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Review Article

Soil Suitability for Pomegranate Cultivation

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Abstract

Pomegranate is important horticultural crop of semi-arid and arid conditions. There is great scope for increasing per hector productivity by selecting proper soils. The soil suitability studies, for pomegranate can be worked out with the help of multi criteria and GIS application. As per fuzzy classification different GIS based thematic maps for different characters of soil qualities can be developed and by aggregating data of different thematic maps, soil suitability can be worked out. The shallow soils with less clay content can be preferred by this crop. High organic matter with low $CaCO_3$ (<156 g kg^{-1}) is best suited soil situation for pomegranate. As this crop is best suited for shallow soils, low fertility status can be managed with high organic carbon content (up to 10 mg kg^{-1}) and well managed fertilizer / fertigation schedule. The optimum DRIS norms for soil depicted in the paper were specific for cv. *Bhagwa* (*hasta bhahar*), which is grown in Western Maharashtra region. It is also concluded that the DRIS or CND norms for pomegranate should be developed for specific conditions.

Keywords

Soil Suitability; Pomegranate; DRIS.

Pomegranate (*Punica granatum* L.) is the important horticultural crop of semi-arid and arid regions of India. This plant is hardy and can tolerate drought and alkalinity conditions. Pomegranate comparatively can stand at lower requirement of water and easily adoptable to adverse soil and waste land situations.

In India, during 2013-14, it was cultivated over 1.31 lakh ha with a production of 13.46 lakh MT and productivity 10.27 MT ha^{-1} (Anonymous, 2015). It is proposed that by the year 2025, the area under pomegranate is projected to increase to 7.5 lakhs ha with expected production to increase by 10 folds and export by 6.97 folds by the year 2025 (Mohd, *et al.* 2014).

The area of pomegranate in Maharashtra during 2013-14 was 0.9 lakh ha^{-1}, production 9.45 lakh MT and productivity 10.5 MT ha^{-1}. In South Western Maharashtra, the major pomegranate growing districts are Solapur, Satara and Sangali, the area under pomegranate is 44,593 ha, which is 49.54 per cent of the total area of Maharashtra, with the production 5.13 MT and productivity 11.5 MT ha^{-1}. In North western Maharashtra the major pomegranate growing districts are Nashik, Pune and Ahmednagar with the total area of 45807 ha (Anonymous, 2015). Maharashtra state is producing about 70 per cent of the total India's production of pomegranate and Solapur district is highest producer for pomegranate in Maharashtra state. Thailand ranks first as an exporter of pomegranate, followed by Spain, Iran and India (Anonymous, 2011)

Yedage, *et al.* (2013) carried out a study to evaluate the suitability of the land for pomegranate production by using multi criteria (fuzzy logic) and GIS application in Sangola tehsil of Solapur district. The flow diagram for the suitability as per Yedage, *et al.* (2013) is attached herewith.

As per fuzzy classification Yedage, *et al.* (2013) developed different GIS based thematic maps for slope, texture, depth, drainage, coarse fragments, pH, EC, OC, OM and NPK as soil qualities.

The soil attributes were ranked on a scale of 1 to 9 and fuzzifed using the Gussian model. Fuzzy membership value for each cell, ranging from 0 (low suitability) to 1 (high suitability) was generated using map algebra in GIS. The study was carried out based on 59 soil sample locations distributed in the study area. Accordingly following data was developed.

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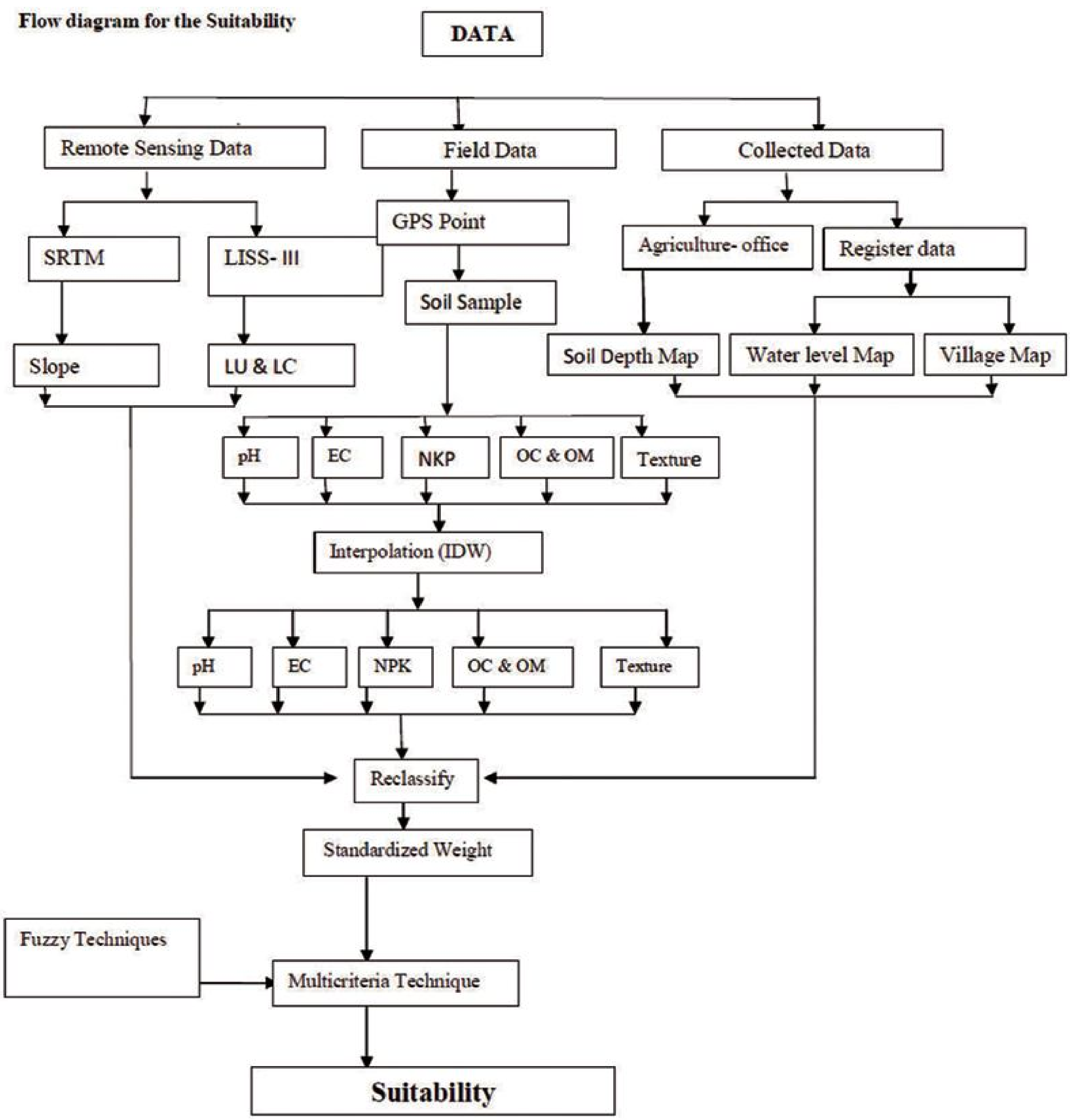


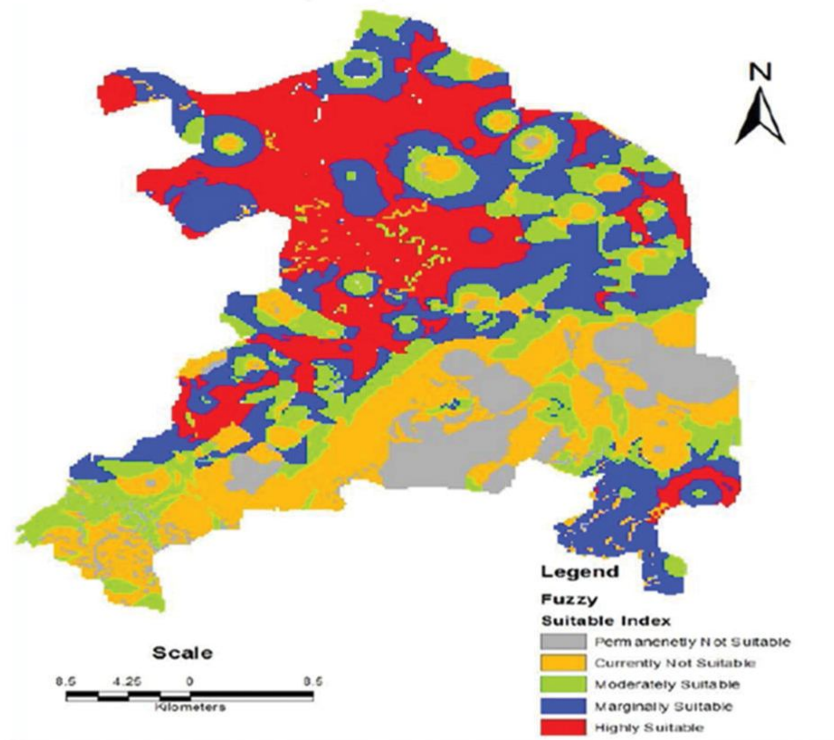
The results of Yedage, et al. (2013) showed that the crop-land evaluation results identified that in the study area, 4986 ha of total pomegranate crop area is currently being used, which were under highly suitable areas and 3255 ha were under moderately suitable areas. A substantial portion (5596 ha) was under marginally suitable areas. Thus, the average yield of the study area was substantially affected because of a significant proportion of pomegranate crop was under marginally suitable areas (Fig.1).

Table 1: Soil suitability for pomegranate cultivation in Sangola tehsil of Solapur district (M.S.) as per fuzzy classification

Sr. No.	Class	Area (ha)
1	Moderately suitable	3255
2	Marginally suitable	5596
3	Highly suitable	4986
4	Permanently not suitable	3816
5	Currently not suitable	880
	Total	18533

Soil Survey

Deshpande and Patil (2011) reported that the status of N, P, K, Ca and Mg in well managed pomegranate orchards of Solapur district of Maharashtra was sufficiently high. The distribution of all the macro nutrients decreased with increasing depth of soil in the entire orchard studied. The higher values of EC, $CaCO_3$ and Mg and lower values of organic carbon, available N, P, K and Ca were observed in poorly managed gardens as compared with well managed gardens.



yedage et al. 2013

Fig. 1: Land suitability map for horticulture crops (pomegranate)

Raghupathi and Bhargava (1998[a]) had done a regional survey in 112 commercial pomegranate (*Punica granaturm* L., cv. *Ganesh*) orchards in the northern dry region of peninsular India (Bijapur and Pune) in order to evaluate approaches for diagnosis of yield limiting nutrients in low yielding sub populations. They reported highly significant positive correlation between DRIS and CND indices. They also reported that pomegranate was mainly grown on marginal soils with low fertility and hence yields were limited by more than 2 or 3 nutrients.

Raghupathi and Bhargava (1998[b]) conducted a survey in pomegranate orchards in Bijapure district of north Karnataka, India to determine DRIS norms for the nutritional status of plants and soil. They reported the optimum available NPK concentrations in soils were 44-103, 10-20 and 73-115 mg kg^{-1} respectively (pH 8.1 – 8.6). Yield of 15.5 – 18.8 t ha^{-1} were recorded for the optimum concentrations of nutrients. Norms for other nutrients were also reported and discussed by them.

Some work on optimum norms of nutrients for pomegranate was carried out by Raghupathi and Bhargava during recent past based on leaf and soil analysis, particularly related with *Ganesh* variety which was average out conclusion of Pune and Bijapur (Vijaypura) samples (Bhargava, 2002). Reviewing the present norms for pomegranate, these are irrespective of crop growth stages and ecological zone for crop variety *Ganesh.*

In a review paper on Diagnostic Recommendation Integrated System (DRIS), Bangroo, *et al.* (2010) concluded that DRIS norms should be developed for specific conditions, in which all other factors to be correlated with yield or quality (or any other variable) be known and isolated: cultivar, climate, soil and crop management, productivity etc. attaining the specific objectives.

Mahatma Phule Agricultural University, Rahuri released new promising variety *Bhagwa* which is gaining considerable area in Maharashtra, India and also in the world. Hence, present paper relates with DRIS soil norms particularly developed for *Bhagwa* variety in general and at different growth stages of *hasta bahar* related with specific climatic situations in particular. The optimum DRIS norms for soil at different growth stages of pomegranate cv. *Bhagwa* (*hasta bahar*) grown in Western Maharashtra are given in Table 2. The DRIS norms developed for soils of South Western Maharashtra (SWM) are for Solapur Sangali and Satara districts and for North Western Maharashtra (NWM) are for Nashik, Pune and Ahmednagar districts. The optimum DRIS norms for whole Western Maharashtra(WM) are the highest and lowest values from SWM and NWM.

Soil Physical Properties

Soil Depth

Pomegranate can grow from marginal soils (30cm) to moderately deep soils (30-60cm). However on marginal soils size of pit in which plant is established is most important. The minimum pit size is 60x60 cm, however it can be extended upto 90x90 cm looking to the marginality of soil. The soil which is used for filling the pit is also equally important and it should be as per standard recommended norms. Deep soil due to their high water holding capacity can sustain pomegranate crop with less irrigation during pre and post monsoon season, however excess moisture conditions during monsoon create wilt problem and flowering can be affected due to excess moisture conditions. Most ideal depth for pomegranate cultivation is 30 – 60 cm soil depth. Pawar *et al.* (2014) also indicated that, shallow inceptisols exhibited higher productivity as these soils offer better drainage than deep vertisols.

Soil Texture

The 150 pomegranate gardens soil survey for *hasta bahar* from South Western Maharashtra (Solapur, Sangli, Satara districts) indicated that the per cent gravel, coarse sand, fine sand, silt and clay was in the range of 3.9 – 15.0, 1.3 – 23.6, 11.4 - 57.4, 4.2-47.4 and 8.4 to 55.4 respectively (Gosavi, 2015).

However, he pointed out that, there was significant positive correlation between pomegranate yield and fine sand (0.179*). This might be due to good response of pomegranate crop for well drained soils as

Table 2: The optimum DRIS norms for soil at different growth stages of pomegranate cv. *Bhagwa* (*hasta bahar*) grown in Western Maharashtra .

Particulars	***Bahar***		**50% flowering**		**Fruit development**		**1st harvest**		**Optimum range for WM**
	SWM	NWM	SWM	NWM	SWM	NWM	SWM	NWM	
pH (1:2.5)	7.78-8.88	7.18-8.10	7.79-8.85	7.27-8.21	7.86-8.87	7.25-8.19	7.92-8.89	7.18-8.11	7.2-8.9
EC (dSm^{-1})	0.20-0.46	0.19-0.29	0.19-0.48	0.17-0.28	0.19-0.50	0.18-0.28	0.21. -0.50	0.19-0.29	0.2-0.5
OC ($g\ kg^{-1}$)	4.1-9.7	3.7-7.9	4.3-9.6	4.1-8.2	4.5-9.8	4.4-8.5	4.6-9.8	3.8-7.9	3.7-9.8
$CaCO_3$($g\ kg^{-1}$)	86.6-156.3	45.4-102.9	91.8-155.5	45.7-101.8	91.5-148.5	45.7-102.1	86.8-136.6	45.8-101.8	45-156
Av. N ($kg\ ha^{-1}$)	161.5-255.5	146.1-201.3	152.2-241.9	152.5-182.3	153.6-228.8	147.7-181.3	141.7-222	140.0-172.1	140-255
Av. P ($kg\ ha^{-1}$)	11.78-23.01	12.0-20.9	13.5-23.9	11.5-14.9	13.1-24.1	12.7-16.2	12.72-23.25	12.3-15.6	11.5-24
Av. K ($kg\ ha^{-1}$)	232.3-440.9	322.9-657.6	311-533	422.9-518.6	311.3-635.5	424.4-525.0	245.7-580.5	404.4-492.3	232-658
Ex. Ca ($cmol(p^+)kg^{-1}$)	27.65-46.92	22.4-37.9	30.2-46.0	21.4-28.9	29.7-44.3	22.4-27.8	28.5-41.6	20.9-26.4	21-47
Ex. Mg ($cmol(p^+)kg^{-1}$)	10.81-21.89	10.5-17.6	13.3-23.2	12.5-18.6	11.9-22.1	12.6-17.8	10.2-18.8	12.0-17.3	10-23
S ($mg\ kg^{-1}$)	6.94-16.95	4.5-10.9	7.19-17.24	5.5-8.9	7.36-17.69	6.6-9.1	7.35-17.53	6.6-9.0	4.5-17.7
DTPA Cu ($mg\ kg^{-1}$)	2.12-6.06	3.6-5.9	2.79-6.85	5.6-6.1	2.89-7.11	5.5-6.4	2.64-6.37	5.3-6.0	2.1-7.1
DTPA Fe ($mg\ kg^{-1}$)	3.71-8.85	6.4-9.3	3.02-7.77	8.4-10.3	3.54-6.74	8.2-9.9	2.35-5.89	8.0-9.2	3.0-9.9
DTPA Mn ($mg\ kg^{-1}$)	7.72-15.96	7.3-13.4	9.74-19.12	12.3-16.4	10.25-17.52	12.2-16.0	8.51-16.77	12.0-15.2	7.3-19.1
DTPA Zn ($mg\ kg^{-1}$)	0.52-0.92	0.44-0.93	0.48-0.96	0.74-0.86	0.50-1.00	0.79-0.90	0.48-0.95	0.73-0.84	0.44-1.0
B ($mg\ kg^{-1}$)	0.17-0.40	0.17-0.43	0.22-0.50	0.38-0.52	0.24-0.50	0.36-0.58	0.16-0.44	0.29-0.42	0.16-0.58
Mo ($mg\ kg^{-1}$)	0.06-0.13	0.05-0.13	0.06-0.14	0.05-0.13	0.06-0.13	0.05-0.13	0.06-0.13	0.04-0.10	0.04-0.14
Ex. Na ($cmol(p^+)kg^{-1}$)	0.23-0.45	0.40-0.74	0.24-0.43	0.38-0.73	0.24-0.43	0.39-0.74	0.21-0.40	0.40-0.74	0.21-0.74

Note: SWM – South Western Maharashtra, NWM – North Western Maharashtra WM – Western Maharashtra

(Deshmukh, 2014; Gosavi, 2015)

provided under coarse textured soil and ill drained conditions under clayey soils which can create unfavorable conditions for *bahar* treatment as well as wilt problems due to high water holding capacity. Hence it is advisable to select soils for pomegranate cultivation which is having clay per cent < 40.

Bulk Density

As per Gosavi (2015) the high yielding pomegranate gardens (>20 Mg ha^{-1}) were having soil bulk density in the range of 1.2 to 1.5 Mg m^{-3} with average bulk density 1.32 Mg m^{-3}. Regarding the correlation of bulk density, it showed negative and significant correlations with yield (-0.377**) of pomegranate. Higher bulk density of clayey soils might be due to the higher compaction, which was also supported by Bhattacharyya *et al.* (2003). The organic carbon of soil was also having negative correlation with bulk density and positive correlation with yield. It clearly indicated that as the bulk density reduces, the aeration and nutrient availability from soil increases which might be helpful for increasing yield. Approach should be as such, which will decrease the bulk density towards 1.0.

Hydraulic Conductivity

The hydraulic conductivity of pomegranate gardens should be optimum. High hydraulic conductivity is responsible for nutrient and water loss through leaching while low hydraulic conductivity is ultimate effect of high bulk density which creates impeded drainage and anaerobic conditions. The ideal saturated hydraulic conductivity of disturbed soil samples from pomegranate gardens in Western Maharashtra should be in the range of 0.15 – 1.6 cm h^{-1} (Deshmukh, 2014 ; Gosavi, 2015).

Soil Chemical Properties

Soil pH

The best pH for availability of all nutrients is 7.0. However, pomegranate crop is always taken in arid or semi-arid area where soils are generally alkaline in nature. This crop can tolerate slightly alkaline pH up to 8.5. The soil pH more than 8.5 creates abiotic stress in plant which create problems in availability of soil nutrients particularly micronutrients like Fe, Zn in the gardens of Western Maharashtra. This creates chlorotic or in server conditions necrotic conditions on leaves of pomegranate.

Soil EC

Soil electrical conductivity is indication of salt concentration in soil solution. In arid and semi-arid climatic conditions most of the dominant salts are Na^{+} origin combined with Cl^{-}, SO_4^{2-}, CO_3^{2-} and HCO_3^{-} However, salts of Mg^{2+}, Ca^{2+} and K^{+} are also present. Excess salts are indicative of salinity of soil and represent with high EC, which can create problems in water extraction and ultimately results in nutrient imbalance conditions. Optimum range of EC for pomegranate cultivation under Western Maharashtra conditions is 0.2 – 0.5 dSm^{-1} and it has significant negative correlation with pomegranate yield (-0.162** at 50% flowering, Gosavi, 2015).

Soil Organic Carbon

Soil organic carbon is key factor in deciding pomegranate yield because it influences soil biological, physical and chemical properties. The optimum range of soil organic carbon for growing pomegranate crop varies from 4.5 to 9.8 g kg^{-1}. The study of Gosavi (2015) reveled that the soil organic carbon was significantly and positively correlated with pomegranate yield at all four growth stages studied i.e. *Bahar* (0.606**) 50% flowering (0.597**), fruit development (0.631**) and at 1st harvesting (0.638**). The soil organic carbon even though it exceed above 10 g kg^{-1}, it is good for pomegranate growth and yield, but such situation is rarely seen in semi arid and arid conditions due to its fast mineralization under such climatic conditions. High soil organic carbon content promote good aggregation, aeration, water retention etc. in soil and also keep balance nutrient supply to pomegranate plant. Most of the ill effects on availability of nutrients due to high free $CaCO_3$ content in soil can be nullified by high organic carbon content.

Free $CaCO_3$ Content

Generally, pomegranate crop is grown under semi arid and arid conditions, soils under such climatic environment are generally base saturated and having high free $CaCO_3$ content. It can tolerate free $CaCO_3$ content of soil up to 156 g kg^{-1} of soil. The $CaCO_3$ content of pomegranate garden soil was having significant negative correlation with pomegranate yield particularly at fruit development (-0.269**) and 1st harvesting stage (-0.311**) (Gosavi, 2015). The high content of $CaCO_3$ in pomegranate garden soils is ultimately related with low availability of phosphorus and DTPA micronutrients (*viz*, Fe, Mn, Cu, Zn). The bicarbonate toxicity to pomegranate plants can be increased in anaerobic conditions.

Macronutrients

Available Nitrogen

The optimum range of available nitrogen for pomegranate (cv. *Bhagwa*) crop of Western Maharashtra is in the range of 140-255 kg ha^{-1} (Deshmukh, 2014; Gosavi, 2015). The initial requirement of nitrogen by pomegranate crop is slightly high and it declines towards maturity of fruits. Raghupathi and Bhargava (1998[b]) observed the range of available nitrogen from 29 to 126 mg kg^{-1}. They also reported the optimum available nitrogen requirement for pomegranate was met even at very low N, indicating that the crop can be grown successfully even in the soils of marginal fertility. The correlation studies showed that there were significantly positive correlations between available N at *Bahar*, fruit development and 1st harvest stage with pomegranate yield (0.341**, 0.163** and 0.257** respectively) (Gosavi, 2015), indicating positive role of nitrogen in pomegranate fruit yield.

Available Phosphorus

The optimum range of available phosphorus for pomegranate (cv. *Bhagwa*) crop from Western Maharashtra was in the range of 11.5 – 24 kg ha^{-1} (Deshmukh, 2014; Gosavi, 2015). The correlation studies showed significantly positive correlations between available phosphorus at *Bahar* (0.170**) and harvest stage (0.198**) with pomegranate yield (Gosavi, 2015).

Available Potassium

Next to nitrogen, potassium is important soil nutrient for pomegranate crop. The optimum range of available potassium for pomegranate (cv. *Bhagwa*) grown in Western Maharashtra is 232-658 kg ha^{-1}. Gosavi (2015) indicated that, the available K content from *Bahar* to fruit development stage was in increasing trend and declined at 1st harvest stage. Deshpande and Patil (2011) observed the average of available potassium content of 547.80 and 382.15 kg ha^{-1} at soil sampling depth of 0-30 cm in well managed and neglected gardens of pomegranate from Solapur (M.S.) district. Raghupathi and Bhargava (1998[a]) observed the mean available K content 62 to 364 mg kg^{-1}. The available K content of soil showed significantly positive correlation with pomegranate (cv. *Bhagwa*) yield at *Bahar* (0.198**), 50% flowering (0.245**), fruit development (0.246**) and at 1st harvest stage (0.209**).

Semi- Macro Nutrients

Calcium

With respect to pomegranate nutrition, calcium is the most important nutrient among the semi-macro nutrients. It is the third important nutrient followed by N and K in pomegranate crop nutrition. The optimum range of exchangeable Ca in the soils of Western Maharashtra gardens was 21-47 c mol (p^+) kg^{-1}. (Deshmukh, 2014; Gosavi, 2015). Deshpande and Patil (2011) also observed the range of exchangeable Ca from 4.7 to 22.6 c mol (p^+) kg^{-1}.

Magnesium

The optimum range of exchangeable Mg in the soils of Western Maharashtra pomegranate gardens was 10-23 c mol (p^+) kg^{-1} (Deshmukh, 2014; Gosavi, 2015). Deshpande and Patil (2011) observed the range of exchangeable magnesium from 0.6 to 6.5 c mol (p^+) kg^{-1} in the soils of pomegranate gardens of *Ganesh* variety. Raghupathi and Bhargava (1998[b]) also reported the exchangeable Mg content in the range of 187 to 726 mg kg^{-1}. The exchangeable Mg also showed significant positive correlations with pomegranate yield at *Bahar* (0.609**), 50% flowering (0.639**), fruit development (0.613**) and 1st harvesting (0.510**) stage (Gosavi, 2015).

Sulphur

The sulphur content of soils of pomegranate gardens of Western Maharashtra ranged from 3.59 to 19.40 mg kg^{-1} and optimum values were 4.5 to 17.7 mg kg^{-1}. The variation of S content of soil in pomegranate gardens was less as per different crop growth stages. The S contents at *Bahar*, 50% flowering, fruit development and 1st harvesting stage of pomegranate garden soils were positively correlated with yield (0.432**, 0.455**, 0.470** and 0.473** respectively) (Gosavi, 2015). Raghupathi and Bhargava (1998[b]) observed the sulphur content of soil from 25 to 394 mg kg^{-1}.

Micronutrients

The optimum range of DTPA extractable micronutrients from pomegranate gardens of Western Maharashtra ranged from 2.1 – 7.1 (Cu), 3.0 – 9.9 (Fe), 7.3 – 19.1 (Mn), 0.44 – 1.0 (Zn) mg kg^{-1} and for B and Mo it was recorded as 0.16 to 0.58 and 0.04 – 0.14 mg kg^{-1} respectively. All of the soil micronutrients were positively correlated with yield of pomegranate at *Bahar*, 50% flowering, fruit development and 1st harvest stages studied by Deshmukh (2014) and Gosavi (2015).

There was positive correlation of DTPA extractable micronutrients with organic carbon content of soil and negative correlation with free $CaCO_3$ of soil .In most of the gardens where $CaCO_3$ was high, the availability of micronutrients particularly DTPA extractable micronutrients was affected seriously (Deshpande and Patil, 2011). The soil status of DTPA extractable Fe and Zn from 10 districts of Western Maharashtra where 85% pomegranate gardens located were in deficient range (Dhage, *et al.* 2005).

Beneficial Nutrient

Sodium

Subbarao, *et al.* (2003) reviewed the sodium requirement of different plants and concluded that Na is a functional nutrient in many higher plants due to its requirement for maximal biomass growth and demonstrated ability to replace K in a number of ways, such as being an osmoticium for cell enlargement and as an accompanying cation for long distance transport. Greenwood and Stone (1998) reported that the critical level for K in presence of Na was reduced as a function of the Na supply to the plant. Naeini, *et al.* (2006) studied effects of four levels of salinity on leaf and root chlorine (Cl), sodium (Na) and potassium (K) partitioning and shoot growth in three major commercial cultivars of pomegranate. The results find that there was an increase in the growth rate of the *Malas Shirin* cultivar with increasing salinity up to 40 mM.

Looking to the review, it is decided to report soil DRIS norms for pomegranate. The optimum range of exchangeable Na for pomegranate (cv. *Bhagwa*) located in Western Maharashtra was from 0.21 – 0.74 c mol (p^+) kg^{-1} (Deshmukh, 2014; Gosavi, 2015). However, more research is needed for Na requirement by pomegranate. The Na concentration in soil is mostly related with electrical conductivity and exchangeable Na and both these issues are very sensitive for soil physical conditions. However, research trials, on pomegranate can be conducted on foliar nutrition of sodium.

Conclusion

Pomegranate is generally grown in semi-arid or arid climate with alkaline soil conditions. The soils for pomegranate cultivation should be non clayey in nature with good hydraulic conductivity. As the plant is hardy, it can stand on slightly saline soils, however high EC is detrimental to the crop. High organic carbon content is a key factor in success of pomegranate cultivation. It also with stand with calcareous nature of soil, but high $CaCO_3$ content can create nutrient deficiencies in the plant and affect yield seriously. Among the nutritional requirement of crop, N stands first and next to that K and Ca occupies 2nd and 3rd ranking. The P requirement of crop is small. Due alkalinity of soil, generally DTPA exactable micronutrients are in deficient range, however B and Mo are in sufficient range. The role of Na in Pomegranate crop should be investigated by foliar feeding.

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Footnote

A lecture presented in workshop on “Fruit Cracking and Soil Health Management in Pomegranate” organized by Society for Advancement of Research on Pomegranate (SARP) and National Research Centre on Pomegranate, Solapur (M.S., India) on 3rd October, 2015 at ICAR-NRCP, Solapur, India.