CHARACTERIZATION AND SUITABILITY OF SOME POMEGRANATE-GROWING SOILS OF SOLAPUR DISTRICT, MAHARASHTRA

THESIS

Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
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(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

(Land Resource Management)

By

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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the thesis entitled **“CHARACTERIZATION AND SUITABILITY OF SOME POMEGRANATE-GROWING SOILS OF SOLAPUR DISTRICT, MAHARASHTRA”** or part thereof has not been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or Scientific Organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Place :Akola (Jadhao Laxman Bhagavantrao)

Date : Enrolment No. FF/28

CERTIFICATE

This is to certify that the thesis entitled **"CHARACTERIZATION AND SUITABILITY OF SOME POMEGRANATE-GROWING SOILS OF SOLAPUR DISTRICT, MAHARASHTRA"** submitted in partial fulfillment of the requirements for the degree of "**Master of Science in Agriculture (Soil Science and Agricultural Chemistry - Land Resource Management)"** of the Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, Akola is a record of bonafide research work carried out by Jadhao Laxman Bhagavantrao under my guidance and supervision.

The subject of the thesis has been approved by the Student's Advisory Committee.

Place: Nagpur

Date:

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THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER (AFTER VIVA-VOICE)

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(C) LIST OF ABBREVIATIONS

%	:	Per cent
˚C	:	Degree Centigrade
$CuSO_4$	:	Copper sulphate
AWC	:	Available water content
BD	:	Bulk Density
BS	:	Base saturation
Ca/Mg	:	Calcium: Magnesium ratio
$CaCO_3$	:	Calcium carbonate
CBD	:	Citrate bicarbonate dithionite
CEC	:	Cation Exchange Capacity
Cm	:	Centimeter
dSm^{-1}	:	Deci Simen per meter
E	:	East
EC	:	Electrical Conductivity
EDTA	:	Ethylene diamine tetra acetic acid
EMP	:	Exchangeable magnesium percentage
ESP	:	Exchangeable sodium percentage
et al.	:	Et alia (and others)
Exch Ca	:	Exchangeable calcium
Exch K	:	Exchangeable potassium
Exch Mg	:	Exchangeable magnesium
Exch Na	:	Exchangeable sodium
FAO	:	Food and Agricultural Organization
Fig	:	Figure
H_2O_2	:	Hydrogen Peroxide
H_2SO_4	:	Sulfuric Acid
ha	:	Hectare
HCl	:	Hydrochloric acid
i.e.	:	That is
kPa	:	Kilopascal
K_2SO_4	:	Potassium sulphate

LGP	:	Length of Growing Period
M	:	Moist
M	:	Meter
Mgm^{-3}	:	Mega gram per metre cube
mm	:	Millimeter
MSL	:	Mean Sea Level
N	:	North
NaCl	:	Sodium chloride
NaOAC	:	Sodium Acetate
NaOH	:	Sodium Hydroxide
NH_4OAC	:	Ammonium Acetate
NE	:	North East
OC	:	Organic Carbon
OM	:	Organic Matter
PSD	:	Particle Size Distribution
r	:	Correlation coefficient
Viz	:	Namely

(D) THESIS ABSTRACT

a)	Title of thesis	:	**"Characterization and Suitability of Some Pomegranate- Growing Soils of Solapur District, Maharashtra."**
b)	Full name of the Student	:	Jadhao Laxman Bhagavantrao
c)	Name and address of Major Advisor	:	Dr. Jagdish Prasad Principal Scientist, SRS Division, ICAR-NBSS&LUP Nagpur
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ABSTRACT

The present study entitled “Characterization and suitability of some pomegranate-growing soils of Solapur district, Maharashtra” was an attempt to analyse the constraints of pomegranate farming in Maharashtra so that area under pomegranate and productivity can be enhanced. After traversing the area, four pomegranate-growing pedons (P1, P3, P5 and P7) and four associated crop land (P2, P4, P6 and P8) were selected in Velapur, Adatmala, Bhalwani and Supli villages of Solapur district and site characteristics and pedons were examined. The soils were shallow (38 cm). The soils of all the pedons had their colour ranging from 10YR to 2.5YR, value 3 to 5 and chroma 3 to 8. The dominant structure was fine weak to medium, moderate, subangular blocky except AC horizon of P5 (Bhalwani) which had fine weak granular structure. Pedons (P1, P2, P3, P5 and P6) had silt content more than 40 per cent. The soils of Supli (P8) had clay content more than 50 per cent and the highest sand content (40.55%) has been observed in P6. Bulk density ranged from 1.38 to 1.64 Mg m^{-3} and increased with depth. Water retention at field capacity (33 kPa) and wilting point (1500 kPa) ranged from 22.64 to 41.69 per cent and 11.38 to 25.91 per cent respectively. The soils were slightly alkaline (pH 7.7) to moderately alkaline (pH 8.3) and pH increased with depth whereas organic carbon (0.19 to 0.49%) recorded the decrease down the profile. The soils were calcareous (0.65 to 2.95 $CaCO_3$%). Cation exchange capacity of soils varied from 17.3 to 30.2 cmol(p^+)kg^{-1}.Available N, P and K content in pomegranate-growing soils ranged from 114.3 to 134.8, 9.4 to 11.4 and 191.2 to 399.8 kg ha^{-1} respectively whereas in soils of associated crop land they ranged from 116.9 to 142.3, 9.1 to 13.6 and 139.0 to 412.8 kg ha^{-1} respectively and decreased with depth. DTPA-Fe, Mn, Zn and Cu in pomegranate-growing soil ranged from 12.1 to 19.6, 3.6 to 19.0, 0.19 to 1.60 and 2.2 to 4.0 mg kg^{-1} whereas in soils of associated crop land it ranged from 12.5 to 17.5, 6.3 to 18.5, 0.33 to 1.6 and 2.7 to 4.4 mg kg^{-1} respectively. The concentration of total N, P and K in the leaves of pomegranate at different sites (P1, P3, P5 and P7) varied from 1.6 to 2.2, 0.11 to 0.20 and 0.36 to 0.63 per cent respectively. Micronutrient cations (Fe, Mn, Zn and Cu) in pomegranate leaves at different sites ranged from 47.2 to 68.9, 7.8 to 9.8, 1.8 to 7.9, 5.1 to 7.4 mg kg^{-1} respectively. Pedons

were classified as Typic Haplustept (P1, P2, P3 and P4) and Typic Ustorthent (P5, P6, P7 and P8) at subgroup level.

P1,P2, P3 and P4 were found to be moderately suitable with the limitations imposed by LGP, soil depth, pH and coarse fragments whereas P5, P6, P7 and P8 were marginally suitable having limitations imposed by LGP, soil depth, texture, slope, drainage, pH and coarse fragments. The suitability rating based on limitation method did not corroborate with the productivity of pomegranate on different sites because the agro-management practices overrides the suitability and in turn productivity.

Chapter I

INTRODUCTION

1.1 Background information

The Pomegranate (*Punica granatum L.*) is one of the most important fruit crop in our country. Pomegranate belongs to genus Punica and the family Punicacea. Pomegranate has anti-oxidant, anti-viral, and anti-tumour properties and is said to be a good source of vitamins, especially vitamin A, C, E, folic acid and possess other benefits. It is originated in Iran and has been cultivated since ancient times. Today, it is widely cultivated throughout the Mediterranean region of southern Europe, the Middle East, Northern Africa and tropical Africa, the Indian sub-continent, Central Asia.

At the global level, India is world largest producer of pomegranates followed by Iran. Other countries like Turkey, Spain, Morocco, Afghanistan, China, Greece, Japan, France, Egypt and Italy also cultivate this fruit crop. Pomegranate plays important role in the Indian economy. During the year 2011-12, India exported 30,150 tonnes of pomegranate valued at Rs.1472.68 million. During 2013-14, pomegranate was cultivated over 1.13 lakh ha with an annual production of 13.46 lakh tones and productivity of 10.27 tonnes ha^{-1} in India. In 2015-16, the area under pomegranate cultivation has sizably increased from 1,31,000 hectares to 1,81,000 hectares, with an annual production of 1.8 million tonnes and an average productivity of 9.88 tonnes ha^{-1}(NRCP 2015-16). At present, Maharashtra is leading state in acreage covering about 68.7 per cent of the area under pomegranate sharing about 70.2 per cent production. The other important states next to Maharashtra are Karnataka, Gujarat, Andhra Pradesh, Rajasthan, Tamil Nadu and Himachal Pradesh. In Maharashtra, pomegranate is concentrated in 4-5 districts namely Solapur, Nashik, Sangli, Ahmadnagar, Osmanabad and Beed .Maximum area of pomegranate is occupied by the variety Ganesh (90%) and other important variety include Mrudula, Bhagawa and Arkata. Solapur district is one of the well-marked belts of pomegranate in Maharashtra having an area 21,433 ha with production of 10,6560 tonnes and productivity of 5 tonnes ha^{-1}.

Solapur district is situated on the south east fringe of central Maharashtra plateau at an elevation ranging from 450-600 m above MSL. Annual mean rainfall is 713 mm (semi-arid) with maximum and minimum temperature of this district is 40°C and 14°C, respectively. The pomegranate is drought resistant, hardy plant, which can be grown under wide range of climatic and soil conditions, however, the deep loamy or alluvial soil are ideal for its cultivation though it can be grown in medium or light or black soil with minimum of 60 cm depth under appropriate agro-management practices.

Pawar etal*.* (2014) studied the pomegranate-growing soils of Osmanabad district, Maharashtra and reported that pedons were shallow, moderately deep, deep to very deep andthe texture of soils were loam, clay loam to sandy loam, clay to silty clay.

Marathe et al*.* (2015) identified the suitable soils for cultivation of pomegranate *cv.* Ganesh and reported that plants grown on heavy textured soil have better macro-nutrient uptake, leaf chlorophyll content and vigorous plant growth compared to light textured soil. Fruit yield was highest in the plants grown on clayey soils having 30 cm depth. Plant growth and fruit yield were drastically reduced with the increase in depth of clayey soil (90 and 120 cm). Better quality fruits were produced on the plants grown in gravelly sandy loam texture soil having depth of 60 cm.

Patil (2014) reported that orchards having low potassium levels are more prone to disease especially bacterial blight mainly responsible for pomegranate decline in Maharashtra state.

1.1 Importance of study

Extensive surveys undertaken in pomegranate growing areas of Maharashtra revealed that different types of lands are cultivated inadvertently on least promising soils, barren lands and even on the hilly terrains without properly assessing its suitability for pomegranate (Marathe et al*.* 2006).

In order to increase the area under production of pomegranate, it is necessary to conduct the systematic study of soil to ascertain soil-site parameter responsible for influencing productivity of pomegranate. It would be more appropriate if the assessment could be based on land qualities, as they are directly related to the requirement of specific land use. The characteristics and suitability criteria for pomegranate-growing soils of Solapur district, Maharashtra is virtually lacking and hence present investigation was carried out with the following objectives.

1.2 Objectives of study

- To characterise some pomegranate-growing soils of Solapur district.
- To study the nutrient status of pomegranate-growing soils and nutrient concentration in leaves.
- To assess the suitability of landscape and soil characteristics for pomegranate.

1.3 Hypothesis

The morphological, physical and chemical properties of soil are some of the chief factors governing the relative growth of pomegranate. A comprehensive and complete knowledge of soil-site characteristics and suitability analysis will aid considerably in increasing the productivity of pomegranate.

1.4 Scope and limitations

Scope

- Characterization of soils can be considered to determine the present and future potential of soils for optimizing productivity of pomegranate.
- Nutrient status of pomegranate-growing soils can be related with the uptakes of nutrients ultimately leading to judicious fertility management.

Limitations

- Fruit quality parameters and incidence of pests, diseases of pomegranate are economically indispensible but they were not studied as it was beyond our subject domain.
- The soil-suitability of pomegranate needs an extensive survey of representative areas with similar environmental conditions to elaborate the whole complex of soils and geological formations.

Chapter II

REVIEW OF LITERATURE

The review of literature that has been presented here covers the following aspects.

2.1 Climatic requirement

2.2 Landscape and soil characteristics

2.2.1 Morphological properties

2.2.2 Physical properties

2.2.3 Chemical properties

2.2.4 Soil fertility status

2.3 Nutritional status of leaves

2.4 Soil - site suitability assessment

2.1 Climatic requirement

Pomegranate plant has a versatile adaptability to wide range of climatic conditions. It grows best in semi-arid climate, where cool winter, hot and dry summer prevail. In areas of low temperature, the tree is deciduous but in tropical and sub-tropical conditions it is evergreen or partially deciduous. Pomegranate tree requires hot and dry climate having the range of temperature of 32-38°C during the period of fruit development and ripening. It cannot produce sweet fruits, unless the temperature is high for long period. The quality of fruit is adversely affected in humid climate. The pomegranate tree can withstand frost, it is injured by temperatures below -12ºC (Singh, 1980). Further, the crop withstands heat, drought and moisture deficit (Jalikop and Sampathkumar, 2000). The unique plasticity of pomegranate is evident from the threshold limit it exhibits for higher (44°C) and lower -12°C temperature (Westwood, 1978). It flowers well in clear, dry weather, bright sunshine. Availability of these ideal climatic conditions promote shining, attractive red colour of rind as well as to seeds (aril), fair size of fruit, sweet test and overall best quality. Pomegranate is winter-hardy, and drought tolerant plant and can thrive under desert conditions but bears well only under irrigation.

2.2 Landscape and soil characteristics

Pomegranate can be grown on a wide range of soils but is found to do well on light and medium type of soil. The soil should be well drained. Fruit quality and colour development is good in light soils but poor in heavy soils. Pomegranate cultivation is successful in arid ecosystem as it can withstand the hostile agro-climate and adverse soil conditions prevailing in arid ecosystem (Chandra and Jadhav, 2008). Being shallow rooted crop, pomegranate comes up well even in marginal lands with poor fertility and shallow depth. Pomegranate can be grown on well drained land with moderate slope (3-5%) and light soil having pH range of 6.5-7 is most suitable for pomegranate but under well managed condition, it can tolerate pH up to 8.5 (Technical bulletin, NRCP Solapur, 2014).

2 .2.1 Morphological properties of soil

Pawar et al. (2014) studied the pomegranate-growing soils of Osmanabad district, Maharashtra and reported that pedons were shallow to very deep and colour of Lithic Ustorthents varied from dark brown (10 YR 4/3) to dark yellowish brown (10YR 4/4) . Typic Haplusterts have very dark grey (10YR 3/1) to dark brown (10YR 3/3) colour whereas Typic Haplusterts are black (10 YR 2.5 /1) to very dark greyish brown (10 YR 3/2) in colour. Soil structure varies from granular to angular blocky structure. The texture of soils were loam, clay loam, sandy loam, clay, silty clay.

Marathe et al. (2016) surveyed pomegranate orchards grown under hot, semi-arid to arid tropical climate of Maharashtra, Karnataka and Andhra Pradesh states during 2007 to 2013 and reported that most of the pomegranate cultivation is on shallow and light textured soils.

2.2.2 Physical properties of soil

Pawar et al. (2014) reported that the bulk density of Typic Hyplusterts (P1 and P5) varies from 1.38 to 1.68 Mg m^{-3} and in Typic Ustochrepts (P4 and P8) it varied from 1.55 to 1.79 Mg m^{-3}, Lithic Ustorthents (P2, P3 P6, P7 and P9) had bulk density ranging from 1.29 to 1.78 Mgm^{-3} in pomegranate-growing soils of Osmanabad district of Maharashtra.

2.2.3 Chemical properties of soil

Raghupati and Bhargava (1998) reported pH range of 8.1 to 8.6 in soils supporting pomegranate orchards of Bijapur district, Karnataka while Deshpande (2002) reported pH range of 7.6-9.1 in pomegranate orchard of solapur district of Maharashtra.

Raj-Kumaret al. (2010) reported that electrical conductivity ranged from 0.16 to 0.303 dSm^{-1}while organic carbon varied from 0.10 to 0.21% in pomegranate cv. Ganesh orchards of Bikaner district, Rajasthan.

Pawar et al. (2014) reported that the pomegranate-growing orchards of Osmanabad district, Maharashtra were slightly to moderately alkaline in reaction (pH 7.3 to 8.02). Electrical conductivity of the soil is < 1.0 dSm^{-1}(0.31 to 0.74 dsm^{-1}). The calcium carbonate of soils ranged from 3.0 to 21.1 per cent indicating the soils were calcareous.

Marathe et al. (2016) reported that the pH of pomegranate-growing soils varied from 6.2 to 8.2 in Maharashtra, 6.8 to 8.9 in Karnataka, 6.4 to 8.7 in Andhra Pradesh and electrical conductivity ranged from 0.07 to 1.74 dSm^{-1} in Maharashtra, 0.12 to 1.86 dSm^{-1} in Karnataka, 0.13 to 0.45 dSm^{-1} in Andhra Pradesh, calcium carbonate ranged from 0.26 to 25.2 , 0.26 to 25.9 and 0.77 to 6.14 per cent in Maharashtra, Karnataka and Andhra Pradesh respectively. The organic carbon varied from 0.11 to 3.69, 0.26 to 3.04 and 0.26 to 1.72 per cent in Maharashtra, Karnataka and Andhra Pradesh respectively.

Patil (2017) reported that soils of pomegranate orchards in Jalna District were neutral to alkaline in reaction (7.0 to 8.5) and their electrical conductivity was in safe limit for the crop growth (0.27 to 0.72 dSm^{-1}). The soils were highly calcareous having free $CaCO_3$ ranging from 4.3 to 20.5 g kg^{-1} while organic carbon ranged from 0.18 to 1.07 per cent.

2.2.4 Soil fertility status

Raghupati and Bhargava (1998) reported that the pomegranate orchards of Bijapur district, Karnataka had nitrogen (44-103 mg kg^{-1}) and phosphorus (10-20 mg kg^{-1}) and potassium (75-115 mg kg^{-1}) while DTPA extractable Fe, Mn, Zn and Cu were in the range of 0.11 to 0.94,0.32 to 2.20, 0.34 to 1.64 and 0.49 to 2.36 mg kg^{-1}, respectively.

Deshpande (2002) observed that well managed pomegranate orchard from solapur district of Maharashtra had available nitrogen ranging from 191-290 kg ha^{-1} while neglected soils contained 130-214 kg ha^{-1}. Similarly phosphorus in well managed soils was in the range of 20-29 kg ha^{-1} and in neglected soils it was 8-30 kg ha^{-1}. Potassium present in well managed soils was 459-708 kg ha^{-1} and in neglected soils it was 187-548 kg ha^{-1}. The well managed soil had DTPA-Fe to the tune of 5.1 to 11.5 kg ha^{-1}, DTPA-Mn 6 to 16 kg ha^{-1}, DTPA-Zn 0.28 to 0.80 kg $ha^{-1}$and DTPA-Cu 1.7 to 4.1 kg ha^{-1} and corresponding values for DTPA-Fe, Mn, Zn and Cu in neglected soils were 4.2-13.4 kg ha^{-1}, 6-17 kg ha^{-1}, 0.30-0.90 kg ha^{-1} and 1.2-3.3 kg ha^{-1} respectively.

Raj-Kumaret al. (2010) reported that N, P, K, S and Zn ranged from 68.85 to 102.60 kg ha^{-1}, 10.39 to 25.37 kg ha^{-1}, 81.46 to 142.27 kg ha^{-1}, 11.27 to 21.28 mg kg^{-1} and 0.18 to 0.49 mg kg^{-1}, respectively in different pedons associated with pomegranate (cv. Ganesh) in Bikaner district, Rajasthan.

Mir et al.(2014) reported that combined application of vermi-compost at 20 kg $tree^{-1}$, biofertilizer at 80 g $tree^{-1}$, FYM at 20 kg $tree^{-1}$ along with 75 per cent of the recommended dose of nitrogen–phosphorus–potassium (N–P–K) chemical fertilizers resulted in maximum fruit set (52.03 per cent) and fruit yield

(34.02 kg tree^{-1}) of pomegranate. This combination also resulted in considerable greater concentration of leaf macro and micronutrients: N (2.63 per cent), P (0.25 per cent), K (1.57 per cent), iron (197.87 mg kg^{-1}), copper (14.65 mg kg^{-1}), zinc (59.36 mg kg^{-1}), and manganese (200.45 mg kg^{-1}).

Pawar et al. (2014) studied the nutritional status of pomegranate-growing soils in Osmanabad district, Maharashtra and reported that the available N, P and K ranged from 88.8 to 389.87, 13.9 to 24.24 and 207.20 to 557.13 kg ha^{-1},respectively. In general, the available nitrogen, phosphorous and potassium content of these soils decreased with increase in depth. Available Fe, Mn, Zn, Cu, and Br varied from 2.97 to 11.85, 4.70 to 11.57, 1.78 to 2.81, 2.06 to 5.3, 0.22 to 0.68 mg kg^{-1}, respectively.

Marathe et al. (2016) reported that the available nitrogen, phosphorus and potassium ranged from 83.9 to 922, 0.82 to 105.4 and 11.2 to 4256 kg ha^{-1} respectively. The available Fe, Mn, Zn and Cu varied from 0.19 to 126, 1.2 to 91.8, 0.15 to 80.9 and 0.2 to 29.9 mg kg^{-1}, respectively in pomegranate orchards of Maharashtra, Karnataka and Andhra Pradesh.

Patil (2017) reported that available N,P and K ranged from 98.56 to 250.64 kg ha^{-1}, 6.53 to 24.70 kg ha^{-1}, 98.54 to 999.30 kg ha^{-1} respectively in the soils of pomegranate orchards in Jalna district. Available Fe, Mn, Zn and Cu ranged from 0.12 to 0.46 mg kg^{-1}, 2.39 to 50.60 mg kg^{-1}, 0.31 to 2.17 mg kg^{-1}, 4.57 to 17.29 mg kg^{-1} respectively.

2.2 Nutritional status of leaves:

Many factors influence the accumulation of nutrients in pomegranate *viz*., cultivar, soil, water management and nutrient application. Karimi and Hasanpour (2014)indicated that the salinity and drought affected the concentration and distribution of sodium (Na^+), potassium (K^+), chloride (Cl^-), calcium (Ca^{2+}), magnesium (Mg^2+), and phosphorus (P^+) in pomegranate leaves. Mineral concentrations of sodium (Na^+), chloride (Cl^-) and potassium

(K^+) in shoots and roots increased with increasing salinity. Drought increased the concentration of Cl^-, Na^+ and Mg^{2+} in the shoot.

Raghupathi and Bhargava (1998) reported that N, P, K in the leaves of pomegranate of Bijapur district, Karnataka ranged from 0.91 to 1.66 , 0.12 to 0.18 5 and 0.61 to 1.59 per cent respectively and iron, zinc, manganese, copper contents varied from 25 to 297, 7 to 44, 14 to 99 and 21 to 86 mg kg^{-1}, respectively.

Bhargava (2002) interpreted the leaf nutrient status using DRIS and CND for pomegranate in Pune, Maharashtra. The correlation structure among the nutrients was extracted by PCA. Pomegranate is mainly grown on marginal soil with low fertility and hence more than two or three nutrients were found to limit the yield. However, N and Zn were most common yield limiting nutrients.

Raj-Kumaret al. (2010) reported that N, P, K, S and Zn ranged from 0.92 to 1.05 per cent, 0.18 to 0.27 per cent, 1.39 to 1.58 per cent, 0.18 to 0.21 mg kg^{-1} and 9.5 to 23 mg kg^{-}1, respectively in the leaves of pomegranate cv. Ganesh orchards of Bikaner district, Rajasthan.

Pawar et al. (2014) studied the leaf nutrient status of pomegranate orchards of Osmanabad district, Maharashtra and observed that N, P, K Zn, Cu, Mn, Fe and B content ranged from 1.18 to 2.57 per cent , 0.12 to 0.15 per cent, 0.72 to 1.41 per cent, 20.5 to 29.3 mg kg^{-1}, 83.5 to 158.5 mg kg^{-1}, 21.5 to 55.4 mg kg-1, 96.0 to 132.4 and 29.14 to 50.76 mg kg^{-1} respectively and the content of leaf nutrients had significant positive correlation with available nutrients in soil.

Marathe et al. (2016) surveyed pomegranate orchards grown under hot, semi-arid to arid tropical climate of Maharashtra, Karnataka and Andhra Pradesh states during 2007 to 2013 and reported that N, P and K in leaf samples collected from Maharashtra, Karnataka and Andhra Pradesh varied from 0.42 to 2.74, 0.023 to 0.282 and 0.32 to 3.6 per cent and Fe, Mn, Zn and Cu 94.7 to 253.4, 16.2 to 94.3,16.6 to 69.0 and 6.7 to 88.3 mg kg^{-1} respectively.

Deshmukh et al. (2017) reported that the optimum values of micronutrient concentrations in leaf as: Fe (161.5 - 198.5, 164.4-201.3, 160.2-197.2 mg kg^{-1}), Mn (40-60.4, 41.4-64.3, 40.3-61.2 mg kg^{-1}), Zn (15.37-31.28, 19.77-35.92, 12.86-29.44 mg kg^{-1}), Cu (21.35-49.77, 25.47-54.22, 17.25-41.94 mg kg^{-1}), B (23-35, 20-29, 13-25 mg kg^{-1}), and Mo (0.24-0.48, 0.24-0.50 and 0.24-0.49 mg kg^{-1}) at 50% flowering , fruit development and harvesting stages respectively. The micronutrients influenced fruit yield in the order of Fe< B < Zn <Cu < Mn < Mo at 50% flowering, Fe < B < Zn < Cu < Mn < Mo at fruit development and Cu < Fe < B < Mn < Zn < Mo at harvest.

Patil (2017) reported that the N, P and K content of pomegranate leaves varied from 1.61 to 3.39 per cent, 0.04 to 1.25 per cent and 1.62 to 9.98 per cent respectively and Fe, Mn, Zn and Cu content ranged from 153 to 282 mg kg^{-1}, 51.7 to 86.0 mg kg^{-1}, 6.19 to 24.80 mg kg^{-1} and 6.52 to 37.00 mg kg^{-1} respectively in pomegranate orchards of Jalna d istrict.

The leaf N, P and K concentration of pomegranate orchards of Latur district varied from 1.61 to 3.40, 0.05 to 1.80 and 1061 to 9.91 per cent with average values of 2.28, 0.30 and 4.90 percent, respectively (Kolekar et al. 2018). Data indicated high content of nitrogen and potassium and low content of phosphorus in pomegranate leaves. The leaf Fe, Mn, Zn, Cu and B concentration of pomegranate orchards varied from 152 to 283, 50.4 to 86.1, 6.21 to 24.81, 7.43 to 36.32 mg kg^{-1} and 7.05 to 51.60 mg kg^{-1} respectively. The of Zn and Cu in leaf was deficient, but Fe and Mn were found to be sufficient. The boron deficiency in pomegranate leaf was to the tune of 72 per cent. The leaf nitrogen and potassium were sufficient while phosphorus was deficient in pomegranate leaf.

2.3 Soil-site suitability

The principal objectives of the land evaluation is to select the optimum land use for ea ch defined land unit taking into account both physical and socio-economic consideration and the conservation of environmental resources for suitable use (FAO, 1983). The FAO framework provides a set of principles from which land evaluation can be established keeping into account the local conditions. For the land use specific evaluation the comprehensive system of land suitability evaluation has been suggested by Sys et al. (1991). The evaluation is carried out by comparing the land characteristics with the limitations levels of the requirement tables. One single limitation level is attributed to each characteristic and the suitability class is determined by the number and intensity of the limitations. Such evaluation is the basic for the interpretation of soil in term of their suitability for optimum land use planning.

Sehgal (1991) reported that soil depth is an important criteria for land evaluation. Most of the crop produce excellent yield with an effective soil depth of 90-100 cm.

Yedage et al. (2013) evaluated the suitability of the land for pomegranate in Sangola tahsil of Solapur district using Multicriteria (fuzzy logic) and GIS application. They reported that out of cultivated area (10,046.1 ha), 4986 ha was highly suitable, 3255 ha moderately suitable, and 5596 ha was marginally suitable. The results showed that agricultural practices prevailing in the study area did not match with the potential suitability in the marginally suitable area. Thus, the average yield of the study area was substantially affected because of a significant proportion of pomegranate crop was under marginally suitable areas. This research provided information at local level that could be used by farmers to select cropping patterns and suitability.

Marathe et al. (2016) identified the suitable soils for cultivation of pomegranate *cv.* Ganesh and reported that plants grown on heavy textured soil have better macro-nutrient uptake, leaf chlorophyll content and vigorous plant growth compared to light textured soil. Fruit yield was highest in the plants grown on clayey soils having 30 cm depth. Plant growth and fruit yield were drastically reduced with the increase in depth of clayey soil (90 and 120 cm). Better quality fruits were produced on the plants grown in gravelly, sandy loam texture soil having depth of 60 cm.

Meshram et al. (2016) identified the suitable land for pomegranate (*Punica granatum* L.) cultivation in Gujrat, India based on total rainfall, site characteristics (slpoe, erosion, drainage and surface stoniness) and soil characteristics (texture, depth, pH and EC) reported that highly suitable districts are Bhuj, Banaskata, Mehsana, Sabarkanta, Panchmahal, Khed and some part of Surendranagar; the moderately suitable districts are Jamnagar, Rajkot, Junagarh, Bhavnagar, Dangs, Valsad, Amreli, Bharuch, part of Surat and kheda; the marginally suitable are Rann of Kutch, part of Surat and Bhavnagar and not suitable districts are some part of Rann of Kutch, Banaskata, Vadhodara, Surat and Jamnagar.

Chapter III

MATERIALS AND METHODS

The study was conducted to characterize and find out suitability of some pomegranate-growing soils of Solapur district in Maharashtra. Materials used and methods adopted for the present investigations are presented in this chapter.

3.1 Materials

3.1.1 General Description of Study Area

Solapur is situated on Deccan plateau which comes under central Maharashtra Plateau and semi-arid region. The district is spread over an area of around 14,886 Km^2. It is located on the south east edge of Maharashtra state and lies entirely in the basin of Bhima and Seena rivers. The entire district is drained by the Bhima river. The district lies between 17°10′ to 18°32′ North latitude and74°42′ to 76.15°East longitude at an altitude of 450-600 from mean sea level. The location map of the study area is given in figure 3.1.

3.1.2 Geology

The geographical foundation of soils prevailing in Solapur district are mainly from Deccan trap of volcanic origin i.e. “Basalt”. The soil is underlain by partially basaltic rock locally known as “Murrum” which overlies parent material. On account of more or less complete absence of leaching the soils are base saturated the exchangeable calcium being the pre-dominant cation. The free lime content is fairly high (5 to 10 per cent). The soils exhibit varying degree of erosion and truncated profile. Generally soils are clayey in texture with predominant smectite clay mineral. Broadly about 45 per cent area of the district have medium deep soil (22.5 to 90 cm) fallowed by shallow soil (<22.5 cm) having an area of 30 per cent and 25 per cent area have deep soil (>90 cm).

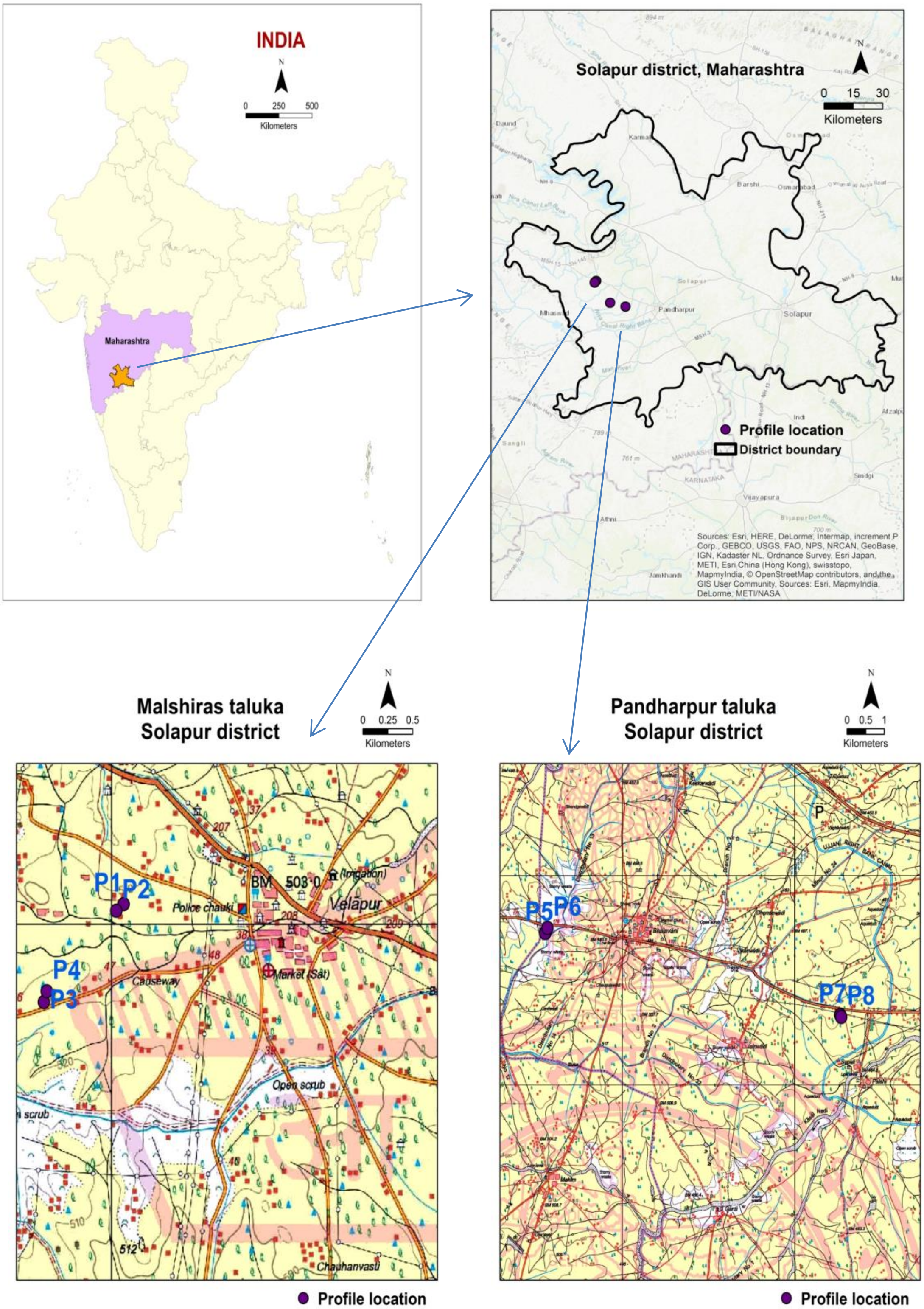


Fig. 3.1 Study area showing pedon location

3.1.2 Climate

Solapur falls under the arid and semi-arid region. Climate of the district is characterized by cold season, an oppressive summer followed by well distributed and heavy rainfall during the south-west monsoon season. The cold season starts from December to February followed by summer from March to May. The mean daily maximum temperature is 40°C and mean daily minimum temperature is 14°C. The highest temperature ever recorded is 48°C in April 1988. The southwest monsoon season is from June to September while October and November constitute the post monsoon season. The district receives rains from south-west as well as from north-east monsoon. The main precipitation during June to August is rather precarious. The normal rainfall for the monsoon period, *i.e.* June to September is 549 mm. which is 76.99 per cent of the total annual rainfall.

3.1.4 Natural Vegetation

The vegetative cover includes all naturally grown trees, plants, bushes. The forest cover in Solapur district is very poor and occupies only 357 Km^2, in that 345 Km^2 shared by forest area and 12 Km^2 have unclassified forest. At present, hill slopes and low lying areas in Malshiras, Sangola sand Barshi tehsil have forest inpatches. Naturally occurring species are *Ziziphus mauritiana*(Ber)*, Azadirachtaindica* (Neem), *Acacia nilotica* (Babul), *Delonix regia*(Gulmohar), *Molinga oleifera* (Drum stick) *Laucaena leucocephala* (Subabul), *Butea monosperma* (Palas) *Annona squmosa* (Custard apple), *Annona reticulate* (Ramphal), *Terminalia catappa* (Badam) *Acras zapota/ Poulteria sapota* (chicku/sapota), *Mangifera indica* (Mango), *Cocus nucifera* (Coconut), *Ficus benghalensis* (Banyan tree), *Ficus regliosa* (Pipal/sacred fig) etc.

Pearl millet, sunflower, redgram, groundnut, horsegram, mothbean and Blackgram are the major rainfed Kharif crops of the district and sorghum, safflower, gram are main rainfed Rabi crops. Sugarcane, sunflower, wheat and summer groundnut are the major irrigated crops grown in the district. The area under fruit and vegetable crops under irrigated condition is increasing speedily. Jujube (Ber), pomegranate and grape has occupied major area while few hectarage is under mango, kagzi lime and sapota and these fruits of the district have captured the national as well as international market common. Vegetables under irrigated are onion, chilli, brinjal, tomato, okra, bitter gourd, cucumber and leafy vegetables. A little area is under flowers and are mainly marigold, chrysanthemum, tuberose and rose.

Table 3.1 Climatological data of study areas, Solapur District (Maharashtra) (Anonymous, 2017)

Month	Average Rainfall (mm)	Maximum Temp. (^oC)	Minimum Temp. (^oC)
Jan	1	30.8	15.7
Feb	3	33.7	17.4
Mar	5	37.2	21
Apr	13	39.3	24.4
May	30	40.4	25.5
Jun	110	35.1	23.3
Jul	125	31.5	22.4
Aug	120	31.3	22
Sep	194	31.6	21.6
Oct	82	32.3	20.7
Nov	24	31	17.2
Dec	6	30	14.9
Total	713		

3.2 Methods

3.2.1 Field investigations

a) Site selection- Traversing of the study area

Traversing of the study area was carried out initially for site selection. Pomegranate-growing and associated soils were selected for profile studies.

Representative four pedons from pomegranate-growing soils and four from non-pomegranate-growing soils (Associated crop land) were exposed. Profiles were dug at selected sites representing dominant landscape units.

b) Soil-site characteristics

The soil-site characteristics such as landform, location, slope, runoff, drainage, erosion, land use and natural vegetation were also studied and recorded in the profile sheet.

c) Soil morphological properties and sample collection

Soil morphological examination was carried out to study horizonation, depth, colour, structure, texture, consistency, pores, roots, soil reaction and special features such as presence of concretions, pressure faces and slicken slides etc, as per the procedures laid down in Soil Survey Manual (Soil Survey Division Staff, 2000). Representative soils samples from each horizons were collected, labeled and brought to the laboratory for detailed analysis.

d) Collection of leaf samples

The leaf samples were collected from four pomegranate-growing orchards at 8th leaf from the apex with sample size about 60 leaves (Bhargava and Dhandar, 1987; Marathe and Babu, 2015).

3.2.2 Laboratory Investigations

a) Soil sample processing

The soil samples were air dried at room temperature. The samples were ground using wooden mortar and pestle and sieved through <2 mm size, labeled and stored in polythene bags for subsequent physical and chemical analysis. Samples for organic carbon determination was ground and sieved through 100 mesh sieve and kept for analysis.

b) Analysis of Soil Samples

Brief description of the standard procedure followed for various physical and chemical characteristics of the soil samples are given here. Moisture percentage of the processed samples was determined to a constant weight at 105°C and analytical data was expressed on oven dry basis.

3.2.3 Physical Properties

Particle-size distribution

Particle-size distribution was determined as per the International pipette method. A known amount of air-dried soil sample was treated with 1 N NaOAC buffer (pH 5.0) to remove $CaCO_3$. After oxidizing organic matter with 30% H_2O_2, the samples were treated with citrate-bicarbonate-dithionite (CBD) for removal of free iron and aluminium oxides (Mehra and Jackson, 1960). Excess salts were removed by washing with deionised water. Dispersion and particle-size fractionation were accomplished by standard procedure (Jackson, 1979). Percentage of different soil size fractions were separated as per standard procedure and their percentage was calculated.

Water retention characteristics

The moisture retention and release behavior within the available range of 33 kPa to 1500 kPa were measured on <2 mm soil sample using pressure plate membrane apparatus as per method outlined by Richards (1954).

Bulk density (BD)

The bulk density of soil was determined by a field moist method using core samplers. The core samples of known volume were used to collect the soil core from moist soil. The bulk density was calculated by dividing the oven dry weight of soil by corresponding volume of core samplers (Black, 1965 and Richards, 1954).

The bulk density was calculated as follows:

$$BD\ (d) = \frac{W_d - S}{V}$$

BD (d) = bulk density (dry)

W_d = weight of oven dry soil

S = weight of core sampler

V = volume of core sampler

Available water content

Available water content (AWC) was determined using the expression suggested by Gardner et al. (1984) and latter modified by Coughlan et al. (1986).

$$AWC = \frac{(Wmax - Wdry)}{DW} \times BD \times Depth\ (100cm)$$

Where,

Wmax = gravimetric water content (g g^{-1}) at the upper soil storage limit (33 kPa),

Wdry = gravimetric water content after the plant water extraction *i.e.* lower soil storage limit (1500 kPa),

BD = bulk density,

DW = density of water (approximately 1 Mgm^{-3})

3.2.4 Chemical properties

Soil reaction (Soil pH)

pH in soil suspension (1:2.5 soil:water) was measured by a glass electrode pH meter after equilibrating the soil with water for 30 minutes with occasional stirring (Jackson, 1973).

Electrical conductivity (EC)

The clear supernant extract obtained from the suspension used for pH (soil:water, 1:2.5) was utilized for EC measurement by conductivity bridge (Jackson, 1973).

Cation exchange capacity (CEC)

The fine earth samples (soils) were saturated with 1 *N* sodium acetate (pH 8.2) by keeping it for 24 hrs. After removal of excess sodium acetate by washing with alcohol, the absorbed Na^{+} was extracted by washing with 1 *N* ammonium acetate (pH 7.0) and the leachate was made up to a known volume.

The Na^+ ions present in the leachate were determined with a flame emission spectrophotometer (Jackson, 1973) to determine cation exchange capacity of soils.

Exchangeable cations

For determination of exchangeable cations such as Na^+ and K^+ ions, the soil samples were pre-washed with ethanol and there after saturated with NH_4OAc (pH 7.0). The extractant was used to determine Na and K by flame photometer.

Due to presence of $CaCO_3$, Ca^{2+} and Mg^{2+} ions were determined by saturating soil samples with 1 *N* NaCl solution (Piper, 1950) and the extracts were used to measure it through atomic absorption spectrophotometer.

Exchangeable sodium percentage

Exchangeable sodium percentage (ESP) was calculated by the formula given below.

$$\text{ESP (\%)} = \frac{\text{Exchangeable Na}^+}{\text{Cation exchange capacity}} \times 100$$

Base saturation

Base saturation was calculated (Black et al, 1965) as sum of cations (cmol (p+) kg^{-1}) divided by CEC (cmol (p+) kg^{-1}) and multiplied by 100. It is expressed as percentage.

Organic carbon (OC)

Carbon is the chief element present in soil organic matter comprising about 48 to 58 per cent of the total weight. Therefore, organic carbon determinations are often used as the basis for estimating the organic matter by multiplying the organic carbon value by factor 1.724.

Organic carbon was determined by Wet-oxidation method (Walkley and Black, 1934) and for that 100 mesh soil samples were used.

Calcium carbonate ($CaCO_3$)

For the determination of calcium carbonate, the soils were first treated with a known volume of warm 0.5 *N* excess hydrochloric acid solution to neutralize all carbonates and the excess hydrochloric acid was back titrated with standardized NaOH solution.$CaCO_3$ determined by Rapid titration method (Piper 1966).

3.2.5 Available macronutrient analysis

Available nitrogen

Available nitrogen was determined by alkaline potassium permanganate method as described by Subbaiah and Asija (1956).

Available phosphorus

Available phosphorus was determined by Olsen's modified method using 0.5*M* sodium bicarbonate extractant (pH 8.5) and determining P by Ascorbic acid method, as described by Olsen et al. (1954).

Available potassium

Available potassium in the soil was extracted by neutral *N* ammonium acetate and potassium was determined by flame photometer as described by Schollenberger and Simon (1945).

3.2.6 Available micronutrient analysis

Available micronutrients *viz*. Fe, Mn, Cu, and Zn were determined by using DTPA extractant (Lindsay and Norvell, 1978) and estimated by using atomic absorption spectrophotometer.

3.3.7 Preparation of leaf sample

Leaf and samples of pomegranate were air dried and further dried in a hot airoven at 60 °C, after drying samples were powdered using a grinder fitted with stainless steel blades and passed through 0.5 mm sieve and stored in polythene bags for further analysis (Jackson, 1973).

Total nitrogen

Nitrogen in leaf samples were determined by Kjeldahl's method. Powdered sample of 0.5 g was digested using concentrated H_2SO_4 and digestion mixture (containing K_2SO_4 and $CuSO_4{:}5H_2O$ and selenium in the ratio of 100:20:1) and distilled in alkaline medium. The liberated ammonia was trapped in boric acid and titrated against standard H_2SO_4 as described by Jackson (1973).

Digestion of leaf samples with di-acid mixture

Powdered leaf samples were pre-digested with HNO_3 and digested with di-acid mixture containing HNO_3 and $HClO_4$ in the proportion of 9:4 as described by Jackson (1973). The volume of the digest was made up to 100 ml with distilled water and used it for analysis of various nutrients (P, K, Ca, Mg, S, Zn, Fe, Mn and Cu).

Total phosphorus

Phosphorus content in digested leaf samples were estimated by vandomolybdophosphoric yellow colour method in nitric acid system as described by Jackson (1973).

Total potassium

Two ml of the di-acid digest was diluted to 25 ml with distilled water and fed to acalibrated flame photometer. By comparing the flame photometer readings of the sample with the calibration curve of potassium, per cent potassium in the leaf sample was calculated (Jackson, 1973).

Micronutrients

Micronutrients (Zn, Fe, Mn and Cu) concentrations in plant digest were determined by atomic absorption spectrophotometer (AAS) using suitable measuring conditions (Page et al*.* 1982).

3.3 Soil-site suitability classification

Land suitability refers to the fitness of a given type of land for a defined use. Sys et al. (1991), described suitability class levels i.e. S1- highly suitable, S2- moderately suitable, S3- marginally suitable, N- Not suitable. The suitability units differ in management requirement. The soil-site suitability criteria as suggested by Naidu et al., (2006) have been used for evaluating the suitability of soils for pomegranate.

Chapter IV

RESULTS AND DISCUSSION

The results of present investigation on characterization of pomegranate-growing soils of Solapur district are discussed in this chapter under the following heads:

4.1 Morphological properties of soils

4.2 Physical properties of soils

4.3 Chemical properties of soils

4.4 Soil fertility status

4.5 Nutritional status of leaves

4.6 Soil Classification (Soil Taxonomy)

4.7 Suitability assessment

4.1 Morphological properties of soils

Soil morphology refers to the inherent characteristics of the soils such as soil depth, colour, texture, structure, consistency, presence or absence of pans, concretions and other such features of horizons of soil profile that can be perceived in the field. The soil morphological characteristics have been studied in the field as mentioned in the USDA Soil Survey Manual (Soil Survey Division Staff, 2000). The morphological characteristics of eight soil pedon have been listed in Table 4.1.

4.1.1 Soil depth

Soil depth plays important role in withstand of crop, moisture holding capacity and nutrient supply. The depth of soils ranged from 13 cm to 38 cm underlain by weathered basalt (about more than 150 cm) and at places mixed with powdery lime and lime nodules which do not prevent the penetration of roots. The susceptibility of basalt owing to variation in chemical composition and physical characteristics at different sites (slope) might have resulted in solum depth.

4.1.2 Soil slope

Topography relates to the configuration of the land surface and is described in terms of differences in elevation, slope and landscape position. Topography can delay the work of climatic forces. Steep slopes generally encourage erosion of the surface layers and allow less rainfall to enter the soil before run-off.

The pedon P1, P2, P3, P4 and P7 occur on very gently sloping (1-3% slope) land whereas P5, P6 and P8 occur on gently sloping (3-5% slope) land. It was observed that at few sites leveling has been carried out before planting of the pomegranate.

4.1.3 Soil colour

Soil colour is most observable feature and serves as one of the criteria to differentiate the horizon of a pedon. Soil mineralogy, chemical composition, soil moisture, and organic matter content mostly influence the soil colour.

In the field, soil colour is conveniently measured by comparison with a Munsell colour chart consisting of separate notation for hue, value and chroma which are combined in that order to form the colour designation.

Pedons had their Munsell colour notation in the hue of 7.5YR / 5YR / 2.5YR / 10YR (Table 4.1). The Ap horizon of P1 (pomegranate-growing soil) and P2 (associated crop land) exhibited brown and dark brown colour (7.5YR 4/3, 3/3) in dry and moist conditions respectively. The sub-surface horizon (Bw) of P1 and P2 had dark brown (7.5YR 3/3) colour. The pomegranate-growing soil of Adatmala (P3) and associated crop land (P4) was associated with reddish brown (5YR 5/4, 4/4) colour.

The pomegranate-growing pedon of Bhalwani (P5) both surface (Ap) and sub-surface horizon (AC) had red (2.5YR 5/8) colour. The surface horizon (Ap) of associated crop land of Bhalwani (P6) had yellowish red (5YR 4/6) colour and sub-surface (AC) had red (2.5YR 4/8) colour.

The surface horizon of pomegranate growing soils of Supli (P7) and associated crop land of Supli (P8) had dark brown (10YR 3/3). The colour of the surface soil is the reflection of parent material of that site because the area is under semi-arid condition and question does not arise for ponding either by rainwater or by irrigation water as farmer practice drip irrigation. The sub-surface colour of places got modified by the presence of powdery lime.

4.1.4 Soil texture

Soil texture is relative proportion of sand, silt and clay in soil. The soil behaviour and management is directly related to soil texture.

The of Ap horizons of P1, P2 and Bw horizon of P2 had loam texture while silt loam was observed in Bw horizon of P1. The Ap horizon of P3 and both the horizon of P4 are associated with clay loam texture and that of Bw (P3) had gravelly clay loam texture. The Ap and AC horizons of P5 had silty clay loam and silt loam texture respectively. Loam and clay loam textures are associated with Ap horizons of P6. The Ap horizons of P7 and P8 had silt loam and silty clay texture respectively. (Table 4.1)

4.1.5 Soil structure

The term structure is related to the arrangement of primary soil particles into grouping called aggregates or peds. Soil structure greatly influence water movement, heat transfer, aeration and porosity in soils which are vital to its fertility. The various soil management practices such as tillage, cultivation, application fertilizer and manures, amendments (liming, gypsum) and irrigation, bring about change in soil structure that influence other properties (microbial and biochemical) which affect root growth, water and nutrient uptake, crop growth and yield.

Both the horizon of pomegranate-growing soil (P1) and associated crop land (P2) had medium moderate subangular structure. The grade of structure in Bw horizon (crop land) seems to be improved over Ap horizon. The surface horizon of pomegranate-growing soil (P3) is characterized by fine weak subangular blocky structure whereas sub-soil had medium moderate subangular blocky structure. The Ap horizon of P4 (associated crop land) had medium weak and that of Bw horizon exhibit medium moderate subangular blocky structure. The pomegranate-growing soil (P5) had fine weak granular (Ap) to fine weak sub angular blocky structure (AC) because pedon is composed of more than 50 per cent fine gravels (mixing of weathered basalt with soil by deep ploughing). Simiar to P5, P6 (associated crop land) is characterized by fine weak (Ap) to medium weak subangular blocky structure (AC) owing to more than 50 per cent fine gravels in horizon. In soil supporting pomegranate (P7), Ap horizon exhibit medium moderate subangular blocky structure while that of P8 (associated crop land) had medium strong subangular blocky structure. (Table 4.1)

4.1.6 Coarse fragment in soil

Coarse fragments are considered as part of the soil mass, though not a constituent of fine earth fraction of soil and threir study in the field is important since it largely influence soil moisture storage, run-off and infiltration. The amount of coarse fragment (V/V) is also used along with texture to assign phases of soil mapping units, skeletal textural family class helps in defining other taxa and also indicates soil genetic status and weathering state of a soil system.

The P1 had fine gravels to the tune of 5 to 8 per cent while 8 to 10 per cent fine and coarse gravels were recorded in sub-surface horizon. Both the horizons of P2 had 3 to 5 per cent fine gravels. The fine gravels constitute 10 to 15 per cent in surface horizon of P3 but amount of gravels (fine + coarse) increased to 15 to 20 per cent in sub-soil. P4 had 5 to 8 per cent fine and coarse gravels in surface layer while sub-surface horizon was associated with fine and coarse gravels in equal proportion i.e. (3-5%). The Ap horizon of P5 and P6 occuring on plateu haebour 50-60 per cent fine gravels which got increased to 60-70 per cent (fine + coarse) in AC of both the pedons. About 3 to 5 per cent fine gravels occur in Ap horizon of P7 (Pomegranate-growing soil) while associated grassland had 8 to 10 per cent fine gravels (Table 4.1).

Table 4.1: Morphological Properties of soils

Horizon	Depth (cm)	Boundary		Matrix Colour	Texture	Coarse fragments (%)	Structure			Consistence			Pores		Roots		Nodules		Effervescen-ce	Other features
		D	T				S	G	Ty	D	M	W	P	Q	S	Q	S	Q		
Pedon 1 Velapur : Pomegranate growing soil (Loamy, smectite, hyperthermic Typic Haplustept)																				
Ap	0 – 14	c	s	7.5 YR 4/3,3/3	l	5-8 (fg)	m	2	sbk	sh	fr	ss, ps	f, m	m, f	m, f	m, c	vf, f,m	m, f	ev	
Bw	14-35	a	s	7.5 YR 3/3	sil	8-10 (fg+cg)	m	2	sbk	sh	fr	s,p	f, m	m, f	vf	fm	vf, f, m	m, c, f	ev	
Cr	35-55*	Weathered basalt with lime nodules +powdery lime																		
Pedon 2 Velapur : Associated crop land (Loamy, smectite, hyperthermic Typic Haplustept)																				
Ap	0 – 15	c	s	7.5 YR 4/3,3/3	l	3-5 (fg)	m	2	sbk	sh	fr	ss, ps	f, m	m, f	m, f	f, c	f, m	m, c	ev	
Bw	15 - 38	a	s	7.5YR 3/3	l	3-5 (fg)	m	2	sbk	sh	fr	s,p	f, m	m, f	vf, f	f, f	f,m	m, m	ev	
Cr	38 - 56	Weathered basalt with lime nodules/powdered lime																		
Pedon 3 Adatmala : Pomegranate growing soil (Clayey, smectite, hyperthermic Typic Haplustept)																				
Ap	0 – 15	c	s	5 YR 5/4,4/4	cl	10- 15 (fg+cg)	f	1	sbk	sh	fr	ss,ps	f, m	m, c	m, f	c, m	f, m	m, c	es	
Bw	15 – 37	a	s	5 YR 4/4	cl	15-20 (fg+cg)	m	2	sbk	sh	vfr	s,p	f, m	m, f	m, f	c, m	m, f	m, c	es	
Cr	37 - 58	Weathered basalt mixed with nodules																		
Pedon 4 Adatmala : Associated crop land (Loamy, smectite, hyperthermic Typic Haplustept)																				
Ap	0 – 14	c	s	5 YR 5/3	cl	5-8 (fg+cg)	m	1	sbk	-	vfr	s,p	f, m	m, f	m vf	f, c	f	m	es	
Bw	14 - 38	g	s	5 YR 4/3	cl	3-5 (fg+cg)	m	2	sbk	-	fr	s,p	vf, m	m, f	vf	c	f, m	m, f	es	
Cr	38 - 57*	Weathered basalt																		

Horizon	Depth (cm)	Boundary		Matrix Colour	Texture	Coarse fragments (%)	Structure			Consistence			Pores		Roots		Nodules		Effervescen -ce	Other feature s
		D	T				S	G	Ty	D	M	W	P	Q	S	Q	S	Q		
Pedon 5 Bhalwani : Pomegranate growing soil (Loamy-skeletal, smectite, hyperthermic Typic Ustorthent)																				
Ap	0 – 13	g	i	2.5YR 5/8	sicl	50 – 60 (fg+cg)	f	1	gr	sh	fr	sp	f	m	f, vf	f, c	-	-	es	
AC	13 - 26	a	s	2.5YR 5/8	sil	60 – 70 (fg+cg)	f	1	Sbk	-	fr	sp	f	m	f, vf	f, c	-	-	es	
Cr	26 - 52*	Weathered basalt																		
Pedon 6 Bhalwani : Associated crop land (Loamy-skeletal, smectite, hyperthermic Typic Ustorthent)																				
Ap	0 – 20	g	i	5 YR 4/6	l	50 – 60 (fg+cg)	f	1	sbk	sh	fr	sp	f	m	m, f, vf	f, c, m	-	-	es	
AC	20 – 28	a	s	2.5 YR 4/8	cl	60 – 70 (fg+cg)	m	1	sbk	-	fr	sp	f	m	vf	m	-	-	es	
Cr	28 - 55*	Weathered basalt																		
Pedon 7 Supli : Pomegranate growing soil (Loamy, smectite, hyperthermic Typic Ustorthent)																				
Ap	0 – 19	a	s	10 YR 3/3	sil	3 – 5 (fg)	m	2	sbk		fr	sp	m, f	c, m	m, f, vf	f, f, f	f	f	es	
Cr	19 - 58*	Weathered basalt					-	-	-	-	-	-	-	-	-	-	-	-	es	
Pedon 8 Supli : Associated crop land (Clayey, smectite, hyperthermic Typic Ustorthent)																				
Ap	0 - 16	a	s	10 YR 3/3	sic	8 – 10 (fg)	m	3	sbk	h	fr	sp	f, m	m, f	f, vf	c, c	f	f	e	
Cr	16 - 56*	Weathered basalt																		

∗ May go upto 150 cm

Abbreviations are according to Soil Survey Manual (Soil Survey Division Staff, 1995)

1. Boundary: D =Distinctness, a= abrupt, c = clear, g = gradual, i= irregular, T = topography, s= smooth.
2. Texture: l=loam, sil= silt loam, cl=clay loam, sicl=silty clay loam, sic=silty clay.
3. Coarse fragments: fg-fine gravel (<2.5 cm), cg-coarse gravel (2.5-7.5 cm), st- stony (7.5-25 cm), b-boulders (>25 cm).
4. Structure: S = size, m=medium; G=grade, 1=weak, 2=moderate, 3= strong,Ty=type, sbk=sub angular blocky, abk= angular blocky.
5. Consistence: D=dry, sh = slightly hard, h= hard; M=moist, fr = friable, fi= firm, vfi = very firm, W=wet, s= sticky, p=plastic, vs= very sticky, vp= very plastic.
6. Roots: S=size, vf= very fine, f=fine, Q=Quantity, f=few, c-common, m-many.
7. Effervescence: e= slightly effervescent, es= strongly effervescent, ev= violently effervescent.
8. Nodules: S=size, f=fine, m = medium, Q=Quantity, f=few, c-common, m-many. **9. Other features:** ss=slicken sides, pf=pressure face.

4.1.7 Soil consistency

The manifestation of the physical forces of cohesion and adhesion acting within the soil at various moisture content are designated by the term soil consistency. It includes such properties of the soil as resistance to compression, friability, plasticity, stickiness etc. A soil can be dense, loose or compact depending on the quantity and type of pores in the soil and the way the soil particle cohere. If a soil is compact, then it may contain clay minerals (possibly smectite minerals) which compacts due to shrinking when dry and swell when wet.

The consistency is examined at three moisture condition namely dry, moist and wet. The dry peds observed from Ap and Bw horizon of P1 and P2 exhibited slightly hard consisteny. It was friable in moist condition and slightly sticky and slightly plastic in wet condition. Pedon 3 showed slightly hard (dry consistency), friable (moist consistency) and slightly sticky and slightly plastic (wet consistency) in Ap horizon but it was very friable (wet consistency) and sticky and plastic (moist consistency). It was noticed very friable and friable (wet consistency) in surface and sub-surface horizon of P4 but sticky and plastic (moist plasticity) in the both horizons. The dry consistency in Ap and AC horizons of P5 and P6 was examined slightly hard while these horizon had friable (moist consistency) and slightly sticky and plastic (wet consistency). It was friable (moist consistency) for Ap horizon of P7 and sticky and plastic in wet condition but P8 possessed hard consistency (dry consistency), friable (moist consistency) and sticky and plastic (wet consistency) (Table 4.1).

4.1.8 Effervescence

Cold dilute hydrochloric acid was used to test for the presence of carbonates in the soils during field study. The amount and expression of effervescence is affected by size, distribution and mineralogy as well as the amount of carbonates.

Violent effervescence was observed in different horizons including underlying saprolite in P1 and P2 (Table 4.1). Strong effervescence was observed in P3, P4, P5, P6, P7 and intensity of effervescence got increased with depth. Slight effervescence was observed in Ap horizon of P8.

4.2 Physical properties of soils

The physical properties of eight pedons are presented in Table 4.2 and discussed in following sections.

4.2.1 Particle-size distribution

Particle-size distribution provides many clues about physical, chemical and biological properties of the soils which largely contribute towards plant growth through aeration, water retention and availability of nutrients. This indirectly modifies the environment of rhizospere for better biochemical reactions to keep the soils in good health.

Data presented in table 4.2 showed that sand content in P1 ranged from 26.45 to 32.21 per cent and decreased with depth. The Ap horizon of P2 had less sand content than the surface layer of P2 but sand was higher in Bw horizon of P2 than corresponding horizon of P1. The silt content was more than 46 per cent in P1 and P2 and its content increased with depth in P1 but reverse trend was observed in P2. P1 and P2 had more than 20 per cent clay in Ap and Bw horizon but decreased with depth.

The sand content in pomegranate-growing pedon (P3) and associated pedon 4 (crop land) constitute more than 20 per cent but solum of P4 had 7 per cent more sand than the P3. In general silt content in sub-surface horizon of P3 and P4 increased with depth but magnitude of increased was higher in P4. The clay content in Bw horizon of P3 and P4 decreased than the corresponding value associated with surface horizon.

Silt was the dominant fraction constituting more than 40 per cent in P5 and P6 and its content slightly increased in lower horizon. An increase in sand content with depth was observed in P7 while reverse trend was recorded in P6. The decrease/increase in sand was compensated by increase/decrease in clay content accordingly as silt was more than 40 per cent in in all the horizons.

Clay constitute more than 50 per cent of particle size distribution in P8 while P7 had nearly half of the clay that of P7 (27.2 %). The distribution of silt in these pedons was in reverse order that of clay.

Pedons of Supli (P7 and P8) had relatively low sand content (≈10 per cent) than the other pedons.

4.2.2 Bulk Density

Bulk density is the ratio of mass of oven dry soil solid particles to the total volume of the soil. This volume includes the volume of the soil solids, soil water and soil air. The latter two i.e. volume of water volume of air constitute the total volume of pores. Bulk density of soil is influenced by soil texture, structure, organic matter content and land management practices. Bulk density affects root growth by modifying the edaphic factors. It is also useful parameter in prediction of organic carbon stock and placement of specific soils in different taxa.

In general, bulk density (Table 4.2) ranged from 1.38 to 1.64 Mg m^{-3}. Irrespective of land uses, the bulk density increased with depth owing to presence of more gravels in lower horizons and / or might be due to more organic matter/root mass in surface layer (Sehgal et. al 1980; Nikam, 2002)

Table 4.2: Physical Properties of soil

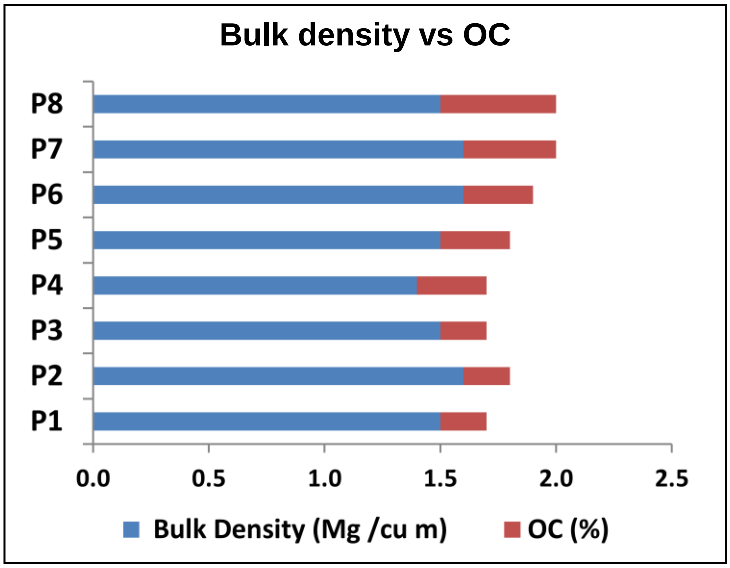
Horizon	Depth (cm)	Particle-size distribution			B D (Mg m^{-3})	Textural class	Moisture retention (%)		AWC (%)
		Sand (%)	Silt (%)	Clay (%)			33 kPa	1500 kPa	
Pedon 1 Velapur : Pomegranate growing soil (Loamy, smectite, hyperthermic Typic Haplustept)									
Ap	0 – 14	32.21	45.64	22.15	1.53	l	24.44	12.46	11.99
Bw	14 − 35	26.45	53.08	20.47	1.54	sil	24.47	13.64	10.83
Pedon 2 Velapur : Associated crop land (Loamy, smectite, hyperthermic Typic Haplustept)									
Ap	0 – 15	25.58	47.53	26.89	1.56	l	26.95	15.54	11.40
Bw	15 − 38	27.64	46.62	25.74	1.58	l	27.69	17.43	10.26
Pedon 3 Adatmala : Pomegranate growing soil (Clayey, smectite, hyperthermic Typic Haplustept)									
Ap	0 – 15	21.04	40.10	38.86	1.38	cl	33.96	20.31	13.64
Bw	15 – 37	25.04	40.27	34.69	1.52	cl	33.04	19.74	13.30
Pedon 4 Adatmala : Associated crop land (Loamy, smectite, hyperthermic Typic Haplustept)									
Ap	0 – 14	38.34	32.80	28.86	1.39	cl	28.16	15.54	12.62
Bw	18 – 38	32.24	39.58	28.18	1.42	cl	28.15	17.65	10.51
Pedon 5 Bhalwani : Pomegranate growing soil (Loamy-skeletal, smectite, hyperthermic Typic Ustorthent)									
Ap	0 – 13	16.32	47.38	36.30	1.51	sicl	31.86	19.71	12.16
AC	13 − 26	22.94	51.16	25.90	1.58	sil	29.88	19.01	10.87
Pedon 6 Bhalwani : Associated crop land (Loamy-skeletal, smectite, hyperthermic Typic Ustorthent)									
Ap	0 – 20	40.55	41.30	23.15	1.60	l	22.64	13.66	8.98
AC	20 − 28	25.58	42.62	31.80	1.64	cl	29.29	19.54	9.75
Pedon 7 Supli : Pomegranate growing soil (Loamy, smectite, hyperthermic Typic Ustorthent)									
Ap	0 – 19	10.50	68.30	27.20	1.57	sil	25.69	11.38	14.31
Pedon 8 Supli : Associated crop land (Clayey, smectite, hyperthermic Typic Ustorthent)									
Ap	0 – 16	9.52	32.67	51.81	1.54	sic	41.69	25.91	15.78

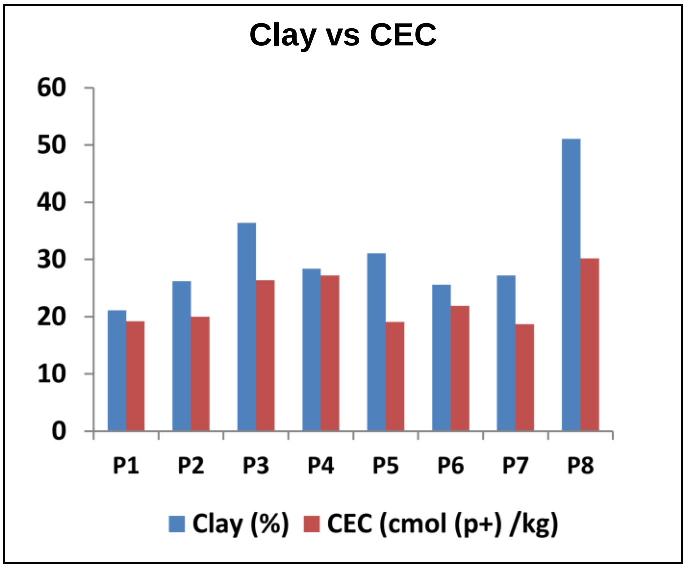
4.2.3 Water retention characteristics of soils

Water content under certain standard conditions are referred to as soil moisture constants, but under field conditions water content of soil is always changing constantly with time and also with depth of soil and is not static or constant. The concept of soil moisture constants greatly facilities in taking decision for irrigation management. The water content of soil at which all the pores are filled with water is referred to as saturation or maximum water holding capacity. The energy status of water at saturation is zero. Water content of soil at saturation is approximately double that of field capacity. The quantity of water retained in soil between the limits of field capacity and permanent wilting point is available water for plant use. Moisture retention characteristics depend upon the amount, type and surface area of the clay fraction.

In general, water retention characteristics of horizons were closely related to texture with finer soil (higher in clay) exhibiting higher retention and *vice-versa*. It ranged from 24.44 per cent (Ap horizon of P1) to 27.69 per cent in Bw horizon of P2 at 33 kPa and corresponding values were 12.46 to 17.43 per cent. The available water content in different horizons of P1 and P2 did not vary significantly (10.26 to 11.99%). Pedon 3 had higher water retention at 33 kPa (≈ 33%) and 1500 kPa (19.74 to 20.31%) than the moisture retention of respective horizons of P4 which clearly indicate that water retentions commensurate with higher clay content (Nikam et. al. 2006) which also reflected on available water content of the soils. The Ap horizon of P5 and AC horizon of P6 had nearly similar values for water retentions at both suctions and these data closely related with clay content. The higher water retention at 33 and 1500 kPa by Ap horizons of P7 and P8 seems to be dependent on silt+clay and clay contents of respective horizons and in turn higher AWC (r = 701**).

Correlation studies indicated that clay had significant positive correlation with water retention at 33 kPa ($r=0.960^{**}$) and at 1500 kPa ($r= 0.870^{**}$) but sand had significant negative correlation with water retention at 33 kPa ($r=0.614^{**}$). CEC also had significant positive correlation with water.





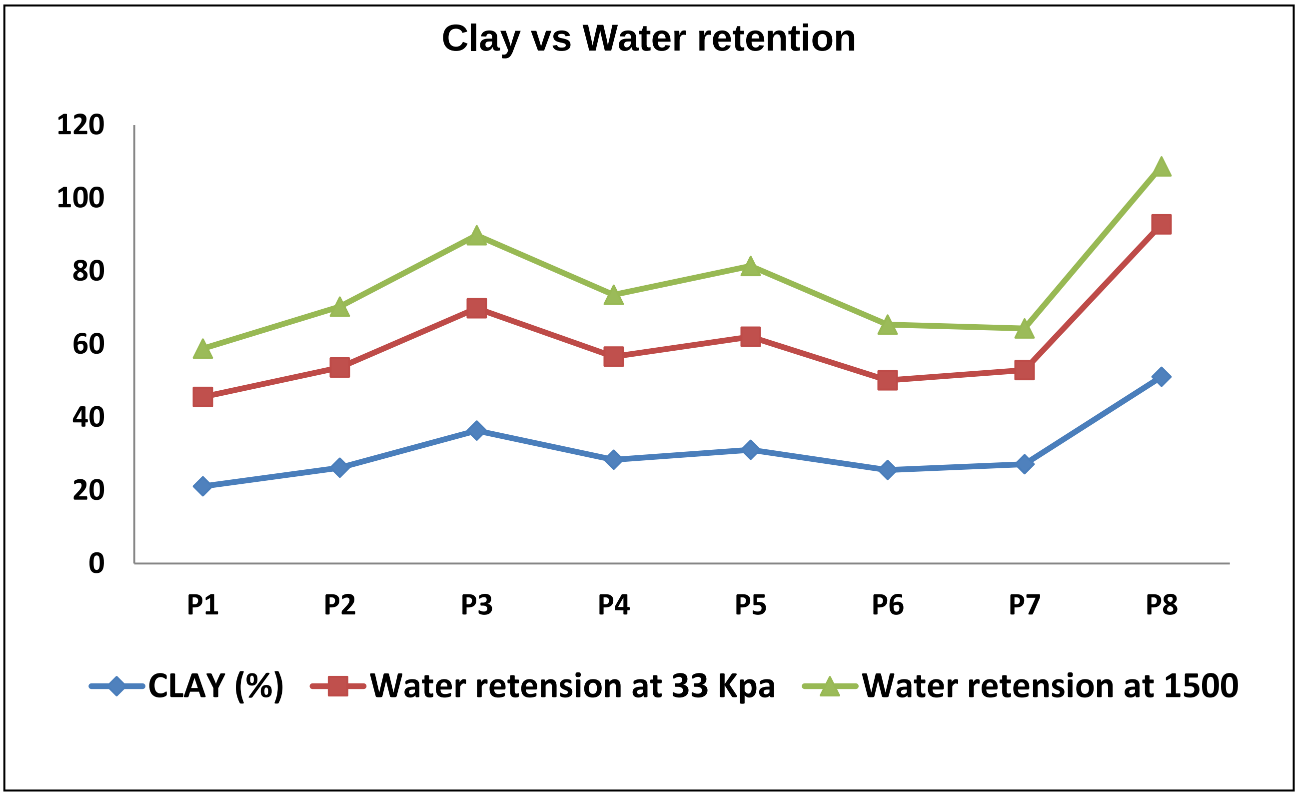


Fig. 4.1 Variation of Bulk density *vs* Organic carbon, Clay *vs* CEC, Clay *vs* Water retention.

retention at 33 kPa (r=0 .656**) and at 1500 kPa (r= 0.603**). Srivastava et al. (1998) and Nikam et al. (2006) reported that water retained at 33 kPa and 1500 kPa tensions was significantly and positively correlated with clay, silt and CEC and negatively correlated with sand content of the soil, (Appendix II).

4.3 Chemical properties of soils

4.3.1 Soil Reaction (pH)

The pH (soil reaction) is an important property of the soil as it determines salinity, alkalinity, nutrients availability, microbial activity and physical condition of soil and its intrinsic relationship with other soil constituents determined by chemical analysis.

The pH of pedon (Table 4.3) P1, P2, P3 and P4 is moderately alkaline (7.9 to 8.3) and increased with depth might be due to leaching of soluble salts and bases from upper horizons. Ap horizon of P5, P6 and P8 had slightly alkaline (7.7 to 7.8) but AC(P5) and Ap (P7) had moderately alkaline pH. It seems that pH of soils show its close reliance with parent material i.e. basalt. Pawar et al. (2014) and Marathe et al. (2016) reported pH ranging from 7.3 to 8.0 and 6.2 to 8.9 respectively in pomegranate-growing soils of Maharashtra.

The pH had negative correlation with CEC (r = 0.181), organic carbon (r = 0.284) and clay (r = 0.199). but positive with ESP (r = 0.335) and CaCO3 (r = 435) (Appendix II).

4.3.2 Electrical conductivity

Electrical conductivity gives an insight about the presence of total soluble salts and used as one of the criteria to differentiate between saline and non-saline soils.

The electrical conductivity (EC) ranged from 0.17 to 0.58 dSm^{-1} in different horizons of soils (Table 4.3) which is within safe limit against <1 dSm^{-1} (Richards, 1954). Pawar et al. (2014) reported EC in the range of 0.31 to 0.74

dSm^{-1} in pomegranate-growing soils of Osmanbad district, Maharashtra while Patil (2017) reported EC of 0.27 to 0.72 dSm^{-1} in pomegranate orchards of Jalna district, Maharashtra. Raghupati and Bhargava (1998) observed wide range of EC (0.11to 0.50 dSm^{-1}) in pomegranate-growing soils.

4.3.3 Soil organic carbon

Soil organic carbon is of prime importance for various plant nutrient cycles and influence soil colour, water retention, bulk density, susceptibility to erosion and soil structure. Soil organic carbon has very specific role in genesis of soil and used as criteria for placement of soils in some taxa.

The organic carbon distribution in soils (pomegranate-growing and associated crop land) showed variation within and across pedon. In general, the Ap horizons of crop lands (P2, P4 and P6) had higher organic carbon than that of pomegranate-growing soils and decreased with depth owing to higher pH and CaCO3. Bhattacharyya et al. (2004) also reported similar findings. The highest organic carbon (0.49%) was recorded in Ap horizon of P8 being under grassland followed by 0.36 per cent in cultivated land (P7) having reasonably good canopy of crop (well managed one). It was observed that pomegranate is being cultivated since last 5 to 7 years and hence could not sequests higher organic carbon than that of associated crop land being under cultivation for longer period. Marathe et al. (2016) reported that organic carbon ranged from 0.11 to 3.69 per cent in pomegranate-growing soils of Maharashtra while organic carbon was found to be ranged from 0.18 to 1.07 per cent in pomegranate orchards of Jalna district, Maharashtra (Patil, 2017) Organic carbon of soil had positive significant correlation with clay ($r = 727^*$), 33 kPa ($r = 593^*$) and AWC ($r = 604^*$) and positively correlated with CEC (r = 0.487), 1500 kPa (r = 0.453) but negatively correlated with pH (r = 0.284), sand ($r = 0.543^*$) and silt (r = 0.193), (Appendix II).

Table 4.3: Chemical Properties of soil

Horizon	Depth (Cm)	pH (1:2.5)	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Extractable Bases cmol (p^+) kg^{-1}					CEC cmol (p^+)kg^{-1}	ESP	EMP	Exch Ca:Mg ratio	Base Saturation (%)	CEC/ Clay ratio
						Ca^{++}	Mg^{++}	Na^+	K^+	Sum						
Pedon 1 Velapur : Pomegranate growing soil (Loamy, smectite, hyperthermic Typic Haplustept)																
Ap	0 – 14	8.1	0.38	0.22	2.06	15.8	1.3	0.96	0.73	18.7	20.2	4.7	6.3	12.8	95.0	0.91
Bw	14 − 35	8.1	0.52	0.19	2.95	14.3	1.4	0.99	0.29	17.0	18.5	5.4	7.7	10.3	94.6	0.91
Pedon 2 Velapur : Associated crop land (Loamy, smectite, hyperthermic Typic Haplustept)																
Ap	0 – 15	8.0	0.48	0.25	2.84	17.7	1.0	0.49	0.37	19.5	21.0	2.3	4.8	18.1	95.2	0.78
Bw	15 − 38	8.3	0.50	0.24	2.73	14.9	1.8	0.98	0.25	17.8	19.3	5.1	9.3	8.5	94.8	0.75
Pedon 3 Adatmala : Pomegranate growing soil (Clayey, smectite, hyperthermic Typic Haplustept)																
Ap	0 − 12	8.1	0.23	0.26	1.18	21.2	1.5	0.83	0.62	24.2	25.7	3.2	5.9	14.2	96.1	0.66
Bw	12 − 33	8.2	0.25	0.23	1.51	22.6	1.8	0.70	0.21	25.3	26.8	2.6	6.8	12.7	96.2	0.77
Pedon 4 Adatmala : Associated crop land (Loamy, smectite, hyperthermic Typic Haplustept)																
Ap	0 – 14	7.9	0.49	0.28	1.17	21.6	2.5	0.43	0.23	24.7	26.2	1.7	9.5	8.8	96.1	0.91
Bw	18 − 38	8.0	0.58	0.26	1.72	22.0	3.3	0.55	0.43	26.2	27.7	2.0	11.9	6.8	96.3	0.98
Pedon 5 Bhalwani : Pomegranate growing soil (Loamy-skeletal, smectite, hyperthermic Typic Ustorthent)																
Ap	0 – 13	7.8	0.42	0.29	0.65	15.7	2.8	0.56	0.33	19.3	20.8	2.7	13.5	5.7	95.2	0.58
AC	13 − 26	7.9	0.47	0.22	0.76	13.0	2.3	0.36	0.29	15.8	17.3	2.1	13.0	6.0	94.2	0.67
Pedon 6 Bhalwani : Associated crop land (Loamy-skeletal, smectite, hyperthermic Typic Ustorthent)																
Ap	0 – 20	7.7	0.22	0.30	1.60	16.2	3.0	0.91	0.22	20.3	21.8	4.2	13.8	5.6	95.4	0.95
AC	20 − 28	7.8	0.27	0.27	1.78	17.1	2.2	1.00	0.27	20.5	22.0	4.5	10.0	8.0	95.4	0.69

Horizon	Depth (Cm)	pH (1:2.5)	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Extractable Bases cmol (p^+) kg^{-1}					CEC cmol (p^+)kg^{-1}	ESP	EMP	Exch Ca:Mg ratio	Base Saturation (%)	CEC / Clay ratio
						Ca^{++}	Mg^{++}	Na^+	K^+	Sum						
Pedon 7 Supli : Pomegranate growing soil (Loamy, smectite, hyperthermic Typic Ustorthent)																
Ap	0 – 19	8.2	0.21	0.36	1.40	10.9	4.8	1.21	0.35	17.2	18.7	6.5	25.7	2.4	94.6	0.69
Pedon 8 Supli : Associated crop land (Clayey, smectite, hyperthermic Typic Ustorthent)																
Ap	0 − 16	7.8	0.17	0.49	1.90	20.5	5.9	1.50	0.76	28.7	30.2	1.9	28.3	2.9	96.6	0.58

4.3.4 Calcium carbonate

The presence of calcium carbonate denotes the calcareousnessof soil. Calcareousness of soil can be identified in field if it effervescence when reacted with cold dilute HCl. The calcium not only improves the structure of soil but is also concerned with the decomposition of soil organic matter and the synthesis of humus. High lime concentration may restrict the water movement and prevent root penetration.

The surface and sub-surface horizon of P1 and P2 (Table 4.3) showed violent effervescence due to presence of calcium carbonate ranging from 2.06 to 2.95 per cent while pedon P3, P4, P5, P6, P7 and P8 had strong effervescence owing to the presence of calcium carbonate to the tune of 0.60 to 1.90 per cent. It was observed that $CaCO_3$ in general, increased with depth barring sub-surface horizon of P2**.** Pawar et al. (2014) reported that pomegranate-growing soils of Osmanbad district, Maharashtra had $CaCO_3$ in the range of 3.0 to 21.1 per cent while Marathe et al. (2016) reported wide variation in $CaCO_3$ (0.26 to 25.2%) in soils under pomegranate. Patil (2017) while characterizing the pomegranate orchards of Jalna district, Maharashtra reported $CaCO_3$ contentranging from 0.43 to 2.05 per cent.

The $CaCO_3$ content of soils had positive correlation with clay (r = 0.343), 33 kPa (r = 0.266), 1500 kPa (r = 0.186) and CEC (r =0. 439) and negatively correlated with organic carbon (r = 0.541*), (Appendix II).

4.3.4 Exchangeable cations

Exchangeable cations give an idea about exchange phenomena of soils. They also give clue about parent material and pedo-climate. It helps in computation of base saturation which is used to categorize at different taxonomic levels.

The data presented in table 4.3 show that soils are calcareous and Ca^{++} asdominant cation on exchange complex followed by Mg^{++}, Na^{+} and K^{+}. Surface and sub-surface horizon of associated crop land (P2) had higher exchangeable Ca^{++} than pomegranate-growing soil (P1) which ranged from 14.3 to 17.7 cmol (p^{+}) kg^{-1}. Thesurface and sub-surface horizon of P3 and P4 had relatively higher exchangeable Ca^{++} (21.2 to 22.6 cmol (p^{+}) kg^{-1})than the respective horizons of P1, P2, P5 and P6 (14.3 to 17.7 cmol (p^{+}) kg^{-1}). P8 had exchangeable Ca^{++} nearly twice than that of P7 (10.9 cmol (p^{+}) kg^{-1}).

Exchangeable Mg^{++} was relatively high in P4, P5, P6, P7 and P8 ranging from 2.2 to 5.9 cmol (P^{+}) kg^{-1}than P1, P2 and P3 (1.0 to 1.8 cmol (p^{+}) kg^{-1}). The exchangeable Mg^{++} increased in Bw horizons of P1 to P4 but it was not so in AChorizons of P5 and P6.

The Na^{+} ranged from 0.36 to 1.0 cmol (p^{+}) kg^{-1}in different horizons of pedons (P1 to P6) but it was higher in P7 and P8 (>1.2 cmol (p^{+}) kg^{-1}). In general, Na^{+} increased with depth with the exceptionof P3 and P5.

In general, K^{+}ranged from 0.21 [cmol (p^{+}) kg^{-1}] in Bw horizon of P3 to 0.76 [cmol (p^{+}) kg^{-1}] in P8 with tending to decreased with depth barring sub-surface horizon of P4 and P6. Wide variation in Ca^{++} /Mg^{++} ratio (2.4 to 18.1) was observed in different horizons of pedons.

4.3.5 Cation Exchange Capacity

Cation exchange capacity is the single most important soil chemical property which governs nutrient availability, rhizosperic microbial population and it is used at many category levels in taxanomic classification and also in understanding the clay mineraloagical make-up of the soil.

Cation exchange capacity of the soil ranged between 17.3 to 30.2 cmol(p^{+}) kg^{-1} in different horizons of pedons (Table 4.3). Maximum CEC of 30.2 cmol(p^{+}) kg^{-1} was observed in Ap horizon of P8 and minimum CEC of 17.3

cmol(p^+) kg^{-1} was associated with AChorizon of P5. The P3, P4 and Ap horizon of P8 higher CEC (>25 cmol(p^+) kg^{-1}) than P1, P3, P5 and P7. The higher CEC/Clay ratio indicate that the soil have smectite as the dominant clay mineralogy class. Moreover, as smectites are the immediate weathering products of basalt (Bhattacharyya et al., 1993).

CEC had significant positive correlation with clay (r = 0.709^{**}), 33 kPa (r = 0.656^{*}), 1500 kPa (r = 0.603^{*}) and $CaCO_3$ (r = 0.439) and negative correlation with silt (r = 0.787^{*}), (Appendix II).

4.3.6 Base Saturation

Base saturation provides an idea about the distribution of difference cations on exchange complex, parent material and weathering environment. It is very useful in predicting the buffering capacity of soil and used in classifying different taxa even at higher category level i.e. order.

Base saturation in these soils have been found to be higher (>90%) in all pedons. It ranged from94.2 to 96.6 per cent in different horizons of pedons. The higher base saturation reflects basalt, a basic igneous rock (parent material). The cursery view of data indicate there was no definite trend in distribution of base saturation with respect to depth because it is derived value.

4.3.7 ESP and EMP

Exchangeable sodium percentage of soil ranged from 1.7 to 6.5 (Table 4.3). The ESP of P1, P6, P7 and Bw horizon of P2 was more than 4.0 which indicate that these soils may become sodic in future if appropriate actions are not initiated now. The ESP of P3, P4, P5, P8 and Ap horizon of P2 ranged from 1.7 to 3.2.

Exchangeable magnesium percentage of soil ranged from 4.8 to 28.3 in different pedons of soils which is also of concern.

Table 4.4: Status of available macro and micronutrients in soil and nutrient concentration in leaves

Horizon	Depth (cm)	Macro-nutrient						Micro-nutrient							
		Soil (Kg ha-1)			Leaf (%)			Soil (mg kg-1)				Leaf (mg kg-1)			
		N	P	K	N	P	K	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
Pedon 1 Velapur : Pomegranate-growing soil (Loamy, smectite, hyperthermic Typic Haplustept)															
Ap	0 – 14	121.7	10.4	208.5	1.8	0.19	0.36	17.7	14.9	0.93	2.9	68.9	9.8	7.9	5.9
Bw	14−35	114.3	9.4	199.9	-	-	-	15.4	10.3	0.54	2.5	-	-	-	-
Pedon 2 Velapur : Associated crop land (Loamy, smectite, hyperthermic Typic Haplustept)															
Ap	0 – 15	119.1	13.6	256.3	-	-	-	16.2	18.5	0.39	2.8	-	-	-	-
Bw	15−38	116.9	10.5	204.2	-	-	-	14.0	11.4	0.34	2.7	-	-	-	-
Pedon 3 Adatmala : Pomegranate-growing soil (Clayey, smectite, hyperthermic,Typic Haplustept)															
Ap	0 − 12	134.8	11.2	399.8	1.6	0.11	0.42	15.5	19.0	0.91	4.0	52.5	7.8	5.6	7.4
Bw	12−33	126.1	9.6	334.6	-	-	-	12.1	9.8	0.43	2.7	-	-	-	-
Pedon 4 Adatmala : Associated crop land (Loamy, smectite, hyperthermic Typic Haplustept)															
Ap	0 – 14	139.3	12.9	412.8	-	-	-	15.0	15.9	1.60	2.8	-	-	-	-
Bw	18−38	132.2	11.6	325.9	-	-	-	12.5	14.0	1.10	3.5	-	-	-	-
Pedon 5 Bhalwani : Pomegranate-growing soil (Loamy-skeletal, smectite, hyperthermic Typic Ustorthent)															
Ap	0 – 13	123.8	11.4	212.9	1.9	0.15	0.44	16.8	3.6	0.48	4.0	47.2	8.0	1.8	5.1
AC	13−26	122.5	10.9	191.2	-	-	-	15.3	3.9	0.36	3.7	-	-		-
Pedon 6 Bhalwani : Associated crop land (Loamy-skeletal, smectite, hyperthermic Typic Ustorthent)															
Ap	0 – 20	125.8	9.8	195.5	-	-	-	16.5	9.4	0.24	3.7	-	-	-	-
AC	20−28	131.7	9.1	186.86	-	-	-	14.1	6.3	0.39	4.4	-	-	-	-
Pedon 7 Supli : Pomegranate growing soil (Loamy, smectite, hyperthermic Typic Ustorthent)															
Ap	0 –19	124.8	11.2	252.0	2.2	0.20	0.63	19.6	11.5	0.19	2.2	59.4	7.8	5.9	5.7
Pedon 8 Supli : Associated crop land (Clayey, smectite, hyperthermic Typic Ustorthent)															
Ap	0 − 16	142.3	11.8	139.0	-	-	-	17.5	16.6	0.33	4.1	-	-	-	-

4.4 Soil fertility status

4.4.1 Macronutrients

Macronutrient or major nutrient are so called because these are required in large quantities. These include C, H, O, N, P, K, Ca, Mg and S.

The data (Table 4.4) showed that available N ranged from 114.3 to 143.3 kg ha^{-1} in pomegranate-growing soil and associated crop land. Available N content in pomegranate-growing soil (P1, P3, P5 and P7) ranged from 114.3 to 134.8 Kg ha^{-1} whereas available N content in associated crop land (P2, P4, P6 and P8) varied from 116.9 to 142.3 kg ha^{-1}. Pawar et al. (2014), Marathe et al. (2016) and Patil (2017) reported available N in the range of 88.8 to 389.8, 122.4 to 922 and 98.5 to 250.6 kg ha^{-1} respectively in pomegranate-growing soils of Maharashtra.

Data (Table 4.4) pertaining available P in pomegranate-growing soils (P1, P3, P5 and P7) showed that surface horizon had higher available P than sub-surface horizon. Available P ranged from 9.4 to 11.4 kg ha^{-1} in pomegranate-growing soils (P1, P3, P5 and P7) and 9.1 to 13.6 kg ha^{-1} available P content in associated crop land (P2, P4, P6 and P8). Pawar et al. (2014) and Patil (2017) reported available P in the range of 13.9 to 24.2 and 6.5 to 24.7 Kg ha^{-1} in pomegranate-growing soils of Maharashtra which got decreased with depth.

The available K content in pomegranate-growing soil (P1, P3, P5 and P7) ranged from 191.2 to 399.8 kg ha^{-1} whereas in associated crop land (P2, P4, P6 and P8) it ranged from 139.0 to 412.8 kg ha^{-1} and decreased with depth (Table 4.4). Pawar et al. (2014) and Patil (2017) reported available K in the range of 207.2 to 557.1 and 98.5 to 999.3 kg ha^{-1} in pomegranate-growing soils of Maharashtra.

4.4.2 DTPA-extractable micronutrients

The term micronutrients denote the elements, which are essential for the plant but are required in small amounts. The main source of micronutrients in soil is the parent material or rocks from which it has been formed. From the nature of the parent material of soil, it is possible to have an idea of the deficiency or excess of micronutrient in it.

The over-exploitation of soil which are naturally degraded are confronted by a number of problems, among them micronutrient deficiency is common feature in soils of India (Ram sakal, 2001). The deficiency of micronutrients cations are of permanent importance in soils of Maharashtra in view of the fact that mainly pH, ESP and $CaCO_3$controls their availabilities in shrink-swell soils.

The scrutiny of data (Table 4.4) showed that DTPA-Fe in surface horizon of pomegranate-growing soil (P1, P3, P5 and P7) was more than the sub-surface layer and it ranged from 12.1 to 19.6 mg kg^{-1}in different horizon.The associated crop land (P2, P4, P6 and P8) had DTPA-Fe ranging from 12.5 to 17.5 mg kg^{-1}. All the pedons had DTPA-Fe higher than the critical value of 4.5 mg kg^{-1}(Lindsay and Norvel 1978). Pawar et al. (2014) and Marathe et al. (2016) reported DTPA-Fe in range of 2.97 to 11.85 and 0.19 to 126.6 mg kg^{-1} respectively in pomegranate-growing soils of Maharashtra.

DTPA-Fe positively correlated with OC (r = 0.476), $CaCO_3$(r = 0.476), silt (r = 0.458), clay (r = 0.039), ESP (r = 0.526), Mn (r = 0.115) and negatively correlated with pH (r = 0.090), EC (r = 0.066), CEC (r= 328), Zn (r = 0.251), Cu (r = 0.077), (Appendix II).

DTPA-Mn (Table 4.4) was higher in surface horizon of pomegranate-growing soil (P1, P3, P5 and P7) than sub-surface soil and it ranged from 3.6 to 19.0 mg kg^{-1}in different layers of pedons. In associated crop land (P2, P4, P6 and P8) and it ranged from 6.3 to 18.5 mg kg^{-1}**.** Pawar et al. (2014), Marathe et al. (2016) and Patil (2017) reported DTPA-Mn in the range of 4.7 to 11.5, 1.2 to 84.6 and 2.3 to 50.6 mg kg^{-1} respectively in pomegranate-growing soils of Maharashtra indicating large variation in the content of DTPA-Mn.

DTPA-Mn positively correlated with OC (r = 0.176), $CaCO_3$(r = 0.554*), sand (r = 0.072), clay (r = 0.205), Fe (r = 0.115), Zn (r = 0.438) and negatively correlated with silt (r = 0.332), ESP (r = 0.018), Cu (r = 0.219), (Appendix II).

DTPA-Zn varied from 0.19 to 1.60 mg kg^{-1} in different horizons of peds being highest in Ap horizon of P4 (Adatmala-associated crop land). In general, DTPA-Zn decreased down the depth. The associated crop land (P2, P4, P6 and P8) had DTPA-Zn ranging from 0.33 to 1.6 mg kg^{-1}in different layers while Ap horizon retained higher DTPA-Zn (Table 4.4). Pawar et al. (2014), Marathe et al. (2016) and Patil (2017) reported DTPA-Zn in range of 1.7 to 2.8 mg kg^{-1}, 0.5 to 80.9 and 0.31 to 2.17 mg kg^{-1} in pomegranate-growing soils of Maharashtra.

DTPA-Zn positively correlated with EC (r = 0.462), CEC (r = 406), sand (r = 0.489), Mn (r = 0.438), Cu (r = 0.070) and negatively correlated with pH (r = 0.026), OC (r = 0.238), $CaCO_3$(r = 0.029), silt (r = 0.491), clay (r = 0.064), ESP (r = 0.506), Fe (r = 0.259), (Appendix II).

Data related to DTPA-Cu (Table 4.4) gave an idea that surface horizons of pomegranate-growing P1, P3, P5 and P7 had relatively higher content than the corresponding sub-surface but distribution pattern of DTPA-Cu was in reverse order for associated crop barring P2. Highest DTPA-Cu (4.4 mg kg^{-1}) was noticed in sub-surface horizon of P6 while lowest was linked to Bw horizon of P7. Pawar et al. (2014), Marathe et al. (2016) and Patil (2017) reported DTPA-Cu in the range of 2.0 to 5.3 mg kg^{-1}, 0.2 to 29.9 and 4.5 to 17.2 mg kg^{-1} in pomegranate-growing soils of Maharashtra.

DTPA-Cu positively correlated with OC (r = 0.318), clay (r = 0.539*), CEC (r = 0.315), Fe (r = 0.259) and negatively correlated with pH (r = 0.695**), EC (r = 0.306), $CaCO_3$ (0.008), sand (r = 0.126), silt (r = 0.472), CEC (r = 0.315), (Appendix II).

4.5 Nutrient concentration in leaves

Leaf analysis is used as primary indicator of nutrient of orchad whiles the soil analysis as nutrient source available to the plant.

4.5.1 Macronutrients in leaves

The concentration of total nitrogen (Table 4.4) in the leaves of pomegranate at different sites (P1, P3, P5 and P7) varied from 1.6 (P3) to 2.2 (P7) per cent. The Velapur site (P1) and Bhalwani (P5) had leaf-N to the tune of 1.8 to 1.9 per cent respectively. Raghupathi and Bhargava (1998) reported that total nitrogen in the leaves of pomegranate of Bijapur district, Karnataka ranged from 0.91 to 1.66 per cent. Raj-Kumaret al. (2010) reported that total N ranged from 0.92 to 1.05 per centin the leaves of pomegranate cv. Ganesh orchards of Bikaner district, Rajasthan. Pawar et al. (2014), Marathe et al. (2016) and Patil (2017) found total leaf- N in the range of 1.18 to 2.57, 0.42 to 2.74 and 1.61 to 3.39 per cent respectively in pomegranate-growing soils of Maharashtra.

The total phosphorus content of pomegranate leaves at different sites (P1, P3, P5 and P7) varied from 0.11 (P3) to 0.20 (P7) percent. The leaves of P1 and P5 sites had 0.19 and 0.15 per cent leaf-P, respectively. Raghupathi and Bhargava (1998) reported that total phosphorus in the leaves of pomegranate of Bijapur district, Karnataka ranged from 0.12 to 0.18 per cent. Raj-Kumaret al. (2010) observed that leaf-P ranged from 0.18 to 0.27 per cent in the leaves of pomegranate *cv*. Ganesh orchards of Bikaner district, Rajasthan. Pawar et al. (2014), Marathe et al. (2016) and Patil (2017) reported total phosphorus in the range of 0.12 to 0.15, 0.023 to 0.282 and 0.04 to 1.25 per cent respectively in pomegranate-growing soils of Maharashtra.

The concentration of total potassium (Table 4.4) in the leaves of pomegranate at different sites (P1, P3, P5 and P7) varied from 0.36 to 0.63 per cent. The lowest amount of total potassium (0.36 per cent) was recorded in leaves at P1 site (Velapur village) whereas, highest amount of total potassium (0.63 per cent) was observed in leaves collected from Supli village (P7). Raghupathi and Bhargava (1998) reported that potassium concentration in the leaves of pomegranate of Bijapur district, Karnataka ranged from 0.61 to 1.59 per cent. Raj-Kumaret al. (2010) reported that K content ranged from 1.39 to 1.58 per centin the leaves of pomegranate cv. Ganesh orchards of Bikaner district, Rajasthan. Pawar et al. (2014), Marathe et al. (2016) and Patil (2017) reported leaf-K in the range of 0.72 to 1.41, 0.32 to 1.27 and 1.62 to 9.98 per cent respectively in pomegranate-growing soils of Maharashtra.

4.5.2 Micronutrients in leaves

Pomegranate grown at different sites (P1, P3, P5 and P7) had leaf-Fe ranging from 47.2 to 68.9 mg kg^{-1}**.** Lowest concentration of leaf-Fe (47.2 mg kg^{-1}) was noticed at P5 site (Bhalwani village). Highest content i.e. 68.9 mg kg^{-1} leaf-Fe was recorded at P1 site (Velapur village). Pawar et al. (2014), Marathe et al. (2016) and Patil (2017) reported leaf-Fe in the range of 96.0 to 132.4, 94.7 to 194.7 and 153.0 to 282.0 mg kg^{-1} respectively in pomegranate-growing soils of Maharashtra.

Total Mn content (Table 4.4) in the leaves of pomegranate at different sites (P1, P3, P5 and P7) ranged from 7.8 to 9.8 mg kg^{-1}**.** Lowest leaf-Mn concentration (7.8 mg kg^{-1}) was found at P3 (Adatmala) and pedon 7(Supli) sites. Velapur site (P1) had highest leaf-Mn (9.8 mg kg^{-1}). Pawar et al. (2014), Marathe et al. (2016) and Patil (2017) reported leaf-Mn in the range of 21.4 to 54.4, 16.2 to 70.5 and 51.0 to 86.0 mg kg^{-1} respectively in pomegranate-growing soils of Maharashtra.

Zinc concentration (Table 4.4) in the leaves of pomegranate at different sites (P1, P3, P5 and P7) ranged from 1.8 (P5) to 7.9 (P1) mg kg^{-1}. Pawar et al. (2014), Marathe et al. (2016) and Patil (2017) reported leaf-Zn in the range of 20.5 to 29.3, 24.4 to 59.5 and 6.1 to 24.8 mg kg^{-1} respectively in pomegranate-growing soils of Maharashtra.

The leaves of pomegranate at different sites (P1, P3, P5 and P7) had copper concentration ranging from 5.1 to 7.4 mg kg^{-1}. Lowest and highest leaf-Cu were noticed at P5 and P3 respectively. Pawar et al. (2014), Marathe et al. (2016) and Patil (2017) reported that leaves of pomegranate had 83.5 to 158.5, 8.0 to 78.1 and 6.5 to 37.0 mg kg^{-1} leaf-Cu respectively in pomegranate-growing soils of Maharashtra.

Table 4.5 Nutrient status of leaf (Proposed by IIHR Banglore) and leaf nutrient status of pomegranate-growing leaves in study area

Rating						Pedons			
Nutrients	**Deficient**	**Medium**	**Sufficient**	**High**	**Very high**	**Velapur P1**	**Adatmala P3**	**Bhalwani P5**	**Supli P7**
N (%)	< 0.54	0.54 - 0.90	0.91 - 1.66	1.67 - 2.04	> 2.04	1.8 (High)	1.6 (Sufficient)	1.9 (High)	2.2 (Very high)
P (%)	< 0.09	0.09 - 0.11	0.12 - 0.18	0.19 - 0.21	> 0.21	0.19 (High)	0.11 (Medium)	0.15 (Sufficient)	0.20 (High)
K (%)	< 0.20	0.20 - 0.60	0.61 - 1.59	1.60 - 2.26	> 2.26	0.36 (Medium)	0.42 (Medium)	0.44 (Medium)	0.63 (Sufficient)
Fe (mg kg^{-1})	< 34	34 - 70	71 - 214	215 -286	> 2.65	68.9 (Medium)	52.5 (Medium)	47.2 (Medium)	59.4 (Medium)
Mn (mg kg^{-1})	< 15	15 - 28	29 - 69	70-119	> 119	9.8 (Deficient)	7.8 (Deficient)	8.0 (Deficient)	7.8 (Deficient)
Zn (mg kg^{-1})	< 8	8 - 13	14 - 72	73 - 94	> 94	7.9 (Deficient)	5.6 (Deficient)	1.8 (Deficient)	5.9 (Deficient)
Cu (mg kg^{-1})	< 7	7 - 28	29 - 72	73 - 94	> 94	5.9 (Deficient)	7.4 (Deficient)	5.1 (Deficient)	5.7 (Deficient)

4.6 Soil Classification (Soil Taxonomy)

Soil Taxonomy is a comprehensive classification system in which the individual soils are grouped into classes lower categories (e.g. soil series) which are further grouped into classes of higher categories (e.g. soil orders). The lower categories are defined by a large number of differentiating characteristics and higher categories by few differentiating characteristic. Within each class, there is a central core or nucleus to which the individual members are related in varying degree. It is called the central concept or an idealized which typified the class.

Based on morphological, physical and chemical properties, the pedons are under study have been classified as per Keys to Soil Taxonomy (Soil Survey Division Staff, 2006).

All the pedons are associated with ustic and hyperthermic, soil moisture and temperature regime respectively and had ochric epipedon.

Pedon P1, P2, P3 and P4 (Table 4.6) had altered horizon 15 cm or more (cambic horizon) and hence placed in order Inceptisol and Ustept sub-order owing to ustic moisture regime associated with these pedons. As these pedons do not have duripan, calcic horizon, base saturation less than 60 per cent etc and hence grouped under Haplustept great group. These pedons do not possess the required characteristics for their placement in subgroup namely Arid Lithic, Lithic, Udertic, Torrertic, Vertic, Aridic, Vitrandic, Anthraquic, Aquic, Oxyquic, Oxic, Lamellic, Torrifluventic, Udifluventic, Fluventic, Gypsic, Haplocalcidic, Calcic udic, Calcic, Aridic and Dystric Haplustepts and keyed out as Typic Haplustept at sub-group level. At family level these pedons are classified as loamy, smectite, hyperthermic Typic Haplustept as these pedons had less than 35 per cent clay associated shallow family (underlain by weathered basalt within 50 cm) and pedon 3 grouped under clayey textural family (>35% clay) with smectitic mineralogy. The CEC/Clay ratio (>0.77) also justifies its mineralogy as smectitic.

Table 4.6 Classification of soils of study area

Pedon	Order	Sub-order	Great-group	Sub-group	Family
Pedon 1	Inceptisol	Ustept	Haplustept	Typic Haplustept	Loamy, smectite, hyperthermic Typic Haplustept
Pedon 2	Inceptisol	Ustept	Haplustept	Typic Haplustept	Loamy, smectite, hyperthermic Typic Haplustept
Pedon 3	Inceptisol	Ustept	Haplustept	Typic Haplustept	Clayey, smectite, hyperthermic Typic Haplustept
Pedon 4	Inceptisol	Ustept	Haplustept	Typic Haplustept	Loamy, smectite, hyperthermic Typic Haplustept
Pedon 5	Entisol	Orthent	Ustorthent	Typic Ustorthent	Loamy-skeletal, smectite, hyperthermic Typic Ustorthent
Pedon 6	Entisol	Orthent	Ustorthent	Typic Ustorthent	Loamy-skeletal, smectite, hyperthermic Typic Ustorthent
Pedon 7	Entisol	Orthent	Ustorthent	Typic Ustorthent	Loamy, smectite, hyperthermic Typic Ustorthent
Pedon 8	Entisol	Orthent	Ustorthent	Typic Ustorthent	Clayey, smectite, hyperthermic Typic Ustorthent

Pedon P5, P6, P7 and P8 do not meet the requirement of orders (Gelisols, Histisols, Spodosols, Andisols, Oxisols, Vertisols, Aridisols, Ultisols, Mollisols, Alfisols and Inceptisols) further it does not meet the requirement of sub-order Aquents, Arents, Psamments, Fluvents and hence it is keyed out as Orthent. Presence of Ustic moisture regime, pedons have classified under great group Ustorthent. Pedon 5 and 6 having more than 35 per cent coarse fragment (v/v), less than 35 per cent clay in control section (w/w) in fine earth fractions, it is classified as loamy-skeletal at textural family class with smectite mineralogy class. Pedon 7 classified under loamy textural family ($<$ 35% clay) whereas pedon 8 classified under clayey textural family class content (>35% clay). Both pedon (P7 and P8) having more smectite content by weight than any other single kind of charge mineral, hence it was categorized in smectitic mineralogy class. The CEC/Clay (0.69) ratio also justifies, their mineralogy as smectitic. The presence of hyperthermic temperature compelled its (P7 and P8) placement as Loamy, smectitic, hyperthermic Typic Ustorthent and Clayey, smectitic, hyperthermic Typic Ustorthent, respectively.

4.7 Soil Suitability Assessment

First of all**,** the weighted mean of soil physical and chemical properties was determined (Tables 4.7 and 4.8) for the suitability assessment of the pomegranate growing and associated soils. As per the modified Sys method (Naidu et al. 2006) the landscape and the mean values of soil properties (Table 4.9) were compared with the requirements of pomegranate crop (Table 4.10).

Table 4.7: Physical Properties of soil (weighted mean)

Depth (cm)	Particle-size distribution			B.D. (Mg m^{-3})	Moisture retention (%)		AWC (%)	Textural class
	Sand (%)	Silt (%)	Clay (%)		33 kPa	1500 kPa		
Pedon1 Velapur : Pomegranate-growing soil (Loamy, smectite, hyperthermic Typic Haplustept)								
0 – 35	28.8	50.1	21.1	1.5	24.5	13.2	11.3	sil
Pedon 2 Velapur : Associated crop land (Loamy, smectite, hyperthermic Typic Haplustept)								
0 – 38	26.8	47.0	26.2	1.6	27.4	16.7	10.7	l
Pedon3 Adatmala : Pomegranate-growing soil (Clayey, smectite, hyperthermic,Typic Haplustept)								
0 – 37	23.4	40.2	36.4	1.5	33.4	20.0	13.4	cl
Pedon 4 Adatmala : Associated crop land (Loamy, smectite, hyperthermic Typic Haplustept)								
0 – 38	34.5	37.1	28.4	1.4	28.2	16.9	11.3	cl
Pedon 5 Bhalwani : Pomegranate-growing soil (Loamy-skeletal, smectite, hyperthermic Typic Ustorthent)								
0 – 26	19.6	49.3	31.1	1.5	30.9	19.4	11.5	sicl
Pedon 6 Bhalwani : Associated crop land (Loamy-skeletal, smectite, hyperthermic Typic Ustorthent)								
0 – 28	36.3	41.7	25.6	1.6	24.5	15.3	9.2	l
Pedon 7 Supli : Pomegranate growing soil(Loamy, smectite, hyperthermic Typic Ustorthent)								
0 – 19	10.5	68.3	27.2	1.6	25.7	11.4	14.3	sicl
Pedon 8 Supli : Associated crop land (Clayey, smectite, hyperthermic Typic Ustorthent)								
0 – 16	9.5	32.7	51.8	1.5	41.7	25.9	15.8	c

Table 4.8: Chemical Properties of soil (weighted mean)

Depth (Cm)	pH (1:2.5)	EC (dSm^{-1})	OC (%)	$CaCO_3$ (%)	Extractable Bases cmol (p^+) kg^{-1}					CEC cmol (p^+)kg^{-1}	ESP	EMP	Exch Ca:Mg ratio	Base Saturation (%)	CEC/ Clay ratio
					Ca^{++}	Mg^{++}	Na^+	K^+	Sum						
Pedon 1 Velapur : Pomegranate growing soil (Loamy, smectite, hyperthermic Typic Haplustept)															
0 – 35	8.1	0.5	0.2	1.2	15.4	1.4	1.0	0.5	18.2	19.2	5.1	7.2	11.3	95.0	0.9
Pedon 2 Velapur : Associated crop land (Loamy, smectite, hyperthermic Typic Haplustept)															
0 – 38	8.2	0.5	0.2	1.3	16.5	1.5	0.8	0.3	19.0	20.0	4.0	7.5	12.3	95.2	0.8
Pedon 3 Adatmala : Pomegranate growing soil(Clayey, smectite, hyperthermic Typic Haplustept)															
0 − 37	8.2	0.2	0.2	1.0	22.6	1.7	0.8	0.4	25.4	26.4	2.9	6.4	13.3	96.1	0.7
Pedon 4 Adatmala : Associated crop land (Loamy, smectite, hyperthermic Typic Haplustept)															
0 – 38	8.0	0.5	0.3	1.1	22.3	3.0	0.5	0.4	26.2	27.2	1.9	11.0	7.6	96.1	1.0
Pedon 5 Bhalwani : Pomegranate growing soil (Loamy-skeletal, smectite, hyperthermic Typic Ustorthent)															
0 – 26	7.9	0.3	0.3	0.8	14.8	2.5	0.5	0.3	18.1	19.1	2.4	13.2	5.9	95.2	0.6
Pedon 6 Bhalwani : Associated crop land (Loamy-skeletal, smectite, hyperthermic Typic Ustorthent)															
0 – 28	7.7	0.1	0.3	1.7	17.0	2.8	0.9	0.2	20.9	21.9	4.3	12.7	6.3	95.4	0.9
Pedon 7 Supli : Pomegranate growing soil(Loamy, smectite, hyperthermic Typic Ustorthent)															
0 – 19	8.2	0.2	0.4	1.4	11.4	4.8	1.2	0.3	17.7	18.7	6.5	25.7	2.4	94.6	0.7
Pedon 8 Supli : Associated crop land (Clayey, smectite, hyperthermic Typic Ustorthent)															
0 − 16	7.9	0.4	0.5	2.7	21.0	5.9	1.5	0.8	29.2	30.2	5.0	19.3	3.6	96.6	0.6

Table 4.9: Landscape and soil characteristics of the soil pedons

Characteristics	Typic Haplustept (P1)	Typic Haplustept (P2)	Typic Haplustept (P3)	Typic Haplustept (P4)	Typic Ustorthent (P5)	Typic Ustorthent (P6)	Typic Ustorthent (P7)	Typic Ustorthent (P8)
Soil characteristics								
Slope (%)	1-3	1-3	1-3	1-3	3-8	3-8	1-3	3-8
Flooding	No	No	No	No	No	No	No	No
Drainage	Well	Well	Well	Well	Well (somewhat excessively)	Well (somewhat excessively)	well	Well
Physical soil characteristics								
Texture*	sil	l	cl	cl	sicl	l	sicl	c
Depth(cm)	35	38	37	38	26	28	19	16
Sand *(%)	28.8	26.8	23.4	34.5	19.6	36.3	10.5	9.5
Silt *(%)	50.1	47.0	40.2	37.1	49.3	41.7	68.3	32.7
Clay*(%)	21.1	26.2	36.4	28.4	31.1	25.6	27.2	51.8
Soil fertility characteristics								
pH *	8.1	8.2	8.2	8.0	7.9	7.7	8.2	7.9
CEC*cmol(p^+) kg^{-1}	19.2	20.0	26.4	27.2	19.1	21.9	18.7	30.2
OC*(%)	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.5
CaCO3*(%)	1.2	1.3	1.0	1.1	0.8	1.7	1.4	2.7
Soil salinity and alkalinity								
EC*(%) (dSm^{-1})	0.5	0.5	0.2	0.5	0.3	0.1	0.2	0.4
ESP*(%)	5.1	4.0	2.9	1.9	2.4	4.3	6.5	5.0

∗ Based on weighted mean

Table 4.10: Soil-site suitability criteria (crop requirement) for pomegranate

Soil-site characteristics			Rating			
		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable(S3)	Not suitable (N)
Climatic regime	Mean temperature in growing season	°C	30-34	35-38 25-29	39-40	
Land quality	Land requirements					
Moisture availability	Length of growing period	Days	>150	120-150	90-120	<90
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately to imperfectly drained	Poorly drained	Very poorly drained
Nutrient availability	Texture	Class	sl, cl, l, cl	c, sic, sicl	cl, s, ls	
	pH	1:2.5	5.5-7.5	7.6-8.5	8.6-9.0	
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	< 50
	Coarse fragments	Vol (%)	Nil	15-35	>35	
Soil toxicity	Salinity (EC)	dSm^{-1}	Nil	< 9	> 9	
Erosion hazard	Slope	%	< 3	3-5	5-10	

Source: Naidu et al., 2006

Pomegranate adapts to a wide range of climatic conditions, however, it is well adapted in the areas with optimum temperature of 30-34 ^{o}C, annual rainfall of more than 700 mm and LGP of more than 150 days (Naidu et al., 2006). Pomegranate prefers well drained, sandy loam to deep loamy or alluvial oils. It tolerates salinity upto 9.0 dSm^{-1} and ESP of 6.78. It performs well on gravelly red soils. Presence of lime nodules is favourable. Light black soils with minimum depth of 60 cm also support the crop satisfactorily.

The soil depth of all soil profiles was found to be less than 50 cm, however, presence of weathered materials supports the root development and cultivation of pomegranate with economical crop yield. Hence, the soil depth is not considered as severe limitation for cultivation of pomegranate crop in the study area. Accordingly, as per the soil depth, the soils (Typic Haplustept) represented by soil pedons P1, P2, P3 and P4 were assessed as moderately suitable (S2) for pomegranate, however, the soils (Typic Ustorthent) represented by soil pedons P5, P6, P7 and P8 were found be marginally suitable (S3) (Table 4.11). The results of suitability analysis indicate that the soils of all sites are moderately to marginally suitable for pomegranate due to the limitations of LGP, drainage, texture, pH, soil depth, coarse fragments, and slope. Solapur district having less than 750 mm rainfall (uneven distributed) that poses a very severe limitation for pomegranate cultivation. However, as the farmers cultivate the crop under irrigated condition, the rainfall or LGP criteria may not be a limitation for its cultivation. The lowering of suitability due to pH is also not of much consequence because it is somewhat a dynamic soil properties and can be corrected.

As per criteria of suitability for pomegranate indicate that P1 (pomegranate-growing soil) and P2 (Associated crop land) are moderately suitable with limitations of LGP, soil depth and pH (Table 4.11). Soil pedons P3 (pomegranate-growing soil) and P4 (Associated crop land) are also moderately suitable with limitations of LGP, soil depth, pH and coarse fragments. P5 (pomegranate-growing soil) and P6 (Associated crop land) are marginally suitable with limitations of LGP, soil depth, texture, pH, coarse fragments and slope. P7 (pomegranate-growing soil) and P8 (Associatedcrop land) are marginally suitable with limitations of LGP, soil depth, texture, pH, drainage and slope.

Table 4.11: Soil-site suitability analysis of pomegranate-growing and associated soils

Soil-site characteristics			Soil Pedon							
		Unit	Typic Haplustept (P1)	Typic Haplustept (P2)	Typic Haplustept (P3)	Typic Haplustept (P4)	Typic Ustorthent (P5)	Typic Ustorthent (P6)	Typic Ustorthent (P7)	Typic Ustorthent (P8)
Climatic regime	Mean temperature in growing season	°C	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1
Land quality	Land requirements									
Moisture availability	Length of growing period	Days	S_2	S_2	S_2	S_2	S_3	S_3	S_3	S_3
Oxygen availability to roots	Soil drainage	Class	S_1	S_1	S_1	S_1	S_2	S_2	S_1	S_2
Nutrient availability	Texture*	Class	S_1	S_1	S_1	S_1	S_2	S_1	S_2	S_2
	pH*	1:2.5	S_2	S_2	S_2	S_2	S_2	S_2	S_2	S_2
Rooting conditions	Effective soil depth*	cm	S_2	S_2	S_2	S_2	S_3	S_3	S_3	S_3
	Coarse fragments	Vol %	S_1	S_1	S_2	S_1	S_3	S_3	S_1	S_1
Soil toxicity	Salinity (EC)*	dSm^{-1} (soil)	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1
Erosion hazard	Slope	%	S_1	S_1	S_1	S_1	S_3	S_3	S_1	S_3
Overall suitability rating			S_2 (LGP, soil depth, and pH limitations)	S_2 (LGP, soil depth, and pH limitations)	S_2 (LGP, soil depth, pH, and coarse frag., limitations)	S_2 (LGP, soil depth, and pH)	S_3 (LGP, soil depth, texture, pH, coarse frag. and slope limitations)	S_3 (LGP, soil depth, pH, coarse frag. and slope limitations)	S_3(LGP, soil depth, texture and pH limitations)	S_3 (LGP, soil depth, texture, pH, drainage and slope limitations)

Chapter V

SUMMARY AND CONCLUSIONS

The Pomegranate (*Punica granatum L.*) is one of the most important fruit crop in our country. Pomegranate belongs to genus Punica and the family Punicacea.Solapur district is one of the well-marked belts of pomegranate in Maharashtra having an area 21,433 ha with production of 10,6560 tonnes and productivity of 5 tonnes ha^{-1}.

Trough present investigation, pomegranate-growing soils and associated crop land to characterized, classified evaluated for soil-site suitability so that farmers could be advised. The objectives of study given below.

- To characterise some pomegranate-growing soils of Solapur district.
- To study the nutrient status of pomegranate-growing soils and nutrient concentration in leaves.
- To assess the suitability of landscape and soil characteristics for pomegranate.

To achieve these objectives, 4 sites having orchards and associated soils under crop were selected in Velapur and Adatmala villages in Malshiras tahsil, Bhalwani and Supli villages in Pandharpur tahsil of Solapur district (Maharashtra). The climate of the area is arid and semi-arid tropical with an average annual rainfall of 713 mm and maximum and minimum temperature 40 and 14°C. The general elevation of area ranged from 450 to 600 MSL and slope of 1 to 3 and 3 to 8 per cent. The results of the present investigation have been summarized below.

- All the pedons had their colour in 10YR / 7.5YR / 5YR / 2.5YR, value with 3 to 5and chroma 3 to 8.

- The dominant structure is fine weak to medium moderate subangular blocky structure except Achorizon of P5 (Bhalwani) which had fine weak granular structure.

- P1, P2, P3, P5 and P6 had silt content more than 40 per cent. Supli (P8) had clay content more than 50 per cent. Sand, silt and clay content varied from 9.52 to 40.55, 32.67 to 68.30 and 20.47 to 51.81 per cent respectively.

- In general, bulk density ranged from 1.38 to 1.64 Mg m^{-3} increased with depth.

- Water retained at field capacity (33 kPa) and wilting point (1500 kPa) ranged from 22.64 to 41.69 per cent and 11.38 to 25.91 per cent and the available water content of the soils varied from 8.98 to 15.78 percent with an increasing trend with depth. AWC of the soils positively and significantly correlated with clay (r = 701**).

- The soils are slightly alkaline (pH 7.7) to moderately alkaline (pH 8.3) and in general, increased with depth.

- The EC of all the soils varied from 0.17 to 0.58 dSm^{-1} which is within safe limit.

- The organic carbon varied from 0.19 to 0.49 percent in the soils and has a decreasing trend with depth.

- The soils are calcareous and $CaCO_3$ content of in soils ranged from 0.65 to 2.95 per cent.

- Cation exchange capacity of soils ranged from 17.3 to 30.2 $cmol(p^+)kg^{-1}$ and it did not show any distributional trend with depth.

- Base saturation of soils ranged from 94.2 to 96.6 per cent and there was no definite trend in distribution of base saturation with respect to depth because it is a derived value.

- Exchangeable sodium percentage of soil ranged from 1.7 to 6.5. The ESP was more than 4.0 indicate that these soils may become sodic in future and hence appropriate actions are to be initiated now.

- Available N content in pomegranate-growing soil (P1, P3, P5 and P7) ranged from 114.3 to 134.8 Kg ha^{-1} whereas available N content in associated crop land (P2, P4, P6 and P8) ranged from 116.9 to 142.3 kg ha^{-1} and decreased with depth which was low.

- Available P ranged from 9.4 to 11.4 kg ha^{-1} in pomegranate-growing soils (P1, P3, P5 and P7) and it ranged from 9.1 to 13.6 kg ha^{-1} in associated crop land (P2, P4, P6 and P8) but decreased with depthwhich was low.

- The available K content in pomegranate-growing soil (P1, P3, P5 and P7) ranged from 191.2 to 399.8 kg ha^{-1} whereas in associated crop land (P2, P4, P6 and P8) it fluctuated from 139.0 to 412.8 kg ha^{-1} and decreased with depth which was medium to high.

- DTPA-Fe in surface horizon of pomegranate-growing soil (P1, P3, P5 and P7) was higher than the sub-surface layer and it ranged from 12.1 to 19.6 mg kg^{-1}in different horizons.The associated crop land (P2, P4, P6 and P8) had DTPA-Fe ranging from 12.5 to 17.5 mg kg^{-1}which was sufficient.

- DTPA-Mn was higher in surface horizon of pomegranate-growing soil (P1, P3, P5 and P7) than sub-surface soil and it ranged from 3.6 to 19.0 mg kg^{-1}in different layers of pedons. In associated crop land (P2, P4, P6 and P8) it ranged from 6.3 to 18.5 mg kg^{-1}which was sufficient.

- DTPA-Zn varied from 0.19 to 1.60 mg kg^{-1} in different horizons of peds and decreased down the depth. The associated crop land (P2, P4, P6 and P8) had DTPA-Zn ranging from 0.33 to 1.6 mg kg^{-1}in different layers whichwas deficient to sufficient.

- DTPA-Cu was the range of 2.2 to 4.4 mg kg^{-1}in all the pedons**.** The surface horizons of pomegranate-growing P1, P3, P5 and P7 had relatively higher content of DTPA-Cu than the corresponding sub-surface but its distribution pattern was in reverse order for associated crop barring P2, P4 and P6 which was sufficient.

- The concentration of total nitrogen (Table 4.4) in the leaves of pomegranate at different sites (P1, P3, P5 and P7) varied from 1.6 (P3 site) to 2.2 (P7 site) per cent which was sufficient to very high.

- The total phosphorus content of pomegranate leaves at different sites (P1, P3, P5 and P7) varied from 0.11 (P3) to 0.20 (P7) per cent which was sufficient to high.

- The concentration of total potassium in the leaves of pomegranate at different sites (P1, P3, P5 and P7) varied from 0.36 to 0.63 per cent which was medium to sufficient.

- Pomegranate grown at different sites (P1, P3, P5 and P7) had leaf-Fe ranging from 47.2 to 68.9 mg kg^{-1}. Leaf-Fe content in all pedons are in sufficient quantity.

- Total Mn content in the leaves of pomegranate at different sites (P1, P3, P5 and P7) ranged from 7.8 to 9.8 mg kg^{-1} which was deficient.

- Zinc concentration in the leaves of pomegranate at different sites (P1, P3, P5 and P7) ranged from 1.8 (P5) to 7.9 (P1) mg kg^{-1} which was deficient.

- The leaves of pomegranate at different sites (P1, P3, P5 and P7) had copper concentration ranging from 5.1 to 7.4 mg kg^{-1}. Leaf-Cu content in P1 P2 and P3 was deficient while P3 had sufficient amount of copper.

- P1, P2 and P4 were classified as Loamy, smectite, hyperthermic Typic Haplustept, while P3 was classified as Clayey, smectite, hyperthermic Typic Haplustept. Ustic moisture regime present in P5, P6, P7 and P8, pedons have classified under great group Ustorthent. Pedon 5 and 6 were classified as Loamy-skeletal, smectite, hyperthermic Typic Ustorthent whereas P7 and P8 were classified as Loamy, smectitic, hyperthermic

Typic Ustorthent and Clayey, smectitic, hyperthermic Typic Ustorthent, respectively.

- P1 (pomegranate-growing soil), P2 (associated crop land), P3 (pomegranate-growing soil) and P4 (associated crop land) were found to be moderately suitable with the limitations imposed by LGP, soil depth, pH and coarse fragments while P5 (pomegranate-growing soil), P6 (associated crop land), P7 (pomegranate-growing soil) and P8 (associated crop land) were marginally suitable having limitations imposed by LGP, soil depth, texture, slope, drainage, pH and coarse fragments.

From the study, it can be concluded that

❖ The physical and chemical properties of soils were greatly influenced by site characteristics and weatherability of basalt, parent material.

❖ The suitability rating based on limitation method does not corroboratewith the productivity of pomegranate on different sites because as agro-management practices overrides the suitability and in turn productivity.

❖ The variation in nutrient status in pomegranate-growing *vis-à-vis* soils under crop (associated crop land) is the reflection mainly of agro-managements rather than land use and as such suitability of pomegranate-growing soils and soils under crop/ grassland did not vary significantly due to land use.

❖ The information generated to be used in delineating the potential sites for pomegranate plantation and sustainable management of resources to enhance the crop productivity.

Chapter VI

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1.	S.S.C	2005	First	Amravati Board	General
2.	H.S.C	2007	Second	Amravati Board	Science
3.	B.Sc. (Agri.)	2012	Second	Dr. PDKV, Akola	Agricultural Science

6. Field of interest:

- To work in agricultural research sector in order to find solutions for problems faced by Indian Farmer.
- To work with full devotion in rural development field to improve social and economic standards of farming and other population in my country.

Place : Akola

Date : / /2018 **Signature of Student**

APPENDIX I

DESCRIPTION OF PEDONS

Pedon 1(P1): Velapur (Pomegranate-growing soil)

Location	:	Village:Velapur,Tehsil- Malshiras, District-Solapur, Maharashtra
Latitude:	:	17°47' 35" N
Longitude:	:	75°02' 33"E
Elevation	:	513 m above MSL
Geology	:	Basalt
Landform	:	Plain
Parent material	:	Basalt
Topography	:	Very gently sloping
Slope	:	1-3% (50-150 m)
Drainage	:	Well drained
Run-off	:	Slow
Erosion	:	Slight (bunded)
Ground water depth	:	> 10 m
Flooding	:	No
Climate	:	Semi-arid
Natural vegetation	:	Mango, Banyan, Pipal, Ramphal, Sitaphal, Babul, Neem, Badam, Subabul; Sapota
Land use	:	Pomegranate orchad, Sapota, Onion, Maize (cob,grain fodder), French Bean, Wheat, Sorghum.
Classification	:	Loamy, smectitic, hyperthermic Typic Haplustept

Horizon	Depth (cm)	Description of profile
Ap	0-14	Brown (7.5YR 4/3) to dark brown (7.5YR 3/3) loam; medium moderate sub-angular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; many fine, common medium roots; many fine few medium pores; 5-8 per cent fine gravels; violently effervescent; moderately alkaline (pH 8.1); clear smooth boundary.
Bw	14-35	Dark brown (7.5YR 3/3) silt loam; medium moderate sub-angular blocky structure; slightly hard, friable, sticky and plastic; many very fine, common fine and few medium roots;, many fine, few medium pores; 8-10 per cent coarse and fine gravels; violently effervescent; moderately alkaline (pH 8.1); abrupt smooth boundary.
Cr	35-55 +	……Weathered Basalt with lime nodules and lime powder with violently effervescent.

Pedon 2(P2): Velapur (Associated crop land)

Location	:	Village:Velapur,Tehsil- Malshiras, District-Solapur, Maharashtra
Latitude:	:	$17^{O}47'$ 33" N
Longitude:	:	$75^{O}02'$ 31"E
Elevation	:	513 m above MSL
Geology	:	Basalt
Landform	:	Plain
Parent material	:	Basalt
Topography	:	Very gently sloping
Slope	:	1-3% (300-600 m)
Drainage	:	Well drained
Run-off	:	Slow
Erosion	:	Slight (bunded)
Ground water depth	:	> 10 m
Flooding	:	No
Climate	:	Semi-arid
Natural vegetation	:	Mango, Banyan, Babul, Neem, Badam,
Land use	:	Subabul, Sapota, Custard apple, Wheat, onion, Kharif maize
Classification	:	Loamy, smectitic, hyperthermic Typic Haplustept

Horizon	Depth (cm)	Description of profile
Ap	0-15	Brown (7.5YR 4/3) to dark brown (7.5YR 3/3) loam; medium moderate sub-angular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; few medium, common fine roots; many fine, few medium pores; 3-5 per cent fine gravels; violently effervescent; moderately alkaline (pH 8.0); clear smooth boundary.
Bw	15-38	Dark brown (7.5YR 3/3) loam; medium moderate sub-angular blocky structure; slightly hard, friable, sticky and plastic; fine and very fine few roots ;many fine, few medium pores; 3-5 per cent fine gravels ; violently effervescent; moderately alkaline (pH 8.3); abrupt smooth boundary.
Cr	38-56 +	…….Weathered basalt with lime nodules and lime powder with violent effervescence.

Pedon 3(P3): Adatmala (Pomegranate-growing soil)

Location	:	Village:Adatmala,Tehsil- Malshiras, District- Solapur, Maharashtra
Latitude:	:	$17^{O}47'$ 09” N
Longitude:	:	$75^{O}02'$ 07”E
Elevation	:	519 m above MSL
Geology	:	Basalt
Landform	:	Plain
Parent material	:	Basalt
Topography	:	Very gently sloping
Slope	:	1-3% (300-600 m)
Drainage	:	Well drained
Run-off	:	Slow
Erosion	:	Slight (bunded)
Ground water depth	:	> 10 m
Flooding	:	No
Climate	:	Semi-arid
Natural vegetation	:	Coconut, Mango
Land use	:	Pomegranate orchard (earlier Sugarcane was cultivated on this site), Bottle guard, Pumpkin.
Classification	:	Clayey, smectitic, hyperthermic Typic Haplustept

Horizon	Depth (cm)	Description of profile
Ap	0-15	Reddish brown (5YR 5/4 4/4) clay loam; fine weak subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; common medium many fine roots; many fine common medium pores; 10-15 per cent fine and coarse gravels; strongly effervescent; moderately alkaline (pH 8.1); clear smooth boundary.
Bw	15-37	Reddish brown (5YR 4/4); gravelly clay loam; medium moderate sub-angular blocky structure; slightly hard, very friable, sticky and plastic; common medium, many fine roots; many fine, few medium pores; 15-20 per cent fine and coarse gravels; strong effervescent; moderately alkaline (pH 8.2); abrupt smooth boundary.
Cr	37-58	…..Weathered basalt (perforated) mixed with lime nodules.

Pedon 4(P4): Adatmala (Associated crop land)

Location	:	Village: Adatmala,Tehsil- Malshiras, District- Solapur, Maharashtra
Latitude:	:	$17^{O}47'$ 11" N
Longitude:	:	$75^{O}02'$ 08"E
Elevation	:	517 m above MSL
Geology	:	Basalt
Landform	:	Plain
Parent material	:	Basalt
Topography	:	Very gently sloping
Slope	:	1-3% (300-600 m)
Drainage	:	Well drained
Run-off	:	Slow
Erosion	:	Slight (bunded)
Ground water depth	:	> 10 m
Flooding	:	No
Climate	:	Semi-arid
Natural vegetation	:	Drumstick, Ber
Land use	:	Bottleguard, Sorghum (fodder)
Classification	:	Loamy, smectitic, hyperthermic Typic Haplustept

Horizon	Depth (cm)	Description of profile
Ap	0-14	Reddish brown (5YR 5/3) clay loam; medium weak subangular blocky structure; slightly hard, very friable, sticky and plastic; few medium, common very fine roots;, many fine, few medium pores; 5-8 per cent fine and coarse gravels ; strongly effervescent; moderately alkaline (pH 7.9); clear smooth boundary.
Bw	14-38	Reddish brown (5YR 4/3) clay loam; medium moderate subangular blocky structure; slightly hard, friable, sticky and plastic; common very fine roots; many very fine, few medium pores; 3-5 per cent fine and coarse gravels; strongly effervescent; moderately alkaline (pH 8.0); gradual smooth boundary.
Cr	38-57+	……Weathered Basalt.

Pedon 5 (P5): Bhalwani (Pomegranate-growing soil)

Location	:	Village:Bhalwani,Tehsil- Pandharpur, District- Solapur, Maharashtra
Latitude:	:	17^{O}41' 48" N
Longitude:	:	75^{O}06' 22"E
Elevation	:	518 m above MSL
Geology	:	Basalt
Landform	:	Plateau
Parent material	:	Basalt
Topography	:	Gently sloping plateau
Slope	:	3-8 % (150-300 m)
Drainage	:	Somewhat excessively drained
Run-off	:	Medium
Erosion	:	Moderate
Ground water depth	:	> 10 m
Flooding	:	No
Climate	:	Semi-arid
Natural vegetation	:	Ber, Palas, Babul
Land use	:	Pomegranate orchard
Classification	:	Loamy-skeletal, smectitic, hyperthermic Typic Ustorthent

Horizon	Depth (cm)	Description of profile
Ap	0-13	Red (2.5YR 5/8) gravelly silty clay loam; fine weak granular structure; slightly hard, friable, sticky and plastic; few fine, common very fine roots; many fine pores; 50-60 per cent coarse and fine gravels; strongly effervescent; slightly alkaline (pH 7.8); gradual irregular boundary.
AC	13-26	Red (2.5YR 5/8) gravelly silt loam; fine weak subangular blocky structure; friable, sticky and plastic; few fine, common very fine roots; many fine pores; 60-70 per cent coarse fragments with fine and coarse gravels; strongly effervescent; moderately alkaline(pH 7.9); abrupt smooth boundary.
Cr	26-52+	……Weathered basalt.

Pedon 6(P6): Bhalwani (Associated crop land)

Location	:	Village:Bhalwani,Tehsil- Malshiras, Dist-Solapur, Maharashtra
Latitude:	:	$17^{O}41'$ 52” N
Longitude:	:	$75^{O}06'$ 24”E
Elevation	:	518 m above MSL
Geology	:	Basalt
Landform	:	Plateau
Parent material	:	Basalt
Topography	:	Gently sloping plateau
Slope	:	3-8 % (150-300 m)
Drainage	:	Somewhat excessively drained
Run-off	:	Medium
Erosion	:	Moderate
Ground water depth	:	> 10 m
Flooding	:	No
Climate	:	Semi-arid
Natural vegetation	:	Babul, Neem, Subabul,
Land use	:	Watermelon
Classification	:	Loamy-skeletal, smectitic, hyperthermic Typic Ustorthent

Horizon	Depth (cm)	Description of profile
Ap	0-20	Yellowish red (5YR 4/6) gravelly loam; fine weak subangular blocky structure; slightly hard, friable, sticky and plastic; few medium, common fine, many very fine roots; many fine pores; 50-60 per cent fine and coarse gravels; strongly effervescent; slightly alkaline (pH 7.7); gradual irregular boundary.
AC	20-28	Red (2.5YR 4/8) gravelly clay loam; medium weak subangular blocky structure; friable, sticky and plastic; many very fine roots; many fine pores; 60-70 per cent fine and coarse gravels ; strongly effervescent; slightly alkaline (pH 7.8); abrupt smooth boundary.
Cr	28-55+	…..Weathered basalt.

Pedon 7(P7): Supli (Pomegranate-growing soil)

Location	:	Village:Supli,Tehsil- Malshiras, District-Solapur, Maharashtra
Latitude:	:	17^{O}40' 49" N
Longitude:	:	75^{O}10' 39"E
Elevation	:	493 m above MSL
Geology	:	Basalt
Landform	:	Plain
Parent material	:	Basalt
Topography	:	Very gently sloping
Slope	:	1-3% (50-150 m)
Drainage	:	Well drained
Run-off	:	Slow
Erosion	:	Slight
Ground water depth	:	5-10 m
Flooding	:	No
Climate	:	Semi-arid
Natural vegetation	:	Neem, Subabul
Land use	:	Pomegranate orchard, Wheat, Sugarcane, Ground nut
Classification	:	Loamy, smectitic, hyperthermic Typic Ustorthent

Horizon	Depth (cm)	Description of profile
Ap	0-19	Dark brown (10YR 3/3) silt loam; medium moderate subangular blocky structure; friable, sticky and plastic; few fine, few very fine roots; common medium many fine pores; 3-5 per cent with fine gravels ; strongly effervescent; moderately alkaline (pH 8.2); abrupt smooth boundary.
Cr	19-58+	…..Weathered basalt.

Pedon 8(P8): Supli (Associated crop land)

Location	:	Village:Supli, Tehsil- Malshiras, District-Solapur, Maharashtra
Latitude:	:	$17^{O}40'$ 48" N
Longitude:	:	$75^{O}10'$ 49"E
Elevation	:	492 m above MSL
Geology	:	Basalt
Landform	:	Plain
Parent material	:	Basalt
Topography	:	Gently sloping
Slope	:	3-8 % (50-150 m)
Drainage	:	Well drained
Run-off	:	Medium
Erosion	:	Moderate
Ground water depth	:	5-10m
Flooding	:	No
Climate	:	Semi-arid
Natural vegetation	:	Ber, Grasses
Land use	:	Mango orchard (old one and dried)
Classification	:	Clayey, smectitic, hyperthermic Typic Ustorthent

Horizon	Depth (cm)	Description of profile
Ap	0-16	Dark brown (10YR 3/3) silty clay; medium strong subangular blocky structure; hard, friable, sticky and plastic; common fine, common very fine roots; many fine few medium pores; 8-10 per cent coarse fragments with fine gravels; slightly effervescent; slightly alkaline (pH 7.8); abrupt smooth boundary.
Cr	16-56+	…..Weathered basalt.

Appendix II Table : Correlationsamong different soil properties

	pH	EC	OC	CaCO3	Sand	Silt	Clay	33 kPa	1500 kPa	AWC	Ca++	Mg++	Na+	K+	total	Base sat.	ESP	EMP	Ca/Mg	CEC	BD	Avail. N	Avail. P	Avail. K	Fe	Mn	Zn	Cu	CEC.CLAY
pH	1	0.116	-0.284	0.435	-0.204	0.417	-0.199	-0.097	-0.254	0.268	-0.136	-0.212	0.182	0.066	-0.181	-0.206	0.335	-0.100	0.268	-0.181	-0.107	-0.390	-0.094	0.226	-0.090	0.279	-0.026	-.695**	0.039
EC		1	-0.049	0.031	0.077	-0.189	-0.004	0.011	-0.024	0.079	0.192	-0.100	-0.178	0.066	0.132	0.140	-0.184	-0.224	0.172	0.132	-0.399	-0.075	0.482	0.148	-0.066	0.282	0.462	-0.306	0.183
OC			1	-0.541	-.543*	-0.193	.727**	.593*	0.453	.604*	0.112	.909**	.603*	0.412	0.487	0.437	0.298	.734**	-.584*	0.487	0.075	.629*	0.281	-0.270	0.476	0.198	-0.238	0.314	-0.461
CaCO3				1	-0.008	-0.419	0.343	0.266	0.186	0.306	0.288	0.305	.583*	0.431	0.439	0.435	0.327	0.065	0.066	0.439	0.185	0.389	0.160	-0.206	0.182	.554*	-0.029	-0.008	0.029
Sand					1	-0.374	-.614*	-.614*	-0.438	-.689**	0.236	-0.516	-0.448	-0.359	-0.014	0.053	-0.361	-.545*	0.301	-0.014	-0.165	-0.103	-0.094	0.289	-0.417	0.072	0.489	-0.126	.846**
Silt						1	-0.480	-0.478	-.581*	-0.048	-.849**	-0.004	0.113	-0.217	-.787**	-.803**	0.494	0.383	-0.181	-.787**	0.425	-.658*	-0.172	-0.274	0.458	-0.332	-0.491	-0.472	-0.142
Clay							1	.960**	.870**	.701**	0.508	.548*	0.337	0.472	.709**	.671**	-0.071	0.264	-0.185	.709**	-0.224	.712**	0.223	0.024	0.039	0.205	-0.064	.539*	-.680**
33 kPa								1	.933**	.677**	0.501	0.444	0.231	0.443	.656*	.596*	-0.158	0.164	-0.128	.656*	-0.228	.628*	0.199	0.018	-0.096	0.148	-0.049	0.493	-.690**
1500 kPa									1	0.366	0.512	0.311	0.107	0.291	.603*	.554*	-0.268	0.023	-0.115	.603*	-0.113	.556*	0.079	-0.079	-0.310	-0.018	-0.093	.668**	-.623*
AWC										1	0.248	0.512	0.377	.550*	0.463	0.406	0.137	0.377	-0.095	0.463	-0.357	0.487	0.353	0.209	0.386	0.418	0.065	-0.090	-0.509
Ca++											1	-0.021	-0.185	0.194	.911**	.931**	-.562*	-0.396	0.343	.911**	-.646*	.657*	0.246	.603*	-.568*	0.492	.552*	0.245	0.168
Mg++												1	.537*	0.262	0.383	0.311	0.315	.904**	-.814**	0.383	0.076	.548*	0.149	-0.262	0.407	-0.007	-0.223	0.207	-0.330
Na+													1	0.447	0.117	0.085	.884**	0.474	-0.358	0.117	0.364	0.146	-0.358	-0.483	0.442	0.176	-0.423	0.047	-0.239
K+														1	0.353	0.317	0.212	0.063	0.087	0.353	-0.251	0.358	0.212	-0.119	0.418	.550*	0.155	0.280	-0.202
total															1	.990**	-0.328	-0.011	0.010	1.000**	-.553*	.825**	0.260	0.421	-0.328	0.493	0.406	0.315	0.012
Base sat.																1	-0.346	-0.076	0.074	.990**	-.562*	.808**	0.251	0.464	-0.341	0.502	0.431	0.320	0.049
ESP																	1	0.446	-0.332	-0.328	0.524	-0.244	-0.470	-.544*	0.526	-0.018	-0.506	-0.201	-0.131
EMP																		1	-.879**	-0.011	0.255	0.256	0.046	-0.336	.555*	-0.225	-0.381	0.041	-0.353
Ca/Mg																			1	0.010	-0.252	-0.267	0.173	0.396	-0.293	0.478	0.258	-0.225	0.229
CEC																				1	-.553*	.825**	0.260	0.421	-0.328	0.493	0.406	0.315	0.012
BD																					1	-0.474	-0.451	-.841**	0.220	-0.530	-.826**	0.030	-0.206
Avail. N																						1	0.302	0.355	-0.037	0.349	0.429	0.502	-0.180
Avail. P																							1	0.347	0.228	.545*	0.372	-0.119	-0.083
Avail. K																								1	-0.371	0.452	.714**	-0.221	0.266
Fe																									1	0.115	-0.259	-0.077	-0.283
Mn																										1	0.438	-0.219	0.235
Zn																											1	-0.070	0.473
Cu																												1	-0.410
CEC.CLAY																													1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).