guava receive nutrients rarely[8].

Nutritional surveys carried out in different grape growing regions India have revealed that the growers are applying as high as 600 to 800 kg each of N, P_2O_5 and K_2O per ha every year accounting for 30 to 40 per cent of an annual recurring costs. Indian grape is under constant scrutiny of the environment and health protection agencies worldwide, as in India, the cultivation of grapes receives frequent application of large number of pesticides and further, grape is mostly consumed as fresh fruit in intact form without any processing. The residues left on the grapes during harvest can be carried through into the wine[10].

The fertility status of soil is of prime importance for the optimum use of land to increase crop production. Thus knowing fertility status of vineyards is very important in the management of nutrient programme for maximizing vine growth production and fruit quality improvement, so it is very important to determine the fertility status of the soil for the optimum use of land to increase crop production.

Physico-Chemical Characteristics of Grape Orchard Soils

Particle size distribution is important for assessing nutrient supplying power of soils as well as its potential to supply water and air to the plants. The texture also determines the magnitude of surface on which the reactions can occur. Dominant soil texture in grape orchards of Egypt was sandy Shaaban and El-Fouly[34]. Demirer *et al*[13]., observed that soil texture generally ranged from sandy to sandy loam to loam. Patil *et al*[29]., observed that majority of the soils were clay and clay loam in texture with sand, silt and clay content of different soil samples ranging from 16.39 to 54.13, 20.83 to 53.33 and 20.0 to 51.35 per cent with mean values of 30.84, 33.55 and 33.83 per cent, respectively in vine soils of Maharashtra. Yogeeshappa *et al*[43]., reported that all soils were clayey in texture under low and high yielding vineyards in Bijapur Taluk. Moreover the sand, silt and clay content in soils of low yielding and high yielding vineyards ranged from 10.17 to 11.29, 19.64 to 22.61, 65.41 to 67.14 and 9.57 to 11.32, 20.43 to 22.61 and 65.12 to 67.14 per cent, respectively.

The pH of soils being important physico-chemical property, which influences the suitability of soils for crop production, availability of nutrients, microbial activity and physical properties like structure, permeability etc. Yogeeshappa *et al*[43]., reported that the soils of vine orchards of Karnataka were alkaline in reaction with soil pH ranging from 8.19 to 8.50 and EC from 0.26 to 0.3 dS m^{-1}. Kumar and Pathak[24] reported that pH of grape orchard soils varied from 8.0 to 8.4 at Faizabad. Soil pH and EC of different grape orchard soils of Maharashtra ranged from 7.05 to 7.83 and 0.10 to 1.33 dS m^{-1}, respectively[29]. While studying the impact of nutritional status on yield of some grape cultivars in Egypt, Shaaban and El-Fouly[34] reported that the soils were alkaline ranging from 8.0 to 8.4 in soil pH. Demirer *et al*[13]., found that pH of surface and sub-surface soils in vineyards of Turkey ranged from 5.30 to 7.80 and 5.50 to 7.80, respectively. . The EC of an experimental vineyard at SKUAST-K, Shalimar was found to be 0.02 dS m^{-1}[35]. Patil *et al*[29]., revealed that most of the soil samples showed higher percentage of organic matter as organic carbon content of soil samples varied from 0.50 to 1.20 with mean value of 0.87 per cent. Kumar and Bhushan[23] reported that organic carbon content of an experimental vineyard of Ludhiana was 0.29 per cent; similarly Shah[35] found that per cent organic carbon of an experimental vineyard at SKUAST-K was 0.90 per cent. The organic carbon content in surface and sub-surface soils of grape orchards of Turkey ranged from 0.18 to 0.92 and 0.15 to 0.69 per cent, respectively[12]. The per cent organic carbon content in vine orchards surface soils of Egypt varied from 0.37 to 0.55[34].

Muftuoglu *et al*[27]., observed that per cent calcium carbonate content in vineyard surface and sub-surface soils of Turkey showed a variation from 0.10 to 35 and 0.1 to 7.68 with an average value of 6.89 and 7.68, respectively, Whereas, calcium carbonate content was reported to vary from 0.10 to 39.00 with an average value of 12.13 per cent in surface and 0.10 to 36.20 per cent with an average value of 11.27 per cent in sub-surface vineyard soils of the Turkey by Demirer *et al*[13]. The $CaCO_3$ content at commercial vineyard of Cairo, Egypt, at different depths viz; 0-30, 30-60 and 60-90 cm was 12.75, 8.65 and 10.95 per cent, respectively[1]. Calcium carbonate content in vine orchard soils of Nashik district of Maharashtra ranged from 6.20 to 10.20 with an average value of 8.00 per cent[29]. According to Shah[35] per cent calcium carbonate content of an experimental vineyard at SKUAST-K was 0.87 per cent.Yogeeshappa *et al*[43]., while investigating the physico-chemical properties of different vineyards in Bijapur Taluk, Karnataka observed that the CEC of soils ranged from 49.45 to 55.05 Cmol (P^+) kg^{-1} with an average value of 51.91 Cmol (P^+) kg^{-1} in low yielding vineyard soils, whereas, in high yielding vineyard soils it varied from 50.03 to 57.75 Cmol (P^+) kg^{-1} with an average value of 52.86 Cmol (P^+) kg^{-1}. The cation exchange capacity of surface and sub-surface vine orchard soils of Turkey ranged from 6.60 to 29.30 and 8.10 to 21.20 Cmol (P^+) kg^{-1} with an average value of 13.86 and 14.09 Cmol (P^+) kg^{-1}, respectively[13].

Available Nutrient Status of Grape Orchard Soils

The productivity of the grape entirely depends on the cultural requirements and nutritional management is considered as one of the important aspects in successful grape cultivation and nutrient / fertility status of grape orchards plays an important role in increasing the productivity and quality of grapes.

Macronutrient status of soils

Nitrogen (N)

Nitrogen is one of the most important nutrients so far as growth[22], production and fruit quality of grapevines are concerned[31]. Excessive N supply results in increased vegetative growth often at the expense of reproductive growth[39]. Too little N can reduce yield and quality of fruit by reducing fruit set, berry growth, and maturation ultimately by reducing vegetative growth too severely to ripen the crop[2]. Available nitrogen content in surface soils varied from 94.08 to 314.85 with mean value of 174.60 kg ha^{-1} in vine orchards soils of Maharashtra[29]. Muftuoglu *et al*[27]., found that the available nitrogen content in the surface and sub-surface soils ranged from 0.015 to 0.08 and 0.01 to 0.06 per cent, respectively in vine orchard soils of Turkey. The available N content in low and high yielding vine orchard soils of Karnataka varied from 161.90 to 212.21 and 193.50 to 233.47 kg ha^{-1}, respectively[43]. According to Sindhu *et al*[36]., average available N content in vineyard soils of Haryana was 180 kg ha^{-1}. The available nitrogen content of different fruit orchard soils of Ganderbal, Jammu and Kashmir ranged from 233.85 to 434.37 with an average value of 293.66 kg ha^{-1}[26].

Phosphorus (P)

Phosphorous is the second most limiting nutrient to plants and is essential for photosynthesis, respiration and many metabolic processes[33]. Phosphorus deficiency results in reduced root and shoots growth, development of flowers and berries, and induces premature senescence of leaves in grape vines[12], but the deficiency in grapevines is rare in many viticulture areas[32]. Available P content in vine orchard soils of Egypt was in very low range (0.042 to 0.043 ppm)[34] Available P in surface soils of Turkey varied from 2.37 to 25.32 ppm with a mean value of 8.90 ppm, whereas, in sub-surface soil samples it ranged from 2.07 to 26.57 ppm with a mean value of 9.45 ppm[27]. According to Sindhu *et al*[36]., the available P content in vine orchard soils of Hisar, Haryana was 17.1 to 18.3 kg ha^{-1}.Yogeeshappa *et al*[43]., revealed that available phosphorus in the soils of low and high yielding vineyards of Karnataka, ranged from 18.64 to 31.42 and 22.45 to 33.86 kg ha^{-1}, respectively. Available P content in an experimental vineyard of Ludhiana was 24 kg ha^{-1}[23], and its content was 16.50 kg ha^{-1} at an experimental vineyard of SKUAST-Kashmir[35].

Potassium (K)

Potassium is often referred as the quality element for crop production[38] and it has widely proven to have a crucial role in many crop quality parameters. Fruit size, appearance, colour, soluble solids, acidity, vitamin content, taste, as well as shelf-life are significantly influenced by adequate supply of potassium, for grapevines adequate status of K has been emphasized for formation of fruitful buds at bud initiation and differentiation stages[5] and at bud fixation after differentiation (50 to 55 days after pruning) and at cane maturity[41]. Available potassium content of vine orchard soils in Pune, Maharashtra ranged from 5.0 to 672.0 ppm and its availability depends on native K status, type of clay minerals, clay and organic matter content and texture of the soil[9]. While working on nutrition standard for soil and leaf analysis of some grape cultivars grown in Canakkale, Turkey, Demirer *et al*[13]., observed that available potassium values showed variation between 117.0 to 741.0 and

39.0 to 507.0 ppm in surface and sub-surface soil samples, respectively.According to Gursoz *et al*[20]., the available K content of soils in Sanliurfa, Turkey varied from 212.3 to 245.4 ppm with an average value of 224.3 ppm. Available potassium content in different grape orchard soils of Maharashtra ranged from 123.2 to 515.2 with an average of 281.9 kg ha^{-1}[29]. According to Masrat[26] available potassium content in different orchard soils of Ganderbal, Kashmir ranged from 128.2 to 244.0 with an average value of 151.8 kg ha^{-1}.

Calcium (Ca)

Calcium plays important role in root development and root functioning, cell division, chromosome stability and in enzyme system like ATP respiration and amylase. In *Vitis spp.* deficiency symptoms are uncommon but can occur in strongly acidic soils, below pH 4.5. Deficiency symptoms start as a narrow necrotic border at the leaf margin that moves in steps towards the petiole attachment. The growing bunches can also dry up from the tip resembling severe stem necrosis[30].While investigating the nutritional status of some grape cultivars in, Shaaban and El-Fouly[34] observed that available calcium content of vine orchard soils of Egypt was of high range (7800.0 to 8000.0 ppm). At a commercial vineyard of Cairo, Egypt, Abd El-Razek *et al*[1]., revealed the available calcium content at three depths via, 0-30, 30-60 and 60-90 cm was 1560.0, 1680.0 and 1320.0 ppm, respectively. A survey of soil fertility status and index tissue analysis of vineyards of Karnataka was undertaken by Yogeeshappa *et al*[42]., and they reported that the available calcium content varied from 7778.0 to 9766.0 ppm with a mean value of 8708.0 ppm and the available calcium content in all soils was high.

Magnesium (Mg)

Magnesium is an essential component of chlorophyll as well as thefunctional ability of ATP in many reactions. It is also responsible for the activation of many enzymes in photosynthesis, respiration and the formation of DNA and RNA[33]. In *Vitis* spp. deficiency symptoms can basically take two different forms, early in the season it form an interveinal chlorosis and later it shows as interveinal yellowing. Late in the season deficiencies normally occur in the basal leaves, the first signs of deficiency will normally appear just before flowering as small brown-green spots near the margin and in the interveinal tissue of young leaves[30]. Demirer *et al*[13]., reported that available Ca + Mg content of surface soils of grape orchards of Turkey ranged from 864.0 to 6592.0 ppm with a mean value of 3363.0 ppm, whereas, in sub-surface soils it varied from 1216.0 to 6048.0 ppm with an average value of 3702.0 ppm. The available magnesium in the vineyard soils of Karnataka varied from 960.0 to 1171.0 ppm with an average value of 1071.0 ppm[42]. Gursoz *et al*[20]., observed the available magnesium content of vineyard soils in Sanliurfa, Turkey ranging from 606.0 to 728.0 ppm with an average value of 670.67 ppm. Masrat[26] revealed that available magnesium content in different orchard soils of Ganderbal, Kashmir ranged from 278.87 to 402.75 with an average value of 322.18 kg ha^{-1}.

Sulphur (S)

Sulphur is present in proteins and chlorophyll and plays a role in energy metabolism. It is available to the plants either from air or from organic or inorganic sources. Suplhur is found in soil minerals and becomes available to the plants as sulphate ions through weathering. During the survey of vineyards for soil fertility status and index tissue analysis Yogeeshappa *et al*[42]., observed that the available sulphur in the different vine orchards of Karnataka showed a variation from 11.05 to 16.91 ppm with an average value of 13.60 ppm. Shah[35] reported that available sulphur content in the vineyard soil of SKUAST-Kashmir, Shalimar was 8.20 ppm.

Table 1: Critical limits (ppm) of available nutrient elements in soils

Nutrient element	Soil fertility classes			References
	Low	medium	High	
Organic carbon (%)	<0.5	0.5-1.0	1.0	Bhandari and Tripathi[4]
Nitrogen	<125	125-250	>250	FAI[15]
Phosphorus	<4	4-11	>11	FAI[15]
Potassium	<44	44-125	>125	FAI[15]
Calcium	250-500	500-750	>750	Bhargava
Magnesium	42-72	73-148	>148	Rutgers Soils Laboratory
Sullphur	<10	-	-	Kanwar and Mohan
Iron	<4.5	-	-	Lindsay and Norveell
Manganese	<1.0	-	-	Follet and Lindsay
Zinc	<0.6	0.6-1.2	>1.2	Takkar and Mann[37]
Copper	<0.2	0.2-2.0	>2.0	Follet and Lindsay[17]
Boron	-	0.5-1.0	-	De-Turk and Olsen[14]
Molybdenum	0.0-0.1	0.1-0.3	>0.3	Griggs[19] for soils with pH 6.5 and above

Micronutrient status of soils

Bertamini and Nandunchezhian[3] reported that iron (Fe) deficiency in vines decreases vegetative growth affects membrane integrity, decreases leaf CO_2 exchange and photosynthetic efficiency, reduces leaf area and dry matter accumulation, as well as increased fruit abscission or drop.In *Vitis spp.* Zinc deficiency is characterized by abnormal development of internodes (zig-zag growth pattern of shoots), interveinal chlorosis in early summer and small leaves[11]. Also production of clusters with undeveloped shot berries and generally poor fruit set are all characteristics of Zn deficiency[18]. Manganese (Mn) deficiency symptoms in vines occur as interveinal chlorosis that has a mosaic like arrangement and the symptoms are more severe on sun-exposed leaves and advanced conditions can affect the growth of berries and shoots, may also delay veraison. In vines thedeficiency symptoms of Copper (Cu) occur as dark green and twisted leaves[33], but Cu deficiency in the vineyard is rarely found.Boron (B) is taken up as a boric acid, which is translocated slowly within the plant. Boron deficiency has visual symptom on root and leave growth, flower, cluster and berry development in grapevine. Severely reduce internode and shoot length, shoot tip death, low fruit set, and tiny berries (hen and chicken disease) are all common symptoms of boron deficiency[11]. In grapevines deficiency symptoms can start as early as flowering on the tendrils of the shoot tips, which become dark, knotty bulges and become necrotic, flower clusters can also die. Generally it has been thought that vines do not requireMolybdenum (Mo) but work conducted by Williams *et al*[40]., on vines has shown that the application of Mo can increase yield as a result of increase in grapevine fruit set, seed formation, berry formation and development, bunch weight, increase in functional seeds and percentage of coloured berries.

The DTPA extractable Fe, Mn Zn and Cu varied from 5.48 to 194.00, 19.00 to 30.00, 4.00 to 10.00 and 11.00 to 14.00 ppm in vineyards of Peninsular India[7], it was further concluded that DTPA extractable Fe, Mn and Cu was in optimum range but Zn was in low range in most of the soils. The DTPA extractable Fe, Mn, Zn and Cu content in the surface soils of Canakkale, Turkey ranged from 1.90 to 26.90, 1.60 to 27.80, 0.60 to 2.80 and 0.50 to 2.10 with an average values of 12.73, 11.89, 1.20 and 0.98 ppm, respectively, whileas, in sub-surface layers the DTPA extractable Fe, Mn, Zn and Cu content showed a variation from 1.10 to 24.90, 1.30 to 25.70, 0.50 to 1.40 and 0.20 to 2.40 ppm with an average values of 10.30, 10.67, 0.83 and 1.03 ppm, respectively[27]. Shaaban and El-Fouly[34] revealed that DPTA extractable Fe, Mn, Zn and Cu content in the vine orchard soils of Egypt were very low ranging from 2.20 to 2.50, 1.60 to 2.60, 0.40 to 0.50 and 0.20 to 0.40 ppm, respectively. The DTPA extractable

Fe, Mn, Zn and Cu content in the vineyard soils of Karnataka varied from 4.01 to 5.81, 1.37 to 1.74, 7.16 to 8.73 and 0.37 to 0.51 ppm with an average value of 5.18, 1.47, 7.94 and 0.43 ppm, respectively and all the four micronutrients were in higher range[42]. The DTPA extractable Fe, Mn, Zn and Cu in the surface vineyard layers of Turkey varied from 1.00 to 27.00, 1.20 to 25.20, 0.60 to 2.80 and 0.50 to 2.40 ppm with an average values of 6.68, 6.29, 0.92 and 1.30 ppm, respectively, whereas, in sub-surface soils Fe, Mn, Zn and Cu, showed variation from 1.10 to 17.10, 1.30 to 20.10, 0.50 to 1.60 and 0.50 to 1.60 ppm with the mean values of 5.50, 5.48, 0.75 and 0.93 ppm respectively[13].

CONCLUSION

Nutritional surveys are more useful to obtain the effects of applied doses on yield and quality and in developing a leaf nutrient guide than through experiments conducted under controlled conditions. Knowing the fertility status of soils is very important for judicious use of nutrients in saving natural resources for future use and protecting soil, water and air from pollution.

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