



Productivity and suitability assessment of orange (*Citrus reticulata*)-growing soils in Nagpur

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ABSTRACT

Six pedons were evaluated for their productivity and suitability on the basis of variation in physiography, parent materials, soils and productivity of oranges in Nagpur district of Maharashtra. The pedons were shallow underlain by saprolite (P3, P4 and P5) and deep (P1, P2 and P6) classified as Vertisols (P1 and P2), Inceptisols (P3 and P6) and Alfisols (P4 and P5). In general, sand, silt and clay contents ranged from 0.6 to 46.1, 19.3 to 40.0 and 24.1 to 68.2% in different horizons, respectively. The soils were moderately acidic to moderately alkaline in reaction associated with sodicity in sub-soils (P1 and P6). The CEC varied from 18.3 to 59.3 cmol (p+)/kg. The available N, P and K ranged from 50.2 to 250.9, 0.8 to 27.7 and 252.0 to 1 030.4 kg/ha, respectively in different pedons. The Riquier productivity index appears to be more reliable as compared to Storie index and these ratings are not in reliance with the Sys and proposed suitability criteria and yield of oranges realized. On computation of the existing limitations, a new criterion has been proposed (against Sys suitability criteria for *Citrus* spp) which indicated that P3, P4 and P5 were moderately suitable and others were marginally suitable.

Key words: Orange-growing soils, Parent materials, Productivity, Suitability

In Nagpur district, orange (*Citrus reticulata* Blanco) is mainly grown in deep black soils developed over basalt/basaltic alluvium and in general, local variations in soils are observed at shorter distances owing to soil forming factors. Recently, it is being observed that traditional belt of oranges is transcending towards north-eastern part even in shallow soils developed over rock types other than the basalt ones in Nagpur district owing to drainage, aridity, sodicity problem, Phytophthora menace, etc. The potential and constraints of these shallow soils vis-a-vis deep soils for Nagpur oranges developed from basalt/basaltic alluvium have been detailed by Jagdish Prasad *et al.* 2001. As different parent materials give rise to different soils and their properties in a similar pedo-climate, provide an opportunity to relate parent material and soil characteristics which in turn is expected to give differential productivity/suitability and it is not exceptional for mandarin and hence the present study was undertaken.

MATERIALS AND METHODS

The study area is located between 20°47'7.4" and 21°25'19.4" N latitudes and 78°32'4.9" to 79°29'4.5"E

longitudes ranging from 250 to 420 m above msl. Climate of the area is tropical dry sub-humid with mean annual temperature of 26.8°C and mean annual rainfall of 938.4 mm. The area falls under ustic soil moisture regime and hyperthermic soil temperature regime and length of growing period (LGP) is about 196 days in a year.

Depending on variability in physiography, parent materials, soils and productivity of oranges, six pedons developed from basaltic alluvium P1-Wandli (Katol), P2-Mohdi (Narkher); weathered basalt P3-Khandala (Narkher); micaceous-phyllite P4-Tas (Bhivapur), P5-Jawarabodi (Bhivapur) and mixed alluvium P6-Virkhandi-Dhapharla (Bhivapur) were exposed (Jan 2008) and studied for their morphological properties (Soil Survey Division Staff 2000). The horizon-wise soil samples were collected, processed and analyzed using standard analytical procedures (Piper 1950; Jackson 1973, 1979; Richard 1965; Watanabe and Olsen 1956; Lindsay and Norvell 1978) and classified according to Soil Taxonomy (Soil Survey Staff 2006). The productivity of soils were computed and assessed by following the procedures described by Riquier *et al.* (1970) and Storie (1978).

The Riquier system suggests nine factors for the calculation of a productivity index, viz moisture (H), drainage (D), effective depth (P), texture/ structure (T), base saturation

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(N), soluble salt concentration (S), organic matter content (O), mineral exchange capacity / nature of clay (A) and mineral reserve (M)

Productivity index = $H \times D \times P \times T \times N$ or $S \times O \times A \times M$

Each factor is rated on a scale from 0 to 100, the actual percentages being multiplied by each other. The resultant index of productivity, also lying between 0 and 100, is set against a scale placing the soil in one or other of five productivity classes.

Storie Index rating approach can be characterized as a multiplicative parametric method to express the joint influence of soil factors on suitability for productivity of agricultural crops. It does not include management factors. The Storie Index is assessed by assigning percentage ratings to each factor considering ideal soil condition as 100% and then multiplying the observation ratings as per formula:

$$\text{Storie index} = A \times B \times C \times X$$

where, factor A is characteristics of physical profile (depth or permeability); factor B is the surface texture; factor C is the slope factor and factor X is the miscellaneous factor like drainage, alkali, nutrient level, erosion and micro-relief. It is simple quantified expression for soil productivity but its reliability depends on the choice of factor determinants, their weighing and the validity of the assumed multiplicative interaction between the factors.

The pedons were evaluated for their suitability as per Sys *et al.* (1993) and proposed a criterion for orange-growing soils of this tract.

RESULTS AND DISCUSSION

Soil characteristics

The pedons having their legacy with basalt (P1, P2, P3, P6) had their colour in 10YR/ 2.5Y, value with 3 to 4 and chroma 2 to 4, however, soil developed from phyllite

Table 1 Physical properties of soil

Horizon	Depth (cm)	Particle-size distribution (%)			Coarse fragments (%) v/v	Bulk density (Mg/m ³)	Water retention (%)	
		Sand (0.05–2 mm)	Silt (0.05–0.002 mm)	Clay (<0.002 mm)			33kPa	1 500 kPa
<i>Pedon 1 (WANDLI): Very fine, smectitic (calcareous), hyperthermic Typic Haplusterts</i>								
Ap	0–16	1.2	40.0	58.8	1–3	1.8	39.7	22.1
Bw	16–47	1.0	39.7	59.3	1–3	1.8	40.2	23.4
Bss1	47–84	0.7	37.8	61.4	1–3	1.6	46.3	24.9
Bss2	84–117	0.6	35.5	63.9	3–5	1.8	54.9	26.4
BC	117–140	0.9	30.9	68.2	5–8	2.0	59.5	33.3
<i>Pedon 2 (MOHDI): Very fine, smectitic (calcareous), hyperthermic Typic Haplusterts</i>								
Ap	0–15	7.2	39.9	52.9	1–3	1.7	38.3	22.1
Bw1	15–42	4.5	38.5	55.0	1–3	1.7	42.4	25.3
Bw2	42–71	3.9	37.0	59.1	1–3	1.8	44.9	25.8
Bss1	71–102	5.0	39.5	55.5	1–3	1.8	43.6	25.4
Bss2	102–137	5.8	38.7	55.4	1–3	1.7	43.3	25.5
BC	137–155	7.5	35.8	56.7		1.8	44.5	26.5
<i>Pedon 3 (KHANDALA): Clayey, smectitic, hyperthermic Typic Haplustepts</i>								
Ap	0–11	7.2	39.4	53.4	3–5	1.7	38.1	22.6
Bw	11–29	7.1	35.4	57.5	3–5	1.8	36.0	22.1
2Cr	29–52	39.0	19.3	41.7			32.3	20.6
<i>Pedon 4 (TAS): Clayey, mixed, hyperthermic Typic Haplustalfs</i>								
Ap	0–11	24.4	39.5	36.1	1–3	1.8	25.2	11.2
Bt	11–38	11.6	30.2	58.2	1–3	1.6	28.8	16.6
2Cr	38–53	24.1	23.5	52.5			27.1	16.1
<i>Pedon 5 (JAWARABODI): Clayey, mixed, hyperthermic Typic Haplustalfs</i>								
Ap	0–10	46.1	29.8	24.1	5–10	1.7	20.7	7.9
2Bt	10–29	23.1	36.4	40.5	5–8	1.4	25.3	13.4
3Cr	29–53	27.3	19.5	53.2		1.5	26.0	15.3
<i>Pedon 6 (VIRKHANDI): Fine, smectitic (calcareous), hyperthermic Vertic Haplustepts</i>								
Ap	0–13	19.4	28.9	51.7	5–8	1.7	27.0	15.5
Bw1	13–34	17.4	30.7	51.9	3–5	1.5	27.7	15.9
Bw2	34–54	15.2	30.8	54.1	3–5	1.8	28.3	16.9
Bw3	54–77	14.0	31.3	54.7	3–5	1.9	29.5	18.4
Bss1	77–102	14.1	27.7	58.7	5–8	1.9	30.3	18.3
Bss2	102–132	13.2	26.7	60.2	5–8	1.9	32.3	18.9
BC	132–153	12.5	25.9	61.6	-	2.0	33.6	19.3

(micaceous) had their colour in 7.5YR/5YR with value and chroma 3 to 4. The surface and sub-surface horizons of pedons are associated with sub-angular blocky structure of varying grades and sizes but angular blocky structure associated with slickenside is a common feature of subsoil in Vertisol (P1, P2) and Vertic Inceptisol (P6).

The particle-size distribution show inflection in sand, silt and clay content depth distribution (Table 1) and varies significantly in soils having different parent materials. The clay content in soils (shrink-swell) of basaltic origin ranged from 41.7 to 68.2% whereas it was 24.1 to 58.2% in other soils (P4 and P5). The higher clay in Bt horizon of P4 and P5 probably due to translocation of clay from surface horizon. Bulk density ranged from 1.4 to 2.0 Mg/m³. Basaltic soils retain high amount of moisture than soils of other origin at

33 kPa and 1500 kPa and that increased with the depth. Water retention had positive influence on clay, CEC, silt respectively. Nikam *et al.* (2006) also reported similar findings.

The pH of soils was moderately acidic (pH 5.2) to moderately alkaline (pH 8.4) in reaction. The surface horizons of all pedons except P6 had organic carbon > 6 g/kg. The data (Table 2) indicates that organic carbon in general, was low in pedons having higher pH and CaCO₃ (Dhale and Jagdish Prasad 2009). The CaCO₃ content ranged from 70.4 to 134.6 g/kg while it was low (24.9 to 56.4) in P6. In general, CaCO₃ varied from 2.5 to 16.0 g/kg in P3, P4 and P5, respectively. The clay micelle was dominantly saturated with exchangeable Ca, followed by Mg, Na and K. In P1 and P6, exchangeable Na and ESP increased with depth and was

Table 2 Chemical properties of soil

Horizon	pH (1:2.5) (H ₂ O)	EC (1:2.5) (dS/m) (H ₂ O)	Organic carbon (g/kg)	CaCO ₃ (g/kg)	Exchangeable bases				CEC (cmol (p+)/kg)	Base saturation (%)	ESP
					Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺			
<i>Pedon 1 (WANDLI): Very-fine, smectitic (calcareous), hyperthermic Typic Haplusterts</i>											
Ap	7.2	0.22	8.5	43.2	40.8	12.0	0.8	1.5	50.8	108.5	2
Bw	7.6	0.19	3.5	49.4	36.8	15.2	1.7	0.8	49.9	109.1	3
Bss1	8.0	0.28	2.3	46.9	35.6	14.4	4.5	0.8	53.0	104.4	9
Bss2	8.3	0.34	1.9	44.5	34.4	14.8	6.5	0.9	55.6	101.9	12
BC	8.4	0.94	0.7	38.3	32.0	16.0	13.7	0.9	59.3	105.5	23
<i>Pedon 2 (MOHDI): Very-fine, smectitic (calcareous), hyperthermic Typic Haplusterts</i>											
Ap	7.9	0.33	13.1	70.4	37.6	11.2	1.0	1.3	50.0	102.2	2
Bw1	8.0	0.22	5.4	76.6	44.0	12.0	2.0	0.7	52.2	112.5	2
Bw2	8.1	0.27	3.9	85.2	42.8	10.8	1.2	0.7	53.8	103.1	2
Bss1	8.1	0.36	1.5	134.6	40.8	8.4	1.1	0.7	47.8	106.8	2
Bss2	8.1	0.36	1.5	129.6	36.0	13.0	1.1	0.7	46.9	108.4	2
BC	8.0	0.34	0.7	124.7	34.8	14.0	1.2	0.8	47.8	106.4	3
<i>Pedon 3 (KHANDALA): Clayey, smectitic, hyperthermic Typic Haplusterts</i>											
Ap	7.4	0.17	10.0	2.5	36.6	11.4	0.60	1.1	50.8	97.8	1
Bw	7.4	0.28	6.6	6.2	37.4	13.8	0.78	0.7	48.7	108.3	2
2Cr	7.4	0.24	3.5	16.0	35.6	12.0	1.65	0.5	51.2	99.6	3
<i>Pedon 4 (TAS): Clayey, mixed, hyperthermic Typic Haplustalfs</i>											
Ap	6.8	0.17	12.2	9.1	14.0	3.4	0.4	0.7	20.8	88.9	2
Bt	5.4	0.06	8.3	6.8	15.7	4.3	0.4	0.4	29.5	70.5	2
2Cr	5.2	0.07	4.8	11.6	14.4	2.4	0.5	0.3	23.5	75.2	2
<i>Pedon 5 (JAWARABODI): Clayey, mixed, hyperthermic Typic Haplustalfs</i>											
Ap	6.6	0.13	7.5	8.0	10.0	1.6	1.7	0.4	18.3	75.3	1
2Bt	6.1	0.07	4.4	9.1	12.4	3.8	0.5	0.4	21.7	78.8	1
3Cr	5.7	0.06	4.4	9.1	14.4	4.2	0.3	0.4	27.8	69.4	1
<i>Pedon 6 (VIRKHANDI): Fine, smectitic (calcareous), hyperthermic Vertic Haplusteps</i>											
Ap	7.4	0.20	2.1	24.9	28.0	5.6	1.3	0.6	34.3	103.3	4
Bw1	7.4	0.19	2.5	35.8	32.4	3.2	1.4	0.3	39.1	95.4	4
Bw2	7.4	0.22	2.5	25.8	26.4	8.4	1.7	0.4	38.2	96.4	4
Bw3	7.5	0.23	3.6	43.0	25.6	10.4	1.8	0.4	38.2	99.8	5
Bss1	7.6	0.33	3.3	33.4	23.6	12.0	2.7	0.4	39.1	98.8	7
Bss2	7.8	0.38	3.3	43.0	22.8	15.0	3.8	0.5	44.1	102.4	9
BC	8.0	0.48	3.3	56.4	19.2	14.8	4.8	0.5	36.5	107.5	14

higher in sub-soils which is of concern related to initiation of sodicity development (Lingade *et al.* 2008). Higher base saturation indicates the presence of base-rich zeolites of amygdoloidal basalt (Pal *et al.* 2006).

The available N, P and K ranged from 50.2 to 250.9, 0.8 to 27.7 and 252.0 to 1030.4 kg/ha, respectively in different horizons and decreased with depth (barring few exceptions). The available N was optimum in Ap horizons of P2, P3, P4 and P5 and low in P6, whereas deficient in P1. Available P was optimum in surface horizon of P4 and low (P5) to deficient in other pedons and K was above optimum at P1 to P4, optimum in P3 and P5 and low in P6 as per criteria prescribed (Srivastava *et al.* 2007). DTPA-Fe in surface horizons of P1, P3, P4, P5 and P6 was more than 11 mg/kg and it decreased with depth. The DTPA-Mn distribution in the pedons ranged from 4.8 to 40.9 mg/kg. Relatively higher availability of Mn was found in pedons 1, 2, 3, 4 and 6 and decreased in sub-surface horizons. The DTPA-Cu in different horizons of pedons varied from 0.5 to 7.7 mg/kg and in general decreased with depth (except in P3). The DTPA-Zn ranged from 0.2 to 2.2 mg/kg in different horizons. It appears that the variations in DTPA-extractable micronutrients are the reflection of their pH, clay content OC and CEC. As per the norms prescribed by Srivastava and Shyam Singh (2008), it was found that DTPA-Fe (except P2), DTPA-Cu (except P6), Mn and Zn content were optimum in Ap horizons (0-15

cm depth) all the pedons.

Productivity and suitability assessment

As per Riquier *et al.* (1970) index, the soils of P1 (Typic Haplustert), P2 (Typic Haplustert), P4 (Typic Haplustalf) and P6 (Vertic Haplustept) are good in productivity as they are having moderate limitations of drainage, texture and organic matter as shown in Table 3. The productivity of P3 (Typic Haplustept) and P5 (Typic Haplustalf) is average due to severe limitations of soil depth, soluble salts, organic matter and mineral reserves. The data on Storie Index ratings indicates that the values fall between terms of fair (P2) to poor productivity potential and are not suitable for orange cultivation (Table 4). The study area shows severe limitation of climate in terms of rainfall and relative humidity. The irrigation (basin method), however, mitigate these constraints. The computation of limitations as per Sys *et al.* (1993) criteria indicated that P1, P2 and P6 are marginally suitable due to severe fertility and physical soil characteristics, whereas P3, P4 and P5 are non-suitable due to severe limitations of physical soil conditions. The experience gained by researchers in this tract and perception of farmers speaks differently that the guidelines suggested by Sys *et al.* (1993) and that compelled for modified soil-site suitability criteria for oranges for this tract. As per proposed criteria (Table 5), Wandli (P1) and Virkhandi (P6)

Table 3 Productivity index (rating class with assigned values) and productivity class for studied soils

Pedon	Soil moisture H	Drainage D	Soil depth P	Texture/ structure T	Base saturation N	Soluble salts S	Organic matter O	Nature of clay A	Mineral reserves M	Productivity index	Productivity class	Potentiality
Wandli	H4b (100)	D3b (90)	P6 (100)	T5b (80)	N5 (100)	S2 (70)	O2 (90)	A3 (100)	M2c (100)	45.36	Good	II
Mohdi	H4b (100)	D3b (90)	P6 (100)	T5b (80)	N5 (100)	S2 (70)	O3 (100)	A3 (100)	M2c (100)	50.40	Good	II
Khandala	H4b (100)	D4 (100)	P3 (50)	T5b (80)	N5 (100)	S2 (70)	O2 (90)	A3 (100)	M2c (100)	25.20	Average	III
Tas	H4b (100)	D4 (100)	P3 (50)	T7 (100)	N5 (100)	S1 (100)	O3 (100)	A2 (95)	M2a (90)	42.75	Good	II
Jawarabodi	H4b (100)	D4 (100)	P3 (50)	T6b (90)	N5 (100)	S1 (100)	O2 (90)	A2 (95)	M2a (90)	34.62	Average	III
Virkhandi	H4b (100)	D3b (90)	P6 (100)	T5b (80)	N5 (100)	S2 (70)	O1 (85)	A2 (95)	M2c (100)	40.69	Good	II

Source: Riquier *et al.* (1970)

Table 4 Productivity index and productivity class for studied soils

Pedon	Factor A (depth)	Factor B (texture)	Factor C (slope)	Factor X			Productivity index	Productivity class	Grade
				Drainage	Erosion	Nutrient level			
Wandli	92	55	90	85	90	90	31.35	Poor	4
Mohdi	94	55	100	85	100	90	39.55	Fair	3
Khandala	50	55	100	100	90	90	22.27	Poor	4
Tas	51	85	98	100	90	90	34.41	Poor	4
Jawarabodi	51	85	96	100	90	90	33.70	Poor	4
Virkhandi	93	55	96	85	90	90	33.88	Poor	4

Source: Storie (1978)

Table 5 Landscape and soil characteristics for orange cultivation in Vidarbha region (proposed criteria)

Land-use requirement	Class, degree of limitation and rating scale					
	S1		S2	S3	N1	N2
	0 (None)	1 (Slight)	2 (Moderate)	3 (Severe)	4 (Very severe)	
<i>Soil-site characteristics</i>						
Slope (%)	0-1* (3-5)	1-3* (3-5)	3-5* (1-3, 5-10)	5-10* (>10)	>10*	
Flooding	F0					F2
Drainage	Well	Well	Moderately well	Imperfect	Poor but drainab.	Poor, not drainab.
<i>Physical soil characteristics</i>						
Texture/structure	SL, SiL, L, SiCL, CL, Si	SCL, LS, LfS	C<50S, SC, S, FS, SiCs	C>50S, C (50-65)	C < 60v	Cm, SiCm, C>60v
Soil depth (cm)#	>100	100-50	50-25			<25
<i>Soil fertility characteristics</i>						
pH (H ₂ O)	5.5-6.5* (7.0-7.5)	6.5-7.5* (7.5-8.0)	7.5-8.5* (8.0-8.5)	(8.5-9.0)		(>9.0)
Apparent CEC cmol (p+)/kg clay	>16	<16-	<16+			
Organic carbon (%)	>1.5	1.5-0.8	<0.8			
<i>Soil salinity and alkalinity</i>						
EC (dS/m)	0-2	2-3	3-4	4-6		>6
ESP (%)	0-4	4-8	8-12	12-15		>15

Textural class- SiCs, Silty clay blocky; SiCL, silty clay loam; C<50S clay, blocky; SiL, silt loam; CL, clay loam; Si, silt; C>60v, very fine; clayey Vertic; Sc, Sandy clay; C<60v, clay, Vertic, C>50S, very fine clayey, blocky; L, loam; SL, sandy loam; SCL, sandy clay loam; LFs, loamy fine sand; Fs, fine sand; Cm, massive clay; SiCm, massive silty clay; S, sand; LS, loamy sand; LcS, loamy coarse sand

* - soils developed over phyllite

Values in parentheses- soils developed over basalt

- if underlain by saprolite (atleast up to 75 cm) then suitability rating goes in higher side

soils are marginally suitable with severe limitations of texture and moderate limitations of drainage and ESP (sub-soil sodicity). These factors together resulted in alternate bearing (<500 fruits/plant) in P1 but P6 fetches good yield (>1 000 fruits/plant) due to higher clay (but relatively more sand content) which provides good drainage. Mohdi (P2) is rated as marginally suitable owing to severe limitation of texture and moderate limitation of slope and drainage. Khandala (P3) site developed over weathered basalt provides good drainage for the proliferation of roots but thin solum, followed by saprolite and thereafter hardrock limits vertical development of main roots and hence there are horizontal roots relatively thicker one and formation of web of roots. Although plant bears 900-1 000 fruits/plant. If proper agro-management practices and irrigation are provided to these soils they may sustain the longevity and productivity potential. P3 is associated with moderate limitations of texture and organic carbon hence rated as moderately suitable.

As citrus belt is transcending towards eastern Nagpur in particular, Bhivapur tehsil owing to relatively cooler temperature, high rainfall and potential aquifers. Tas (P4)

and Jawarabodi (P5) support high bearing of fruits. However, constraints posed by limited weathering front underlain by saprolite (52cm) hasten the flowering and fruit development (under proper water and nutrient management) and would produce relatively good yield (800-900 fruits/ plant). In general, it is suggested that a soil having solum depth varying from 30 to 50 cm underlain by saprolite atleast up to 75 cm with clay content ranging from 45 to 50%, can be an ideal site for oranges, considering other factors to be congenial.

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