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Fertility Evaluation of Temperate Farm Soils of Krishi Vigyan Kendra Doda in NW Himalayas, India

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ABSTRACT

Fertility evaluation of farm soils of KVK Doda of SKUAST-Jammu (J&K) was carried out using nutrient index approach. Representative soil samples drawn from different land uses viz., HD apple orchard, apricot block, apple mother block, walnut block, apple orchard on different root stocks, nectarine block, almond block, plum block, peach block, crop cafeteria block, apple nursery block and pomegranate block were analyzed for important physico-chemical characteristics and available nutrients. These soils were sandy clay, silty clay and clay in texture with pH, EC and OC varying from 5.42 to 7.14, 0.04 to 0.30 dS/m and 5.8 to 17.6 g/kg, respectively. Contents of available N, P and K for these soils varied from 263.2 to 557.9, 2.73 to 79.0 and 63.57 to 286.72 kg/ha, respectively whereas; available S, Mn, Fe, Zn, Cu and B varied from 2.15 to 17.23, 6.93 to 55.40, 4.0 to 19.60, 0.16 to 2.48, 0.42 to 4.34 and 0.07 to 0.74 mg/kg, respectively. As per NI values, these soils fell in high category of available Mn, Fe, Zn and Cu; medium category of available N, P, K and B: and low category of available S. Soil pH was significantly and negatively correlated with OC, EC, available N, P, Mn and Fe. Soil EC had significant positive correlation with OC, available N, P, K, S, Mn, Fe and Zn. Further, OC and available N showed significant positive correlation with each other as well as with available S, Mn, Fe and Zn. Available P showed strong synergistic relationships with available K and Mn. Also, available K, S and Mn were significantly positively correlated with each other. Further, available Zn was also significantly positively correlated to available K, Mn and B while its correlation with available Cu was significantly negative. Available Fe was significantly and positively correlated to available S and Mn. Regression analysis indicated 97.7% contribution of OC towards total variability in available N. About 67 and 33% of total variability in available P and S, in order, could be attributed to OC and EC together; while nearly 46% of that in available Fe could be attributed to pH and OC together. Nearly 34 and 57% of total variability in available Zn and K, in order, could be attributed to pH and EC together. EC alone could explain about 60% of total variability in available Mn.

Keywords Available nutrients, Land use, Nutrient index, Physico-chemical, Regression.

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INTRODUCTION

Fertility of soil is one of the most important factors which regulate crop growth and yield that leads to crop productivity. Therefore, soil fertility evaluation of an area or region is the basic decision making tool for sustainable soil nutrient management. Fertilizer recommendations can be made based on soil fertility status to maintain soil health and to sustain crop production. Also, physical and chemical attributes of soil regulate soil biological activity and exchange of ions between solid, liquid and gaseous phases which influence nutrient recycling, plant growth and decomposition of organic materials. Soil fertility must be periodically assessed as it changes continuously in time and space, being affected by several factors including land use. The fertility status of soils can be evaluated using nutrient index methods and fertility indicators. However, such information is still lacking for the soils of the study area that are supporting different land uses. Therefore, this study was conducted with the aim to assess the physico-chemical characteristics and evaluate fertility status of soils of study area.

MATERIALS AND METHODS

Geographical setting of study area and climate

Present studies were carried out at Gwari farm (comprising approximately 8.0 ha area) of Krishi Vigyan Kendra (KVK) Doda of Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST)-Jammu. KVK Doda (the study area) is situated at an altitude of 1600 m above msl in tehsil Bhaderwah of district Doda, Jammu and Kashmir, India. Geographically, it lies at 32.9961^0 N latitudes and 75.6948^0 E longitudes in the foot hills of middle Himalayas on Doda-Bhaderwah road some 30 km South of Doda city, the district head quarters. General slope is 70% and aspect mostly East and North-East. The area belongs to high altitude temperate zone of Jammu and Kashmir and is characterized by sub-humid temperate climate. Summers are relatively mild and dry whereas winters are fairly cold and wet with much snowfall due to western disturbances. As per IMD (2022) report, averaged over the period 1991-2020, the mean annual temperature of study area is 15^{0}C, January being the coldest month with mean daily minimum temperature of -0.4^{0}C and July the hottest with mean daily maximum temperature of 30.4^{0}C. Area also receives significant rainfall during July-September months and remains snow covered from mid December-March. The mean annual rainfall of area during the period from 1991-2020 is 1284.58 mm, October being the driest month with 28.5 mm of mean rainfall and February the wettest month of the year with 177.3 mm of the same.

Geology and soils

Bhaderwah is the creation of late Proterozoic consisting of slate, phyllite and quartzite (CGWB 2014). It is composed of six types of geological formations (Kumar 1987) viz., new and sub-recent granite, Sunbain quartzite, Bhaderwah slates, phyllites and schist. Thakur *et al.* (1995) reported muscovite's composition- biotite schist, quartzite, phyllite and limestone. The soil in the area is mostly formed by the physical, chemical and biological weathering of mica schist and granite.

Natural vegetation

The area is bound by high hills supporting Himalayan temperate forests dominated by coniferous type of vegetation comprising mainly blue pine (*Pinus wallichiana*), cedar (*Cedrus deodara*) as pure stands at lower elevations and mixed with fir (*Abies pindrow*) and spruce (*Picea smithiana*) at higher elevations. Other associated species is oak (*Quercus* spp.) found in damp/shady places. Himalayan alder (*Alnus nitida*) and *Ficus palmata* are two broad leaved species occuring along river banks. Shrubs consist mainly of Indian barberry (*Berberis lysium)*, cran berry (*Viburnum grandiflorum*), wild berry (*Rubus ellipticus*), Himalayan rose (*Rosa macrophylla*) and wrinkled leaf isodon/sulei (*Plectranthus rugosus*) as wild flora. Alpine pastures/meadows occur as open or interspersed with moist/ dry alpine scrub forests along snow line.

Land use

It is mostly a mono cropped zone with single growing season (*kharif* only) because of severe, prolonged winters and preponderance of snowfall. Length of growing period (LGP) is 180-240 days. Agriculture, along with its allied sectors is the main occupation of the people of the area. Major field crops are maize (*Zea mays*) and paddy (*Oryza sativa*) with wheat (*Triticum aestivum*) and barley (*Hordium vulgare*) grown to some extent. Fodder crops include oats (*Avena sativa*) along with clovers (*Trifolium* spp.). Fruit crops like apple, pear, walnut, pecan, almond, stone fruits (peach, plum, apricot, cherry and nectarine), berries (kiwi, strawberry, mulberry and blackberry), pomegranate are also cultivated including a variety of temperate vegetables and pulses (especially the beans). The famous *Bhaderwahi Rajmash* has a GI (Geographical Indicator) tag to its credit.

The study area has been divided into twelve different types of land uses followed on terraces namely HD apple orchard, apricot block, apple mother block, walnut block, apple orchard on different root stocks, nectarine block, almond block, plum block, peach block, crop cafeteria block, apple nursery block and pomegranate block (Table 1).

Soil sample collection and analysis

Thirty composite soil samples (0-20 cm depth) were drawn from twelve sites being managed under different land uses (as described earlier) in the study area. The samples were subsequently processed and analyzed for important physico-chemical properties like soil texture, pH, EC and OC along with available nutrients i.e. N, P, K, S, Fe, Mn, Cu, Zn and B using standard laboratory procedures (Jackson 1973). Nutrient index values (NIV) for individual land use as well as overall farm soils were computed using the formula developed by Parker *et al.* (1951) as modified by Motsara (2002):

$$NIV = \frac{Nl+2Nm+3Nh}{Nl+Nm+Nh}$$

Where,

Nl = Number of samples in low category of available nutrients

Nm=Number of samples in medium category of available nutrients

Nh = Number of samples in high category of available nutrients

The NIV classes were categorized by comparing calculated values of NIV with the recommended levels as: Low (NIV<1.67), Medium (NIV=1.67-2.33) and High (NIV>2.33). This study pertains to the period from the year 2017-2020.

Statistical analysis

Descriptive statistics (mean, range, SD, SE and CV) were worked out. Coefficient of variation (CV) was ranked according to the guidelines of Aweto (1982) as: Low (CV<25%), Moderate (CV=25-50%) and High (CV>50%). In order to study the relationship between soil physico-chemical properties and available nutrient content, simple correlation coefficients (r) were computed and multiple linear regression equations developed. Step-wise regression procedure was followed to retain variables exerting maximum influence on available nutrients by progressively eliminating less significant ones. Software package Fast Statistics v2.0.4 Build 0627 was used to compute all the statistics. For proper presentation of the data suitable logarithmic scale was used wherever necessary.

RESULTS AND DISCUSSION

Soil physico-chemical properties

Data presented in Table 1 showed these soils to be sandy clay, silty clay and clay in texture. The studied soils varied from slightly acidic (pH 5.42 in land use VI) to neutral (pH 7.14 in land use XII) in reaction with low variability (CV=7.5%). Ramzan *et al.* (2017) also reported lowest variability in soil pH (CV=7.06%) among the physico-chemical properties of soils of Srinagar in Kashmir. EC ranged from 0.04 to 0.30 dS/m with a mean value of 0.09 dS/m. These soils had EC values <1 dS/m (which is suitable for growing most types of crops) and a pH range suitable for plant availability of most of the nutrient elements. These soils contain medium to very high OC content varying from 5.8 (land use VII) to 17.6 g/kg (land use V) with mean value of 11.5 g/kg having moderate variability (CV=34.43%). High levels of OC may be attributed to the abundant quantities of soil organic matter (SOM) being added every year due to leaf/litter fall from deciduous plant based land use system followed in the area and also the same accu-

Table 1. Land use and important physico-chemical properties (mean values) of studied farm soils.

Sl. No.	Land use	No. of samples	Texture*	pH (1:2)	EC (dS/m)	OC (g/kg)
I	HD Apple orchard	3	Sc	6.43	0.05	15.4
II	Apricot block	2	C	7.14	0.04	13.6
III	Apple mother block	2	Sic	6.74	0.04	13.6
IV	Walnut block	3	Sc	5.72	0.29	16.1
V	Apple orchard on different root stocks	2	Sc	6.13	0.10	17.5
VI	Nectarine block	2	Sc	5.45	0.20	12.7
VII	Almond block	2	Sc	6.33	0.04	5.9
VIII	Plum block	2	Sc	6.33	0.07	12.0
IX	Peach block	2	Sc	6.53	0.07	12.0
X	Crop cafeteria block	4	Sic	6.47	0.04	6.9
XI	Apple nursery block	3	Sc	6.56	0.07	9.1
XII	Pomegranate block	3	Sc	7.12	0.04	6.8
Total/range		30	Sc - C	5.42-7.14	0.04-0.30	5.8-17.6
Overall mean				--	0.09	11.5
SD				0.48	0.08	3.96
SE_{mean} (±)				0.09	0.01	0.72
CV (%)				7.50	92.75	34.43

*Sc- Sandy clay, C- Clay, Sic- Silty clay.

mulated in the form of grass/weed biomass owing to single season (*kharif* only) farming practiced in the area. Fallows help to augment the build up of SOM (Aguilera *et al.* 2013). Moreover, temperate climatic conditions prevailing in the area might have helped to preserve accumulated SOM due to slow rate of its decomposition. EC showed highest CV value (92.75%) among physico-chemical properties indicating high heterogeneity (Cerri and Magalhaes 2012).

Available nutrient content

Primary nutrients

Data presented in Table 2 and depicted in Fig. 1

Table 2. Available nutrient status (mean values) of studied farm soils.

Land use	Available nutrients kg/ha				mg/kg				
	N	P	K	S	Mn	Fe	Zn	Cu	B
I	502.3	6.50	145.29	13.86	34.1	16.2	1.66	0.46	0.09
II	457.8	3.21	95.36	2.52	18.4	6.38	2.22	1.40	0.64
III	457.8	3.38	99.88	2.40	17.9	6.49	1.11	1.31	0.18
IV	519.0	74.0	280.70	15.71	50.8	15.0	2.40	1.59	0.37
V	555.8	6.40	90.81	2.38	16.6	18.7	1.29	2.24	0.09
VI	435.6	62.0	113.52	11.55	54.0	14.4	2.03	1.68	0.68
VII	268.2	3.50	68.50	2.40	14.8	5.15	1.66	1.40	0.64
VIII	418.9	19.66	108.98	7.85	24.7	10.0	1.66	1.96	0.09
IX	418.9	2.80	81.74	15.71	7.65	8.73	0.18	4.26	0.09
X	291.0	34.64	134.10	3.00	20.8	11.4	0.82	1.35	0.24
XI	346.6	63.0	165.10	6.78	18.5	9.5	1.20	1.48	0.30
XII	268.7	32.0	182.50	8.50	24.7	8.4	1.50	1.62	0.21
Range	263.2-557.9	2.73-79.0	63.57-286.72	2.15-17.23	6.93-55.40	4.0-19.6	0.16-2.48	0.42-4.34	0.07-0.74
Overall mean	403.33	28.90	139.16	7.87	25.88	11.12	1.46	1.65	0.29
SD	99.21	26.30	58.68	5.30	13.54	4.24	0.60	0.83	0.21
SE_{mean} (±)	18.11	4.80	10.71	0.97	2.47	0.77	0.11	0.15	0.04
CV (%)	24.60	91.01	42.17	67.38	52.32	38.13	41.26	50.39	71.69

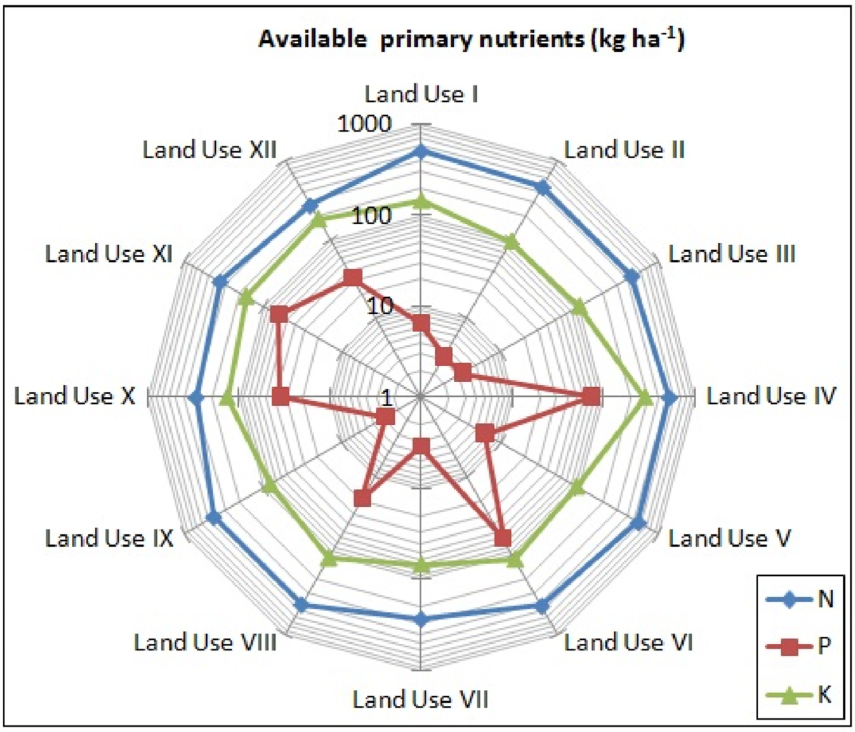

Fig. 1. Primary nutrient status of KVK Doda farm soils (Logarithmic scale).

showed that content of available N varied from 263.2 kg/ha in land use XII to 557.9 kg/ha in land use V with mean value of 403.33 kg/ha. Considering 272-544 kg/ha as available N sufficiency range, 10.0, 83.3 and 6.7% of the studied samples fell in low, medium and high category, respectively (Fig. 2). Adequate levels of available N in these soils may be due to their high organic matter content. The role played by SOM in

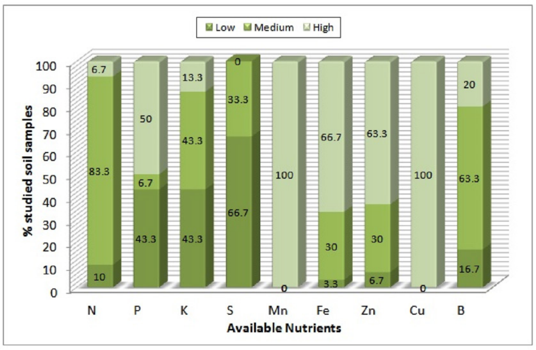

Fig. 2. Extent of nutrient deficiency/sufficiency in KVK Doda farm soils.

the maintenance of general soil fertility (especially N) is well established. High levels of OM not only provide part of the N requirement of crop plants but also enhance nutrients and water retention capacity of soils and create favorable physical, chemical and biological environment. Also, low temperature might have helped in reducing various N losses. Available P varied from 2.73 (land use IX) to 79.0 kg/ha (land use IV) with mean value of 28.9 kg/ha. Considering 12.4-22.4 kg/ha as available P sufficiency range, 43.3, 6.7 and 50% of the studied soils belonged to low, medium and high category, respectively. Sufficient levels of available P in these soils may be ascribed to high input of P fertilizers (especially DAP) and favorable soil pH. Available K varied from 63.57 (land use VII) to 286.72 (land use IV) kg/ha with a mean value of 139.16 kg/ha. Taking 113.3-277.5 kg/ha as available K sufficiency range, 43.3, 43.3 and 13.3% of the studied soil samples fell in low, medium and high category, respectively. Low and medium levels of available K in these soils may be due to the relatively lesser addition of costly potassic fertilizers

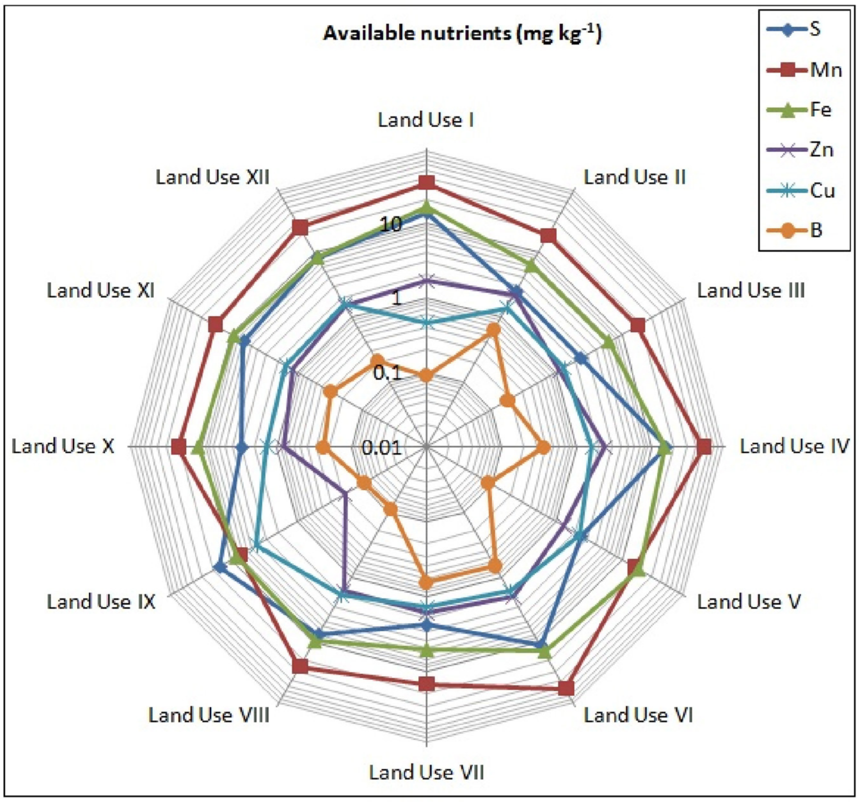

Fig. 3. Secondary and micronutrient status of KVK Doda farm soils (Logarithmic scale).

compared to K removal by crop.

Amongst primary nutrients, available P showed highest variability with CV value of 91.01% (high); whereas it was least (low) in case of available N (CV=24.60%). Ramzan *et al.* (2017) also reported highest variability (CV=56.87%) in available P among the available nutrients in the soils of Srinagar, Kashmir. A high CV is the first indicator of data heterogeneity (Cerri and Magalhaes 2012).

Secondary and micronutrients

Further scrutiny of data presented in Table 2 and depicted in Fig. 3 revealed that available S ranged from 2.15 (land use V) to 17.23 (land use IV) mg/kg with mean value of 7.87 mg/kg and CV value of 67.38%. Considering 10-20 mg/kg as sufficiency range, 66.7 and 33.3% of the studied samples fell in respective low and medium category, whereas none of the sample belonged to high category with respect to available S (Table 3). Deficiencies/low levels of available S observed in these soils despite high OC content may be attributed to low input of S containing fertilizers despite its continuous removal by crops (Amara *et al.* 2017). Fertilizer di-ammonium phosphate (DAP) is the most common source of P used in the area, being easily available at government subsidized rates. Con-

Table 3. Overall nutrient indices and fertility ratings of studied farm soils.

Available nutrients	% samples Low	Medium	High	NIV	Fertility rating
N	10.0	83.3	6.7	1.97	Medium
P	43.3	6.7	50.0	2.07	Medium
K	43.3	43.3	13.3	1.70	Medium
S	66.7	33.3	0.0	1.33	Low
Mn	0.0	0.0	100.0	3.00	High
Fe	3.3	30.0	66.7	2.63	High
Zn	6.7	30.0	63.3	2.57	High
Cu	0.0	0.0	100.0	3.00	High
B	16.7	63.3	20.0	2.03	Medium

tinued use of high analysis DAP/ mono ammonium phosphate (MAP) which contain little S, instead of S containing single super phosphate (SSP)/ammonium sulphate may lead to increasing deficiencies of S (Till 2010). Also, less amount of S bearing minerals and conditions that favor S leaching (hilly topography, heavy rain fall /snow melt) experienced in the area might have contributed to low available S levels.

Among micronutrients, available Mn, Fe, Zn, Cu and B varied from 6.93 (land use IX) to 55.40 (land use VI), 4.0 (land use VII) to 19.6 (land use I), 0.16 (land use IX) to 2.48 (land use II), 0.42 (land use I) to 4.34 (land use IX) and 0.07 (land use IX) to 0.74 mg/kg (land use VI) with respective mean values of 25.88, 11.12, 1.46, 1.65 and 0.29 mg/kg. Considering 2.0-4.0, and 0.2-0.4 mg/kg as respective sufficiency ranges for available Mn and Cu (Lindsay and Norvell 1978); 100% of the studied soils fell in high category with respect to these nutrients. Considering 4.5-9.0 mg/kg as sufficiency range for available Fe, 3.3, 30.0 and 66.7% of the soil samples belonged to low, medium and high category with respect to this micronutrient. Considering 0.6-1.2 mg/kg as sufficiency range for available Zn (Takkar and Mann 1975), 6.7, 30.0 and 63.3% of the total soil samples belonged to low, medium and high category, respectively. Further, taking 0.1-0.5 mg/kg as sufficiency range, 16.7, 63.3 and 20.0% of the soil samples belonged to low, medium and high category, respectively with respect to available B. High content of these micronutrients in studied soils may be attributed to their high OC content, clayey texture, low pH and nature of the parent material. High OC content might have protected these from oxidation, adsorption and precipitation into unavailable forms due to chelation during decomposition, thereby increasing their availability. Amongst micro nutrients, available Fe showed lowest CV (38.13%) with available B having the highest (71.69%).

Nutrient index

Perusal of data given in Table 3 regarding NI values further revealed that these soils fell in high category of available Mn (NIV=3.0), Fe (NIV=2.63), Zn (NIV=2.57) and Cu (NIV=3.0); medium category of available N (NIV=1.97), P (NIV=2.07), K (NIV=1.70) and B (NIV=2.03); and low category of available S (NIV=1.33). Fertility ratings of these soils may be arranged in the order: S<K<N<P and B<Zn<Fe=Mn=Cu with respect to available macro and micronutrients, respectively.

Correlation and regression studies

Data presented in Table 4 revealed that soil pH was significantly and negatively correlated with OC (r=-0.37*) and EC (r=-0.76**) and also with available N (r=-0.41*), P (r=-0.47**), Mn (r=-0.64**) and Fe (r=-0.52**). Decomposition of organic matter releases nutrients and also lowers pH of soil locally that helps in increasing solubility of nutrients, especially the micronutrient cations and also lowers N losses due to volatilization which occur at high pH. Meena and Mathur (2017) also reported significant negative correlations of available micronutrients with soil pH and positive correlations with OC in the soils

Table 4. Significant correlations for studied farm soils.

	pH	EC	OC	Av N	Av K	Av S	Av Mn	Av Zn
pH	-	-0.76**	-0.37*	-0.41*	ns	ns	-0.64**	ns
EC	-0.76**	-	0.48**	0.49**	0.65**	0.55**	0.78**	0. 54**
OC	-0.37*	0.48**	-	0.99**	ns	0.41*	0.40*	0.40*
Av P	-0.47**	0.68**	ns	ns	0.75**	ns	0.64**	ns
Av S	ns	0.55**	0.41*	0.39*	0.52**	-	0.57**	ns
Av Mn	-0.64**	0.78**	0.40*	0.39*	0.63**	0.57**	-	0.71**
Av Fe	-0.52**	0.45*	0.60**	0.59**	ns	0.43*	0.54**	ns
Av Zn	ns	0. 54**	0.40*	0.38*	0.45*	ns	0.71**	-
Av Cu	ns	ns	ns	ns	ns	ns	ns	-0.47**
Av B	ns	ns	ns	ns	ns	ns	ns	0.54**

**,*Significant at p≤ 0.01, p≤ 0.05 respectively; ns-Non significant.

Table 5. Effect of physico- chemical properties on available nutrients in studied farm soils.

Regression equation	Predictability ($R^2 \times 100$)
Av N = 257. 308-20. 194 pH* -73. 886 EC + 24.581 OC**	98.1
Av N = 119.214+ 24.748 OC**	97.7
Av P = 1.876 + 5.827 pH + 327.350 EC** -3.406 OC**	67.1
Av P = 41.588 + 301.056 EC** -3.405 OC**	66.7
Av K = -368. 708 + 72.584 pH** + 866. 067 EC** -2.981 OC	60.1
Av K = -396. 237 + 72.508 pH** + 795. 322 EC**	57.0
Av S = -8. 859 + 1. 646 pH + 37. 307 EC* + 0.251 OC	33.8
Av S = 2.362 + 29.877 EC* + 0.252 OC	32.9
Av Mn = 37. 468 -3.521 pH + 110. 792 EC** + 0.114 OC	61.1
Av Mn = 14.536 +129. 362 EC**	60.4
Av Fe = 29. 404 -3.719 pH -6.099 EC + 0.534 OC**	46.4
Av. Fe = 24.751 -3.024 pH* + 0.504 OC**	45.9
Av Zn = -1.852 + 0.396 pH + 5. 175 EC** + 0.028 OC	36.4
Av Zn = -1.597 + 0.397 pH + 5. 831 EC**	33.9
Av Cu = 0.697 + 0.128 pH + 1.374 EC + 0.001 OC	0.90
Av B = 0.401+ 0.001 pH + 1.115 EC - 0.019 OC	16.7

**,*Significant at p≤ 0.01, p≤ 0.05 respectively.

Note: Av N, P,K (kg/ha); Av S, Mn, Fe, Zn, Cu, B (mg/kg); EC (dS/m); OC (g/kg).

of Rajasthan. The significant negative correlation between pH and available P may be due to conversion of soluble P to insoluble Ca and Mg phosphates, thus reducing its availability with the rise in pH. EC showed significant and positive correlations with OC (r=0.48**), available N (r=0.49**), P (r=0.68**), K (r=0.65**), S (r=0.55**), Mn (r=0.78**), Fe (r=0.45*) and Zn (r=0.54**). These results are in line with those reported by Chaudhary *et al.* (2020) and Bhat *et al.* (2017). Soil OC showed significant and positive correlations with available N (r=0.99**), S (r=0.41*), Fe (r=0.60**), Mn (r=0.40*) and Zn (r=0.40*) indicating that these nutrients are mainly associated with soil OC (Wibowo and Kasno 2021, Meena and Mathur 2017) in the studied soils. Also, available N had similar relationships with available S, Mn (r=0.39*), Fe (r=0.59*) and Zn (r=0.38*). Available K showed strong synergistic relationships with available P (r=0.75**), S (r=0.52**), Mn (r=0.63**) and Zn (r=0.45*). The step down regression equations (Table 5) revealed that contribution of OC to total variability in available N was as high as about 97.7%. About 67 and 33% of total variability in available P and S, in order, could be attributed to OC and EC together; while nearly 46% of that in available Fe could be attributed to pH and OC together. Nearly 34 and 57% of total variability in available Zn and K, in order, could be attributed to pH and EC together. EC alone could explain about 60% of total variability in available Mn.

CONCLUSION

The studied soils were coarse to fine textured, slightly acidic to neutral in reaction having normal EC and medium to very high OC content (conditions ideal for plant growth). Wide variations in their physico-chemical properties and fertility existed across land uses. Majority of these soils contained available nutrients in medium (N, P, K and B) to high (Mn, Fe, Zn and Cu) amounts, however their fertility with respect to available S was low. As such, application of S is expected to be responsive in soils testing low in available S. The results exhibited high degree of dependence of available N on OC; available Fe on OC and pH; available P on OC and EC; available K on pH and EC; and available S, Mn and Zn on EC. Thus, soil physico-chemical characteristics i.e. OC, pH and EC had close association with availability of nutrients in these soils. High degree of heterogeneity existing in these farm soils indicated a strong need for the development of site-specific recommendations to improve and sustain yield and quality of crops. This may also help to develop future research strategy in accordance with the soil database generated.

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