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Long-term effects of organics, fertilizers and cropping systems on soil physical productivity evaluated using a single value index (NLWR)

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Abstract

Effect of different cropping systems, viz. maize–wheat (M–W), rice–wheat (R–W), soybean–wheat (S–W), and perennial grasses (guinea grass and setaria grass), in vogue since 6–32 years, and long-term use of chemical fertilizers (N, NP, NPK and NPK + lime) and organic materials (FYM, wheat straw, lantana biomass) on physical productivity of medium-textured (silt loam and silty clay loams) soils was investigated using non-limiting water range (NLWR) as the soil physical index. Higher the NLWR better is the soil physical condition for crop growth. The sources of N, P and K were urea, single superphosphate and muriate of potash, respectively. The NLWR was highest in S–W (16.8%), followed by grasses (14.4–15.6%) and M–W (13.1–15.4%), and lowest in R–W (7.5–11.0%). Under M–W system (32 years), NLWR was highest in NPK (13.1%), followed by NP (12.2%), NPK + lime (9.4%) and control (9.0%), and lowest in N (7.7%). Application of organics increased the NLWR in both M–W and R–W (6–18 years) systems; the NLWR values with and without organics were 18.0 and 17.1% in M–W, and 14.1–15.9 and 15.7–17.2% in R–W system. The NLWR was linearly, significantly and positively correlated with wheat grain yield ($r = 0.646^{**}$, -0.706^{**}). The NLWR:PAWC (plant available water capacity) ratio (higher the ratio, better is the soil physical condition), which was 0.58 in control, decreased with N (0.49) but increased with NP (0.72) and NPK application (0.77); use of organics further improved the ratio. The NLWR:PAWC ratio was highest in S–W (0.97), followed by grasses (0.88–0.91), M–W (0.77–0.86) and R–W (0.54–0.68) system. Thus, long-term use of urea alone deteriorated, while NPK at recommended rates improved soil physical productivity over the control of no fertilizer application; the effect further improved when NPK were combined with organic sources. Among different cropping systems, the soil physical productivity followed the order: S–W > grasses > M–W > R–W system.

Keywords: Cropping system; Manures and fertilizers; Non-limiting water range; Physical productivity; Plant available water capacity

1. Introduction

Decline in factor productivity has put sustainability of agricultural production systems at stake. Deterioration in natural resources, mainly soil and water, in both qualitative and quantitative terms, due to unscientific management practices is largely responsible for it. Increasing demographic pressures for food and fiber have necessitated research in soil quality of which soil productivity is a vital component. Assessment of soil productivity is thus essential to determine soil quality and sustainability of production system.

Soil physical productivity (soil physical properties in relation to crop yields) may be assessed in broadly two ways: one, by establishing quantitative relationships between commonly measured soil physical properties

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and crop yields, and two, by using single-value soil physical indices. Measurement of few selected physical properties may not serve the purpose of physical characterization of soils with respect to crop performance because of wide spatial and temporal variability in soil physical properties, their strong interdependence, and variable response of crop cultivars and phenological stages to soil physical properties. The use of a single value soil physical index may avoid these constraints provided that the physical index incorporates all or most of the critical measurable sources of stress that the soil imposes on growing plants. The non-limiting water range (NLWR) is such an index, introduced by Letey (1985), which can be effectively used for characterizing soils for their physical productivity (da Silva et al., 1994; Topp et al., 1994; da Silva and Kay, 1997a,b; Carter et al., 1999; Sharma and Bhushan, 2001; Benjamin et al., 2003).

Soil physical productivity is significantly affected by cropping systems and management practices, including tillage and organic residue management (Sharma et al., 1995; Sharma and Acharya, 2000; Bhushan and Sharma, 2002, 2005). It has been observed that continuous use of chemical fertilizers in imbalanced form deteriorates soil physical properties (Biswas et al., 1971; Prasad et al., 1983). Detrimental effects of chemical fertilizers even in balanced form on soil physical properties are also being observed. For example, decline in soil organic carbon and associated decline in system productivity under rice–wheat system with the long-term use of recommended NPK was observed in some field studies (Nambiar, 1994; Abroal et al., 2000; Yadav et al., 2000). The widespread stagnation and occasional decline is rice–wheat productivity over the last about three decades have become a matter of serious concern, as rice–wheat is the major cropping system in south Asia, feeding more than 400 million people world-over (Ladha et al., 2003). Decline in soil physical productivity, among several other factors, is being considered responsible for it.

Land use pattern also has a significant effect on soil physical properties (Sharma and Aggarwal, 1984). The cropping systems that provide maximum ground cover, add organic litter to soils and require minimum soil disturbance through tillage and intercultural operations are expected to maintain good soil structure and productivity, and vice versa.

The objective of the present study was to investigate long-term effects of different cropping systems, and use of chemical fertilizers with and without organic manures on soil physical productivity, using NLWR as a single value soil physical index. Long-term field experiments under four cropping systems, viz. maize (*Zea mays* L.)–wheat (*Triticum aestivum* Linn. Emend. Fiori & Poal), rice (*Oryza sativa* L.)–wheat, soybean (*Glycin max* L.)–wheat, and perennial grasses, viz. guinea grass (*Panicum maxium* Jacq.) and setaria grass (*Setaria italica* L.) were selected for study. These are some of the most common cropping systems followed in north-western Himalayan region.

2. Materials and methods

2.1. Experimental site

The present investigation was carried out in different on-going long-term experiments under different cropping systems (perennial grasses, soybean–wheat, maize–wheat and rice–wheat) at the experimental farm of Himachal Pradesh Agricultural University, Palampur (32°6′N, 76°3′E, 1290 m above mean sea level). The area represents the high rainfall mid-hill wet-temperate zone of North-West Himalayas. The mean annual rainfall (1974–2005) around Palampur is about 2.312 ± 618 mm, with the wettest months being June to September. The annual mean maximum and mean minimum temperatures are about 23.2 ± 0.8 and 13.4 ± 0.5 °C, respectively. The mean monthly rainfall, evaporation and air temperatures at Palampur (HP) for the period 1974–2005 are illustrated graphically in Fig. 1. The experimental soils were silty loam to silty clay loam in texture and classified as Typic Hapludalf (Verma, 1979) as per the taxonomic system of soil classification (Soil Survey Staff, 1975). The soils in the region owe their origin to the fluvio-glacial parent material developed from rocks like slate, phyllites, quartzites, schists and gneisses. The soils are acidic in reaction (pH 5.2–6.2).

2.2. Treatments

Some treatments with and/or without organics in different on-going long-term field experiments under different cropping systems at the university farm were selected (Table 1) for assessing soil physical productivity using a single value soil physical index, called the non-limiting water range (NLWR) (Letey, 1985). All field experiments were arranged in randomized complete block design.

2.3. Non-limiting water range (NLWR)

The NLWR was computed as the difference between the soil moisture content at which the air-filled porosity (f_a) was 10% and the moisture content at which the soil