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Physico-chemical properties, available nutrient content and their inter-relationship in soils under rain fed maize-wheat cropping system, district Reasi (J&K)

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ABSTRACT

Composite soil samples representing rain fed maize-wheat cropping system in district Reasi of Jammu and Kashmir were analyzed for important physico-chemical properties and available nutrients. These soils were found to be sandy loam in texture with pH, EC and OC varying from 5.89 to 8.73, 0.04 to 0.47 dS/m and 3.5 to 21.9 g/kg, respectively. Content of available major nutrients viz. N, P, K and S varied from 207.6 to 663.6, 0.89 to 78.0, 22.71 to 349.45 kg/ha and 0.50 to 52.30 mg/kg, respectively, while that of available micronutrients viz. Fe, Zn and B varied from 0.89 to 30.20, 0.18 to 3.85 and 0.11 to 0.70 mg/kg, respectively. As per Nutrient Index values, these soils fell in high category of available Fe, medium category of available N, P, Zn, B and low category of available K and S. Soil pH, EC and OC were significantly and positively correlated with each other as well as with available N, K and B; and negatively with available Zn. Soil pH was also significantly negatively correlated with available Fe whereas, EC was positively correlated with available S and P. Further, available P was significantly positively correlated with OC, available N, K, S, Fe and B. Available N had a synergistic relationship with available K and B; and antagonistic relationship with available Zn. Available Zn showed significant and positive correlation with available Fe; however its correlation with available K and B was significantly negative. Available B had a significant positive correlation with available K and negative correlation with available Fe. The step down regression analysis indicated that nearly whole of variability in available N could be attributed to OC alone. About 28% of total variability in available P could be attributed to pH and EC together; while 13% of that in available S could be attributed to EC alone. Nearly 58 and 82% of the respective variability in available K and B could be due to OC and EC together. Soil pH and OC together contributed about 80 and 86% of the total variability towards available Fe and Zn in order.

Keywords: Available nutrients, maize-wheat, nutrient index, physico-chemical, rain fed

INTRODUCTION

The overall productivity and sustainability of any agricultural production system is highly dependent on the physico-chemical characteristics and fertility of soil resources (Wakene, 2001; Mohammed *et al.,* 2005). Any sustainable high agricultural production system needs fertile and productive soils. However, soil fertility is a dynamic property that changes under the influence of natural and human induced factors. Continuous farming without replenishing nutrients (loss through continuous crop harvest, removal of crop residue), low levels of fertilizer use and imbalanced application of nutrients can deplete soil fertility over time. In order to replenish soil fertility of an area through fertilizers/manures, it is imperative to know about present soil fertility status and physico-chemical characteristics. Hence, determination of these parameters is important for evaluating nutrient behavior in the soil. This is particularly true for rain fed agriculture where yields are often limited by deficient soil fertility. However, no such information is available so far for the soils of the study area where agriculture is completely rain fed. Therefore, a study was conducted to assess the physico-chemical characteristics and fertility status of soils under rain fed maize-wheat cropping system which is the main land use and major source of agricultural economy for the people of study area.

MATERIALS AND METHODS

Geographical setting of study area

The study area comprised of major villages/Panchayats namely Dassanu, Dadua, Goswan, Bhajta, Tanda and Kanjali of tehsil and district Reasi in Jammu and Kashmir, India. Reasi district lies between 33^0 05' N latitude and 74^0 50' E longitudes in Shiwalik hills of western Himalayas at an altitude of approximately 500 m

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above sea level (a.s.l.), though the elevation in the northern hilly areas may go up to 2500 m a.s.l. (Dhekne *et al.,* 2014). The district shares its boundaries with Udhampur district to the south, Ramban in the east, Shopian of Kashmir in the north and Rajouri district in the west. Geographically, the district can be divided into the hilly and low lying hilly areas (Dhekne *et al.,* 2014). River Chenab is the major river flowing through the district.

Climate

Climate of the area ranges from sub-tropical to semi-temperate type. Summers are generally warm and winters are cold with snowfall on the high ridges dipping the temperature to sub-zero levels. The mean annual maximum and minimum temperature in study area ranges between 35-40^{0}C and 10-12^{0}C, respectively. Winters start by the middle of November and continue until early March. The period of March to end of June constitutes the pre-monsoon season, followed by the southwest monsoon season until September. The district receives abundant rains in the monsoon season. Average rainfall of Reasi is about 1668 mm/yr (Hasan, 1999). Period of October to mid-November is post-monsoon season. The rainfall in the southwest monsoon season (June-September) makes up about 72% of the annual normal rainfall, while that in pre-monsoon months (March-May) accounts for 12% of the annual precipitation (Dhekne *et al.,* 2014).

Geology and soils

Geologically the area can be divided into four rock zones *i.e.* The Pir Panjal Zone, Murree Zone, The Reasi Limestone Inlier and The Shiwalik belt. These four stratigraphic zones are distinct from one another in their constituent rock formation, tectonics and intensity of metamorphism. Rocks range in the age from Pre Cambrian to Shiwaliks of Miocene to Lower Pleistocene age. The soils are made up of Ochrepts, Orchrepts-Orthents and Ochrepts-Orthents-Ustalfs sub order associations. These soils are of brown colour having coarse loamy texture.

Vegetation and land use pattern

Trees like deodar (C*edrus deodara*), kail (*Pinus wallichiana*), fir (*Abies pindrow*) and pine (*Pinus roxburghii*) exist at higher altitudes, whereas at lower slopes and in plain areas bamboo *(Bambusa* spp.), tali (*Dalbergia sissoo*), khair (*Acacia* spp.), tuna (*Tuna ciliata*) and thorny bushes are found in abundance. In addition, stands of oak (*Quercus* spp.) confined to damp and shady places are also seen. Other vegetation comprises of berberis (*Berberis lysium)*, Himalayan cherry (*Prinsepia* spp.) *etc.* including sub-alpine herbs. Among fruit trees mango (*Mangifera indica*), apricot (*Prunus armeniaca*), guava (*Psidium guajava*), apple (*Malus domestica*), quince (*Cydonia oblonga*), walnut (*Juglans regia*) and citrus (*Citrus* spp.) is found over a large area. Maize (*Zea mays*) is the most important food crop followed by wheat (*Triticum aestivum*). In addition, millets, pulses, rice, oilseeds (mustard and lentil) and a variety of vegetables are also cultivated. Agriculture in the area is mostly rain fed.

Soil sample collection and analysis

Based on the heterogeneity in soil-site characteristics, seventy four composite soil samples were collected from the study area under rain fed maize-wheat cropping system. The samples were air dried, grounded and passed through 2 mm sieve. These were subsequently analyzed for important physico-chemical properties like soil texture, pH, EC and OC along with available nutrients *i.e.* N, P, K, S, Fe, Zn and B using standard laboratory procedures (Jackson, 1973). Nutrient index values (NIV) were computed using the formula developed by Parker *et al.* (1951) as modified by Motsara (2002).

Statistical analysis

In order to study relationship between soil physico-chemical properties and available nutrient content, Pearson correlation coefficients (r) were computed and multiple linear regression equations developed. Step down regression procedure was followed to identify soil properties exerting maximum influence on available nutrients by progressively eliminating less significant variables, retaining in the process, equations with highest predictability. Software package Fast Statistics v2.0.4 Build 0627 was used to compute the statistics.

RESULTS AND DISCUSSION

Soil physico-chemical properties

Data presented in Table 1 showed that these soils were sandy loam in texture and slightly acidic to strongly alkaline in reaction (pH 5.89-8.73) with not much variability with respect to these two parameters. EC ranged from 0.04 to 0.47 dS/m with mean value of 0.18 dS/m. Low EC values suggesting low amounts of soluble salts, also indirectly indicate coarse texture of these soils. All the soils had EC value <1 dS/m which may be considered safe for growing most of the crops. These soils contain low to very high OC content varying from 3.50 to 21.90 g/kg with mean value of 11.86 g/kg. Sufficient levels of OC in these soils may be due to large quantities of organic matter (OM) and animal wastes being added to soils in the form of FYM as there is high domestic cattle population observed in the area. EC and OC showed high variability with CV values of 50.38 and 41.91%, respectively. These three parameters were significantly and positively inter- correlated (Table 4).

Table 1: Physico-chemical properties of studied soils

Descriptive statistics	Texture	pH (1:2)	EC (dS/m)	OC (g/kg)
Range	Sandy loam	5.89-8.73	0.04-0.47	3.50-21.90
Mean	-	-	0.18	11.86
SD	-	0.66	0.09	4.97
SE_m (+)	-	0.08	0.01	0.58
CV (%)	-	8.54	50.38	41.91

Available nutrient content

Macronutrients

Data presented in Table 2 showed that available N varied from 207.6 to 663.6 kg/ha with mean value of 414.29 kg/ha. Considering 272-544 kg/ha as N sufficiency range, 10.8, 68.9 and 20.3% of the studied samples fell in respective low, medium and high category (Table 3, Fig.1) with NIV value of 2.09 (medium). Sufficient levels of available N in these soils may be due to their high OC content. The role played by organic matter in maintenance of soil fertility in more than one ways is well established (Johnston, 1986) which is also evident from highly significant positive correlation ($r=0.99^{**}$) between the two as found in the present studies (Table 4). These results are comparable with the findings of Kumar *et al.* (2022) and Singh and Singh (2022) where available N in soils had significant positive correlations with soil OC. 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 creates favourable physical, chemical and biological environment. Available P varied from 0.89 to 78 kg/ha with mean value of 21.17 kg/ha and very high variability (CV=102.54%). These results are in line with those of Ramzan *et al.* (2017) who reported highest variability (CV=56.87%) in available P among the available nutrients in the soils of Srinagar, Kashmir. Considering 12.4-22.4 kg/ha as P sufficiency range, 51.4, 13.5 and 35.1% of the studied samples belonged to respective low, medium and high category with NIV value of 1.84 (medium). Sufficient available P content in these soils may be due to the nature of parent material, application of P fertilizers and high OC content of these soils. This contention finds support from the significant positive correlations occurring between available P and OC ($r=0.24^{*}$) as depicted in table 4. This correlation might be due to the acidulating effect of OC, formation of easily accessible organophosphate complexes, release of P from organic complexes and reduction in P fixation by humus due to formation of coatings on Fe and Al oxides. These results are in harmony with the findings of Ayele *et al.* (2013). Bhat *et al.* (2017) also reported highly significant and positive correlation of OC with available N and P while studying orchard soils of Kashmir. Available K varied from 22.71 to 349.45 kg/ha with mean value of 142.3 kg/ha. Taking 113.3-277.5 kg/ha as K sufficiency range, 43.2, 50.0 and 6.8% of the studied soils fell in low, medium and high category, respectively with NIV value of 1.63 (low). Available S ranged from 0.50 to 52.30 mg/kg with mean value of 8.37 mg/kg. Considering 10-20 mg/kg as sufficiency range, 75.7, 13.5 and 10.8% of the samples fell in respective low, medium and high category with respect to this nutrient having NIV value of 1.35 (low). Low levels/deficiency of available K and S may be ascribed to low fertilizers input of these nutrients in comparison to their crop removal, nature of parent material bearing low amounts/ unavailable forms of these minerals and coarse texture of these soils. High uptake of available K by maize crop as a result of luxury consumption and that of available S by oilseeds (mustard and lentil grown along with wheat) might have resulted in the deficiency of these two nutrients in these soils.

Table 2: Available nutrient status of studied soils

Available nutrients	Range	Mean	SD	$SE_{m\ (+)}$	CV (%)
N (kg/ha)	207.60-663.60	414.29	123.48	14.35	29.81
P (kg/ha)	0.89-78.00	21.17	21.70	2.52	102.54
K (kg/ha)	22.71-349.45	142.30	80.20	9.32	56.36
S (mg/kg)	0.50-52.30	8.37	9.61	1.12	114.91
Fe (mg/kg)	0.89-30.20	13.05	7.55	0.88	57.88
Zn (mg/kg)	0.18-3.85	1.06	1.02	0.12	96.13
B (mg/kg)	0.11-0.70	0.33	0.15	0.02	46.35

Micronutrients

Further perusal of data presented in Table 2 reveals that among micronutrients, available Fe varied from 0.89 to 30.20 mg/kg with mean value of 13.05 mg/kg. Considering 4.5-9.0 mg/kg as sufficiency range (Lindsay and Norvell, 1978) 10.8, 27.0 and 62.2% of the studied soils belonged to low, medium and high category respectively (Table 3, Fig. 1), NIV being 2.51 (high).

Table 3: Nutrient indices and fertility ratings of studied soils

Available nutrients	% Samples			NIV	Fertility rating
	Low	Medium	High		
N	10.8	68.9	20.3	2.09	Medium
P	51.4	13.5	35.1	1.84	Medium
K	43.2	50.0	6.8	1.63	Low
S	75.7	13.5	10.8	1.35	Low
Fe	10.8	27.0	62.2	2.51	High
Zn	55.4	5.4	39.2	1.84	Medium
B	0.00	81.1	18.9	2.19	Medium

High Fe content in these soils may be due to the presence of Fe containing minerals and high OC content that might have protected Fe from oxidation and precipitation thereby increasing its availability (Prasad and Sakal, 1991). Available Zn varied from 0.18 to 3.85 mg/kg with mean value of 1.06 mg/kg. Considering 0.6-1.2 mg/kg as sufficiency range (Takkar and Mann, 1975) 55.4, 5.4 and 39.2% of the studied soils belonged to low, medium and high category, respectively with NIV value of 1.84 (medium). This element occurs as a contaminant in phosphatic fertilizers. Therefore, continuous addition of P fertilizers, together with high OC content might have raised the levels of available Zn in some of these soils. These results are in line with those of Kavitha and Sujatha (2015). Further, both of these micronutrients had highly significant negative correlations with soil pH, value of r being -0.85^{**} and -0.92^{**} for available Fe and Zn, respectively. Low availability of micronutrients at higher pH may be attributed to the reduction in their solubility. These results are in conformity with the findings of Yadav and Meena (2009). Available B ranged from 0.11 to 0.70 mg/kg with mean value of 0.33 mg/kg. Taking 0.1-0.5 mg/kg as sufficiency range for available B, 81.1 and 18.9% of the studied soils fell in medium and high category, respectively with medium NIV values (2.19). Again, high OC content might be responsible for available B in these soils, as OC helps in increasing the availability of B. These findings are also supported by highly positive correlation ($r=0.87^{**}$) existing between the two.

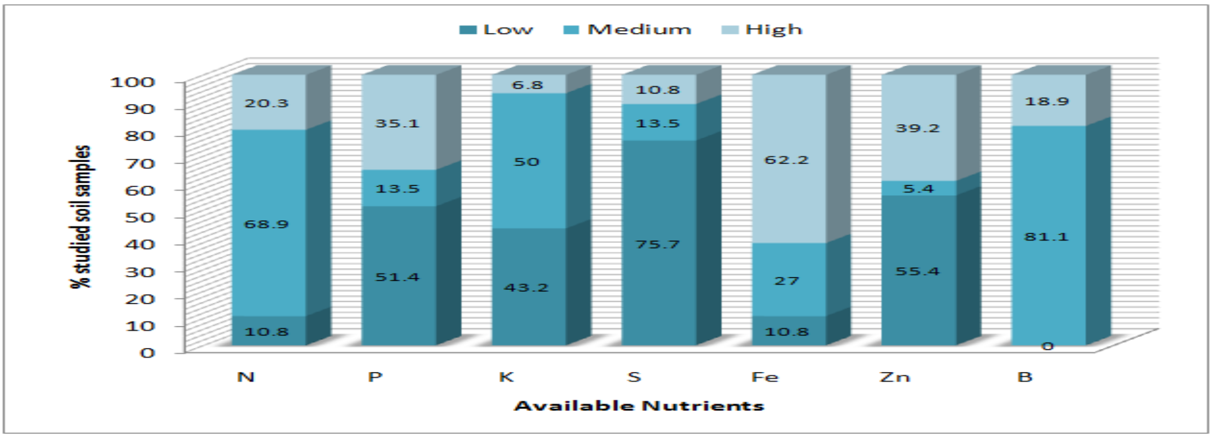

Fig.1: Extent of nutrient deficiency/sufficiency in studied soils

CV values ranged from 29.81% (for available N) to 114.91% (for available S). Heterogeneity observed in physico-chemical characteristics and available nutrient content of studied soils might be the result of variations in intensity of soil forming factors and pedogenic processes at play during the development of these soils and different management practices followed.

Table 4: Correlation coefficients for studied soils

	pH	EC	OC	Av. N	Av. P	Av. Zn	Av. B
EC	0.36^{**}	-	0.67^{**}	0.67^{**}	0.45^{**}	-0.30^{**}	0.78^{**}
OC	0.53^{**}	0.67^{**}	-	0.99^{**}	0.24^{*}	-0.35^{**}	0.87^{**}
Av. N	0.53^{**}	0.67^{**}	0.99^{**}	-	0.24^{*}	-0.35^{**}	0.87^{**}
Av. K	0.48^{**}	0.63^{**}	0.74^{**}	0.74^{**}	0.29^{*}	-0.36^{**}	0.72^{**}
Av. S	ns	0.36^{**}	ns	ns	0.45^{**}	ns	ns
Av. Fe	-0.85^{**}	ns	ns	ns	0.34^{**}	0.91^{**}	-0.27^{*}
Av. Zn	-0.92^{**}	-0.30^{**}	-0.35^{**}	-0.35^{**}	ns	-	-0.37^{**}
Av. B	0.47^{**}	0.78^{**}	0.87^{**}	0.87^{**}	0.28^{*}	-0.37^{**}	-

Regression studies

Data presented in table 5 indicated that available N showed highly significant and positive regression coefficient (24.845^{**}) with OC. Step down regression equations indicated that nearly whole of the variability in available N could be attributed to OC alone. The significant and positive correlation between OC and available N could be because of release of mineralizable N from soil organic matter in proportionate amounts (Vanilarasu and Balakrishnamurthy, 2014) and adsorption of NH_4-N by humus complexes in soil. The results are in conformity with those of Kumar *et al.* (2014). Available P showed significant regression coefficients with pH (-9.713^{**}) and EC (132.819^{**}). Also, available K had significant, positive regression coefficients with OC (9.397^{**}) and EC (204.864^{**}). About 28% of variability in available P could be attributed to pH and EC together; whereas 57.9% of that in case of available K was attributed to OC and EC together. Available S showed significant and positive regression coefficient with EC (37.866^{**}). It was found to be influenced by EC alone to the extent of 13.1% of the total variability. Available Fe and Zn had significant and negative regression coefficients with pH (-11.698^{**} and -1.575^{**} in order) and positive significant coefficients with OC (0.472^{**} and 0.037^{**} in order). Yadav (2011) suggested that the reduced Fe availability with increasing pH might be attributed to the conversion of Fe^{+2} to Fe^{+3} ions. The Fe^{+3} ion compounds have low solubility in solution and so are less bio available. Soil pH and OC contributed 79.8% and 86.4% of the total variability towards available Fe and Zn in order. Available B had significant and positive regression coefficients with OC (0.019^{**}) and EC (0.599^{**}), these two variables explaining 82.1% of the total variability in available B. Similar results were reported by Randhawa and Singh (1995) for the soils of Punjab.

Table 5: Multiple linear regression equations for studied soils

Regression equation	Predictability (R^2x100)
Av. N = 118. 495 + 0.169 pH -0.432 EC + 24.838 OC**	99.9
Av. N = 119.641 + 24.845 OC**	99.9
Av. P = 73. 451 -10.074 pH* + 128. 390 EC** + 0.147 OC	28.3
Av. P = 71.609 -9.713 pH**+ 132.819 EC**	28.2
Av. K = -105. 177+ 14.383 pH + 203.360 EC* + 8.415 OC**	58.9
Av. K = -6.521+ 9.397 OC** + 204.864 EC**	57.9
Av. S = 7.455 -0.610 pH + 50. 638 EC** -0.307 OC	15.0
Av. S = 1.459 + 37.866 EC**	13.1
Av. Fe = 97.528 -11.690 pH** -5.742 EC + 0.543 OC**	80.0
Av. Fe = 97.391 -11.698 pH** + 0.472 OC**	79.8
Av. Zn = 12.768 -1.573 pH** -1.194 EC + 0.051 OC**	87.0
Av. Zn = 12.739 -1.575 pH** + 0.037 OC**	86.4
Av. B = -0.030 + 0.003 pH + 0.599 EC** + 0.019 OC**	82.1
Av. B = -0.007 + 0.019 OC** + 0.599 EC**	82.1

***,*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)*

CONCLUSION

The studied soils under maize-wheat cropping system were found to be coarse textured, slightly acidic to strongly alkaline in reaction, low to very high in OC, having normal EC range ideal for growth of most of the crops. There existed a high degree of heterogeneity in physico-chemical properties and fertility in these soils. Majority of these soils contained medium to high amounts of available nutrients (N, P, Zn, Fe and B); however many of these were found to be deficient in available K and S. There is a high probability of response to the application of K and S in soils testing low in these nutrients. The results exhibited high degree of dependence of available N on OC; K and B on OC and EC; Fe and Zn on pH and OC; P on both pH and EC; and that of S on EC. Thus, soil physico-chemical characteristics OC, pH and EC had great influence on the availability of nutrients in these soils. These properties can be suitably manipulated in order to achieve nutrient balance in these soils.

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