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Long term effect of different crop rotations on soil physical properties in a Mollisol

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ABSTRACT

The present study was conducted for the study about the effect of different rotations on physical properties in a Mollisol. The study area was located at Norman E. Borlaug Crop Research *Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, which lies* at 29^0N latitude, 79^0 3' E longitude and 243.84 m above the mean sea level altitude. The crop rotation selected for study were T_1 (Rice- Wheat-Fallow) T_2 (Rice- Vegetable pea- Summer Rice) T_3 (Maize- Wheat- Cowpea) T_4 (Rice- Wheat- Sesbania) T_5 (Maize- Toria- Urd) T_6 (Rice- Yellow Sarson- Grain Cowpea) T_7 (Multi-Cut Sorghum- Barseem + Oat- Maize + Cowpea) T_8 (Napier + Fodder cowpea- Barseem- Fodder cowpea) T_9 (Basmati rice- Potato- Maize Cob) T_{10} (Maize- Broccoli- Okra) T_{11} (fallow (uncultivated land)). The soil sample was collected from 20cm depth for the study of soil physical properties (soil color, soil texture, bulk density, particle density, porosity, and water holding capacity). Among the different crop rotations, T_4 treatment was obtained a significantly high value (except bulk density) of soil texture, particle density, porosity, and water holding capacity. T_{11} (except bulk density) treatment was obtained a significantly lowest value of soil texture, particle density, porosity and water holding capacity Results indicated that soil under Sesbania rotation was found superior with respect to soil physical properties followed by other crop rotation and the uncultivated land. By taking a crop for a long time on same and using chemical fertilizers that are decrease of soil physical properties. Therefore, in this experiment taking different crop rotations. under the different crop rotations, soil physical properties influenced positively and especially the green manure cycle has had the greatest positive impact. According to experimental data concluded that incorporation of green manure crop rotations was effect more positive an effect on soil physical properties. Crop rotations and green manure crops are improved soil physical properties and soil health.

Keywords: Crop Rotation, Physical Properties, Mollisol.

INTRODUCTION

Soil is a fundamental resource that is directly related to humankind in terms of goods and services. Soil is the basic unit for the production of fuel, fiber, food, and provides many services to humankind. Soil has our production function, protects ecosystems, and enhances ecosystems efficiency by the biological nitrogen fixation, carbon sequestration, groundwater recharging, and biodiversity conservation. Soil matrix is very a diverse and complex system consisting of mineral, organic matter, water, and microbial biomass. The mineral contains mineral nutrients, which are slowly available in the process of weathering; organic matter and humus vary in quantities, resulting from the decomposition of biomass and minute pores are filled with air or water [1] Soils are composed of a high degree of variability due to the interplay of physical, chemical, and biological that operate with different intensities at different scales [2]. These processes in turn affect the nature and properties of soil hence, knowledge of soil properties is important [3]. Intensive cropping at a particular place decreases organic matter and soil physical properties by land degradation [4,5,6]. Due to mismanagement of soil deterioration in physical properties is often associated to decline in OM contend by a decline in aggregate stability of the soil. Appropriate management of crop residues retards degradation of soil physical properties and sometimes improves soil health[7]. Management of crop residue and incorporation in soil that reduces degradation of soil. crop-rotation increase crop residue to the soil and crop residue decreases the bulk density, increases soil aggregate size, and improves water retention. To meet the growing demand for food, Agricultural communities and food demand increasing continues with rising with the increasing population. However, at present time land become a limiting factor, therefore crop rotation is more important for the production of food and conservation of soil health [8].

Morphological, physical properties, and biological of soil are important parameters for soil

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fertility assessment. Soil physical properties provide features related to water and air movement in the soil, as well as various conditions affecting crop growth, root growth, erosion processes, and land degradation[9]. Since, many soils physical properties, form the basis for other chemical and biological processes, which may be further governed by variation by different crop rotations. A highly populous country like India facing the serious problem of man to land ratio because India has a limited geographical area and the population growth rate is high. On the earth pressure of the population is day by day increases and food demand also increase. It is necessary to increase the production of crops with high amounts. On the other side soil health and quality, are decreased with high production. Therefore, conservation of soil health and soil quality is more essential. Crop rotations and green manure are a way of conserving soil health and quality. Therefore, the present study was conducted for the measurement of the physical properties of soil under different crop rotations.

MATERIALS AND METHODS

Physiographic description of the study area

The study was conducted at Norman E. Borlaug Crop Research Centre of Govind Ballabh Pant University, Pantnagar, and District U.S. Nagar of Uttarakhand. The soil order was Mollisol. Pantnagar falls under sub-humid and sub-tropical climates [10]. Soil samples were collected from the 0-20 cm depth representing all areas randomly from the study area.

Treatment details

Ten crop rotation and one fallow land have been taken as a treatment with three replications. The treatment selected for study were T_1 (Rice- Wheat-Fallow), T_2 (Rice- Vegetable pea- Summer Rice), T_3 (Maize- Wheat- Cowpea) T_4 (Rice- Wheat- Sesbania) T_5 (Maize- Toria- Urd) T_6 (Rice- Yellow Sarson- Grain Cowpea) T_7 (Multi Cut Sorghum- Barseem + Oat- Maize + Cowpea) T_8 (Napier + Fodder cowpea- Barseem- Fodder cowpea) T_9 (Basmati rice- Potato- Maize Cob) T_{10} (Maize- Broccoli- Okra) T_{11} (Fallow plots).

Soil color

Soil color was recorded both in dry and moist conditions by Munsell Soil Color Chart.

Soil texture and mechanical composition

The texture of soil was assessed by the relative distribution of sand, silt, and clay in the sample by the Hydrometer method [11]. The textural classification was done by USDA textural triangle.

Bulk density

The bulk density of soil was measured by the core sampler method [3]. The core sampler was put into the soil to 0-20 cm depth. Weight of core sampler keep in moisture box and that moisture box keep in the oven at 105 °C for 24hrs till constant Wight.

Bulk density (g cm^{-3}) was calculated by following formula.

$$\text{Bulk density (g cm}^{-3}) = \frac{\text{Oven dry weight of soil (g)}}{\text{Volume of soil (cm}^3)}$$

Particle density

Particle density was calculated by using the method given by [12]. 20 g of oven-dried soil was added in 100 mL of the graduated cylinder and that cylinder water fill before the soil adds at the 50 ml mark. Soil and content keep for 10 minutes. The difference between the initial volume of water and the volume of soil plus water mixture was recorded which represents the volume of water displaced or volume occupied by the soil particles.

$$\text{Particle density (g cm}^{-3}) = \frac{\text{Oven dry weight of soil (g)}}{\text{Volume of soil solids (cm}^3)}$$

Porosity

Porosity in the soil was determined by the [12] method by using the following formula.

$$\text{Total porosity (\%)} = 1 - \frac{\text{Bulk density of soil}}{\text{Particle density of soil}} \times 100$$

Water holding capacity

Hilgard apparatus used for determining water holding capacity of soil that procedure was given by [13]. The air-dry soil was transferred by spatula in the Hilgard apparatus. The Hilgard apparatus was placed in a water-filled petri-dish and the level of water maintain half-length of Hilgard apparatus submerged in it. Hilgard apparatus keep for overnight for saturation. The next day the apparatus was removed from the pertri-dish, take weight Hilgard apparatus and soil. Dry weight of soil also was recorded.

$$\text{Water holding capacity (\%)} = \frac{\text{Gain in weight at saturation point}}{\text{Dry weight of the soil}} \times 100$$

Statistical analysis

The experiment was conducted according to the complete randomized block design (CRBD). The data of this experimental data were statistically analyzed using analysis of variance of the technique [14]. The difference between treatments was measured by applying the "F" test at a 5 percent level of significance (0.05 LSD).

RESULTS AND DISCUSSION

Soil color

Soil color depends mainly on the amount and state of organic matter (OM) iron oxide (Fe and Al) and microbial product (Humus) as well as the amount of air and water in soil pores.

Dry soil - Variation in soil color was obtained under different crop rotations (Table-1)

Moist soil - Dark grey color of soils indicated high organic matter (OM) and microbial biomass content. Grey and dark grey soils are medium to high organic carbon content and brown soils are well-drained and aerated condition. The studies were confirmed with [15,16]

Table 1: Moist and dry soil color under different crop rotation at 20cm depth.

Symbol	Treatment	Soil Color	
		Dry soil	**Moist soil**
T_1	Rice- Wheat-Fallow	10YR4/2(Light grey)	10YR3/2(Dark olive)
T_2	Rice- Vegetable pea- Summer Rice	5Y2/2(Grey)	5Y2/1(Dark olive)
T_3	Maize- Wheat- Cowpea	10YR5/2(Dark greyish brown)	10YR3/1(very dark grey)
T_4	Rice- Wheat- Sesbania	8YR5/2(Light grey)	10YR3/2(Dark grey)
T_5	Maize- Toria- Urd	10YR5/2(Dark grey)	10YR3/2(Dark olive)
T_6	Rice- Yellow Sarson- Grain Cowpea	10YR5/3(Grey)	10YR3/1(Very dark grey)
T_7	Multi-Cut Sorghum- Barseem + Oat- Maize + Cowpea	10YR5/2(Dark grey)	10YR3/2(Dark Grey)
T_8	Napier + Fodder cowpea- Barseem- Fodder cowpea	10YR5/2(Dark greyish brown)	10YR3/2(Dark grey)
T_9	Basmati rice- Potato- Maize Cob	5YR4/1(Dark grey)	10YR3/2(Dark grey)
T_{10}	Maize- Broccoli- Okra	5YR4/2(Dark grey)	10YR3/1(dark grey)
T_{11}	Fallow plot	10YR5/2(Light grey)	10YR4/2(Greyish brown)

Variation in soil color under different crop rotations was obtained 8YR5/2(Light grey), 10YR5/2(Dark grey), 5Y2/2(Grey), and 10YR5/2(Light grey) (Dry soil) for T_4, T_5, T_2, T_{11} treatments respectively. Soil color variations in moist soil were obtained 10YR3/2(Dark grey), 10YR3/2(Dark olive) 5Y2/1(Dark olive) 10YR4/2(Dark greyish brown) for T_4, T_5, T_2, T_{11} treatments respectively.

Soil texture and mechanical composition
The variation in the sand, silt, and clay content in soil were obtained under different crop rotations. The value of clay content was varied from 25.16 to 31.36 percent. Value of clay content was highest recorded for T_4 (31.26%) treatment among different treatments and minimum value of clay content was obtained for T_{11} (26.16%) treatment among all other different treatments. Silt content varied from 25.89 to 19.68 present among all other treatments. The maximum value of silt content was obtained for T_{11} (25.89%) treatment among all other treatments. The lowest value of silt content was recorded for T_4 (19.68%) treatment among all other treatments. Value of sand content was obtained least variable is present. that research finding supported by [16].

Table 2: Soil mechanical composition under different crop rotations at 20cm depth

Symbol	Treatments	Sand (%)	Silt (%)	Clay (%)
T_1	Rice- Wheat-Fallow	49.12	25.87	25.18
T_2	Rice- Vegetable pea- Summer Rice	49.15	22.81	28.24
T_3	Maize- Wheat- Cowpea	49.16	22.79	28.26
T_4	Rice- Wheat- Sesbania	49.24	19.68	31.36
T_5	Maize- Toria- Urd	49.19	21.75	29.30
T_6	Rice- Yellow Sarson- Grain Cowpea	49.18	21.77	29.28
T_7	Multi-Cut Sorghum- Barseem + Oat- Maize + Cowpea	49.21	20.73	30.32
T_8	Napier + Fodder cowpea- Barseem- Fodder cowpea	49.22	20.70	30.34
T_9	Basmati rice- Potato- Maize Cob	49.13	24.85	27.20
T_{10}	Maize- Broccoli- Okra	49.14	24.83	27.22
T_{11}	Fallow plot	49.11	25.89	25.16

Table 4: Bulk density, Particle Density, Porosity and water holding capacity under different crop rotations at 20 cm depth

Symbol	Treatment	Bulk density (g cm^{-3})	Particle density (g cm^{-3})	Porosity (%)	Water holding capacity (%)
T_1	Rice- Wheat - Fallow	1.43	2.65	45.78	42.37
T_2	Rice- Vegetable pea- Summer Rice	1.38	2.66	48.11	45.01
T_3	Maize- Wheat- Cowpea	1.36	2.63	48.61	46.31
T_4	Rice- Wheat- Sesbania	1.30	2.57	49.84	52.54
T_5	Maize- Toria- Urd	1.33	2.61	48.78	48.11
T_6	Rice- Yellow Sarson- Grain Cowpea	1.34	2.62	48.59	46.71
T_7	Multi-Cut Sorghum- Barseem + Oat- Maize + Cowpea	1.33	2.60	48.71	50.44
T_8	Napier + Fodder cowpea- Barseem- Fodder cowpea	1.32	2.58	48.76	51.21
T_9	Basmati rice- Potato- Maize	1.42	2.61	45.72	43.44
T_{10}	Maize- Broccoli- Okra	1.40	2.67	47.10	44.64
T_{11}	Fallow plots	1.46	2.68	45.45	41.27
SEM ±		0.005	0.009	0.293	0.334
CD at 5%		0.016	0.027	0.871	0.992

Bulk density

The bulk density data are tabulated in table 4. On the basis of bulk density data BD was differ significantly with different treatments. The treatments have a significant effect on bulk density in soil. The highest bulk density was obtained in control T_{11} (1.46 g cm^{-3}) treatment than that T_1 (1.43 g cm^{-3}) T_2 (1.38 g cm^{-3}) T_3 (1.36 g cm^{-3}), T_4 (1.30 g cm^{-3}), T_5 (1.33 g cm^{-3}), T_6 (1.34 g cm^{-3}), T_7 (1.33 g cm^{-3}), T_8 (1.32 g cm^{-3}), T_9 (1.42 g cm^{-3}) and T_{10} (1.40 g cm^{-3}) treatments. The lowest bulk density was recorded with T_4 (1.30g cm^{-3}) than that T_1, T_2, T_{11}, T_3, T_8, T_5, T_6, T_7, T_9, and T_{10} treatments. Bulk density value for T_8 (1.32 g cm^{-3}) treatment was obtained significantly *at par* with T_4 (1.30 g cm^{-3}) treatment.

The lowest value of bulk density was obtained in T_4 treatment i.e. (Rice- Wheat- Sesbania) because of high soil organic carbon content which leads to a decline in soil bulk density of soil. A similar result (different land use) was also reported by [8,16,17]. Generally, the highest bulk density was obtained under uncultivated land (fellow plot) and this is due to low organic carbon and low clay content in the soil. Tillage practice increases soil bulk density is generally high due to less surface soil disruption caused by cultivation practice [18]. A similar finding was also noted by [16].

The highest bulk density in the fallow land (fellow plot) due to compaction in soil, high decomposition rate, and organic matter (OM) degradation was also reported [16,19,20]

Particle density

The data on particle density is illustrated in table 4. The highest particle density was reported with T_{11} (2.68 g cm^{-3}) treatments then that T_1 (2.65g cm^{-3}) T_2 (2.66 g cm^{-3}) T_3 (2.63g cm^{-3}), T_4 (2.57g cm^{-3}), T_5 (2.61g cm^{-3}), T_6 (2.62g cm^{-3}), T_7 (2.60g cm^{-3}), T_8 (2.58g cm^{-3}), T_9 (2.61g cm^{-3}) and T_{10} (2.67g cm^{-3}) treatments. The lowest particle density was reported with T_4 (2.61g cm^{-3}) treatment than that of T_1, T_2, T_{11}, T_3, T_8, T_5, T_6, T_7, T_9, and T_{10} treatments. Particle density influenced significantly under different treatments (T_1 to T_{11}). The lowest value of particle density was observed under Rice- Wheat- Sesbania crop rotation. The lowest particle density under fallow plots because of high organic carbon content. The same result was found by [8, 16].

Porosity

The porosity was influenced significantly under different treatments. The maximum porosity was reported with T_4 (49.84 %) treatment than that of T_1 (45.78%) T_2 (48.11%) T_3 (48.61%), T_{11} (45.45%), T_5 (48.78%), T_6 (48.59%), T_7 (48.71%), T_8 (48.76%), T_9 (45.72%) and T_{10} (47.10%) treatments. The lowest value of porosity was recorded with T_{11} (45.45 %) treatments than that of T_1, T_2, T_4, T_3, T_8, T_5, T_6, T_7, T_9, and T_{10} treatments. Porosity influence significantly differed under different treatments (T_1 to T_{11}) Same results were also reported by [16,21].

Water holding capacity

The water holding capacity was influenced significantly by different treatments. The highest water holding capacity was obtained with T_4 (52.54%) treatment than that of T_1 (42.37%) T_2 (45.02%) T_3 (46.31%), T_{11} (44.64%), T_5 (48.11%), T_6 (46.71%), T_7 (50.44%), T_8 (51.21%), T_9 (43.44%) and T_{10} (44.64%) treatments. The lowest water holding capacity was recorded with T_{11} (41.27%) treatment then of T_1, T_2, T_4, T_3, T_8, T_5, T_6, T_7, T_9, and T_{10} treatments. This was due to the low organic carbon content in the soil. The same result was also reported by [8]. The highest water holding capacity was recorded under Rice- Wheat- Sesbania crop rotation. This was due to more organic matter (OM) containing and the highest percentage of clay which increase the available water. These results are in similarity with those of [16,22]. The lowest water holding capacity was reported under fellow plots that have low organic matter.

CONCLUSION

Soil color indicator about organic matter content and mineralogical composition of the soil. Under this study, soil color was found more darker with more organic matter content in the soil where organic matter was found low in soil that soil has light color. The Bulk density and particle density of soil differed significantly under different treatments. The highest bulk density and particle density were

reported under T_{11} (fallow land) while the lowest was obtained under T_4 (Rice- Wheat- Sesbania) treatments. Porosity and water holding capacity were recorded highest with T_4 (Rice- Wheat- Sesbania) treatment. the lowest values of PD and BD were obtained under T_{11} (fallow land) treatments. The highest clay and the lowest silt are better for plant growth and that type composition found in T_4 (Rice- Wheat- Sesbania) treatment. Among all treatments T_4 (Rice- Wheat- Sesbania) treatment was obtained superiors in terms of soil properties because sesbania contribute more nitrogen and organic matter in the soil. On the basis of these results, concluded that among different treatments better bulk density, particle density, soil color, porosity, water holding capacity, and clay content were found under green manuring base treatment (T_4). So, soil researchers should have been promoted green manuring in crop rotation.

Acknowledgements

Conflict of Interest

None declared.

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