Characterization and classification of orange growing soils in Nagpur district of Maharashtra and the effect of soil parameters on crop performance

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Abstract

Out of twelve pedons studied, five representative pedons of major orange growing soils in Nagpur district of Maharashtra were selected in a transect. These soils fall under agro-ecological subregion 10.2 (K4Cd5). Physiographically these soils occur on foot slopes (pedon 1), upper sectors (pedon 2), middle sectors (pedon 3), lower sectors (pedon 4) of main valley and on narrow flood plain (pedon 5). The soils of foot slopes are situated at an elevation of 520 m above MSL and the soils on flood plain are located at 300 m above MSL. The soils on higher element of topography are moderately deep, well drained and gravelly and the soils in lower element of topography are moderately well drained, deep and clayey. The pH of the soils ranges from 8.1 to 8.4 and the CEC ranges from 30.7 to 67.0 cmol (p+) kg^{-1}. Majority of the soils show calcareousness which ranges from 4.4 to 26.0 per cent. These soils are classified as Typic Haplustepts (pedon 1), Vertic Haplustepts (pedon 2 and 3), Udic Haplusterts (pedon 4) and Typic Haplusterts (pedon 5). A multivariate yield model suggested the combined effect of soil parameters on the performance of the orange orchards in the area.

Additional keywords : Multivariate yield model, soil parameters, regression analysis.

Introduction

Orange (*Citrus reticulata Blanco*) is one of the most important commercial fruit crops grown in different parts of the world. United States of America ranks first and India ranks fifth in its cultivation. In India, Maharashtra state ranks first in area and production of oranges followed by Punjab, Karnataka, Andhra Pradesh, and Tamil Nadu.

Orange is an evergreen sub-tropical fruit crop grown in different soil and climatic conditions, due to which there is a wide variation in performance of the crop. Orange is successfully grown in semi-arid to subhumid areas of Maharashtra. The performance of orange orchards in Nagpur district was directly related to the physical and the chemical characteristics of the soils influencing the plant growth (Kakde 1956). The drainage forms the most important factor for growth of orange in Nagpur district (Pathak 1934). The roots of orange trees penetrate into the soil quite deep, however most of its feeder roots are distributed within one metre of the soil. The clayey soils of Nagpur, underlain by *murrum* (partly weathered rock) layer, that facilitate a good drainage, are quite suitable for citrus cultivation, especially for mandarin. The inferior performance of many gardens in Vidarbha appeared to correlate with the improper selection of soil-site conditions (Joshi 1957; Babrekar 1962; Kalbande *et al.* 1983). In order to study the characteristics of the major soils and their influence on yield performance, the present investigation was undertaken.

Materials and methods

The study area, a part of Nagpur district (MS) (Fig. 1) falls in the agro-ecological subregion 10.2 (K4 Cd5) (Sehgal 1995) and is located between 21°11' to 21°20' N latitudes and 78°45' to 79°00'E longitudes. The physiography of Nagpur district indicates different micro units of landforms with different soils developed predominantly on basaltic materials. The climatic environment comprises tropical dry subhumid with hot and dry summer with mild winter. The mean annual rainfall of last eleven years is 983.3 mm, about 90 per cent of which is received during June to September and the mean annual temperature is 26.4°C. The soil temperature regime is hyperthermic and the moisture regime is Ustic.

The orange growing soils situated on foot slopes (P1); on upper sectors of main valley (P2); on middle sectors of main valley (P3); on lower sectors of main valley (P4) and on narrow flood plain (P5) were selected in a transect (Fig. 1). Horizonwise soil samples were collected and processed. These soils were studied for their physical and chemical properties (Black 1965) by standard procedures. The average yield data from randomly selected trees in each orchard at different locations was collected. The soil characters and yield data were compared through a multivariate step down regression model to decipher the influence of soil-site parameters on the crop performance.

Results and discussion

Geomorphology of the area : The study area has been divided into various geomorphic units viz. highly dissected and denuded plateau spurs, foot slopes, isolated mounds, main valley-side slopes (upper, middle and lower sectors) and narrow flood plains.

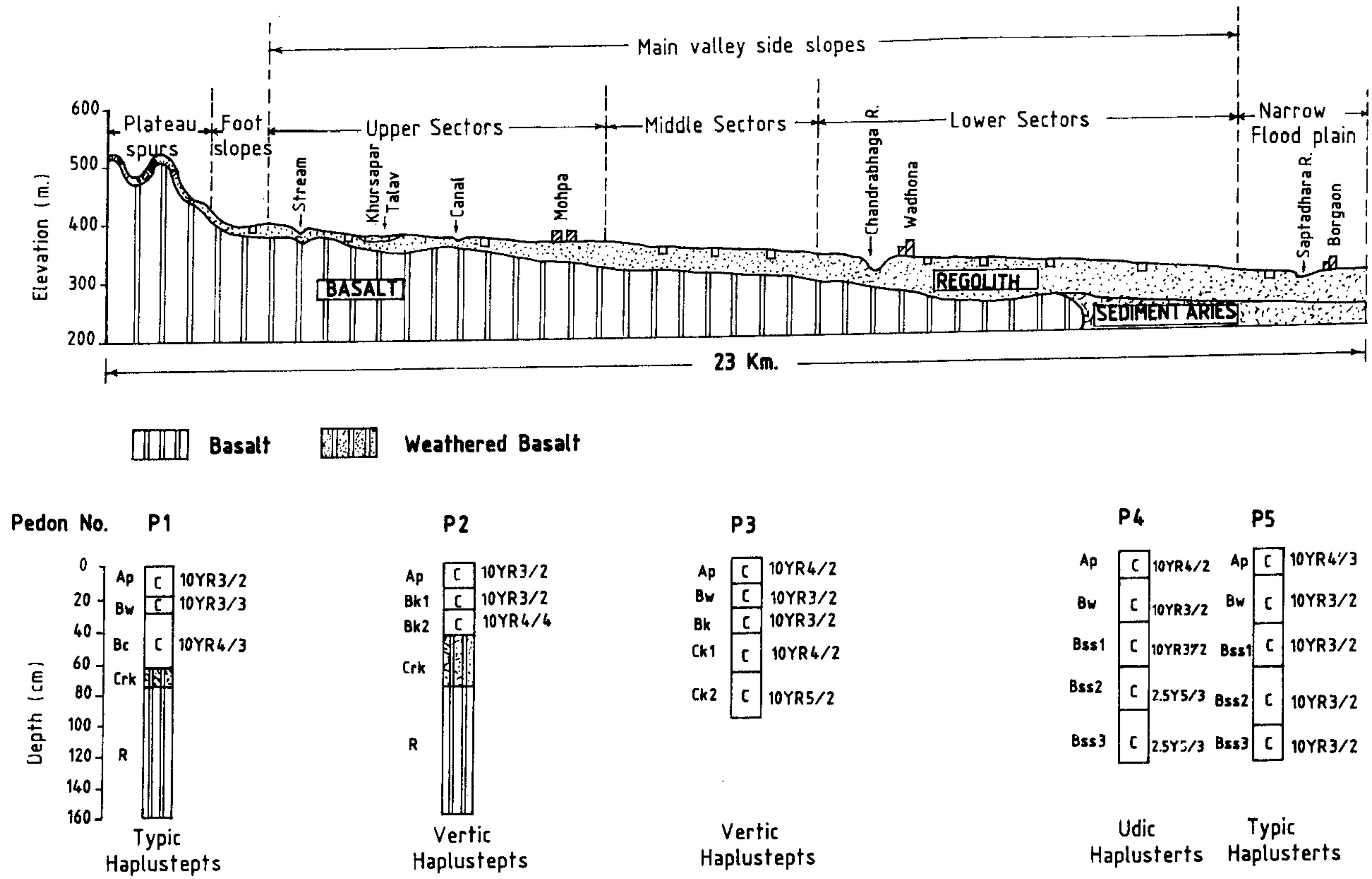

Fig. 1. Landform-soil relationship.

The maximum elevation of 520 m above MSL is on the western most portion and the minimum elevation of 300 m above MSL on the far eastern part of the study area.

Morphological characteristics : The soils of the pedon 1 are gravelly clay, moderately deep, well drained and calcareous occurring on very gently sloping (1-3%) foot slopes. The soils of pedon 2 are clayey, moderately deep, well drained, and calcareous occurring on very gently sloping (1-2%) upper sectors of main valley-side slopes. The soils of pedon 3 are clayey, deep to very deep, moderately well drained and calcareous occurring on level to nearly level (0-1%) middle sectors of main valley side slopes (Table 1). The soils of pedon 4 are very deep and moderately well drained, clayey, occurring on nearly level (0-1%) lower sectors of main valley-side slopes. Whereas the soils of pedon 5 are very deep, moderately well drained, non-calcareous, clayey and occur on level to nearly level (0-1%) narrow flood plains.

The colour of the soil varies from brown to very dark grayish brown. Pedon 1 is brown to dark brown colour and the pedon 2 is very dark grayish brown due to oxidising conditions favouring the release of iron. In the pedons 3, 4 and 5, the colour ranges from dark brown to very dark grayish brown. In pedon 4 the colour changes with depth from dark grayish brown to grayish brown and finally to olive brown which may be due to reducing conditions existing in these layers because of high and continuous moisture (Gaikawad *et al.* 1974 and Singh *et al.* 1994). Very dark grayish brown colour in pedons 4 and 5 may be due to the reduction of the free iron oxides released during weathering from the parent rock and the formation of organo-mineral complexes. Texturally all the pedons are similar except pedon 1 which is gravelly clay due to its topographic position. The surface and subsurface layers of all the pedons show subangular blocky structure except subsurface layers of pedons 4 and 5 exhibiting angular blocky structure. Well developed pressure faces and slickensides were observed in pedons 4 and 5 that occupy the lower sector of the main valley and narrow flood plain, respectively. On critical examination of the data (Table 1) consistency indicates that the stickiness and plasticity increase with soil depth in all pedons which may be attributed to the increase in fine clay and there is a reverse trend in pedon 1. The lime is in powdery form and present in subsurface layers of pedons 1, 2 and 3.

Table 1. Morphometric characteristics of soils

Horizon	Depth (cm)	Matrix colour Munsell-notation	Text-ure	Structure			Consistence			Porosity		Roots		Nodules (conca)		Effe rves cence	Other features	Additional notes
		Moist		S	G	TY	D	M	W	S	Q	S	Q	S	Q			
							Pedon 1 (Foot slopes)											
Ap	0–17	10YR 3/2	gc	m	2	sbk	h	fr	sp	vf	c	f	f	f	c	es	–	Quartz pieces spread over the surface
Bw	17–28	10YR 3/3	gc	m	2	sbk	sh	fr	sp	vf	f	f	f	f	m	ev	–	Powdery lime
BC	28–61	10YR 4/3	gc	m	1	sbk	l	vfr	sspo	vf	c	–	–	f	m	ev	–	Powdery lime
Crk	61–74	Weathered basalt																Powdery lime with weathered basalt
							Pedon 2 (Main valley side slopes, Upper sector)											
Ap	0–13	10YR 3/2	c	m	2	sbk	h	vr	sp	f	m	c	c	f	f	e	–	Cracks seen; roots observed in horizontal position
Bk1	13–28	10YR 3/2	c	m	2	sbk	h	fi	sp	f	c	f	c	f	m	es	–	
Bk2	28–43	10YR 4/4	c	m	2	sbk	h	fr	sp	f	c	c	f	f	m	es	–	Powdery lime
Crk	43–76	Weathered basalt																
							Pedon 3 (Main valley side slopes, Middle sector)											
Ap	0–15	10YR 4/2	c	m	2	sbk	h	fr	sp	f	c	f	c	f	c	es		
Bw	15–30	10YR 3/2	c	m	2	sbk	h	fr	sp	f	c	f/m	c/f	f	c	es	–	
Bk	30–45	10YR 3/2	c	m	2	sbk	vh	fi	sp	f	c	f/vf	f	f	m	ev	pf	
Ck1	45–70	10YR 4/2	c	m	2	sbk	h	fi	sp	f	m	–	–	c	m	ev	–	Powdery lime
Ck2	70–100+	10YR 5/2	c	massive	h	fi	sp	f	m	–	–	c	m	ev	–			Powdery lime
							Pedon 4 (Main valley side slopes, Lower sector)											
Ap	0–16	10YR 4/2	c	m	2	sbk	h	fr	sp	f	c	f/c	f	f	c	es	–	
Bw	16–43	10YR 3/2	c	m	2	sbk	h	fr	sp	f	c	f/c	f	f	f	es	pf	
Bss1	43–72	10YR 3/2	c	c	3	abk	vh	fi	sp	f	f	–	–	f	f	es	ss	
Bss2	72–100	2.5Y 5/3	c	c	3	abk	vh	vfi	vsvp	vf	f	–	–	f	f	es	ss	
Bss3	100–135+	2.5Y 4/3	c	c	3	abk	vh	vfi	vsvp	vf	f	–	–	f/m	c	ev	ss	
							Pedon 5 (Narrow flood plain)											
Ap	0–15	10YR 4/2	c	m	2	sbk	h	fr	sp	f	c	f	c	f	f	–	–	
Bw	15–45	10YR 3/2	c	m	2	sbk	h	fr	sp	f	f	f/c	f	f	f	–	pf	
Bss1	45–72	10YR 3/2	c	c	3	abk	vh	fi	vsvp	vf	f	f/c	f	f	f	–	ss	
Bss2	72–112	10YR 3/2	c	c	3	abk	vh	vfi	vsvp	vf	f	vf	f	f	f	–	ss	
Bss3	112–135+	10YR 3/2	c	c	3	abk	vh	vfi	vf	f	–	–	f	f	–	ss		

Abbreviations are as per Field Manual (Sehgal *et al.* 1989).

Table 2. Physical properties of soils

Hori-zon	Depth (cm)	Coarse frag-ments (>2.0 mm)	Particle size class and diameter (mm)			Text-ure	Bulk density (Air dry) Mg m^{-3})	Moisture retention at		AWC (%)	PAWC (mm/)
			Sand (2.0-0.05)	Silt (0.05-0.002)	Clay (<0.002)			33 kPa (FC)	1500 kPa (PWP)		
			--------------%------------					--------%------			
Pedon 1 : Typic Haplustepts											
Ap	0–17	18.0	10.6	38.5	50.9	gc	1.65	44.2	34.7	9.5	29.1
Bw	17–28	28.6	20.1	27.5	52.4	gc	1.68	38.9	30.9	8.0	
BC	28–61	34.0	22.2	28.0	49.8	gc	1.69	36.3	27.3	9.0	
Crk	61–74	Weathered basalt mixed with powdery lime									
Pedon 2 : Vertic Haplustepts											
Ap	0–13	7.1	15.4	24.6	60.0	c	1.70	42.2	27.8	14.4	65.8
Bk1	13–28	2.1	13.1	23.8	63.1	c	1.74	41.1	30.2	10.9	
Bk2	28–43	8.6	11.6	33.4	55.0	c	1.67	42.9	27.7	15.2	
Crk	43–76	Weathered basalt mixed with lime									
Pedon 3 : Vertic Haplustepts											
Ap	0–15	14.3	7.3	20.7	72.0	c	1.69	41.9	29.2	12.7	64.5
Bw	15–30	7.1	6.4	21.2	72.4	c	1.76	41.0	29.4	11.6	
Bk	30–45	2.1	6.1	23.5	70.4	c	1.75	44.3	31.8	12.5	
Ck1	45–70	17.5	15.9	26.8	57.3	c	1.69	25.7	15.0	10.7	
Ck2	70–100+	19.7	20.4	28.5	51.1	c	1.67	25.0	15.6	9.4	
Pedon 4 : Udic Haplusterts											
Ap	0–16	1.0	4.8	31.4	63.8	c	1.70	41.7	25.7	16.0	222.3
Bw	16–43	2.1	4.2	33.4	62.4	c	1.73	43.4	29.2	14.2	
Bss1	43–72	1.7	4.0	30.1	65.9	c	1.77	46.7	31.3	15.4	
Bss2	72–100	2.1	3.0	32.0	65.0	c	1.81	47.7	30.1	17.6	
Bss3	100–135+	2.1	5.3	32.7	62.0	c	1.74	45.0	32.5	12.5	
Pedon 5 : Typic Haplusterts											
Ap	0–15	2.9	2.8	22.2	75.0	c	1.73	40.6	32.4	8.2	201.3
Bw	15–45	0.4	2.9	17.7	79.4	c	1.79	52.8	37.2	15.6	
Bss1	45–72	0.7	2.4	18.8	78.8	c	1.83	58.2	40.8	17.4	
Bss2	72–112	1.0	2.6	18.4	79.0	c	1.89	56.0	41.3	14.7	
Bss3	112–135+	1.0	2.6	18.3	79.1	c	1.92	60.2	43.0	17.2	

Physical and chemical characteristics : Some of the physical and chemical properties are presented in table 2. The relative proportion of coarse fragments appears to be high in soils (pedon 1) developed on foot slopes (18.0 to 34.0%) as compared to soils (pedon 2, 3 & 4) of the main valley (1.0 to 19.7%) and (pedon 5) the narrow flood plain (0.4 to 2.9%) (Table 2).

The clay content of soils ranges from 49.8 to 79.4 per cent. High clay content is noticed in the soils of narrow flood plain. These soils being smectitic in their mineralogy (Pal and Deshpande 1987) recorded high PAWC (222 mm) except in shallow soils. They are slightly to moderately calcareous with low to moderate calcium carbonate content which ranges from 4.4 to 26.0 per cent except in the non-calcareous soils of narrow flood plain (pedon 5) with 1.10 per cent organic carbon in the surface layers.

Relatively high CEC (30.74 to 66.98 cmol(p+) kg^{-1}) commensurating with the clay content are recorded in all soils. The base saturation ranging from 90.3 to 97.9 per cent increases with depth (Table 3). The exchange complex in all the soils is dominated by calcium, magnesium, sodium and potassium. The exchangeable calcium followed by magnesium are the main sources of base saturation in these soils.

Classification : Based on their morphological, physical and chemical characteristics, the soils were classified (Soil Survey Staff 1998) as clayey, smectitic, hyperthermic, Typic Haplustepts (pedon 1); very fine smectitic, hyperthermic, Vertic Haplustepts (pedons 2 and 3); very fine, smectitic, hyperthermic, Udic Haplusterts (pedon 4) and very fine smectitic, hyperthermic, Typic Haplusterts (pedon 5).

Soil parameters and yield relationship : Soil productivity is the ability of soil to produce the crops. The factors which affect soil productivity are soil and site characteristics, climatic conditions and levels of management. The inherent soil characteristics are compared with orange yield to get a multivariate step down regression model. Important soil characteristics viz. soil depth, sand, silt, clay, bulk density, PAWC, pH, electrical conductivity, calcium carbonate and cation exchange capacity were selected.

The empirical estimates for the relationship between different soil parameters and yield through step down regression analysis (Table 4) indicates that a maximum of 83.7 per cent of variation in yield is expressed by the regression equation when all parameters i.e. depth, sand, silt, clay, BD, PAWC, pH, EC, $CaCO_3$ and CEC are considered. The relationship can be expressed by the following regression equation.

Table 3. Chemical properties of soils

Hori-zon	Depth (cm)	pH (1:2·5)	EC (1:2·5 dSm^{-1})	O.C. (%)	$CaCO_3$ (%)	Exchangeable cations (cmol (p^+) kg^{-1})					CEC (cmol) (p^+) kg^{-1}	BS (%)
						Ca^{++}	Mg^{++}	Na^+	K^+	Sum		
					Pedon 1 : Typic Haplustepts							
Ap	0–17	8.2	0.20	0.87	13.6	30.40	4.64	0.49	0.56	36.09	41.82	86.3
Bw	17–28	8.2	0.22	0.36	16.8	39.74	1.68	0.53	0.45	42.40	44.11	96.1
BC	28–61	8.3	0.24	0.25	18.4	37.92	0.98	0.56	0.34	39.80	41.29	96.4
Crk	61–74	Weathered basalt mixed with lime										
					Pedon 2 : Vertic Haplustepts							
Ap	0–13	8.1	0.24	0.89	13.3	38.81	12.07	0.86	1.09	52.83	56.21	94.0
Bk1	13–28	8.4	0.27	0.81	12.4	42.09	9.48	0.98	0.60	53.15	56.29	94.4
Bk2	28–43	8.4	0.28	0.57	15.6	45.53	6.89	1.01	0.53	53.96	56.53	95.5
Crk	43–76	Weathered basalt mixed with lime										
					Pedon 3 : Vertic Haplustepts							
Ap	0–15	8.2	0.17	0.87	4.4	48.16	3.95	0.48	0.94	53.53	55.88	95.8
Bw	15–30	8.4	0.20	0.59	7.7	52.58	1.98	0.57	0.68	55.81	57.80	96.6
Bk	30–45	8.2	0.21	0.57	12.6	53.30	1.39	0.59	0.69	55.97	57.32	96.0
Ck1	45–70	8.3	0.24	0.19	2.1	28.53	0.58	0.48	0.31	29.90	30.74	97.3
Ck2	70–100+	8.3	0.23	0.13	26.0	34.95	0.33	0.12	0.52	35.92	37.20	96.6
					Pedon 4 : Udic Haplusterts							
Ap	0–16	8.3	0.17	1.04	10.6	41.36	8.90	1.10	1.20	52.56	54.54	96.4
Bw	16–43	8.4	0.19	0.55	12.6	41.80	12.25	2.20	0.68	56.93	59.04	96.4
Bss1	43–72	8.2	0.20	0.40	10.4	36.85	16.20	2.64	0.69	56.38	58.50	96.4
Bss2	72–100	8.3	0.23	0.36	14.2	29.62	16.83	2.64	0.72	49.81	51.28	97.1
Bss3	100–135+	8.4	0.26	0.19	12.5	27.76	19.74	3.30	0.77	51.57	53.06	97.2
					Pedon 5 : Typic Haplusterts							
Ap	0–15	8.1	0.21	1.10	Nil	54.39	7.45	1.21	1.20	64.25	66.79	96.2
Bw	15–45	8.3	0.18	0.95	Nil	56.23	5.83	1.70	0.73	64.49	66.18	97.4
Bss1	45–72	8.2	0.21	0.55	Nil	55.10	7.02	1.32	0.83	64.27	65.84	97.6
Bss2	72–112	8.1	0.18	0.44	Nil	54.50	8.27	0.93	0.78	64.48	65.94	97.8
Bss 3	112–135+	8.1	0.22	0.28	Nil	54.29	9.78	0.59	0.91	65.57	66.98	97.9

$$
\begin{aligned}
Y = & -9235.46 + 5.241\,x_1 + 46.581\,x_2 \\
& + 79.695x_3 + 58.699x_4 - 4436.182x_5 \\
& - 0.912x_6 + 1677.584x_7 - 10780.368x_8 \\
& - 34.880x_9 + 2.596x_{10}
\end{aligned}
$$

where, y = yield; x_1 = soil depth (cm); x_2 = sand (%); x_3 = silt (%); x_4 = clay (%); x_5 = BD; x_6 = PAWC; x_7 = pH; x_8 = EC; x_9 = $CaCO_3$ (%); x_{10} = CEC.

Table 4. Step down regression between yield of orange and soil-site characteristics

Sl. No.	Yield (Y)	Intercept (a)	Depth (b_1)	Sand (b_2)	Silt (b_3)	Clay (b_4)	BD (b_5)	PAWC (b_6)	pH (b_7)	EC (b_8)	$CaCO_3$ (b_9)	CEC (b_{10})	R^2
1	Y	9235.46	5.241	46.581	79.695	58.699	-4436.182	-0.192	1677.584	-10780.368	-34.880	2.596	0.8375**
2	Y	2855.45	5.241	–	3.493	-2.905	-4436.175	-0.192	1677.586	-10780.376	-34.880	2.596	0.8362**
3	Y	2589.05	4.929	–	4.932	–	-4647.305	-0.789	1659.301	-10659.969	-34.107	2.674	0.8340**
4	Y	[illegible]212	5.285	–	4.463	–	-4709.750	-0.946	1628.175	-10370.000	-35.697	–	0.8308**
5	Y	-1641.875	5.452	–	–	–	-4480.495	-1.015	1609.650	-10018.003	-35.550	–	0.8198**
6	Y	-1127.076	3.622	–	–	–	-4766.663	–	1524.191	-10024.224	-35.063	–	0.6927**
7	Y	-8658.023	–	–	–	–	-1111.047	–	1704.090	-10320.861	-24.170	–	0.6668**
8	Y	8053.658	–	–	–	–	–	–	1357.201	-9642.946	-17.247	–	0.4861*
9	Y	-5367.634	–	–	–	–	–	–	1028.812	-9958.438	–	–	0.2907
10	Y	2133.638	–	–	–	–	–	–	–	-9958.438	–	–	–

* Significant at P = 0.05; ** significant at P = 0.01

With the elimination of each parameter, there was reduction in the expression of yield variation through these independent variables. Yield variation of 48.6 per cent was expressed by the regression equation when pH, EC and $CaCO_3$ were only considered. 29.07 per cent variation in yield was expressed through regression when pH and EC were considered and this was found to be non-significant. Thus the combined influence of all soil parameters i.e. depth, sand, silt, clay, BD, PAWC, pH, EC, $CaCO_3$ and CEC seems to be the most important yield influencing factor than that of individual soil parameter.

The mean yield of oranges as per the observations at sites under pedons 1, 2, 3, 4 and 5 are 551, 394, 982, 1076, 1125 number of fruits per tree, respectively.

References

Babrekar, P.G. (1962). Study of the physical and chemical properties of an orange garden soil in relation to drying of branches and non bearing of the trees. M.Sc. (Ag.) thesis (Unpub.), Nagpur University, Nagpur.

Black, C.A., Evans, D.D., Ensminger, L.E., White, J.L., and Clark, F.E. (Eds.) (1965). 'Methods of Soil Analysis Part I'. (American Society of Agronomy, Inc. : Madison, Wisconsin, USA.) 770p.

Gaikawad, S.T., Rao, V.S. and Verma, H.K.G. (1974). Characteristics of catenary soils developed on basalt parent rock in Nagpur district of Maharashtra state. *Journal of the Indian Society of Soil Science* **22,** 181-190.

Joshi, R.H. (1957). Examine soil and irrigation water before planting orange gardens. De partment of Agriculture, Bombay, Marathi leaflet.

Kakde, J.R. (1956). A preliminary survey of the study of relationship of physical properties of the orange orchard areas and the orange performances in Nagpur district. Nagpur Agricultural College Magazine **30,** 19-24.

Kalbande, A.R., Landey, R.J., and Bhattacharjee, J.C.(1983). Characterisation of soils under orange cultivation in Nagpur district of Maharashtra. *Indian Journal of Agri cultural Science* **53,** 57-61.

Pathak, B.R. (1934). Fruit Culture, Nagpur Agriculture College Magazine, **8,** 135-144.

Pal, D.K., and Deshpande, S.B. (1987). Characteristics and genesis of minerals in some bench mark soils of India. *Pedologie* **37,** 259-275.

Sehgal, J., Vadivelu, S., and Saxena,R.K. (1989). 'Field Manual'. NBSS Bull. No. 13.

Sehgal, J. (1995). Land resource appraisal for land use planning to meet the challenges of 21st century, lecture delivered at the 60th Annual Convention of Indian Society of Soil Science, Nov. 3, 1995 at PAU, Ludhiana, 504-528.

Singh, S.K., Das, K., and Shyampura, R.L. (1994). Soil physiographic relationship in basaltic terrain. *Journal of the Indian Society of Soil Science* **42,** 663-664.

Soil Survey Staff (1998). 'Keys to Soil Taxonomy'. SMSS Tech. Monograph No. **19,** (United States Department of Agriculture : Blacksburg, Virginia, USA.)

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