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A Survey Study to Assess Soil and Leaf Major Nutrient Status in Relation to Pomegranate Yield

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A B S T R A C T

A survey study was conducted in one hundred and fifty pomegranate orchards situated in seven villages of Bagalkot district, Karnataka *viz.*, Junnur, Seemikeri, Govinakoppa, Kaladagi, Sokanadagi, Chikkasamshi and Hiresamshi to assess the soil and plant major mineral nutrient concentration and its relation with pomegranate yield. The orchards cultivating *Bhagwa* variety of 3-7 years old and fruiting season during *hasta bahar* 2017-18 were surveyed and categorized into low (LYO) and high yielding orchards (HYO) based on their yield levels by considering the Karnataka state average productivity *i.e.* 11.71 t ha^{-1}. Twenty three orchards having mean yield of 9.91 t ha^{-1} (Range: 7.81-11.32 t ha^{-1}) were grouped under LYO and one hundred and twenty seven orchards were grouped under high yielding orchards with mean yield of 18.12 t ha^{-1}(Range: 12.32-25.63 t ha^{-1}). The average fruit yield (28.9 kg $plant^{-1}$), fruit weight (389.7 g $fruit^{-1}$) and number of fruits (74) were significantly higher in HYO as compared to LYO. Application of higher amount of organic manure and major nutrients through inorganic fertilizer was noticed in HYO as compared to LYO. However, the time of nutrient application varied greatly among the two categories. Relatively higher rate of N and P application at *bahar initiation* stage and very low nutrient application was noticed at rest period in LYO. The soil and leaf status of pomegranate orchards separated based on their yield levels revealed that the nitrogen content both in soil and leaf was significantly higher in LYO as compared to HYO. Hence, negative correlation was observed between pomegranate yield and N content both in soil (-0.539) and leaf (-0.471) at flowering stage. But, the Phosphorus and Potassium content were significantly higher in HYO as compared to LYO indicating positive correlation with pomegranate yield.

Introduction

Pomegranate (*Punica granatum*. L), known as “*Dadima*” in Ayurveda is an important fruit crop in arid and semiarid region. It has high demand in internal markets as well as export potential owing to its anti-oxidant values. The popular crop, native from Iran, belongs to the family, lythraceae. In India, it is extensively grown in Maharashtra, Karnataka and Andhra Pradesh and it is an upcoming crop in Gujarat, Tamil Nadu, Uttar Pradesh, Haryana and Rajasthan. In Karnataka, pomegranate is cultivated on an area of 28.09 thousand ha with an annual production of 328.92 thousand MT and productivity of 11.71 MT ha^{-1} (Ministry of Agriculture and Farmers Welfare, Government of India, 2017), in districts of Vijayapura, Koppal, Bagalkot, Belgaum, Dharwad, Chitrdurga and Bellary. Though the area under pomegranate cultivation has increased tremendously, productivity has not increased to the desired extent. One of the key reasons behind low productivity is inadequate nutrition (Marathe *et al.*, 2016) leading to higher susceptibility to disease infestation. This calls for more studies on nutrient management in pomegranate.

During recent years, pomegranate intensive cropping system involving *bahar* treatment (manipulation of flowering and fruit setting involving plant hormones) calls for proper nutrient management which otherwise may deteriorate plant health and make them susceptible for several biotic and abiotic stresses. The current goals of pomegranate production are to achieve high fruit yield and quality fruit. For achieving this optimum nutrient supply and assimilation by plants are of utmost importance. Long term and continuous application of one favored nutrient may lead to its accumulation in soil resulting in the increased concentration and buildup of nutrient that may interact with other nutrients influencing either synergism or antagonism (Ahmad *et al.,* 2011).

It is obvious that the quality of produce depends up on the inherent fertility and productivity of soil. To increase the crop yield, the efficient use of fertilizers by matching nutrient application to crop requirement is more important. Soil analysis gives an idea about actual status of nutrient availability for the assimilation by the plant while, leaf analysis diagnoses the nutritional status of plant which ascertains the nutrient requirement for a given crop. Optimum requirement is based on the assumption that there is a positive relationship between the doses of nutrient supplied, leaf nutrient and yield. This association between nutritional status and pomegranate productivity helps in affirming site specific recommendations. Hence, the present study aims at measuring the mineral nutrient concentration both in soil and plant and assessing its relation with pomegranate yield through survey study in Bagalkot district, Karnataka.

Materials and Methods

Study area

The present survey was conducted in Bagalkot that comes under Northern Dry Zone of Karnataka. In Bagalkot district, it is majorly grown in talukas of Bagalkot and Mudhol, followed by Bilagi and Hunugund and in small area at Badami and Jamkandi. One hundred and fifty pomegranate orchards were selected randomly from seven villages *viz.*, Junnur, Seemikeri, Govinakoppa, Kaladagi, Sokanadagi, Chikkasamshi and Hiresamshi for the present survey to study the relation between soil and plant nutrient status with pomegranate productivity. The details of the location and orchards are presented in table 1.

The farmers of respective orchards were selected as contact farmers and the basic criteria used for selection of orchards were variety (Bhagwa), crop age (3-7yrs) and season (*hasta bahar* 2017-18).

Categorization of pomegranate orchards

The survey orchards were categorized based on their yield levels by considering the Karnataka state average productivity *i.e.*, 11.71 t ha^{-1}. The orchards with yield levels lesser than 11.71 t ha^{-1} were grouped as low yielding orchards (LYO) and with the yield levels greater than 11.71 t ha^{-1} were considered as high yielding orchards (HYO).

Collection of pomegranate yield and yield parameters

Three healthy pomegranate plants from each orchard were selected randomly and labelled for recording the yield parameters. Weight of marketable fruit from all three labelled plants was recorded in each pickings (4-5) and cumulative weight computed to express fruit yield per plant in kilo gram.

The total number of fruits was counted from all the three labelled plants and average was computed to indicate the number of fruits per plant. Then total weight of fruits harvested from three selected plants was measured and the fruit weight was calculated using following formula and expressed in gram per fruit.

$$\text{Fruit weight (gram/fruit)} = \frac{\text{Total weight of fruits}}{\text{Number of fruits}}$$

The information on marketed pomegranate fruit yield was collected from contact farmers through personal interview. Then, by considering the actual area of the orchard, the fruit yield was computed for one hectare area and expressed in tones per hectare.

Collection of soil and leaf sample

The soil samples were collected from the vicinity of the selected plants for 0-15 cm depth and appropriately 45 cm away from the dripper position using post hole auger and composite samples were prepared using quartering technique. The index tissue identified for pomegranate plant tissue analysis *i.e.* eight pair of leaf from non-bearing shoot (Raghupati and Bhargava 1998b), was collected from the labelled plants where, soil samples were collected from all orchards separately, at flowering stage to study their nutrient contents.

Preparation of samples

The collected soil samples were air dried, pounded using wooden pestle and mortar, sieved (2 mm) and stored in air tight polyethylene bags for further analysis. Similarly plant samples were powdered using stainless steel mixer jar and preserved in air tight plastic cover for further analysis.

Estimation of major nutrients in soil

Alkaline permanganate method developed by Subbiah and Asija (1956) was used to determine available nitrogen content in soil. A known weight of soil was distilled with 0.32 per cent $KMnO_4$ and 2.5 per cent NaOH using semi- automated N-distillation unit. The ammonia liberated is trapped in 2 per cent boric acid + mixed indicator was titrated against standard H_2SO_4 solution for determining available nitrogen content in soil. Available phosphorus from soil was extracted using Olsen's extractant. The blue colour was developed by ascorbic acid method and the intensity was read at 660 nm using spectrophotometer and calculated referring to P-standard curve in terms of P_2O_5 kg ha^{-1} (Jackson, 1973). Available potassium was extracted from soil using neutral normal ammonium acetate (1:5), soil to extractant ratio and the concentration of potassium in the extract was determined using Flame photometer by calibrating with standards and calculated in terms of K_2O kg ha^{-1} (Jackson 1973).

Estimation of major nutrients in plants

Nitrogen content in leaf was determined by Kjeldhal distillation method. A known weight (0.50 g) of sample was digested with conc. H_2SO_4 and digestion mixture ($CuSO_4$: K_2SO_4: Se-100:40:1). The digested samples were distilled for estimating N-content as outlined by Piper (1966).Concentration of phosphorus in di-acid digested sample was estimated by phospho-vanado-molybdate complex method. Yellow colour was read using spectrophotometer at 430 nm and was estimated by referring to standard curve (Piper, 1966). The di-acid digest sample was fed to a calibrated flame photometer and per cent potassium was calculated by following Piper (1966) method.

Statistical analysis

The soil and leaf properties of pomegranate orchards were separated based on their yield levels falling into respective categories. Then one way ANOVA was studied to find the significance difference between the categories. Simple correlation between pomegranate yield and nutrient variables in leaf and soils were calculated using Pearson product moment correlation coefficient (r). The MS-office excel programme was used for calculating the simple correlation matrix. The perfect linear correlation was attained when r = ± 1 and r =0 implies that x and y tend to have no linear relationship. The table r values 0.361 @ $p<0.05$ and 0.467 @ $p<0.01$ were used to determine the significance of relationship between two variables (Snedecor and Cochran, 1981).

Results and Discussion

Pomegranate yield and yield parameters

The average pomegranate productivity of Karnataka state (11.71 t ha^{-1}) was considered for categorizing the pomegranate orchards into low and high yielding. Accordingly, twenty three orchards with their yield ranging from 7.81-11.32 t ha^{-1} and average yield of 9.91 t ha^{-1} were grouped under LYO. Similarly one hundred and twenty seven orchards were grouped under HYO with their yield ranging from 12.32-25.63 t ha^{-1} and average yield of 18.12 t ha^{-1} (Table 2).

Significant variation was found with respect to fruit yield (t ha^{-1} and kg $plant^{-1}$), fruit weight (g $fruit^{-1}$) and number of fruits between the two groups. Significantly higher fruit yield of 18.12 t ha^{-1} and 28.93 kg $plant^{-1}$ were observed in HYO as compared to 9.91 t ha^{-1} and 15.92 kg $plant^{-1}$ in lower yielding orchards (Table 2). Similarly significantly higher fruit weight of 389.7 g $fruit^{-1}$ and fruit number of 74 per plant was recorded in HYO as compared to LYO (264.3 g $fruit^{-1}$ and 60 respectively) (Table 2).

Number of fruits on each plant is one of the important factors that govern yield and quality of pomegranate. It is recommended to retain 60-80 fruits in fully grown up trees (NRCP, Solapur, 2014). However, depending on plant vigor and canopy, farmers regulate fruit number and this plays significant role in developing good size and quality of fruits. Fruit weight is also an important quality parameter used for grading and marketing. Pomegranate fruit weight is governed by many factors *viz.*, number of fruits, fruit position, climatic condition and most importantly mineral nutrition (Sheikh and Rao, 2010). The mineral elements that are contributing for fruit yield are responsible for better fruit weight (Ray *et al.*, 2014).

Nutrient application rates pomegranate orchards

The details of amount of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) and organic matter applied through inorganic and organic fertilizers is presented in table 3. Wide variation was recorded in terms N application rate to pomegranate plants at *bahar* initiation stage recording a range of 0-48 g $plant^{-1}$ in HYO and 70.18-79.61 g $plant^{-1}$ in LYO. But, significantly higher total N application was observed in HYO (412.7 g $plant^{-1}$) as compared to LYO (387.4 g $plant^{-1}$). The total amount of N application through inorganic fertilizer was below the recommended rate for different ages (3-7 years) of pomegranate plants by various farm institutes (400-625 g plant^{-1}; NRCP, Solapur, UHS Bagalkot and UAS Dharward). The contact farmers opined that they discourage N application during *bahar* initiation stage to suppress foliage or vegetation growth and encourage flowering. They indicated that application of organic matter is good during the *Bahar* initiation than inorganic N application. Phosphorus application recorded significantly higher total amount of 200.2 g plant $^{-1}$ in HYO as compared to 182.0 g plant $^{-1}$ in LYO (Table 3). The cumulative information collected from the respondent farmers indicated the use of high P containing inorganic fertilizers *viz.*, DAP for soil application and mono ammonium phosphate (12:61:0), mono potassium phosphate (0:52:34) and phosphoric acid through fertigation. However, the total amount of P application rate was nearer to recommended rate (200-250 g plant^{-1}) by different farm institutes in HYO while it was relatively low in LYO.

The application rate of potassium (K_2O) did not vary significantly among low and high yielding pomegranate orchards (Table 3). However, marginally higher amount of K_2O (226.3 g plant^{-1}) application was noticed in HYO as compared to LYO (205.1 g plant^{-1}). The rate of K_2O application was found to be on par with recommendation (125-250 g plant^{-1}) by various farm institutes. The rate of K_2O application was found to be on par with recommendation (125-250 g plant^{-1}) by various farm institutes. Organic matter application recorded was higher (30.01 kg plant^{-1}) in HYO than LYO (13.30 kg plant^{-1}).

Major nutrient status (N, P_2O_5 and K_2O) in soils of pomegranate orchards

Significant variation in major nutrient status was observed with available N, P_2O_5 and K_2O among various categories of orchards. HYO recorded significantly higher mean available P_2O_5 content of 48.13 kg ha^{-1} and available K_2O content of 219.7 kg ha^{-1} as compared to 41.65 and 192.8 kg ha^{-1} available P_2O_5 and K_2O respectively in LYO (Table 4). Relatively high alkaline soil pH in LYO might have precipitated applied P into insoluble calcium phosphates rendering decreased availability (Wastermann and Leytem, 2003, Abdou, 2006 and Bertnand *et al.,* 2006). Application of higher organic matter content to soil at *bahar* initiation time might have helped to increase soil P by decreasing soil pH through organic acid production (Ritchi and Dolling, 1985) there by process of solubilizing the fixed soil P (Ray *et al.,* 2014), besides release of P during decomposition (Radwaski and Wickens, 1981). Lower K_2O content in LYO may be attributed to lower rate of K_2O and organic matter application at *bahar* initiation stage in LYO as compared to HYO. Whereas available N was significantly higher in LYO with a mean of 451.8 kg ha^{-1} as compared to HYO (406.0 kg ha^{-1}). Relatively higher rate of application of inorganic fertilizer at *bahar* initiation might have contributed to higher availability of N in these soils (Saraf *et al.,* 2001, Sheikh and Rao, 2010, Ghosh *et al.,* 2012, Ahmed *et al.,* 2014, Kashyap *et al.,* 2012).

Pomegranate major leaf nutrient concentration (N, P and K) in low and high yielding orchards

Nitrogen content in pomegranate leaves varied significantly among the two groups. Higher nitrogen content in leaves was noted in LYO orchards ranging from 1.51 to 1.96 per cent, with average N content of 1.73 per cent, as compared to 1.4 per cent in HYO (Table 5). This may be attributed to N application rate and its higher availability in soils that might have resulted in higher accumulation in succulent leaves at flowering stage (Lominadze *et al.,* 2016, Kolekar *et al.,* 2018).

Table.1 Details of pomegranate orchards selected for the study

Sl. No.	Village Name	Longitude	Latitude	No of orchards	Age of orchards
1	Junnur	16.232s10^0 N	075.44176^0 E	12	3.5-6.5
2	Kaladagi	16.19493^0 N	075.50330^0 E	45	3-7
3	Sokanadagi	16.22876^0 N	075.57455^0 E	41	3.5-6
4	Chikkasamshi	16.23474^0 N	075.53139^0 E	23	3-5.5
5	Govinakoppa	16.20231^0 N	075.52857^0 E	14	3-6
6	Seemikeri	16.16227^0 N	075.57851^0 E	10	4-7
7	Hiresamshi	16.22532^0 N	075.52793^0 E	5	3-4.5

Table.2 Yield and yield parameters of low and high yielding pomegranate orchards

Yield Parameters	Low yielding (n=23)		High Yielding (n=127)	
	Range	Average	Range	Average
Fruit yield (tonnes ha^{-1})	7.81-11.32	9.91 ± 0.8^b	12.32-25.63	18.12 ± 3.3^a
Fruit yield (kg plant-^{1})	12.43-18.0	15.92 ± 1.30^b	19.63-40.91	28.93 ± 5.2^a
Fruit weight (gram fruit^{-1})	198.0-306.4	264.3 ± 27.3^b	245.8-587.5	389.7 ± 66.3^a
Number of fruits per plant	53-72	60 ± 3.6^b	61-86	74 ± 6.0^a

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

Table.3 Nutrient application rates in low and high yielding orchards

Nutrients (g plant $^{-1}$)	Category	*Bahar* initiation	Active growth	Rest period	Total	
		Range	Range	Range	Range	Average
Nitrogen	Low yielding	70.18-79.61	221.3-321.3	0-86.3	318.1-420.5	387.4 ± 19.9^b
	High yielding	0-48.8	238.4-332.6	0-94.3	358.6-456.8	412.7 ± 33.5^a
Phosphorus (P_2O_5)	Low yielding	56.6-92.6	78.9-124.3	0-58.6	171.0-215.1	182.0 ± 9.9^b
	High yielding	0-112.6	58.6-110.3	60.1-94.3	173.1-269.4	200.2 ± 13.2^a
Potassium (K_2O)	Low yielding	42.6-59.8	132.2-158.4	0-62.4	178.2-224.1	205.1 ± 12.1^{ns}
	High yielding	51.3-102.3	76.9-138.6	30.1-53.2	152.7-299.9	226.3 ± 50.2^{ns}
Organic matter	Low yielding				0-28	13.30 ± 10.16^b
	High yielding				12-46	30.01 ± 7.93^a

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

Table.4 Available nutrient content in soils of low and high yielding pomegranate orchards

	Low yielding (n=23)		High Yielding (n=127)	
	Range	Average	Range	Average
Soil Nutrient Content (kg ha^{-1})				
Available Nitrogen	318.2 - 598.0	451.8 ± 95.6^{a}	200.9-589.3	406.0 ± 107.9^{b}
Available Phosphorus (P_2O_5)	18.55-56.00	41.65 ± 7.89^{b}	20.14-64.95	48.13 ± 11.81^{a}
Available Potassium (K_2O)	139.9-245.7	192.8 ± 36.1^{b}	184.6-.284.2	219.7 ± 24.2^{a}
Leaf Nutrient Content (%)				
Nitrogen (%)	1.51-1.96	1.73 ± 0.15^{a}	1.04-2.21	1.40 ± 0.36^{b}
Phosphorus (%)	0.09-0.17	0.15 ± 0.08^{b}	0.14-0.29	0.21 ± 0.03^{a}
Potassium (%)	0.77-1.19	0.98 ± 0.12^{b}	1.08-2.11	1.64 ± 0.26^{a}

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

Table.5 Correlation index (r) among major soil nutrients and major leaf nutrient content at flowering stage

	Yield	Soil N	Soil P	Soil K	Plant N	Plant P
Soil N	-0.539*					
Soil P	0.281*	-0.30*				
Soil K	0.623**	-0.42*	0.30*			
Plant N	-0.471*	0.31*	0.00	-0.26*		
Plant P	0.546*	-0.31*	0.20*	0.31*	-0.35*	
Plant K	0.613**	-0.31*	0.13	0.34*	-0.30*	0.41*

Soil N, P and K in (kg ha^{-1}), Plant N, P and K in (%)
*p<0.05 **p<0.01

Significantly higher P mean concentration of 0.21 per cent was recorded in HYO with a range of 0.14-0.29 % as compared to LYO (0.15 %) (Table 5). Higher alkaline soil pH and lower organic matter application (Yu *et al.*, 2013, Kumar *et al.*, 2009, Ahmed *et al.*, 2014, Kashyap *et al.*, 2012) might be the reason for low P accumulation in LYO.

Significant variation was recorded in terms of K content in pomegranate leaves in high and LYO. Higher K concentration of 1.64 per cent was noticed in HYO as compared to low yielding (0.98 %) (Table 5). This may be attributed to lower rate of inorganic K fertilizers and organic matter application during *bahar* initiation stage. The higher organic matter and inorganic fertilizer application resulted in higher K availability in soil (Meek *et al.*, 1982, Sheikh and Rao, 2010, Ghosh *et al.*, 2012, Ahmed *et al.*, 2014, Kashyap *et al.*, 2012) that might enhanced its accumulation in leaves.

Correlations among soil and leaf nutrient contents with pomegranate yield

The correlation analysis among major soil nutrient parameters at flowering stage is presented in Table 5. At flowering stage, significant positive correlation was found between pomegranate yield and P (0.546). Phosphorus application through inorganic fertilizer and organic matter has resulted in higher availability in soil resulting in its optimum accumulation in pomegranate leaf in HYO (Gimenez *et al.*, 2000, Ahmed *et al.*, 2014 and Kashyap *et al.*, 2012) as compared to LYO. Phosphorus is highly essential for active root growth and known to stimulate uptake of other nutrients (Marathe *et al.*, 2016) thus showing positive relation with pomegranate yield. Pomegranate yield also showed a significant positive correlation with K (0.613). Many researches opined that potassium plays vital role in pomegranate yield and fruit quality (Sheikh and Rao, 2010, Kumar *et al.*, 2009, Ahmed *et al.*, 2014, Kashyap *et al.*, 2012).

Amongst the primary nutrients, N showed negative relationship with yield (-0.471). LYO recorded relatively higher amount of N application through in organic fertilizer that resulted in higher availability in soil further, higher N accumulation in leaves. All these might have influenced on flowering pattern and fruit set recording lower number of fruits per plant in these orchards. Many researchers have opined that abundant nutrient supply may reduce flowering (Corbesier, *et al.*, 2002. Bernier *et al.*, 1981 and Rideout *et al.*, 1992) and flowering pattern in pomegranate.

Hermaphrodite flowers are considered as perfect flowers and have positive correlation to fruit bearing (Babu, 2010, Bernier *et al.*, 1981, Rideout *et al.*, 1992) may be affected when N content is high in the plant that promote more of vegetative growth than flowering. Amongst the primary nutrients, soil N, P and K are positively correlated with plant N, P and K (r= 0.31, 0.2 and 0.34 respectively) (Table 5). Higher availability of nutrients in soil might have resulted in its higher accumulation in the succulent leaves at flowering (Lominadze *et al.*, 2016, Kolekar *et al.*, 2018).

The results of the present study has revealed optimum application rate of major nutrients especially nitrogen is essential for obtaining higher fruit number, fruit weight and fruit yield. Organic matter application is crucial in maintaining higher availability of major nutrients in soil. Rate and time of inorganic nutrient application both during rest period and active fruiting stage plays a crucial role in pomegranate productivity.

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