**Diagnosis of yield-regulating soil and plant nutrients in pomegranate orchards of northern Karnataka**

**ABSTRACT**

Pomegranate productivity and quality necessitate the optimum nutrient supply and for this, soil nutrient status and leaf nutrient concentration are very much required. Concerning this, a survey study was conducted to analyse the soil and plant nutrient status of 150 pomegranate orchards of northern Karnataka. Soil pH, EC, OC, available nutrients (K, P, S, Fe, Mn, Zn and Cu), exchangeable calcium and magnesium, and corresponding leaf nutrient concentrations were analysed in orchards. The high yielding orchards with yield greater than mean productivity of Karnataka (11.71 t ha-1) were further categorized as category 1 (12.32-13.61 t ha-1), category 2 (14.32-22.64 t ha-1) and category 3 (22.84-25.63 t ha-1). The availability of soil nutrients *viz*., K, S, and Mn content were higher in category- 3 HYO whereas, available N, exchangeable Ca & Mg and Cu content were higher in category 1. Similarly, total P, K, S & Fe content in pomegranate leaf was higher in category 3 while leaf N, Ca, Mg & Cu content were found high in category 1 and category 2. These can be the basis for the application of the optimum dose of fertilizers.

Keywords*:* Leaf nutrient, Pomegranate, Soil nutrient, Soil survey, Yield

**Introduction**

Pomegranate (*Punica granatum*. L), is a subtropical fruit crop with a high demand in internal markets. It has a very high export potential attributed to its anti-oxidant values. Although a significant increase in the area under pomegranate cultivation, productivity has not improved to the anticipated level owing to inadequate nutrition and higher susceptibility to disease infestation (Marathe *et al.*, 2016). Thus, more studies are needed on nutrient management in pomegranates. Nutrient addition and assimilation by plants at optimum level is essential for increasing crop yield. Pomegranate plants are typically grown in poor soils, producing lower-quality fruits that are more prone to pests and diseases (Glozer *et al*., 2008). Soil analysis determines the actual soil nutrient availability whereas leaf analysis diagnoses the plant nutrient content which then establishes the nutritional requirement for a certain crop. crop productivity and the amounts of nutrients in leaves and the dosages of nutrients supplied are positively correlated.. Therefore, it is necessary to study the soil availability of nutrients, plant nutrient uptake, and its effect on pomegranate productivity. The relationship between pomegranate productivity and nutritional status can be used to derive recommendations for particular sites.

**MATERIALS AND METHODS**

**Study area crop variety and season**

The orchards with the cultivation of pomegranate variety Bhagwa of 3-7 years old, situated in Bagalkot district that lies between 16.181700’ northern latitude and 75.695801’ eastern longitude selected to assess the soil availability of nutrients and plant nutrient concentration in relation to yield (Fig. 1). One hundred and fifty pomegranate orchards were surveyed random basis from seven villages *viz.*, Junnur, Seemikeri, Govinakoppa, Sokanadagi, Chikkasamshi, Kaladagi, and Hiresamshi. The orchards were selected randomly and later grouped based on their yield levels. As per the Karnataka state average productivity of 11.71 t ha-1 (GOI, 2017), out of the 150 orchards surveyed, 117 were classified as high yielding orchards, with an average yield of 18.12 t ha-1 (Range; 12.32-25.63 t ha-1). These were categorized into three with high, medium and low yielders. The season opted for the survey was *hasta bahar*. In this season, ethrel (2–2.5ml/litre) is sprayed on the plants during the second–fourth week of August to remove their leaves. Next, light pruning and irrigation are used, after which manures and fertilizers are applied. Fruits were harvested during the fortnight of March – early April.

**Categorization of pomegranate orchards**

To understand the factors influencing the higher yield levels in high-yielding orchards, were further categorized into three groups using their mean yield of 18.12 t ha-1 as follows (Gosavi *et al*., 2017).

Category I Mean - 8/3SD to Mean - 4/3SD

Category II Mean - 4/3SD to Mean + 4/3 SD

Category III Mean + 4/3SD to Mean + 8/3 SD

Where SD = Standard deviation

 Mean = Average pomegranate yield (18.12 t ha-1)

**Soil analysis**

Within the selected plot, soil sampling was done in a zig-zag manner. Using a post-hole auger, samples were collected from the area around the chosen plants at a depth of 0 to 15 cm and at a distance of 45 cm from the dripper position. Two sub-samples from each plant and six sub- samples from each orchard were collected and The quartering approach was used to prepare the composite sample. The same method was used to collect soil samples from all the one hundred and fifty orchards at the flowering stage of crop growth.

Conventional laboratory methods were used to obtain the data on soil nutrient content. Using a pH metre as suggested by Jackson (1973), the pH of the soil was measured in the soil:water suspension ratio of 1:2.5. The same extract was used for measuring electrical conductivity using conductivity bridge. Available nitrogen (N) content in soil was determined by alkaline permanganate method developed by Subbiah and Asija (1956). Available P was determined using Olsen’s extractant (1:5) and the available K, Ca and Mg were extracted using neutral normal ammonium acetate. Available S was determined using the turbidimetric method by Black (1965) by extracting with CaCl2. The Lindsay and Norvell (1978) method,  by using DTPA (Diethylene Triamine Penta Acetic Acid) was adopted  for extracting  Zn, Fe, Mn, and Cu.

**Plant analysis**

The plant tissue analysis was done by collecting the index leaves specified for pomegranate *i.e.* eight pair of leaf from the nonbearing shoot (Raghupathi and Bhargava, 1998b) from the same plants where, soil samples were taken, at the flowering stage to study their nutrient contents. Plant nitrogen was estimated by the Kjeldhal distillation method. The concentration of phosphorus, potassium, calcium and magnesium, sulphur and micro nutrients (iron, manganese, copper, and zinc) in digested leaf sample was determined using phospho-vanado-molybdate complex method, flame photometry, versenate method, turbidimetric method and microwave plasma atomic emission spectrophotometer respectively.

**Assessing relation of soil and plant nutrient status in to pomegranate yield**

The soil properties and plant nutrient content of high-yielding orchards were separated based into respective three categories as explained in pomegranate yield. Significant difference between the categories was found using one way ANOVA.

Simple correlation between soil and plant nutrient content and pomegranate yield were calculated using Pearson method via OPSTAT software.

Multiple linear regression models (Snedecor and Cochran, 1981) were determined to assess the relative contribution of all leaf nutrient variables (N, P, K, Ca, Mg, S, Fe, Zn, Mn, Cu and B) and soil variables (pH, EC, OC, N, P., K, Ca., Mg, S, Zn, Cu, Fe and Mn) on fruit yield (Y) as following

Y= a. + b1N. + b2P.+ b3K .+ …….. + bn Mn

Where,

Y = Dependent variable (pomegranate fruit yield)

a = Intercept

b1, b2, b3,… bn . = The slope of the regression line or the amount of change produced in dependent variable, Y by a unit change in independent variables.

N, P, K…, Mn = Independent variables (essential nutrients indicated by their chemical symbol)

Nutrient variables in the regression equation which are unimportant, were omitted using stepwise backward regression analysis. Open Stat version 1.9 was utilised to do the backward stepwise multiple regression analysis as recommended by William (2007).

**RESULTS AND DISCUSSION**

**Categorization of high-yielding pomegranate orchards and yield parameters**

To clearly understand the factors contributing to higher yield, the high yielding orchards were further classified to three categories using the standard classification protocol suggested for nutrient norms. The category 1 orchards (32 number) had yield levels ranging from 12.32-13.61 t ha-1 with mean of 12.88 t ha-1. Similarly sixty seven orchards with average yield of 18.47 t ha-1 (range : 14.32-22.64 t ha-1) are grouped in category 2 and twenty eight orchards with average yield levels of 23.94 t ha-1 (range : 22.84-25.63 t ha-1) are classified as category 3 . Fruit weight (g fruit-1) and number of fruits varied among the categories (Table 1).

**Soil properties and leaf nutrient status among different categories of high yielding orchards**

***Electrochemical properties***

The data on soil reaction indicated the soil was alkaline in nature. But there was no significant variation among different groups of HYO. The variation in EC was significant among the categories. Category 1 showed significantly higher EC as compared to category 2 and 3. The EC values were well within the safer limits in all the categories (range: 0.24-0.85; Table 2). This might be caused by the presence of calcium carbonate that is sparingly soluble and typically appears in soil as filaments, nodules, and as a component of the colloidal complex rather than in the soil solution (Hamid, 2009). Good drainage conditions brought on by the predominance of gravel in most orchards may have also mitigated the negative effects of soil salinity in these orchards.

The organic carbon content in soils varied significantly among the categories of HYO. Highest mean OC of 1.28 per cent was recorded in category 3 and significantly lowest OC of 0.61 per cent was observed in category 1. This may be owing to the organic materials application during *bahar* initiation to the high yielding orchards (Table 2 & Fig.2).

***Major soil and leaf nutrient status*** *(****N****,* ***P, and K****)*

The soil available N in the various categories of high-yielding orchards is presented in Table 3. It was in medium range in the high yielding orchards. The variation was significant among the categories. The highest N content ranging from 354.9 to 589.3 kg ha-1, was noticed in category 1, which was significantly superior to category 3 and category 2. Similarly, among the different categories of HYO, significantly higher leaf nutrient content of 1.91 percent was noticed in category 1 followed by category 3 and category 2 (Table 4). The leaf N content of category 1 was in higher range, while for category 2 and 3, it was in optimum range. It was reported that nitrogen fertilization improved plant growth, yield, and quality. However excess N application rate and its higher soil availability might have resulted in higher accumulation in leaves at the flowering stage. The N fertilization at optimal levels, were most beneficial for having high-quality marketable fruit (Lominadze and Nakashide, 2016; Kolekar and Bhagyaresha, 2018)

Available P showed the values in high range. It was highest in category 3 (57.81 kg ha-1) and lowest in category 1. Comparatively high soil pH in category 1 HYO might have caused the applied P to precipitate into insoluble calcium phosphates causing its reduced availability (Westernmann and Leytem, 2003; Betrtrand *et al.,* 2006; Abdou, 2006) (Table 3 & Fig.3). Among HYO categories, category 3 recorded significantly higher leaf P content of 0.23 per cent followed by category 2 (0.2 %) and both the values were in optimum range. The category 1 recorded P content of 0.16 percent that was in low concentration range (Table 6 and Fig. 4).

The variation in available potassium content in soils were insignificant in different pomegranate orchards (Table 3 & Fig. 3). Irrespective of yield level, the availability of potassium was in medium range in soil. But among various categories of HYO, significantly higher K content in plant was noticed in category 3 followed by category 2 and category 1 (Table 6 & Fig. 5). However, the K nutrient content was within the optimum range. Dhillon *et al*. (2011) reported that P and K applications enhanced the yield of pomegranate with improvement in fruit size and quality. Moreover, improvement in the fruit set percentage and reduction in the fruit drop were noticed with the foliar application of potassium nitrate at 3 and 2% (Al-Saif *et al.*, 2002).

**Secondary soil and leaf nutrient status (Ca, Mg and S)**

The variation in exchangeable Ca in soil was insignificant among the orchards. Significantly higher exchangeable Ca was noticed in category 1 recording mean Ca content of 31.27 cmol (p+) kg-1 as compared to category 3 and category 2 (Table 4). A similar pattern was noted in leaf nutrient status also (Table 7). However, the highest deviation was found in category 3 (0.3).

The variation in magnesium content in soil and leaf was not significant among different categories. The leaf sulfur content varied significantly among the orchards. Category 3 showed a higher range of S content (0.34-0.39 %) as compared to category 2 (0.23-0.38%) and category 1 (0.18-0.28 %) (Table 7 and Fig. 6). Barker and Pilbeam (2006) reported that sulfur compounds are of great significance in plant functioning and fruit size and quality.

***Soil and leaf micro nutrient status (Zn, Cu, Fe and Mn)***

The micronutrient status in different categories of high-yielding orchards is presented in Table 5. Significant variation was noticed among the orchards with respect to DTPA- Zn and DTPA-Fe while variation in DTPA-Cu and DTPA-Mn was insignificant. Higher amount of DTPA Zn was found in category 2 which was significantly superior over category 3 and category 1 (1.83 mg kg-1). Similarly maximum Fe availability was observed in category 2 which is superior over category 3 and category 1 (Table 5).

Significant variation was observed in terms of leaf Zn, Cu, Fe and Mn content among the different categories. The highest Zn content ranging from 38 to 52 mg kg-1, was noticed in category 2, significantly superior to category 3 and category 1. A similar trend was shown by leaf Mn content (Table 8). Category 2 and category 3 recorded significantly lower leaf Cu than category 1. Highest mean leaf Fe of 196.6 mg kg-1 was recorded in category 3 and significantly lowest Fe of 146.3 mg kg-1 in category 1 (Table 8). This was in accordance with the results obtained with Fe, Mn or Zn sprays. The application had positive significant effects on fruit fresh and dry weights, fruit dimensions and fruit yield as well as juice volume/fruit, and fruit juice quality(Hamouda *et al*., 2016).

A significant positive association between pomegranate yield and leaf Fe content was discovered by Gimenez *et al*. (Gimenez *et al*., 2000)when they examined the micronutrient content in pomegranate leaves from various yield categories.

**Associations between pomegranate yield and soil nutrient content at flowering stage**

**Correlations among soil available nutrients and pomegranate yield**

The correlation analysis between available soil nutrients at flowering stage is given in Table 9.

A significant positive correlation was found at flowering stage, between pomegranate yield and OC (0.685), K (0.623), Ca (0.380), Mg (0.314), S (0.657), Mn (0.476), Zn (0.469) and Fe (0.434). Soil pH (-0.577), N (-0.539), and Cu (-0.202) recorded a significant negative correlation with yield.

**Regression analysis of soil parameters with pomegranate yield**

The regression models developed from pomegranate yield and soil parameters were found significant. The regression model through the step wise reduction of soil variables at flowering stage is as below

Y= -1.78- 0.01N + 0.02K+0.15 Mg+0.16 S+0.62 Fe+0.20Mn+0.84 Zn+3.02 OC

The data showed significant positive contribution from OC (3.02), K (0.02), Mg (0.15), S (0.16), Fe (0.62) and Zn (0.84) on pomegranate yield. But N (0.01) showed a negative contribution to the yield (Table 10).

**Correlations among pomegranate yield and leaf nutrients**

The correlation matrix formed among leaf nutrient contents and yield is given in Table 11. A significant positive correlation was seen between pomegranate yield and P (0.546), K (0.613), Ca (0.447), Mg (0.237), S (0.306), Mn (0.444), Zn (0.415) and Fe (0.455) at flowering stage. The other nutrient parameters *viz.*, N (-0.471) and Cu (-0.240) were negatively correlated with yield.

**Regression analysis of leaf nutrients and pomegranate yield**

The regression analysis with pomegranate yield and leaf nutrient concentration at flowering stage is as following.

Y= -5 +18.02 P+4.13 K+9.52 S+0.02Fe+0.05Mn-2.53N-0.10

The above equation was again analysed to exclude the unimportant parameters by using stepwise regression analysis which produced the following equation (Table 12).

Y= 0.5+18.02P + 4.13 K+ 9.52 S+0.02Fe+ 0.05 Mn-2.53N-0.10Cu

A significant. positive correlation was found among these variables on pomegranate yield with F value 67.77.

It is evident from the study that the pomegranate yield was influenced by soil and leaf nutrient status at varying levels. The soil status of OC, available K, available Mg, available S, available Fe, and Zn and leaf nutrient status of P, K, Ca, Mg, S, Mn, Zn, and Fe influenced the pomegranate yield significantly and positively.

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**Table 1: fruit yield and yield parameters of Pomegranate among different categories of high yielding orchards.**

|  |  |  |
| --- | --- | --- |
| **Category.** | **Fruit yield (t ha-1)..** | **Fruit yield (kg plant-1).** |
| **Range** | **Mean** | **Range** | **Mean** |
| Category 1 (n=32) | 12.32-13.61 | 12.88± 0.49c | 19.63-21.76 | 20.62± 0.78c |
| Category 2 (n=67) | 14.32-22.64 | 18.47± 2.26b | 20.00-36.00 | 29.47±3.72b |
| Category 3 (n=28) | 22.84-25.63 | 23.94± 0.88a | 34.8-40.91 | 37.44 ± 1.55a |
| **Total** | 12.32-25.63 | 18.12 ± 3.37 | 19.63-40.91 | 28.93 ± 5.25 |

|  |  |  |
| --- | --- | --- |
| **Category** | **Fruit weight (g fruit-1)** | **No. of fruits per plant** |
| **Range.** | **Mean** | **Range** | **Mean** |
| Category 1 (n=32) | 245.8-320.0 | 291.0± 24.5c | 63-82 | 71± 5.3c |
| Category 2 (n=67) | 263.1-530.0 | 398.0± 53.7b | 61-85 | 74± 5.5b |
| Category 3 (n=28) | 409.4-587.5 | 464.0± 46.9a | 64-86 | 81± 5.8a |
| **Total** | 245.8-587.5 | 389.7 ± 66.3 | 61-86 | 74 ± 6.0 |

 ns non-significant., means of same parameter with different letters are statistically significant at p < 0.05 among low and high yielding orchards

**Table 2: Electro chemical properties of soils among different categories of high yielding pomegranate orchards**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameters** | **pH** | **EC (dS m-1)** | **OC (%)** |
| **Category.** | **Range.** | **Mean.** | **Range.** | **Mean.** | **Range.** | **Mean.** |
| **Category 1 (n=32)** | 8.13-8.81 | 8.40± 0.11 ns | 0.51-0.85 | 0.68± 0.17a | 0.46-1.14 | 0.61± 0.26c |
| **Category 2 (n=67)** | 7.80-8.57 | 8.16± 0.14 ns | 0.24-0.81 | 0.42± 0.12b | 0.39-1.29 | 0.84± 0.22b |
| **Category 3 (n=28)** | 7.30-8.21 | 7.95± 0.15 ns | 0.31-0.79 | 0.44± 0.13b | 1.24-1.32 | 1.28± 0.04a |
| **Total** | 7.30-8.81 | 8.18 ± 0.29 | 0.24-0.85 | 0.52 ± 0.25 | 0.39-1.32 | 0.85 ± 0.18 |

**Table 3: Major nutrient content in soils of high yielding orchards**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameters** | **Available nitrogen (kg ha-1)** | **Available phosphorus (Pkg ha-1)** | **Available potassium (K kg ha-1)** |
| **Category** | **Range.** | **Mean.** | **Range.** | **Mean.** | **Range.** | **Mean.** |
| **Category 1 (n=32)** | 354.9-589.3 | 481.5 ± 74.8a | 20.14-54.86 | 39.14± 9.31c | 185.6-243.6 | 214.3± 37.0 ns |
| **Category 2 (n=67)** | 212.3-499.5 | 347.2 ± 83.7b | 24.29-64.95 | 48.11± 11.33b | 184.6-254.3 | 210.2± 17.1 ns |
| **Category 3 (n=28)** | 200.9-578.3 | 362.1± 107.3b | 38.16-64.56 | 57.81± 6.44a | 210.6-284.2 | 248.4± 23.5 ns |
| **Total** | 200.9-589.3 | 406.0 ± 107.9 | 20.14-64.95 | 48.13 ± 11.81 | 184.6-.284.2 | 219.7 ± 24.2 |

ns non-significant, means of same parameter with different letters are statistically significant at p < 0.05among the various categories of high yielding orchards

**Table 4: Secondary nutrient content in soils of high yielding orchards**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameters** | **Exchangeable calcium.** **(cmol (P +) kg -1).** | **Exchangeable magnesium (cmol (P +) kg -1).** | **Available sulphur.****(mg kg-1).** |
| **Category** | **Range** | **Mean** | **Range** | **Mean** | **Range** | **Mean** |
| **Category 1 (n=32)** | 16.55-36.97 | 31.27± 4.75a | 7.28-18.35 | 12.81± 3.78 ns | 24.37-46.55 | 37.49± 6.13 ns |
| **Category 2 (n=67)** | 16.84-27.22 | 19.25± 3.37b | 8.11-13.75 | 10.93± 1.92 ns | 23.89-42.94 | 33.41± 6.50 ns |
| **Category 3 (n=28)** | 13.37-31.71 | 20.04± 6.46 b | 7.17-15.95 | 11.56± 2.99 ns | 39.34-49.15 | 46.98± 3.47 ns |
| **Total** | 16.55-36.97 | 22.82 ± 6.72 | 7.17-18.35 | 12.76ns ± 3.81 | 23.89-49.15 | 36.52 ± 8.62 |

ns non-significant, means of same parameter with different letters are statistically significant at p < 0.05among the various categories of high yielding orchards

**Table 5: Micro nutrient content in soils of high yielding orchards**

|  |  |  |
| --- | --- | --- |
| **Parameters** | **DTPA-Zinc (mg kg-1)** | **DTPA-Copper (mg kg-1)** |
| **Category** | **Range** | **Mean** | **Range** | **Mean** |
| Category 1 (n=32) | 1.72-1.94 | 1.83± 0.07c | 3.26-8.49 | 5.87± 1.78ns |
| Category2 (n=67) | 2.91-3.62 | 3.26± 0.24a | 2.64-6.89 | 4.76± 1.45ns |
| Category 3 (n=28) | 2.64-3.02 | 2.83± 0.12b | 2.17-4.13 | 3.15± 0.66 ns |
| **Total** | 1.72-3.62 | 2.67 ± 0.64 | 2.17-8.49 | 5.33± 2.15 |
| **Parameters** | **DTPA-Iron (mg kg-1).** | **DTPA-Manganese (mg kg-1).** |
| **Category** | **Range** | **Mean** | **Range** | **Mean** |
| Category 1 (n=32) | 2.54-4.26 | 3.40± 0.58c | 11.23-16.45 | 13.88± 1.78ns |
| Category2 (n=67) | 4.16-5.94 | 5.04± 0.60a | 12.16-23.30 | 17.73± 3.80 ns |
| Category 3 (n=28) | 3.18-5.64 | 4.41± 0.84b | 12.20-20.76 | 16.48± 2.98ns |
| **Total** | 2.54-5.94 | 4.24 ± 1.16 | 11.23-23.30 | 17.26± 4.12 |

ns non-significant,

means of same parameter with different letters are statistically significant different at p < 0.05

among various categories of high yielding orchards

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameters** | **Nitrogen (%)** | **Phosphorus (%)** | **Potassium (%)** |
| **Category** | **Range.** | **Mean.** | **Range.** | **Mean.** | **Range.** | **Mean.** |
| **Category 1 (n=32)** | 1.74-2.21 | 1.91± 0.08a | 0.14-0.19 | 0.16± 0.01c | 1.08-1.63 | 1.38± 0.08c |
| **Category 2 (n=67)** | 0.69-1.72 | 1.16± 0.22c | 0.17-0.29 | 0.20± 0.02b | 1.45-1.87 | 1.67± 0.11b |
| **Category 3 (n=28)** | 1.04-1.72 | 1.41± 0.20b | 0.17-0.27 | 0.23± 0.03a | 1.67-2.11 | 1.89± 0.05a |
| **Total** | 1.04-2.21 | 1.40 ± 0.36 | 0.14-0.29 | 0.21 ± 0.03 | 1.08-2.11 | 1.64 ± 0.26 |

**Table 6: Index leaf major nutrient content among different categories of high yielding pomegranate orchards**

**Table 7: Index leaf secondary nutrient content among different categories of high yielding pomegranate orchards**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameters** | **Calcium (%)** | **Magnesium (%)** | **Sulphur (%)** |
| **Category** | **Range.** | **Mean.** | **Range.** | **Mean.** | **Range.** | **Mean.** |
| **Category 1 (n=32)** | 1.10 – 2.12 | 1.97± 0.22a | 0.31-0.56 | 0.51 ± 0.07 ns | 0.18-0.28 | 0.19± 0.01c |
| **Category 2 (n=67)** | 1.12-1.96 | 1.68± 0.23b | 0.31-0.53 | 0.43± 0.08 ns | 0.23-0.38 | 0.28 ± 0.02b |
| **Category 3 (n=28)** | 1-10-1.99 | 1.62± 0.30b | 0.30-0.48 | 0.41± 0.06 ns | 0.34-0.39 | 0.36 ± 0.01a |
| **Total** | 1.10-2.12 | 1.74 ± 0.28 | 0.30-0.56 | 0.44 ± 0.08 | 0.18-0.39 | 0.28 ± 0.06 |

**Table 8: Index leaf micro nutrient content among different categories of high yielding pomegranate orchards**

|  |  |  |
| --- | --- | --- |
| **Parameters** | **Zinc (mg kg-1)** | **Copper (mg kg-1)** |
| **Category** | **Range.** | **Mean.** | **Range.** | **Mean.** |
| Category1 (n=32)  | 24-30 | 26.84± 1.62c | 38-45 | 43.12± 1.43a |
| Category 2 (n=96)  | 38-52 | 40.62± 3.17a | 18-43 | 29.91± 5.68b |
| Category3 (n=12)  | 26-38 | 33.28± 2.93b | 20-41 | 26.97± 9.02c |
| **Total** | 24-52 | 35.43 ± 6.29 | 18-45 | 32.0 ± 8.69 |
| **Parameters** | **Iron (mg kg-1)** | **Manganese (mg kg-1)** |
| **Category** | **Range.** | **Mean.** | **Range.** | **Mean.** |
| Category1 (n=32)  | 122-162 | 146.3± 6.1c | 51-56 | 52.78±1.0c |
| Category 2 (n=96)  | 156-222 | 185.3± 15.1b | 57-79 | 69.84± 4.48a |
| Category3 (n=12)  | 150-230 | 196.6± 24.0 a | 55-75 | 65.82± 6.77b |
| **Total** | 122-199 | 175.0 ± 28.25 | 51-79 | 64.65 ± 8.44 |

ns non-significant,

means of same parameter with different letters are statistically significant different at p < 0.05

among various categories of high yielding orchards

**Table 9: Correlation index (r) among pomegranate yield and soil parameters at flowering stage**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Yield** | **pH** | **EC** | **OC** | **Av. N** | **Av. P** | **Av. K** | **Ex. Ca** | **Ex. Mg** | **Av. S** | **Av. Zn** | **Av. Cu** | **Av. Fe** | **Av. Mn** |
| **Yield** | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **pH** | -0.577\* | 1.000 |  |  |  |  |  |  |  |  |  |  |  |  |
| **EC** | -0.202\* | -0.076 | 1.000 |  |  |  |  |  |  |  |  |  |  |  |
| **OC** | 0.685\*\* | 0.026 | -0.088 | 1.000 |  |  |  |  |  |  |  |  |  |  |
| **Av. N** | -0.539\* | -0.087 | 0.054 | -0.328\* | 1.000 |  |  |  |  |  |  |  |  |  |
| **Av. P** | 0.281\* | -0.161 | 0.058 | 0.207\* | -0.295\* | 1.000 |  |  |  |  |  |  |  |  |
| **Av. K** | 0.623\*\* | 0.078 | -0.149 | 0.423\* | -0.420\* | 0.300\* | 1.000 |  |  |  |  |  |  |  |
| **Ex. Ca** | 0.380\* | 0.052 | -0.105 | 0.388\* | -0.236\* | 0.128 | 0.181 | 1.000 |  |  |  |  |  |  |
| **Ex. Mg** | 0.314\* | 0.052 | -0.211\* | 0.264\* | -0.198\* | 0.115 | 0.213\* | 0.228\* | 1.000 |  |  |  |  |  |
| **Av. S** | 0.657\*\* | 0.133 | -0.106 | 0.436\* | -0.345\* | 0.264\* | 0.425\* | 0.359\* | 0.147 | 1.000 |  |  |  |  |
| **Av. Zn** | 0.469\* | -0.080 | -0.104 | 0.362\* | -0.113\* | 0.019 | 0.262\* | 0.197\* | 0.056 | 0.215\* | 1.000 |  |  |  |
| **Av. Cu** | -0.202\* | -0.061 | 0.055 | -0.180\* | 0.124\* | -0.148\* | -0.195\* | -0.069 | -0.085 | -0.125\* | 0.129 | 1.000 |  |  |
| **Av. Fe** | 0.434\* | -0.070 | -0.225\* | 0.229\* | -0.096 | 0.085 | 0.270\* | 0.163 | -0.068 | 0.354\* | 0.348\* | -0.082 | 1.000 |  |
| **Av. Mn** | 0.476\* | -0.010 | -0.101 | 0.417\* | -0.352\* | 0.248\* | 0.415\* | 0.258\* | 0.162 | 0.227\* | 0.103 | -0.143 | 0.056 | 1.00 |

N, P and K in (kg ha-1) \*p<0.05 \*\*p<0.01

 Ca, Mg and S in (C mol (p+) /kg)

 Zn, Cu, Fe and Mn in (mg kg-1)

**Table 10: Iterated multiple regression model for pomegranate yield and soil nutrient content at flowering stage**

|  |
| --- |
| **Iterated multiple regression** |
| R2=0.79 |
| F value=67.77\* |
| Constant= -1.78 |
| **Parameters** | **Co- efficient** | **t- value** |
| OC | 3.02 | 4.27 |
| N | -0.01 | 4.44 |
| K | 0.02 | 3.15 |
| Mg | 0.15 | 3.00 |
| S | 0.16 | 6.09 |
| Fe | 0.62 | 3.62 |
| Mn | 0.20 | 3.17 |
| Zn | 0.84 | 4.48 |

**Table 11: Correlation index (r) among pomegranate yield and leaf nutrient content**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Yield** | **Nitrogen** | **Phosphorus** | **Potassium** | **Calcium** | **Magnesium** | **Sulfur** | **Iron** | **Manganese** | **Copper** | **Zinc** |
| Yield | 1.000 |  |  |  |  |  |  |  |  |  |  |
| Nitrogen | -0.471\* | 1.000 |  |  |  |  |  |  |  |  |  |
| Phosphorus | 0.546\* | -0.351\* | 1.000 |  |  |  |  |  |  |  |  |
| Potassium | 0.613\*\* | -0.300\* | 0.413\* | 1.000 |  |  |  |  |  |  |  |
| Calcium | 0.447\* | -0.056 | 0.097 | -0.034 | 1.000 |  |  |  |  |  |  |
| Magnesium | 0.237\* | 0.278\* | -0.295\* | -0.283\* | 0.060 | 1.000 |  |  |  |  |  |
| Sulfur | 0.306\* | -0.160 | 0.177\* | 0.123 | 0.045 | -0.264\* | 1.000 |  |  |  |  |
| Iron | 0.455\* | -0.201\* | 0.328\* | 0.320\* | 0.039 | -0.234\* | 0.205\* | 1.000 |  |  |  |
| Manganese | 0.444\* | -0.235\* | 0.357\* | 0.477\* | 0.072 | -0.235\* | 0.177\* | 0.246\* | 1.000 |  |  |
| Copper | -0.240\* | 0.051 | -0.171\* | -0.048 | -0.118 | -0.054 | 0.004 | -0.115 | 0.145\* | 1.000 |  |
| Zinc | 0.415\* | -0.083 | 0.368\* | 0.375\* | 0.064 | -0.291\* | 0.306\* | 0.337\* | 0.336\* | -0.023 | 1 |

N, P and K in (%) \*p<0.05 \*\*p<0.01

Ca, Mg and S in (%)

Mn, Fe, Zn, Cu and B in (mg kg-1)

**Table 12: Iterated multiple regression equation model for pomegranate yield and leaf nutrient content at the flowering stage**

|  |
| --- |
| **Iterated multiple Regression** |
| R2=0.63 |
| F value=67.77\* |
| Constant= -5.0 |
| **Parameters** | **Co- efficient** | **t- value** |
| N | -2.53 | 3.79 |
| P | 18.02 | 2.79 |
| K | 4.13 | 5.31 |
| S | 9.52 | 2.68 |
| Fe | 0.02 | 3.02 |
| Mn | 0.05 | 2.17 |
| Cu | -0.10 | 3.54 |



 **Fig. 1. Geographic location of the study site within the district where the survey was**

 **conducted**

**Fig. 2: Scatter diagram of pomegranate yield (t ha-1) and organic C (%) at flowering stage**

 **Fig. 3: Scatter diagram of pomegranate yield (t ha-1) and available K (kg ha-1) at flowering stage**

 **Fig. 4: Scatter diagram of pomegranate yield (t ha-1) and plant P (%) at flowering stage**

 **Fig. 5:** **Scatter diagram of pomegranate yield (t ha-1) and plant K (%) at flowering stage**

 **Fig. 6: Scatter diagram of pomegranate yield (t ha-1) and plant S (%) at flowering stage**