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Identification of edaphic constraints for crop production in Warangal district of central Telangana Zone

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ABSTRACT

Land characterization based on general soil physical and fertility status was done in terms of soil physical and nutrient index for soils of Warangal district of Andhra Pradesh. Fourteen pedons representing the major traditional soil types of the district were selected for physical index and 20 surface samples from each administrative division (9 nos) were collected for nutrient index computations. Physical rating index computed from the weightages assigned to the major edaphic parameters *viz.,* soil depth, bulk density, moisture storage capacity, infiltration/hydraulic conductivity, aggregation, non-capillary pore space, depth of water table and slope varied from 0.47 to 0.73 for their wide ranged soil properties and thus Bachannapet and Wardhannapet soils were classified to suitability class IV. The Tadvai, Nallabelli, Eturunagram, Eletiramyapalli, Raghunathapalli, Pakala, Malyal, Duganndi, Regonda, Khanpur, Ghanapur and Warangal RS soils were grouped as moderately suitable (Class-III). The soil available N, P and K content of studied regions ranged from 145-270, 8.1-22.4 and 171-355 kg ha^{-1}, respectively. The calculated soil nutrient index indicated that most soils were low in nitrogen, medium in phosphorus and high in potash. The major edaphic constraints identified were high sub-soil bulk density, low available water storage capacity and low infiltration and low nitrogen and medium in phosphorus. The need based management practices such as application of organic matter, deep ploughing, provision of good drainage and contour cultivation were suggested for management practices to increase the crop productivity of the studied regions.

1. INTRODUCTION

Crop production capacity is determined by genetic, edaphic and climatic factors. The edaphic constraints are physical and chemical and some are caused by human activities. Land under the intensive mono cropping system, faulty irrigation methods, heavy machinery and inappropriate tillage practices, improper organic and inorganic input management and obsolete soil management technology with time affected the soil properties and played down in the level of soil health that threats food security of the world (Liu *et al.,* 2005; Gardi *et al.,* 2008). Magnitude of degradation and restoration of soil properties is varied for soil types and their inherent nature and resilient properties (Arthur *et al.,* 2012). It is very important to assess the existing edaphic constraints of different soil types or regions, in order to rectify it or change the prevailing causes of faulty cultivation practices to achieve maximum crop yield potential. Rice, cotton, sorghum, maize, red gram, black gram, chillies, turmeric and other vegetable crops had been in cultivation covering a signification portion in the cultivated areas of the study regions (Reddy *et al.,* 1998). Crops stress is being complex, the index based approach is an effective tool for identification and quantification of stress level to predict respective crop yield potential by optimum level of nutrient management where it gives the condition of soil function rather meaningless soil properties alone (Kumar *et al.,* 2014). Similarly, the fertility index has been used from long time back to assess the soil foil fertility status for N, P and K over the time and space (Pathak, 2010). Hence, an attempt was made to identify the major soil physical and nutrient constraints of Warangal district and suggest management practices for better crop performance.

2. MATERIALS AND METHODS

Warangal district (17°19' and 18° 36' N; 78°49' and 80°43' E) is located in Andhra Pradesh covering an area of

12,846 km^2. Generally, summer is dry, hot with maximum temperature of 50°C and dips to 13°C in winters. Warangal district receives maximum rainfall during south-west monsoon with mean annual rainfall of 994 mm. However, the areas of Cheriyal and Bachannapet receive only 750 mm rainfall. Maximum rainfall is received in Mulug, Parkal and Narsampet Mandals. The soil moisture and temperature regimes are ustic and isohyperthermic, respectively. River Godavari serves as border on one side and hills, undulation and plain land gives the complex physiographical region associated with red soil, black soil and alluvial soil.

Horizon-wise soil samples were collected from 14 pedons representing different traditional soil types of the district and were analyzed for soil physical properties (Fig. 1). Infiltration rates were measured *in-situ* using double ring infiltrometer and bulk density was determined by core sampler method (Blake and Hartge, 1986). The particle-size analysis was carried out by the hydrometer method (Piper, 1966). Aggregate analysis was done by wet sieving method as described by Yoder (1937) and the percentage of aggregates more than 0.25 mm diameter and the per cent aggregate stability were calculated from the equation:

Per cent aggregates more than 0.25 mm=

$$\frac{\text{Weight of aggregates more than 0.25 mm diameter}}{\text{Weight of soil}} \times 100$$

Per cent aggregate stability=

$$\frac{\text{Weight of aggregates more than 0.25 mm diameter - weight of sand}}{\text{Weight of sample weight of sand}} \times 100$$

The hydraulic conductivity of the undisturbed samples was measured by the constant head method as per the procedure outlined by Klute and Dirksen (1986) and water retention capacity of soil samples at 33 kPa and 1500 kPa using pressure plate apparatus (Klute, 1986) and expressed in terms of percentage on dry weight basis. The organic carbon content was determined by Walkley and Black (1934) rapid titration method. Information on the water table depth and slope of the study area was collected and used in index computation. The index was calculated following the system of an estimation of the production potential of soil in relation to physical properties of its profile as suggested by Gupta (1985). A product of weightings given to 8 soil physical properties has been used to compute the physical index (PI).

$$PI = A.B.C.D.E.F.G.H$$

Where, A to H are weightings given to soil depth (A), bulk density (B), moisture storage capacity (C), cumulative infiltration/apparent hydraulic conductivity (D), aggregation (E), non-capillary pore space (F), water table depth (G) and slope (H) values as per the categories prescribed by Gupta (1985). Based on soil variability, 180 surface soils, 20 from each of nine administrative divisions were collected for identification of nutrient constraints for crop production. Soil samples, dried under shade and passed through 2 mm sieve, were used for estimation of available nitrogen (Subbaiah and Asija, 1956), available phosphorus using Olsen's reagent (Olsen *et al.,* 1954) and available potassium extracted by neutral normal ammonium acetate (Jackson, 1973). From the surface soil available nutrient content and nutrient index were calculated as per methodology given by Parker *et al.* (1957).

$$\text{Soil Nutrient Index} = \frac{N_l + 2N_m + 3N_h}{N_l + N_m + N_h}$$

Where, N_l= Number of soils falling under low category; N_m= Number of soils falling under medium category and N_h= Number of soils falling under high category.

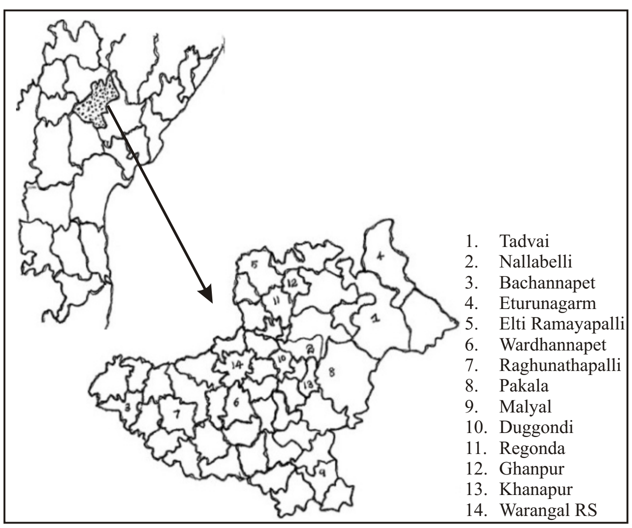

Fig.1. The Pedon locations on Warangal district Map

3. RESULTS AND DISCUSSION

Soil Physical Properties

Soil depth varied from 55 cm in Eleti Ramayapalli to 120 cm in Eturunagaram. The per cent aggregates greater than 0.25 mm and aggregate stability were high in the surface horizons and decreased with depth in tune with the soil organic carbon status. Zibilske *et al.* (2002) reported that nature of management practices and cropping system naturally play role in controlling the different pools and quantity of organic matter in soils and the aggregate stability of soils mostly influenced by microbial biomass and soil protein.

The infiltration rate of pedons varied from 0.3 to 8.3 cm hr^{-1} being high in the surface layers due to high bulk density and high clay content. Tadvai, Bachannapet, Eturunagaram, Wardhannapet and Raghunathapally pedons were grouped into moderately rapid; Nallabelli, Eleti Ramayapalli and Pakala pedons into moderate; Mayal into moderately slow and others in slow class (Table 1).

Table: 1
Soil properties of Warangal district

Location	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	BD (mg m^{-3})	Organic carbon (%)	Percent aggregate >0.25 mm	Aggregate stability (%)	HC (cm hr^{-1})	Available water content (% w/w)	Infiltration rate (cm hr^{-1})	Available water storage capacity (cm m^{-1})
Pedon 1 (Tadvai): Fine-loamy, mixed isohyperthermic Typic Haplustalf												
	0-15	75.7	8.0	16.3	1.6	0.72	69.4	54.2	18.3	4.6	8.3	9.5
	15-37	66.1	8.6	25.3	1.6	0.60	68.4	53.4	8.6	5.6		
	37-55	64.0	8.8	27.2	1.6	0.58	62.5	52.4	5.7	6.9		
	55-70+	62.5	9.6	27.9	1.6	0.58	61.9	49.2	2.2	7.1		
Pedon 2 (Nallabelli): Fine-loamy, mixed isohyperthermic Typic Haplustalf												
	0-15	65.9	11.6	22.5	1.6	0.60	70.7	54.6	8.5	7.6	3.8	13.2
	15-30	61.6	9.9	28.5	1.6	0.62	69.5	54.5	8.0	8.7		
	30-70+	60.2	10.2	29.6	1.7	0.50	67.5	52.4	5.6	8.8		
Pedon 3 (Bachannapet): Fine-loamy, mixed (calcareous) isohyperthermic Typic Natrustalf												
	0-8	76.9	10.6	12.5	1.6	0.65	69.3	52.4	14.4	5.1	6.4	9.1
	8-50	65.4	11.8	22.8	1.6	0.52	68.1	51.3	8.9	5.4		
	50-65+	59.9	12.2	27.9	1.7	0.43	68.1	48.7	4.8	5.5		
Pedon 4 (Eturunagaram): Fine-loamy, mixed isohyperthermic Typic Rhodustalf												
	0-15	77.6	8.0	14.4	1.5	0.67	68.7	54.7	14.2	5.5	6.8	9.6
	15-47	68.1	8.3	23.6	1.6	0.62	68.0	54.4	8.4	6.1		
	47-80	63.1	8.6	28.3	1.6	0.35	66.2	52.6	5.9	6.2		
	80-120	61.5	9.9	28.6	1.6	0.25	66.0	48.4	3.1	6.4		
Pedon 5 (Eleti Ramayapalli): Fine-loamy, mixed isohyperthermic Typic Haplustalf												
	0-11	68.8	9.0	22.2	1.5	0.62	73.1	55.6	8.6	7.5	3.8	13.9
	11-30	65.9	10.6	23.5	1.6	0.51	72.2	55.2	5.9	8.3		
	30-55	60.5	11.2	28.3	1.6	0.51	69.4	55.2	3.2	8.5		
	55+	58.7	12.1	29.2	1.6	0.36	66.1	54.8	2.6	9.4		
Pedon 6 (Wardhannapet): Fine-loamy, mixed isohyperthermic Typic Haplustept												
	0-8	74.2	10.2	16.1	1.6	0.72	71.1	54.6	16.2	5.1	7.3	12.0
	8-33	61.8	11.6	26.6	1.7	0.65	70.7	52.1	9.4	6.8		
	3-80+	59.7	12.0	28.3	1.7	0.63	69.1	50.6	5.8	7.6		
Pedon 7 (Raghunathapalli): Fine-loamy, mixed isohyperthrmic Typic Haplustalf												
	0-25	74.9	9.7	15.4	1.5	0.58	70.7	54.1	15.6	6.8	7.2	12.6
	25-55	66.8	8.6	24.6	1.6	0.51	70.2	53.1	8.9	7.5		
	55-75+	63.6	10.2	26.2	1.6	0.44	69.7	50.6	5.7	9.0		
Pedon 8 (Pakala): Fine-loamy, mixed isohyperthermic Typic Haplustept												
	0-10	65.7	8.1	26.2	1.6	0.71	71.5	53.7	9.2	8.2	2.1	13.4
	10-35	61.6	9.8	28.8	1.6	0.68	70.8	53.3	6.4	8.2		
	35-55	+60.4	9.9	29.6	1.6	0.63	66.6	52.6	4.2	8.4		
Pedon 9 (Malyal): Fine-loamy mixed isohyperthermic Typic Haplustept												
	0-20	56.2	14.2	29.6	1.5	0.81	74.6	61.7	3.3	7.0	0.6	12.5
	20-40	52.2	17.1	30.7	1.5	0.66	73.1	61.2	0.3	7.0		
	40-65	56.3	12.4	31.3	1.5	0.56	72.8	60.4	0.2	8.4		
	65-95	+60.2	13.5	26.3	1.5	0.31	70.1	60.3	0.1	10.1		
Pedon 10 (Duggondi): Fine-loamy, smectitic (calcareous) isohyperthermic Typic Haplustert												
	0-15	56.0	10.3	33.7	1.4	0.71	75.3	62.3	1.4	11.0	0.4	16.2
	15-37	49.0	15.8	35.2	1.4	0.51	74.9	62.1	0.4	11.8		
	37-65	+48.3	14.3	37.4	1.4	0.44	72.3	61.3	0.3	11.9		
Pedon 11 (Regonda): Fine-loamy, smectitic (calcareous) isohyperthermic Typic Haplustert												
	0-11	52.7	16.6	30.7	1.3	0.72	77.9	64.3	1.5	10.9	0.3	18.5
	11-35	50.6	17.2	32.2	1.3	0.51	76.7	63.3	0.7	12.3		
	35-55	51.1	15.2	33.7	1.4	0.31	76.1	61.3	0.5	13.1		
	55-75	48.9	17.0	34.1	1.4	0.25	73.8	61.3	0.2	13.2		
	75+	47.1	13.4	39.5	1.4	0.19	73.6	59.3	0.1	16.2		
Pedon 12 (Ghanpur): Fine-loamy, smectitic isohyperthermic Typic Haplustert												
	0-17	60.8	11.6	32.6	1.3	0.71	76.7	63.3	1.4	10.1	0.4	17.3
	17-45	54.3	13.5	37.2	1.3	0.54	75.8	61.3	0.5	11.6		
	45-60	48.2	18.0	33.8	1.3	0.39	75.1	61.2	0.2	12.8		
	60-65	+40.9	19.9	39.2	1.4	0.28	73.8	60.2	0.1	14.6		
Pedon 13 (Khanapur): Fine-loamy, smectitic isohyperthermic Typic Haplustert												
	0-12	47.8	18.9	33.3	1.4	0.78	76.8	64.2	1.1	10.2	0.3	17.3
	12-30	51.5	12.9	35.5	1.4	0.52	76.2	62.5	0.6	11.8		
	30-45	44.6	19.1	36.2	1.5	0.45	76.0	62.3	0.4	12.1		
	45-65	+43.2	18.2	38.6	1.5	0.36	75.6	60.3	0.2	12.3		
Pedon 14 (Warangal): Fine-loamy, smectitic (calcareous) isohyperthermic Typic Haplustert												
	0-15	54.6	15.0	30.4	1.41	0.79	76.2	64.6	1.6	10.5	0.3	18.0
	15-55	48.8	15.2	36.0	1.41	0.58	75.5	62.8	0.6	11.5		
	55-72	49.6	14.2	36.2	1.45	0.46	75.2	62.2	0.1	12.4		
	72+	48.4	12.6	39.0	1.48	0.44	74.9	60.1	0.1	15.2		

Water retention of soils at 33 kPa varied from 9.52 to 32.86% and increased with depth owing to increase in clay content (Lingade *et al.,* 2008; Pankaj *et al.,* 2012). The water retention at 1500 kPa varied from 4.40 to 17.70%. Available water content was low in surface horizons and increased with depth in most of the pedons (Rao *et al.,* 2008). The soil available water storage capacity of the pedons varied from 9.06 to 18.54 cm m^{-1}. It was low (5-10 cm m^{-1} depth) in Tadvai, Bachannapet and Eturunagaram, medium (10-15 cm^{-1}) in Nallabelli, Eleti Ramayapalli,Wardannapet, Raghunathapally, Pakala and Malyal and high (15-20 cm m^{-1}) in Duggondi, Regonda, Ghanpur, Khanapur and Warangal RS broadly. The soils having a high clay content and organic matter recorded high available water storage capacity. Saturated hydraulic conductivity (Ks) of soils varied from 0.08 to 18.26 cm hr^{-1}. The Ks was higher in surface horizons and decreased with depth. This could be attributed to increase in bulk density and clay content with soil depth. Decrease in hydraulic conductivity with depth has been reported by Prabhu Prasadini *et al.* (2009).

Physical Index

Physical rating index (PI) computed from the product of weightages assigned to 8 soil physical properties varied from 0.47 to 0.73 (Table 2). Wardhannapet and Bachannapet was categorized under category IV (slightly suitable) while all the other pedons were under category III (moderately suitable). The major constraints identified where they are low available water storage capacity, slow infiltration and high sub-surface bulk density. In Malyal soils did not have any constraints. Management practices (based on the local situation and experience) *i.e.,* application of organic matter, deep ploughing, contour cultivation and gypsum application were suggested (Table 3 and Table 4).

Soil Nutrient Index

There are totally nine administrative divisions and each administrative division has 6 numbers of mandals except in Mulug and Akulavari Ghanapur where they have only 3 mandals. On the basis of acreage and soil variability, an average of 3-8 numbers of surface soil samples were collected from each mandals to assess their soil fertility status and the mean value of available N, P and K content (mean value) of each administrative division is given in Table 3. The soil available N ranged from low of 145 kg ha^{-1} in Dharmasagar to high 270 kg ha^{-1} in Govindraopet. It might have been for low level organic matter returns to the field as it contributes more than 98% of the soil nitrogen (Jansson and person, 1998; Dev *et al.,* 2014). Soil available phosphorous content varied from low of 8.1 kg ha^{-1} in Devaruppala to the medium of 22.4 kg ha^{-1} in Gudur as it could have been derived from soil organic matter content and residual accumulation phosphorous from fertilizer application (Vijay Kumar *et al.,* 1994; Tiwari, 2001). Similarly, the soil available potassium content varied from a low of 171 kg ha^{-1} in Kothagudem to a high of 355 kg ha^{-1} in Mulug. It might have been for the difference in weatherability of potassium minerals and soil organic matter (Rao *et al*., (2008). As a whole, the available nitrogen, phosphorous and potassium content in surface soils of Warangal district was rated as low (NI<1.5), medium (1.98) and high (2.68), respectively.

Table: 2
Computation of physical rating index (PI), suitability class, constraints and suggestion for improved crop production

Location	Weightages given to the soil physical property value								PI	Suitability class	Constraints	Management options
	Soil depth (A)	BD (B)	MSC (C)	IR (D)	Aggregation (E)	Non-capillary pore space (F)	Water table depth (G)	Slope (H)				
Tadvai	0.90	1.00	0.80	0.80	0.95	0.95	1.00	1.00	0.51	III	Low AWSC and high sub soil BD	Addition of OM and deep ploughing
Nallabelli	0.90	1.00	0.90	0.90	0.95	0.95	1.00	0.90	0.59	III	Alkali soil, High sub soil BD	Gypsum application, deep ploughing
Bachannapet	0.90	1.00	0.80	0.80	0.95	0.95	1.00	0.90	0.47	IV	Low AWSC	Addition of OM
Eturunagaram	0.95	1.00	0.80	0.80	0.95	0.95	1.00	1.00	0.54	III	Slopy land, low AWSC, high sub soil BD	Contour cultivation, addition of OM, deep ploughing
Eleti Ramayapalli	0.90	1.00	0.90	0.90	0.95	0.95	1.00	0.95	0.62	III	High sub soil BD	Deep ploughing
Wardhannapet	0.90	1.00	0.85	0.80	0.95	0.95	1.00	0.90	0.50	IV	High sub soil BD	Deep ploughing
Raghunathapalli	0.90	1.00	0.80	0.80	0.95	0.95	1.00	1.00	0.51	III	High sub soil BD	Deep ploughing
Pakala	0.90	1.00	0.90	1.00	0.95	0.95	1.00	1.00	0.73	III	High subsoil BD	Deep ploughing
Malyal	0.95	1.00	0.80	0.95	0.95	0.95	1.00	0.95	0.62	III	High subsoil BD	Deep ploughing
Duggondi	0.90	0.85	0.95	0.90	0.95	0.95	1.00	0.90	0.53	III	Slow infiltration	Provision of drainage
Regonda	0.95	0.85	0.90	0.90	0.95	0.95	1.00	0.95	0.56	III	Alkali soil and slow infiltration	Gypsum application & provision of drainage
Ghanpur	0.90	0.85	0.90	0.90	0.95	0.95	1.00	0.95	0.53	III	Slow infiltration	Provision of drainage
Khanapur	0.90	0.85	0.95	0.90	0.95	0.95	1.00	0.90	0.53	III	Slow infiltration	Provision of drainage
Warangal RS	0.90	0.85	0.90	0.90	0.95	0.95	1.00	0.95	0.53	III	Slow infiltration	Provision of drainage

Table: 3
Available N, P and K content (mean value) in soils of Warangal district

Administrative Division	Mandals	Mean value of available nutrients (kg ha^{-1})			Administrative Division	Mandals	Mean value of available nutrients (kg ha^{-1})		
		N	P	K			N	P	K
Hanamakonda	Hanamakonda	223	14.7	320		Kodakundla	257	19.4	255
	Hasanparthy	166	15.5	307		Torur	253	11.7	235
	Geezugonda	234	20.1	294		Nellikudur	254	14.8	237
	Sangam	222	16.1	268		Narasimhulapeta	254	14.8	237
	Wardhannapet	228	17.2	315		Marripeda	254	14.8	237
	Parvathagiri	242	17.3	318	Narsampet	Nallabelli	254	14.8	237
Ghanpur	Dharmasagar	145	12.6	295		Duggondi	254	14.8	237
	Raghunathapalli	188	13.7	287		Warangal	254	14.8	237
	Zaffargath	168	8.3	324		Narsampet	254	14.8	237
	Palakurthi	254	10.5	313		Khanapur	254	14.8	237
	Ghanapur station	251	12.3	296		Chennaraopet	254	14.8	237
	Devaruppala	255	8.1	345		Nekkonda	254	14.8	237
Janagaon	Cherial	165	12.3	187	Parkal	Chityal	254	14.8	237
	Maddur	198	15.6	203		Mogulapalli	254	14.8	237
	Narmeta	229	17.4	311		Regonda	265	19.4	285
	Bachannapet	247	15.4	215		Parkal	214	17.3	301
	Jangaon	239	18.0	229		Shyampet	240	17.7	329
	Lingal ghanpur	197	11.3	243		Atmakur	222	20.6	320
Mahabubabad	Kothagudem	192	13.4	171	Mulug	Bhoopalpally	221	17.2	331
	Gudur	224	22.4	332		Ghanpur	232	14.7	297
	Kesamudram	267	15.4	175		Venkatapur	260	15.8	294
	Mahabubabad	254	18.9	195	Akulavari Ghanapur	Mulug	248	20.2	355
	Korivi	231	17.9	223		Eturunagaram	244	14.9	294
	Dornakal	251	17.2	215		Govindraopet	270	14.6	323
Maripeda	Raiparthi	230	14.6	341		Tadvai	269	14.2	291

Table: 4
Nutrient index of soils

Nutrients	Range (kg ha^{-1})	Nutrient index	Nutrient critical value	Category	Suggested practices for improved crop production
N	137-345	1.09*	< 1.50	Low	Application of fertilizers, FYM, green manures and green leaf manures and other organic inputs on the basis of soil test value
P	6.35-26.50	1.98*	1.50-2.50	Medium	
K	121-392	2.68*	> 2.50	High	

* Mean value

4. CONCLUSIONS

The major edaphic constraints of Warangal district were identified as high sub-soil bulk density, low available water storage capacity and low infiltration and low nitrogen and medium in phosphorus. According to Gupta *et al.* (1985), the Tadvai, Nallabelli, Eturunagram, Eletiramyapalli, Raghunathapalli, Pakala, Malyal, Duganndi, Regonda, Khanpur, Ghanapur and Warangal RS soils came under moderately suitable category (Class-III) and it is expected to have an impact on soil productivity about 50% of yield potential with optimum fertilizer management practices (Aggarwal and Choudkurp, 2005; Huang *et al*., 2006). The soil available N, P and K content of studied regions ranged from 145-270, 8.1-22.4 and 171-355 kg ha^{-1}, respectively. The calculated soil nutrient index indicated that the soils were low in nitrogen (1.09), medium in phosphorus (1.98) and high in potash (2.68). Therefore, the need based management practices such as application of organic matter, deep ploughing, provision of good drainage and contour cultivation were suggested for improvement of crop productivity in the studied regions where it follows the Law of Minimum.

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