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Improvements in the physical and chemical characteristics of degraded soils supplemented with organic–inorganic amendments in the Himalayan region of Kashmir, Pakistan

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ABSTRACT

Efficient use of organic amendments and changing cropping pattern are important management strategies for restoring the degraded upland soils of Himalayan region. This study was conducted to determine the quantitative effect of poultry manure (PM) and wheat straw residues (WSR) repetitively applied alone or in combination with urea N (UN) on physical and chemical properties of soil under wheat–soybean cropping sequence over three years (2008–09, 2009–10, 2010–11). Treatments included PM_{100}, WSR_{100}, $PM_{50} + WSR_{50}$, UN_{100}, $UN_{50} + PM_{50}$, $UN_{50} + WSR_{50}$, $UN_{50} + PM_{25} + WSR_{25}$ and a control. Added amendments were applied on N equivalent basis at the rate of 100 kg N ha^{-1}. Results indicated that organic amendments applied alone or in combination with UN significantly improved soil physical characteristics by lowering bulk density 7–12%, penetration resistance 3–4% and increasing hydraulic conductivity 15–32%, and aggregate stability 13–35%. Application of UN_{100} alone was ineffective in improving any of these characteristics. Combination of organic–inorganic amendments increased soil organic matter content by 3–9%, total N 14–29%, available P 5–35% and extractable K 12–39%. Response of micronutrient to organic or organic–inorganic amendments was even higher than that recorded for macronutrients. Organic amendments increased soil pH while UN displayed acidifying effect. The C sequestration and nutrient pool of the soil amended with WSR remained rich over PM even though PM contains a lot more nutrients. The study clearly demonstrated that organic amendments applied alone or combined with UN improved the physical characteristic and fertility status of the soils and may be considered as a useful management strategy for restoration of degraded soils in the mountain ecosystem of the Himalayan region of Kashmir, Pakistan.

1 . Introduction

Land degradation can be considered in terms of long-term loss of actual or potential productivity or utility of plant and animal resources (useful to human beings) as a result of natural or anthropic factors (Milton, 1994). The Food and Agriculture Organization (FAO, 1980) defines the concept of land degradation as the deterioration or total loss of the productive capacity of the soils for present and future use. It has been estimated that about 1.9 billion hectares of land worldwide (an area approximately the size of Canada and the USA) are affected by land degradation (United Nations, 1997). The problem is especially serious in the heavily populated, under-developed, and ecologically fragile areas of the Hindu Kush Himalaya (HKH) region where large amounts of soil and nutrients are lost from sloping uplands mainly as a result of soil erosion and surface run-off each year (Tiwari et al., 2010). Mandal and Sharda (2013) explained in detail the environmental problem of the region and reported that soil erosion is a major issue because of undulating topography, steep slopes and high rainfall. In the state of Jammu and Kashmir (Indian part), land degradation scenario has been assessed and found that about 13.19% of the area has undergone moderate to high degradation, whereas about 44.12% of the area has undergone slight degradation (Rashid et al., 2011). The report suggested that about 4.13 million hectares of land in Jammu and Kashmir has to be subsumed under different categories of soil erosion. Land resource degradation in the Himalayan region is mainly caused by landslides, mudslides, collapse of man-made terraces, soil loss from steep slopes and decline of forest/pasture areas (ICIMOD, 1994).

Several management practices have been suggested for restoration of degraded lands. Raizada and Juyal (2012) used low cost bioengineering and vegetative methods for the improvement of degraded soils in the North West Indian Himalayas. Kirkby et al. (2013) suggested that degraded soils can be restored by increasing the size of the soil organic carbon (SOC) pool. Integrated use of organic–inorganic nutrient sources is considered a useful management strategy for improving soil quality, soil fertility and crop productivity especially under low input agricultural systems susceptible to degradation (Abbasi and Tahir, 2012; Abbasi et al., 2010; Behera et al., 2007; Bhattacharyya et al.,

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2008; Fallah et al., 2013). However, the in-depth studies on the effect of different crop rotations (instead of maize-wheat normally practiced in the region) along with integrated use of organic–inorganic amendments on improving soil quality characteristics in the Himalayan region are very limited.

Combined application of organic nutrient sources along with inorganic fertilizers assured high and sustained productivity in a cereal–legume cropping system due to continuous nutrient supply and minimizes losses, besides lowering costs (Behera et al., 2007; Manna et al., 2003; Subbarao et al., 1998). A long-term (30 years) soybean–wheat experiment in India indicated that combined use of NPK and farmyard manure (FYM) increased SOC, oxidizable SOC, total N, total P, Olsen P, and exchangeable K by 37.8, 42.0, 20.8, 30.2, 25.0, and 52.7%, respectively compared to the sole application of NPK (Kundu et al., 2007). In another study, soil physical and chemical properties have shown a similar response to organic–inorganic amendments and SOM, total soil N, total P and Olsen P under NPK + FYM were 10, 42, 52 and 71%, respectively higher than those recorded under NPK alone (Bhattacharyya et al., 2010). Under semi-arid tropical conditions of India, Panwar et al. (2010) reported that organic manures applied alone or with mineral N over a 3-year period strongly built up SOC and significantly increased mineral N, available P and K, and micronutrient (Fe, Mn, Zn, and Cu) in the order organic > integrated > mineral amendments. It had been reported that the sequestration of C-rich crop residue material into the fine fraction soil organic matter pool become doubled by adding supplementary nutrients (N, P and S) into the residues (Kirkby et al., 2013).

Keeping in view the importance of organic amendments as ameliorants in improving soil quality characteristics especially in the Himalayan region that is under continuous threat of soil erosion and land degradation, the objective of this study was to evaluate the quantitative influence of organic–inorganic amendments i.e. poultry manure (PM), wheat straw residues (WSR) and urea N (UN) on the changes in physical–chemical characteristics and nutrient status of the soils under soybean–wheat cropping sequences over three years in the Himalayan region of Rawalakot Kashmir, Pakistan. The results and findings reported here have specific implications of using organic amendments to improve highly eroded soils that could be applicable to many areas across the globe.

2 . Materials and methods

2.1 . Sites description

A series of field experiments was initiated during the rabi (winter, November–May) 2008–09 and kharif (summer, June–October) 2009 season for three consecutive years of 2008–09, 2009–10 and 2010–11 at two locations i) Rawalakot at the research farm of the Faculty of Agriculture, The University of Poonch and ii) Hajira at farmer's field. Rawalakot is located at latitude 33°51′32.18″N, longitude 73° 45′34.93″E and an elevation of 5374 ft above the sea level while Hajira is located at latitude 33° 46′ 18.12″ N, longitude 73° 73° 53′ 45.96″ E and an altitude of 3168 ft. Both the sites were located in the north–east of Pakistan under the foothills of great Himalayas district Poonch Azad Jammu and Kashmir, Pakistan. The soil in the study sites was loam in texture, classified as a Humic Lithic Eutrudepts (Inceptosols). The climate of the region is sub-temperate. Mean daily maximum and minimum air temperatures of the Rawalakot site ranged from 27 to 29 °C (June–July) and 1.0 to −3.5 °C (January–February). The maximum–minimum temperature at Hajira site was relatively higher with a maximum of 38 to 41 °C (June–July) and a minimum of a 2.6 to−1.7 °C (January–February). The mean (average of three years) annual rainfall was 1388 mm with 45% of the total precipitation during June–September and 43% during January to April. Initial soil characteristics (0–15 and 15–30 cm soil depths) of the two sites are shown in Table 1. The geographical map of the area is presented in Fig. 1 while the overall landscape view of the region is given in Fig. 2.

2.2 . Experimental details

The wheat–soybean cropping sequence was adopted at two sites (Hajira and Rawalakot) for three years i.e. 2008–2011. Crop rotation includes wheat during November to April/May and soybean during June to October. The individual plots were prepared according to the

Table 1
The initial physio-chemical characteristics of soil collected from the fields used for wheat–soybean cropping system.

Soil Properties	Site-1 (Hajira)			Site-2 (Rawalakot)		
	Depth (cm)			Depth (cm)		
	0–15	15–30	Mean	0–15	15–30	Mean
Physical						
Bulk density (g cm^{-3})	1.36	1.48	1.42	1.32	1.44	1.38
Sand g kg^{-1}	500.6	488.3	494.5	433.9	427.8	430.9
Silt g kg^{-1}	289.0	295.5	292.3	326.0	342.5	334.3
Clay g kg^{-1}	210.4	216.2	213.3	240.1	229.7	234.9
Textural class		loam			loam	
Infiltration rate cm h^{-1}	3.64	–	–	3.48	–	–
Water stable aggregates (>0.25 mm diameter)	47.21	43.56	45.4	49.83	47.92	48.9
%Mean weight diameter (MWD) mm	0.53	0.47	0.50	0.56	0.48	0.52
Chemical						
Soil pH (1:2H_2O)	7.42	7.59	7.51	6.89	7.01	6.95
Organic matter g kg^{-1}	8.64	7.45	8.05	10. 3	8.92	9.61
Organic carbon g kg^{-1}	4.55	3.68	4.12	5.64	4.88	5.26
Total N g kg^{-1}	0.49	0.35	0.42	0.53	0.45	0.49
NH^{+}_{4}–N g kg^{-1}	8.76	8.62	8.69	8.85	8.71	8.78
NO^{-}_{3}–N g kg^{-1}	6.83	7.13	6.98	7.21	7.03	7.12
Available P mg kg^{-1}	5.08	4.87	4.98	5.49	5.12	5.31
Available K mg kg^{-1}	94.7	87.9	91.3	98.5	87.8	93.2
Iron (Fe) mg kg^{-1}	15.9	7.28	11.6	17.8	7.36	12.6
Manganese (Mn) mg kg^{-1}	4.5	2.9	3.7	6.2	4.0	5.1
Zinc (Zn) mg kg^{-1}	5.7	2.6	4.15	8.4	3.9	6.15
Copper (Cu) mg kg^{-1}	3.71	0.96	2.34	3.79	0.82	2.31
Cation exchange capacity (CEC) $cmol_{(+)}$ kg^{-1} soil	10.5	9.9	10.2	11.9	10.6	11.3