Int. J. Forest, Soil and Erosion, 2019 9 (3)
ISSN 2251-6387

Research Paper

Identifying association between pomegranate fruit yield and nutrient variables using correlation and linear multiple regression models

ARCHANA, M[1]., ANUSREE, T[2]., SUMA, R. [*3] and MANJUNATHA, G.[4]

[1] Archana M., Post Graduate Student, Department of Soil Science and Agricultural Chemistry, College of Horticulture, University of Horticultural Sciences, Bagalkot, Karnataka, India. E-mail: 369archana@gmail.com

[2] Anushree, T. Post Graduate Student, Department of Soil Science and Agricultural Chemistry, College of Horticulture, University of Horticultural Sciences, Bagalkot, Karnataka, India. E-mail: anusreesoilscience@gmail.com

[3*] Associate Professor, Zonal Agricultural Research Station, V.C.Farm, Mandya, Karnataka, India. E-mail: sumassac@gmail.com

[4] Assistant Professor (Plant Pathology), Directorate of Research, University of Horticultural sciences, Bagalkot, Karnataka, India. E-mail: gmanjunath2007@gmail.com

***Corresponding author : Suma R., Associate Professor,Department of Soil and Water Management, Zonal Agricultural Research Station, University of Agricultural Sciences, V.C.Farm, Mandya, Karnataka, India.-571 405, E-mail: sumassac@gmail.com**

Abstract: Soil and pomegranate index leaf nutrient content were analysed in thirty pomegranate orchards of Bagalkot district, Karnataka to study their association with fruit yield using correlation and linear multiple regression analysis models. These orchards were categorised into low (mean; 9.42, Range; 8.3-10.13 t ha^{-1}), medium (mean;13.17, Range; 11.50 -14.50 t ha^{-1}) and high yielding (mean;19.81, Range; 15.5-22.0 t ha^{-1}) orchards and high yielding orchards recorded significantly higher number of fruit (77) and fruit weight (342 g $fruit^{-1}$) as compared to medium and low yielding. The correlation matrix indicated positive relationship between yield and leaf N, P, K, Ca, Mg, S, Mn and B at all stages of crop growth. Only Cu was found to have significant negative correlation with yield at fruit formation and maturation stage. The availability of N, K, Mn, B and organic carbon content in soil was positively related to pomegranate yield. The various multiple regression models obtained in the present investigation indicated N, B and S are the critical leaf nutrient variables showing positive association with pomegranate yield followed by potassium and calcium. Copper was the single nutrient factor which had negative impact on yield at all crop growth stage, however was insignificant. Similarly in soil, the regression equations indicated organic carbon, N and K as critical soil variables explaining most variations in pomegranate yield followed by B and Ca. However, pH negatively influenced the yield and deficiency of S and Fe in soil was found to have negative impact on pomegranate productivity.
Keywords: Boron, Copper, High yielding orchards, Nitrogen, Potassium

Introduction:

Pomegranate (*Punica granatum* L.) is one of the important fruit crops in arid and semi-arid regions. The fruit is popular for its nutrition, unique flavour, taste and health promoting characters. 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 Koppal, Bijapur, Bagalkot, Chitradurga, Belgaum, Dharwad and Bellary. Pomegranate has wide adaptability and requires relatively low cost for its cultivation with drought tolerance and good economic returns with potential of export attributes. Hence, its area is expanding in recent years. In this context, it is crucial to evolve strategies to sustain pomegranate productivity. Amongst the cultural practices, nutrient application and its availability, uptake and assimilation by pomegranate plays a key role in influencing productivity. Hence, the present research programme was planned to evaluate the relation between the soil and plant nutrient status on pomegranate productivity.

Mineral nutrition plays an important role in influencing the yield and quality of pomegranate. It is fact that an intensive cropping, involving *bahar* treatment without proper nutrient management is the cause for deteriorating plant health. Further, continuous use of high analytical fertilizers with less organics has increased the incidence of nutrient deficiencies. For achieving higher and sustainable pomegranate productivity, balanced nutrient application is most important, which emphasize recommendation of nutrients based on soil and plant testing. Soil testing provides valuable information on nutrient availability and helps in ensuring balanced application of nutrients to meet crop requirements (Dev, 1998). Whilst, plant tissue testing provides information on plant assimilated nutrient content, which is crucial for evolving nutrient application strategies to obtain higher pomegranate yield and quality (Hamouda *et al.,* 2015). To achieve this, basic information on relationship between nutrient status and pomegranate production is obligatory.

The soils under pomegranate cultivation are dynamic in nature and vary in their properties due to wide range of geographical and climatic conditions. Farmers usually follow distinct management practices and regularly manipulate them hence; wide variation is noticed with nutrient availability and uptake by crop plants. It has been observed under field conditions that pomegranate plants raised under poor soils produced lower yields, poor quality fruits and were more susceptible to the pests and disease (Yenjeerappa, 2009). Further, poor plant vigour found associated to plant mortality particularly in critical stages *viz.*, flowering and fruit setting, which is linked to nutrition (Patil and Patil 1982).This emphasizes need for understanding region specific nutrient management practices and its effect on nutrient availability and uptake by pomegranate plants and ultimately its effect on their productivity. Hence, the present investigation is carried out to study the nutritional pattern in the soils and plant tissues and its relation to pomegranate productivity to evolve best possible nutrient management strategies for sustaining pomegranate productivity.

Material and methods

Survey area: A survey was conducted in and around Kaladagi village – a renowned area for pomegranate cultivation in Bagalkot district, Karnataka state for selection of pomegranate orchards. Thirty pomegranate orchards of 3-7 years old cultivated with Bhagwa variety were randomly selected from five villages *viz.*, Govinakoppa, Kaladagi, Sokanadagi, Chikkasamshi and Hiresamshi for the present study.

Crop season and *bahar* treatment: The *hasta bahar* season was selected to implement the present investigation. The pomegranate plants were put into artificial stress by withholding water for one month and artificially defoliated during first – second week of August by spraying ethrel (2-2.5ml/litre). Then, light pruning and irrigations are practiced, followed by application of manures and fertilizers during August month. The new flushes appeared on the tree between 8-12 days and profuse flowering were observed during first to second week of September

Collection of data and samples : The farmers were interviewed periodically to collect the information on cultivation practices *viz.*, spacing, spray schedule, irrigation system, inter-cultural practices *etc*., in general and nutrient management practices in specific using the questionnaire developed for the purpose. The composite soil samples were collected from 0-15cm depth along plant canopy circumference (approximately 1.0 m away from trunk) at 30, 70 and 210 days after *bahar* treatment (DABT) that coincides with bud differentiation, fruit formation and maturation stages respectively. Similarly, the index leaf *i.e* 8^{th} pair of leaf counting from the tip of non-bearing shoots were sampled from the trees where soil samples were collected at foresaid period.

Yield parameters: Three healthy pomegranate plants from each orchard were selected randomly to record yield parameters. Number of fruits from three selected plants was counted and average was computed. The total number and total weight of fruits harvested from three selected plants at second picking was measured. Then, 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 fruit yield per plant was calculated by multiplying total number of fruits in each plant and average fruit weight (g $fruit^{-1}$) to express as kg $plant^{-1}$. 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

Soil and Plant Analysis: The collected soil samples were dried and passed through 2 mm sieve to determine its nutrient contents following the standard protocol as mentioned in Table 1. The nutrient concentrations in pomegranate index leaves were determined by using standard protocol as described by Piper, 1966 after subjecting it to di-acid digestion using HNO_3:$HClO_4$ (9:4) for mineral estimation other than nitrogen. The leaf nitrogen content was determined by digesting with conc. H_2SO_4 and digestion mixture ($CuSO_4$:K_2SO_4: Se-100:40:1) and quantified using Kjeldhal distillation method.

Categorizing pomegranate orchards: Pomegranate fruit yield (t ha^{-1}) was considered as base for classifying orchards into high, medium and low yielding using following statistical criteria as developed by Ahmed *et al*, 2015 for small population group.

1. (Mean + 0.5×SD) were categorised as high yielding orchards
2. < (Mean - 0.5×SD) were categorised as low yielding orchards
3. (Mean + 0.5×SD) to (Mean – 0.5×SD) were categorised as Medium yielding orchards

Where, Sd = standard deviation and Mean = average pomegranate yield

Correlation index: 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).

Table 1: Methods followed for estimation of soil properties

Parameters	Methods	References
pH	Potentiometric method	Jackson, 1973
EC (dS m^{-1})	Conductometric method	Jackson, 1973
OC (%)	Wet oxidation method	Walkey and Black, 1934
Avail. N (kg ha^{-1})	Alkaline potassium permanganate method	Subbiah and Asija, 1956
Avail. P (kg ha^{-1})	Olsen's extractant method, Colorimetry	Jackson, 1973
Avail. K (kg ha^{-1})	N NH_4OAC extractant method, Flame photometry	Jackson, 1973
Exch. Ca [cmol (p^+) kg^{-1}]	Versenate titration method	Jackson, 1973
Exch. Mg [cmol (p^+) kg^{-1}]	Versenate titration method	Jackson, 1973
Avail. S (kg ha^{-1})	$CaCl_2$ extractant method, Turbidimetry	Black, 1965
Fe, Mn, Zn and Cu (mg kg^{-1})	Atomic absorption spectrophotometry	Lindsay and Norvell, 1978

Multiple linear regression models: Multiple linear regression models (Dahal and Routray, 2011) to evaluate the relative contribution of all leaf nutrient variables (N, P, K, Ca, Mg, S, Fe, Zn, Mn, Cu and B) on fruit yield (Y) were determined as following

$Y= a + b_1N + b_2P + b_3K + …….. + b_n B$

Where,

Y = Dependent variable (pomegranate fruit yield)

a = Intercept

b_1, b_2, b_3… bn = The slope of the regression line or the amount of change produced in Y by a unit change in independent variables.

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

Similarly, the multiple linear regression models were developed to evaluate the relative contribution of all soil variables (pH, EC, OC, N, P, K, Ca, Mg, S, Fe, Zn, Mn, Cu and B) on fruit yield (Y) as per the above mentioned formula.

Nutrient variables in the above regression equation which are unimportant or redundant explanatory variables were screened out using stepwise backward regression analysis. The analysis was employed by eliminating single nutrient variable each time, till improved significant model (in terms of F and t values) was obtained. Open Stat version 1.9, a computer program was used for carrying out the backward stepwise multiple regression analysis as suggested by William (2007).

Results and Discussion:

Pomegranate yield and major nutrient inputs

The orchards yield levels less than11.1 t ha^{-1} were considered as low, while yield level between11.1 to 15.5 t ha^{-1} was consider as medium and more than 15.5 t ha^{-1} as high yielding. Amongst the thirty pomegranate orchards studied, 13 orchards were grouped under low category and their yield ranged from 8.25-10.25 t ha^{-1}, with a mean yield of 9.42 t ha^{-1}. Medium category orchards (9 numbers) recorded significantly higher average yield of 13.17 t ha^{-1} showing yield range of 11.5 to 14.5 t ha^{-1}, compared to low category. Eight orchards recorded significantly highest mean yield of 19.81 t ha^{-1} and their yield levels ranged from 15.5 to 22.0 t ha^{-1} (Table 2)

Table 2: Pomegranate fruit yield and yield parameters among different categories of pomegranate orchards

Category	Yield (t ha^{-1})		Fruit yield (kg $plant^{-1}$)	
	Range	Average	Range	Average
Low (n=13)	8.30 - 10.30	9.42 ± 0.76	9.24 - 11.71	10.54 ± 0.82
Medium (n=9)	10.50 - 14.50	13.17 ± 1.33	10.38 - 13.86	13.45 ± 1.32
High (n=8)	15.50 - 22.0	19.81 ± 1.94	14.22 - 17.63	19.77 ± 1.59
SE m±		**0.459**		**0.512**
CD @ 5%		**1.616**		**1.477**
Category	**No. of fruits per plant**		**Fruit weight (g $plant^{-1}$)**	
	Range	**Average**	**Range**	**Average**
Low (n=13)	58.00 - 66.00	62.69 ± 1.64	206.00 - 243.0	224.10 ± 12.18
Medium (n=9)	64.00 - 74.00	70.00 ± 2.10	228.90 - 288.70	256.20 ± 21.80
High (n=8)	71.00 – 81.00	77.00 ± 2.50	312.80 - 364.20	342.00 ±15.55
SE m±		**1.035**		**5.66**
CD @ 5%		**3.442**		**19.93**

Number of fruits per plant

Number of fruits on each plant is one of the important yield parameters in pomegranate plants. However, depending on the plant vigour and canopy farmers regulate number of fruits on each plant. Optimum fruit number helps for developing good size and quality of fruits. It is recommended to retain 60-80 fruits in fully grown up trees (National Research Centre for Pomegranate, Solapur, 2014). In the present investigation, significantly higher number of fruits was observed in the high yielding orchards (71-81) compared to medium (65-74) and low yielding (58-66) (Table 2). The better canopy growth with optimum supply of nutrients in high yielding orchards could sustain higher number of fruits, which might have resulted in higher fruit yield in these orchards.

Fruit weight (g fruit^{-1})

Fruit weight is an important quality parameter for grading and marketing in pomegranate. In the present investigation, high yielding orchards recorded significantly higher fruit weight of 342.0 g compared to medium (256.20 g) and low (224.10 g) yielding orchards (Table 2). Pomegranate fruit weight is governed by many factors of which number of fruits, fruit position and climatic condition are some of the important external factors. In high yielding orchards, though the numbers of fruits was high they found to be optimum and the fruits retained on lower portion of branches found to have higher weight and size compared to fruits on top portion. Besides, mineral nutrition plays a significant role in fruit quality. In present investigation, higher nutrient concentration of N, K, Ca, S, Mn, Zn and B in pomegranate leaves might have attributed to better fruit weight in high yielding pomegranate orchards. All these nutrients have manifested into good crop growth, fruit set and development that ultimately produced good quality fruits. (Sheikh and Rao 2005, Rao and Subramanyam 2009, Khayyat *et al.,* 2012, Mir *et al.,* 2013 and Ray *et al.,* 2014).

Pomegranate yield and its association with soil nutrient parameters

Soil variables indicate the nutrient level and its supplying power to crop uptake. It also suggests the probable occurrence of nutrient deficiency and imbalance. In the present investigation, at bud differentiation stage, significant positive correlation was found between OC (0.815), N (0.789), K (0.397), S (0.364), Mn (0.470) and B (0.531) with pomegranate yield. Soil pH (-0.166), Mg (-0.085) and Fe (-0.113) recorded negative correlation with yield but were not significant (Table 3). The organic carbon content of soils recorded positive relationship with available N (0.749) and S (0.707) content in soil, signifying the high supplying power of pomegranate soils for said nutrient. The result indicates alkaline soil pH is hurdle for higher pomegranate production and mining of S and Fe in these soils.

Similar trend was observed at fruit formation and maturation stage where, OC, N, K, Mn and B were significantly and positively correlated to yield at both the stages but, K and Mn were found significant only at fruit maturation stage. Among the different soil parameters, significant synergistic correlation was found between OC & N and OC & S at all stages of crop growth while, antagonistic relation was found between OC & Cu but was insignificant.

The multiple linear regression models developed employing pomegranate yield against soil parameters found significant at all stages of crop growth. The best regression model through reduction of soil variables have at different growth stages is as below (Table 4)

Bud differentiation stage;

$$Y= -4.928- 2.84pH + 17.18OC + 0.02N + 0.06P- 0.30S- 1.20Fe + 12.26B$$

Fruit formation stage;

$$Y=-7.84 + 8.04EC + 17.79OC + 0.02N + 0.03K-1.81Fe$$

Fruit maturation stage;

$$Y= -11.58 + 11.85OC + 0.05N + 0.03K$$ at

In general, OC, N and K levels in soil significantly and positively influenced pomegranate yield at all stages of crop growth, emphasizing their role in higher pomegranate productivity (Saraf *et al.,* 2001, Shiekh and Rao, 2005, Mir *et al.,* 2015, Mohamed *et al.,* 2014, Raghupathi and Bhargava 1998a and Ray *et al.,* 2014). Optimum supply of nutrients in soil is a key factor for obtaining better crop yield. In the present investigation, application of organic matter, nitrogen, potassium and boron found to play critical role in availability of these nutrients in soil and further their uptake by pomegranate plants. However, availability of some nutrients was decreased with advance of crop growth *viz.*, N, S, B, Zn and Fe, which emphasizes their optimum application for succeeding crop to have higher pomegranate productivity (Raghupathi and Bhargava 1998b and Awasti and Singh 2010).

Pomegranate yield and its association with leaf nutrient parameters

The correlation matrix generated among leaf nutrient variables and yield is shown in Table 5. The matrix reveals significant positive correlation between pomegranate yield with N (0.852), P (0.456), K (0.592), Ca (0.750), Mg (0.496), S (0.609), Mn (0.681) and B (0.637) at bud differentiation stage. The other nutrient parameters *viz.*, Fe (0.190), Cu (0.067) and Zn (0.10) were positively correlated with yield but were not significant.

Table 3: Correlation index (r) among pomegranate yield and soil nutrient content at various crop growth stages

Soil parameter	Growth Stage	Yield	pH	EC	OC	N	P	K	Ca	Mg	S	Mn	Fe	Zn	Cu
pH	*30 DABT*	-0.166	1.000												
	70 DABT	-0.044	1.000												
	210 DABT	-0.016	1.000												
EC	*30 DABT*	0.171	-0.165	1.000											
	70 DABT	0.089	-0.063	1.000											
	210 DABT	0.031	-0.093	1.000											
OC	*30 DABT*	0.815**	-0.123	0.086	1.000										
	70 DABT	0.754**	-0.029	-0.165	1.000										
	210 DABT	0.524**	-0.281	-0.238	1.000										
N	*30 DABT*	0.789**	-0.156	0.200	0.749**	1.000									
	70 DABT	0.710**	-0.096	0.069	0.627	1.000									
	210 DABT	0.635**	0.233	-0.019	0.081	1.000									
P	*30 DABT*	0.239	0.615**	-0.008	0.209	0.071	1.000								
	70 DABT	0.201	0.612	-0.070	0.215	-0.160	1.000								
	210 DABT	0.133	0.533**	-0.352	0.061	0.065	1.000								
K	*30 DABT*	0.397*	-0.178	0.040	0.296	0.547**	-0.208	1.000							
	70 DABT	0.307	0.341	-0.231	0.181	0.209	0.176	1.000							
	210 DABT	0.521**	0.193	-0.096	0.082	0.468**	0.082	1.000							
Ca	*30 DABT*	0.093	0.330	-0.039	-0.046	0.004	0.268	0.008	1.000						
	70 DABT	0.084	0.274	0.007	-0.048	-0.074	0.190	0.133	1.000						
	210 DABT	0.100	0.126	-0.039	0.036	-0.059	0.226	0.115	1.000						
Mg	*30 DABT*	-0.085	0.490**	0.159	-0.223	-0.052	0.371*	0.129	0.554**	1.000					
	70 DABT	-0.114	0.591**	0.292	-0.236	-0.155	0.310	0.079	0.546**	1.000					
	210 DABT	-0.054	0.525**	-0.019	-0.378*	0.183	0.373*	0.239	0.558**	1.000					
S	*30 DABT*	0.364*	-0.247	0.102	0.707**	0.335	0.006	0.028	-0.041	-0.299	1.000				
	70 DABT	0.288	-0.253	-0.144	0.600**	0.256	0.022	0.134	-0.038	-0.250	1.000				
	210 DABT	0.224	-0.330	-0.153	0.544**	-0.001	0.048	-0.118	-0.049	-0.244	1.000				
Mn	*30 DABT*	0.470**	-0.200	0.589**	0.370	0.446*	0.237	0.360*	-0.017	0.116	0.306	1.000			
	70 DABT	0.442*	0.049	0.270	0.329	0.316	0.190	0.133	-0.022	0.070	0.307	1.000			
	210 DABT	0.452*	0.090	0.224	0.108	0.351	0.152	0.273	0.069	0.162	0.192	1.000			
Fe	*30 DABT*	-0.113	0.040	0.020	0.190	0.105	0.088	-0.011	0.011	-0.117	0.355	0.152	1.000		
	70 DABT	-0.125	0.110	-0.024	0.227	0.006	0.008	0.149	-0.005	-0.005	0.508**	0.219	1.000		
	210 DABT	-0.177	0.018	-0.259	-0.054	-0.207	0.029	0.013	-0.028	0.149	0.296	0.237	1.000		
Zn	*30 DABT*	0.305	-0.164	0.321	0.244	0.285	0.025	0.231	-0.038	-0.094	0.117	0.242	-0.014	1.000	
	70 DABT	0.282	-0.278	0.407	0.119	0.220	0.042	-0.062	-0.072	-0.118	0.088	0.200	0.101	1.000	
	210 DABT	0.211	-0.195	0.180	0.235	0.035	-0.007	0.185	-0.113	-0.246	0.138	0.078	-0.173	1.000	
Cu	*30 DABT*	0.041	0.230	0.231	-0.005	0.098	0.213	0.340	0.380*	0.337	-0.034	0.426*	0.190	0.117	1.000
	70 DABT	-0.058	0.173	0.102	-0.079	0.053	0.133	0.006	0.161	0.247	-0.144	0.378*	-0.060	-0.084	1.000
	210 DABT	-0.162	0.154	0.347	-0.271	-0.005	0.058	-0.018	0.139	0.169	-0.056	0.367*	-0.062	-0.270	1.000
B	*30 DABT*	0.531**	-0.246	0.155	0.320	0.326	-0.064	0.351	0.211	-0.044	0.253	0.252	-0.066	0.134	0.074
	70 DABT	0.331	-0.124	0.468*	0.201	0.329	-0.099	0.080	0.120	0.170	-0.024	0.154	-0.096	0.227	0.035
	210 DABT	0.371*	-0.261	0.185	0.086	0.236	-0.084	0.136	0.184	0.161	0.073	0.272	0.112	0.102	-0.168

N, P and K in kg ha^{-1}, Ca and Mg in meq $100g^{-1}$, S, Mn, Fe, Zn, Cu and B in mg kg^{-1}, $*p<0.05$,$**p<0.01$

Table4: Regression model between pomegranate yield and soil nutrient content at different growth stages

30DBT			70DBT		210DBT	
R^2=0.92			R^2=0.89		R^2=0.823	
F value=12.88*			F value=8.59*		F value=4.98*	
Constant=8.967			Constant= 27.37		Constant= -9.87	
Parameters	**Co- efficient**	**t- value**	**Co- efficient**	**t- value**	**Co- efficient**	**t- value**
pH	-1.394	-0.67	-4.20	-1.04	-0.38	-0.10
EC	-1.389	-0.41	5.87	1.32	8.96	1.42
OC	18.89	4.13	12.26	3.66	7.46	1.75
N	0.01	1.28	0.03	1.85	0.04	2.39
P	0.02	0.62	0.05	0.95	0.08	1.25
K	-0.004	-0.42	0.03	2.23	0.04	2.29
Ca	0.10	1.34	0.13	1.65	0.14	1.14
Mg	-0.22	0.55	-0.09	-0.17	-0.94	-1.39
S	-0.40	-2.50	-0.25	-1.29	0.08	0.31
Mn	0.16	1.55	0.20	2.14	0.22	1.48
Fe	-1.22	-2.16	-1.50	-2.20	-0.60	-0.69
Zn	0.17	0.50	0.24	0.36	-1.21	-1.07
Cu	-0.20	-0.62	-0.56	-1.78	-0.89	-1.66
B	10.71	2.47	-4.66	0.50	6.32	0.74

Table 4a: Regression model iterated for selected soil nutrient content with pomegranate yield at different growth stages

At bud differentiation stage			At fruit formation stage			At fruit maturation stage		
R^2=0.902			R^2= 0.804			R^2= 0.681		
F value=29.02*			F value= 19.68*			F value= 18.54*		
Constant= -4.928			Constant= -7.843			Constant= -11.58		
Parameters	**Co- efficient**	**t- value**	**Parameters**	**Co- efficient**	**t- value**	**Parameters**	**Co- efficient**	**t- value**
PH	-2.84	-1.79	EC	8.04	2.42	OC	11.85	4.18
OC	17.18	4.36	OC	17.79	5.45	N	0.05	3.79
N	0.02	2.09	N	0.02	1.74	K	0.03	2.08
P	0.06	2.27	K	0.03	2.47			
S	-0.30	-2.19	Fe	-1.81	-3.27			
Fe	-1.20	-2.37						
B	12.26	3.44						

Table 5: Correlation index (r) among pomegranate yield and leaf nutrient content at various crop growth stages

		Yield	N	P	K	Ca	Mg	S	Mn	Fe	Zn	Cu
N	*30 DABT*	0.852**	1									
	70 DABT	0.871**	1									
	210 DABT	0.853**	1									
P	*30 DABT*	0.456*	0.381*	1								
	70 DABT	0.631**	0.590**	1								
	210 DABT	0.163	0.1	1								
K	*30 DABT*	0.592**	0.509**	0.343	1							
	70 DABT	0.542**	0.519**	0.479**	1							
	210 DABT	0.489**	0.515**	-0.205	1							
Ca	*30 DABT*	0.750**	0.659**	0.364*	0.406*	1						
	70 DABT	0.625**	0.593**	0.455*	0.367*	1						
	210 DABT	0.593**	0.549**	-0.066	0.324	1						
Mg	*30 DABT*	0.496**	0.486**	0.063	0.432*	0.657**	1					
	70 DABT	0.553**	0.559**	0.251	0.197	0.497**	1					
	210 DABT	0.686**	0.667**	0.131	0.261	0.451*	1					
S	*30 DABT*	0.609**	0.583**	0.518**	0.427*	0.305	-0.004	1				
	70 DABT	0.660**	0.596**	0.549**	0.419*	0.533**	0.178	1				
	210 DABT	0.602**	0.520**	0.200	0.294	0.253	0.369*	1				
Mn	*30 DABT*	0.681**	0.609**	0.447*	0.457*	0.595**	0.404*	0.414*	1			
	70 DABT	0.565**	0.546**	0.367	0.473**	0.466**	0.327	0.331	1			
	210 DABT	0.123	0.062	0.062	0.165	0.181	-0.082	-0.092	1			
Fe	*30 DABT*	0.19	0.059	0.114	0.201	0.257	0.062	0.133	0.189	1		
	70 DABT	0.214	0.082	0.055	0.176	-0.06	0.104	0.143	0.035	1		
	210 DABT	0.044	-0.03	0.075	-0.212	-0.131	0.085	-0.057	-0.137	1		
Zn	*30 DABT*	0.101	0.163	0.047	0.044	0.192	0.113	0.335	0.193	0.1	1	
	70 DABT	0.165	0.147	0.195	0.091	0.168	0.095	0.406*	0.058	-0.09	1	
	210 DABT	0.516**	0.439*	-0.259	0.205	0.126	0.425*	0.438*	-0.229	0.251	1	
Cu	*30 DABT*	0.067	-0.08	0.118	0.069	0.113	0.149	-0.045	0.285	0.044	0.022	1
	70 DABT	-0.236	-0.215	0.077	0.016	-0.207	-0.321	-0.183	0.078	-0.203	0.067	1
	210 DABT	-0.440*	-0.38	-0.276	-0.044	-0.359	-0.509**	-0.346	0.006	-0.212	-0.124	1
B	*30 DABT*	0.637**	0.460*	0.347	0.215	0.588**	0.242	0.154	0.485**	0.28	-0.196	0.3
	70 DABT	0.643**	0.515**	0.429*	0.287	0.487**	0.347	0.373*	0.582**	0.386*	-0.104	-0.118
	210 DABT	0.729**	0.583**	0.261	0.407*	0.619**	0.448*	0.417*	0.238	0.122	0.248	-0.449*

N, P, K, Ca and Mg in per cent, S, Mn, Fe, Zn, Cu and B in mg kg^{-1}, *p<0.05, **p<0.01

The relationship among the nutrients were also positively correlated except in Mg and S (-0.004), Cu and S (-0.045), Zn and B (-0.196) and Cu and N (-0.08) which recorded negative relationship. However they were not significant.

Similar trend was observed at fruit formation and maturation with exception to Cu content where, negative relationship was observed between Cu and yield recording -0.236 and -0.440 at fruit formation and maturation stage respectively. However, the significance was observed only at fruit maturation stage. Negative correlation was observed between Cu and other plant nutrients except Mn. However, the significance was only between Cu and N, Mg & B.

The regression model between pomegranate yield and eleven nutrient content in leaf at bud differentiation stage was as following,

$$Y = -7.66 + 3.40N - 4.98P + 2.30K + 2.15Ca + 5.29Mg + 13.0S + 0.04Mn - 0.004Fe - 0.02Zn - 0.02Cu + 0.48B$$

The F ratio (13.40) was significant indicating the overall explanatory power of the above equation and regression line explaining about 89.1 per cent (R^2=0.891) of variation in pomegranate yield by these independent variables. However, when all these nutrient parameters were taken together, B (t=2.28) and S= (2.236) were significant (t-value) and all other nutrient variables were insignificant as evident from the low t-values, which indicate the impacts of these predictor nutrient variables. However, negative impact was noticed from P, Fe, Zn and Cu nutrients at bud differentiation stage. Thus, the above model was further screened to exclude some unimportant or redundant variables (Table 6) in the equation by employing stepwise regression analysis which yielded the following equation.

Table 6: Regression model between pomegranate yield and leaf nutrient content at different growth stages

30DBT			70DBT		210DBT	
R^2= 0.891			R^2= 0.857		R^2= 0.869	
F value= 13.40*			F value= 9.83*		F value= 10.86*	
Constant= -7.66			Constant= -7.191		Constant=14.87	
Parameters	**Co- efficient**	**t- value**	**Co- efficient**	**t- value**	**Co- efficient**	**t- value**
N	3.40	1.89	5.85	2.96	5.63	2.52
P	-4.98	-0.50	7.87	0.72	15.04	0.82
K	2.30	0.22	1.45	0.68	1.99	0.59
Ca	2.15	1.03	0.07	0.04	1.81	0.84
Mg	5.29	0.79	5.95	0.95	9.15	1.06
S	13.00	2.28	9.37	1.15	15.21	1.05
Mn	0.04	0.77	0.01	0.16	0.04	0.87
Fe	-0.004	-0.32	0.004	0.30	0.002	0.11
Zn	-0.019	-0.476	0.01	0.13	0.29	1.53
Cu	-0.02	-0.48	-0.02	-0.41	0.002	0.05
B	0.48	2.24	0.35	1.36	0.39	1.37

Table 6a: Regression model iterated for selected leaf nutrient content with pomegranate yield at different growth stages

At bud differentiation stage			At fruit formation stage			At fruit maturation stage		
R^2= 0.881			R^2= 0.835			R^2= 0.809		
F value= 35.55*			F value= 43.73*			F value= 57.17*		
Constant= -8.062			Constant= -2.620			Constant= -3.823		
Parameters	**Co- efficient**	**t- value**	**Parameters**	**Co- efficient**	**t- value**	**Parameters**	**Co- efficient**	**t- value**
N	4.51	3.36	N	9.01	7.53	N	9.57	6.27
K	2.86	1.95	B	0.46	2.70	B	0.68	3.38
Ca	2.83	1.97	S	10.78	1.94			
S	9.20	2.34						
B	0.43	3.07						

$$Y = -8.06 + 4.51N + 2.86K + 2.83 Ca + 9.20 S + 0.43 B$$

In the above model both F (35.53) and t values were improved over the previous model, which stated that the cumulative effect of total N, K, Ca, S and B content in leaf accounted for about 88.1 per cent variation in pomegranate yield. The significant positive relation was found between these variable on pomegranate yield. The remaining about 11.9 per cent variation in the yield may be attributed to eliminate variables *viz.*, P, Mg, Mn, Fe, Zn and Cu that is explained by the above model.

Similarly the effects of leaf nutrient content at fruit formation and maturation stage on pomegranate leaf were analyzed using backward stepwise multiple regression models. At fruit formation stage (70DBT) significant positive (F=43.73) effect was observed with N, B and S nutrients, that accounted for 83.5 per cent variation in pomegranate yield (Y= -2.62 + 9.01N + 0.46B + 10.78S). Similarly at fruit maturation stage only N and B (Y=-3.82 + 9.57N + 0.68B) were positively and significantly influenced 80.9 per cent variation in pomegranate yield.

All seventeen nutrients are essential and indispensible for growth and production of any crop, but the nutrient management practices over the time may create an imbalance and make some nutrients critical for crop growth and yield. In the present investigation among the major nutrients, N was found to have critical role in pomegranate production. The optimum supply of N is essential for stimulating the uptake of other essential nutrients *viz.*, P, K, Ca, Mg, S, Mn and B (Mengle *et al.*, 2001 and Malvi, 2011), for many key plant metabolic process in general (Agarwal and Sharma 1976, Childer, 1996 and Sharma *et al.*, 2014) and pomegranate growth and productivity in particular (Shiekh and Rao, 2005, Rao and Subramanyam, 2009, Mohamed *et al.*, 2014 and Ray *et al.*, 2014). Phosphorus is highly essential for root growth and known to stimulate uptake of nutrients (Sharma *et al.*, 2014). However, excessive amount of P reduces uptake of some cationic micronutrients *viz.*, Fe, Zn, Mn & Cu (Malvi, 2011). The data collected from farmers indicated at higher rate of P application through inorganic fertilizers but, its accumulation in plant did not exert any significant negative impact on growth and yield and found to be in optimum level (Raghupathi and Bhargava, 1998b). The alkaline pH condition precipitates applied P into plant unavailable thus, reducing its excess accumulation in plant (Serrao *et al.*, 1998 and Delgado *et al.*, 2002). Amongst, the nutrients analyzed potassium concentration was highest in pomegranate leaves in most of the orchards. This signifies high amount of K requirement for pomegranate (Kashyap *et al.*, 2012) and it plays vital role in increasing pomegranate yield and fruit quality (Shiekh and Rao 2005, Kashyap *et al.*, 2012 and Mohamed *et al.*, 2014).

The secondary nutrient content in pomegranate leaves was significantly and positively related to pomegranate yield at all stages of crop growth, as revealed in correlation matrix analysis. However, when the cumulative effect of nutrients was considered in multiple regression analysis, only sulphur was turned out to be an important nutrient in explaining the most variations in pomegranate yield among the secondary nutrients. Sulphur is usually deficient in alkaline soils and crop responds to sulphur application resulting in improved yield and quality (Skwierawska *et al.*, 2008).

Amongst the micronutrients, B was found to be the most important nutrient that was critically influencing the variation in pomegranate yield at all stages of crop growth. Many studies reported enhanced productivity and fruit quality of pomegranate with B application (Khalil and Aly, 2013, Tehrnifer and Taber, 2009). In the present investigation only Cu showed negative relationship with yield at all stage of crop growth. Farmer's use Cu based pesticides for control of many diseases in pomegranate this might have resulted in its higher accumulation in leaves. This emphasizes its cautious application for control of diseases which otherwise may decrease yield.

References

Agarwala, S. C. and Sharma, C. P., 1976, Plant nutrients-their functions and uptake. Soil Fertility Theory and Practice (Es. J. S. Kanwar) ICAR, New Delhi, pp.7-64.

Awasthi, O. P. and Singh, I. S., 2010, Effect of ber and pomegranate plantation on soil nutrient of typic torripsamments. *Indian Journal of Hort*iculture, 67: 138-142.

Black, C. A., 1965, *Methods of Soil Analysis*. Part 2, Agronomy monograph No. 9, *American Society of Agronomy*, Madison, Wisconsin, USA, 15-72.

Childer, N. F., 1966, Fruit nutrition. Horticultural Publication, Rutgers State University, Nichol- Avenue, New Bransuick, New Jersey, U.S.A.

Dahal, H. and Routray, J. K., 2011, Identifying associations between soil and production variables using linear multiple regression models. *The* Journal *of Agriculture and Environment,* 12: 27-37.

Delgado, A., Antonio, M., Kase, S., Luis, A. and Maria, C. C., 2002, Phosphorus fertilizer recovery from calcareous soils amended with humic and fulvic acids. *Plant and soil*, 245: 277-286.

Dev, G., 1998, Balanced fertiliser use increases crop yield and profit. *Better Crops International*, 12 (2) : 26-27.

Hamouda, Elham, H. A., Motty, Z. A. and Zahran, N.G., 2015, Nutritional status and improving fruit quality by potassium, magnesium and manganese foliar application in pomegranate shrubs. *International Journal of ChemTech Research,* 8 (6) : 858-867.

Jackson, M. L., 1973, *Soil Chemical Analysis,* Prentice Hall of India Pvt. Ltd., New Delhi.

Kashyap, P., Pramanick, K. K., Meena, K. K. and Meena, V., 2012, Effect of N and K application on yield and quality of pomegranate cv. Ganesh under rainfed conditions. *Indian Journal of Horticulture,* 69 (3) : 322-327.

Khalil, H. A. and Aly, H. S. H., 2013, Cracking and fruit quality of pomegranate (*Punica granatum* L.) as affected by pre-harvest sprays of some growth regulators and mineral nutrients. *Journal of Horticultural Science and Ornamental Plants,* 5 (2) : 71-76.

Khayyat, M., Tehranifar, A., Zaree, M., Karimian, Z., Aminifard, M. H., Vazifeshenas, M. R., Amini, S., Noori, Y. and Shakeri, M., 2012, Effects of potassium Nitrate spraying on fruit characteristics of malasyazdi pomegranate. *Journal of plant nutrition*, 35: 1387-1393.

Lindsay, W. L. and Norvell, W. A., 1978, Development of a DTPA soil test for Zn, Fe, Mn and Cu. *Jornal of American Soil Science Society,* 42: 421-428.

Malvi, R. U., 2011, Interaction of micronutrients with special reference to potassium. *Karnataka Journal of Agricultural Science,* 24 (1) : 106-109.

Mengel, K. E., Kirkby, A., Koesgarten, H. and Appel. T., 2001, Principles of plant nutrition. 5th El- Kluwer Academic Publishers, Dordrecht pp.1- 311.

Mir, M., Hassan G I., Mir A., Hassan A. and Sulaimani, M., 2013, effects of bio-organics and chemical fertilizers on nutrient availability and biological properties of pomegranate orchard soil. *African Journal of Agricultural Research*, 8 (37) : 4623-4627.

Mir, M., Sharma, S. D. and Kumar, P., 2015, Nutrient Dynamics: Effect on cropping behavior, nutrient profile and quality attributes of pomegranate (*Punica granatum* L.) under rainfed agroclimatic Conditions. *Journal of Plant Nutrition.* 38: 83-95.

Mohamed, M. A., Ibrahiem, H. I. M. and Omar, M. O. A., 2014, Selecting The Best N, P and K Levels For The Newly Introduced Wounderful Pomegranate Trees Grown Under Minia Region *World Rural Observations* 6 (4) : 23-29.

Patil, P. K. and V. K. Patil, 1982, Effect of soil ESP on the growth and chemical composition of pomegranate (*Punica granatum* L.) *Prog. Hort*., 14: 1–5.

Piper, C. S., 1966, *Soil and Plant Analysis*. Han's Publication, Bombay.

Raghupathia, H. B. and Bhargava, B. S., 1998a, Leaf and soil nutrient diagnostic norms for pomegranate (*Punica granatum* L.). *Communication in Soil Science and Plant Analysis*, 29: 19-20.

Raghupathia, H. B. and Bhargavaa, B. S., 1998b, Leaf and soil nutrient diagnostic norms for pomegranate (*Punica granatum* L.). *Journal of Indian Society of Soil Science*, 46: 412-416.

Rao, K. D. and Subramanyam. K., 2009, Effect of nitrogen fertigation on growth and yield of pomegranate var. mridula under low rainfall. *Agricultural Science Digest,* 29 (2) : 54-56.

Ray, S. K., Takawale, P. V., Chatterjee, R. and Hnamte, V., 2014, Yield and quality of pomegranate as influenced by organic and inorganic nutrients. *The Bioscan*, 9 (2) : 617-620.

Saraf, R. K., Samaiya, R. K. and Shukhla, K. C., 2001, Effect of different sources of nutrients on growth of pomegranate (*Punica granatum* L.). *Proceedings of National Conference on "Biodiversity and sustainable utilization of biological resources",* pp. 203–208. Sheikh, M. K. and Rao, M. M., 2005, Effect of split application of N and K on growth and yield of pomegranate. *Karnataka Journal Agricultural Sciences,* 18 (3) : 854-856.

Serrao, M. G., Fernandes, M. L., Fernandes, M., Castelo, B. M. and Vieira, E. S. J., 1998, Transformations of phosphorus in calcareous soils as affected by phosphorus and pyrite additions. *16th World Science Congress*, 20th - 26th August, Montepellier, France.

Sharma., Kumar, V., Tiwari, R. and Chouhan, P., 2014, Effect of N, P and their interaction on physico- chemical parameters of guava (*Psidium guajava*) cv. L-49 under Malwa Plateau Conditions. *International Journal of Scientific and Research Publications*, 4 (11) : 1-4.

Sheikh, M. K. and Rao, M. M., 2005, Effect of split application of N and K on growth and yield of pomegranate. *Karnataka Journal Agricultural Sciences*, 18 (3) : 854-856.

Skwierawska, M., Zawartka, L. and Zawadzki, B., 2008, The effect of different rates and forms of sulphur applied on changes of soil agrochemical properties. *Plant and Soil Environment*, 54 (4) : 171-177.

Snedecor, G.W., Cochran, W.G., 1981, Statistical methods, seventh ed. Iowa State UniversityPress, Iowa, USA.

Subbiah, B. V. and Asija, G. L., 1956, A rapid procedure for the estimation of available nitrogen in soil. *Current Sciences.* 25: 259-260.

Tehranifar, A. and Taber, S. M., 2009, Foliar application of potassium and boron during pomegranate (*Punica granatum*) fruit development can improve fruit quality. *Horticultural Environment and Biotechnology,* 50 (3) : 1-6.

Walkley, A. J. and Black, C. A., 1934, An examination of the method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science,* 37: 29-38.

William M. 2007. Open Stat For Windows, version 1.9, Tutorial Manual. I. S. U., USA.

Yenjeerappa. S. T., 2009, Management of bacterial blight of pomegranate caused by *xanthomonas axonopodis* pv. punicae. Ph.D *Thesis,* University of Agricultural Sciences, Dharwad, Karnataka (India).