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Long term impact of different cropping systems on soil quality under silty loam soils of Indo-Gangetic plains of India

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Abstract: In a multi-enterprise agriculture model, six different cropping systems have been evaluated at research farm of CSSRI Karnal for nutrient availability in surface soil. All the cropping systems left tremendous effect on soil quality. Among the different cropping systems, sorghum-berseem maintained lowest soil pH (8.14) followed by cowpea-cauliflower-potato cropping system (8.35). Sorghum-berseem cropping system was significantly build-up of soil fertility in terms of available nitrogen, (221.1kg/ha) and soil organic carbon (0.59%) as compared to other cropping systems. However, phosphorus (59.80 kg/ha) availability was higher in vegetable system followed by wheat-green gram cropping systems (48.85 kg/ha) than the other cropping systems. Vegetable system of multi-enterprise agriculture model showed more availability of Ca (3.20 me/L), Mg (2.63 me/L) and S (11.71 me/L) than other cropping systems. Higher amount of Fe (8.44 mg/kg) was observed in maize-wheat-green gram cropping system, whereas higher Mn (6.37 mg/kg) was noticed in sorghum-berseem fodder system than the other cropping system. Zn and Cu availability was relatively higher in vegetable system. Under prevailing climatic conditions of Karnal, sorghum-berseem fodder system was found to be the best with respect to soil quality and ready adaptability by the farmers as it was not much changed by climatic variability over the last 6 years. Vegetable system and fruits + vegetable were more or less similar in accelerating the availability of nutrients. Thus, leguminous crop (green gram) in any cropping system helped in improving the soil health, which is a good indicator of soil productivity.

Keywords: Available nutrient status, Cropping systems, Multi-enterprise model

INTRODUCTION

Efficient management of water and fertilizers along with synergistic interaction with other appropriate production factors is the most critical for any crop cultivar to achieve its genetic yield potential under different cropping systems (Singh, 2010). In all the management practices, choice of crops under a specific set of climatic conditions influence the soil quality (physical, chemical and biological) to a great extent. Soil health is an assessment of ability of a soil to meet its range of ecosystem functions appropriate to its environment (Lal, 2010). Soil health is generally used to measure the competence of soil to sustain plant and animal productivity, determine structural and functional diversity of microbes, maintain or enhance water and air quality, and support human health and habitation. This influences agriculture production of different cropping systems in general and soil quality in particular. In some cases, elevated atmospheric CO_2 increases plant photosynthesis rates and thus crop yields (Kimball *et al.,* 2002). Global climate models (GCM) predicted increase in temperature and related precipitation may also affect crop photosynthesis, plant development rates, as well as water and nutrient budget in cropping systems (Banerjee, *et al.,* 2014).

Continuous adoption of rice-wheat system in IGP with maximum exploitation of natural resources has weakened the resource base. Therefore, to achieve sustainable fertility and productivity efforts must be focused on reversing the trend in natural resource degradation by adopting efficient cropping systems. There is an urgent need to stabilize soil health and increase profitability by adopting suitable cropping systems. Limited information is available on the long term impact of different cropping systems on the soil nutrient status in IGP. Therefore, to achieve the sustainability in soil quality, the present study was undertaken to determine the effect of different crop production systems on nutrient availability status after 6 years of continuous cultivation under silty loam soils. This investigation was carried out to study the long term impact of different cropping systems on soil quality under silty loam soils of Indo-Gangetic plains of India.

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MATERIALS AND METHODS

Experimental site and soil: The present study was conducted at Central Soil Salinity Research Institute (CSSRI), Karnal, Haryana. Karnal District lies on the Western Bank of the Yamuna. Karnal is situated at 29.42^{o} N latitude, 76.57^{o} E longitude and at an elevation of 243 m above mean sea level. Karnal has a typical sub-humid and sub-tropical type of climate with extreme weather conditions. The rainfall of last six years varied from 477.1 to 1098 mm/year. Minimum temperature was ranged from 17.0 to 17.73 ^{o}C and maximum temperature from 29.21 to 30.78 ^{o}C (Fig.1). The multi-enterprise agriculture model was started during 2006. The soil samples were collected from 0-15 cm soil layer of each cropping system plots. Soil samples were air-dried in shade, ground using a wooden pestle and mortar and passed through a 2-mm sieve and analyzed for soil physico-chemical properties. The main physico-chemical properties of pre-experimental soil were: texture silty loam with sand 34%, silt 50% and clay 16% (Bouyoucos, 1962); pH_w (1:2, soil:water) 8.1 to 8.4; electrical conductivity (EC_w 1:2, soil : water) 0.20 to 0.40 dS m^{-1}; CEC 11.68 cmol (p^+) kg^{-1} soil (Jackson, 1973); available N 103-123 kg/ha (Subbiah and Asija, 1956); 0.5 *M* $NaHCO_3$-extractable P 23 to 26 kg/ha (Olsen et al., 1954) and neutral 1 *N* NH_4OAc-extractable K 300 to 400 kg/ha (Hanway and Heidel, 1952). DTPA extractable Zn, Fe, Mn and Cu ranged from 0.85 to 2.41; 7.51 to 8.56; 5.56 to 8.40 and 0.81 to 2.18 mg/kg, respectively (Lindsay and Norvell, 1978).

Post harvest soil analysis: The soil samples were collected from 0-15 cm soil layer of each cropping system. Soil samples were air-dried in shade, ground using a wooden pestle and mortar and passed through a 2-mm sieve and analyzed for organic carbon (Walkley and Black, 1934), available N (Subbiah and Asija, 1956), available P (Olsen *et al.,* 1954) and available K (Hanway and Heidel, 1952). Soil pH (1:2, soil: water) and electrical conductivity (EC 1:2, soil: water) was determined with the method described by Jackson, 1973. Versanate titration method was used for Ca and Mg determination. Available sulphur was determined by the method given by Chesnin and Yien (1950). Available soil micronutrients were determined following a method described by Lindsay and Norvell (1978) using DTPA extractant.

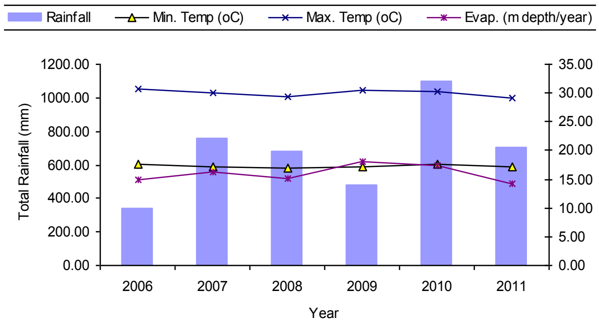

Fig. 1. *Annual variation in average rainfall and temperature.*

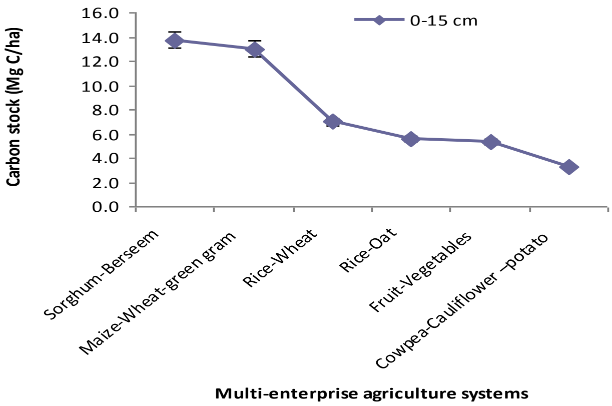

Fig. 2. *Carbon stock (Mg C ha^{-1}) at surface soil depth (0-15 cm) under different cropping systems.*

RESULTS AND DISCUSSION

Data generated on soil pH under different cropping system are showed in table 1. Soil pH varied from 8.14 to 8.60. Whereas, higher value of soil EC with cowpea -cauliflower-potato (0.22 dS/m) system and lowest with maize-wheat-green gram cropping system (0.13 dS/m) it may be attributed that more organic matter provided by these crops which decrease bulk density, an enhancement of soil porosity, aeration and permeability of soil thereby reducing soil salinity (Rathod *et al.,* 2003). Soil organic carbon (SOC) ranged from 0.14 to 0.59 % under different cropping systems. Highest SOC was recorded in sorghum-berseem (0.59%) across the cropping systems as it depends on nature and type of crops, leaf foliage and supply of inputs (Table 1). The present results are in agreement with the work done by Majumder *et al*. (2008) who observed that the application of NPK along with FYM SOC.

Table 1. Physico-chemical properties and available N, P and K in surface (0-15 cm) soil of multi-enterprise agriculture model with three replication.

Cropping systems	pH	EC (dS /m)	OC (%)	N (kg/ha)	P_2O_5 (kg/ha)	K (kg/ha)
Sorghum-Berseem	8.14±0.04	0.17±0.02	0.59±0.60	221.1±16.6	24.3±0.27	186.1±3.1
Maize-Wheat-green gram	8.39±0.02	0.13±0.01	0.56±0.60	172.1±1.5	48.85±0.79	178.3±9.5
Rice-Wheat	8.60±0.01	0.18±0.01	0.30±0.32	156.1±8.1	31.73±9.10	193.1±5.1
Rice-Oat	8.50±0.05	0.16±0.05	0.24±0.33	148.3±20.6	46.89±3.56	235.3±12.6
Fruit-Vegetables	8.58±0.07	0.14±0.05	0.23±0.28	119.7±4.6	21.65±8.04	234.1±1.0
Cowpea-Cauliflower-Potato	8.35±0.05	0.22±0.01	0.14±0.23	166.2±12.2	59.80±19.6	442.3±9.2

Table 2. Secondary nutrients and DTPA extractable macronutrients in surface (0-15 cm) soil of multi-enterprise agriculture with three replications.

Cropping systems	Ca (me/L)	Mg (me/L)	S (me/L)	Fe (mg /kg)	Mn (mg /kg)	Zn (mg /kg)	Cu (mg /kg)
Sorghum-Berseem	2.40±0.21	2.03±0.15	7.76±0.91	8.05±0.11	6.37±26.7	1.40±0.07	1.35±0.21
Maize-Wheat-green gram	1.43±0.28	1.23±0.25	10.7±1.22	8.44±1.01	4.97±14.7	1.63±0.08	1.16±0.23
Rice-Wheat	1.87±0.57	1.50±0.52	11.19±0.45	5.53±4.49	5.48±29.2	1.85±0.02	0.86±0.09
Rice-Oat	2.07±0.30	1.77±0.25	11.36±0.39	5.17±4.09	2.86±12.2	2.74±0.59	0.76±0.17
Fruit-Vegetables	2.53±0.30	2.23±0.15	9.82±1.45	5.33±0.06	1.62±7.6	1.31±0.08	0.95±0.04
Cowpea-Cauliflower-Potato	3.20±0.34	2.63±0.15	11.71±4.90	5.01±0.13	1.63±6.3	2.73±0.15	0.93±0.08

Available N varied from 119.7 to 221.1 kg/ha in different cropping systems of the experimental field. The same trend of available nitrogen was observed in sorghum-berseem cropping system, but relatively lower value was recorded in fruit-vegetable cropping system because fruits and vegetable crops are nutrient exhaustive and highly effective in nutrient mining from soil . Available phosphorus ranged from 21.65 to 59.80 kg/ha in surface soil. The highest value of P_2O_5 was observed in cowpea-cauliflower-potato (59.8 kg/ha) system and lowest was observed in fruit-vegetable (21.7 kg/ha) cropping system in surface soil. The available potassium ranged from 178.3 to 442.3 kg/ha in surface soil. Potassium availability was highest in cowpea-cauliflower-potato cropping system. Potato being a K exhaustive crop requires more K than the other crops in the system. Maize-wheat-green gram cropping system recorded the lowest available K (Table 1).

The maximum amount of Ca in the surface soil was 3.20 me/L under vegetables amongst all the other cropping systems. Positive build-up of Ca in vegetable system might be due to the combined use of FYM and *in-situ* green manuring after last picking of vegetables, which resulted in higher biomass accumulation in the system. The lowest amount of Ca was registered under maize-wheat-green gram (1.43 me/L) Table 2. It was reported that highest value of magnesium was (2.63 me/L) in cowpea-cauliflower-potato cropping system and the lowest in maize-wheat-green gram (1.23 me/L) system. However, sulphur ranged from 7.76 to 11.71 mg/L in all the systems and the highest value was observed in cowpea-cauliflower-potato (11.71 mg/L) as this system provides more biomass than the other cropping systems of multi-enterprise agriculture model.

Iron (Fe) and Manganese (Mn) ranged from 5.01 to 8.44 mg/kg and 1.62 to 6.37 mg/kg, respectively in surface soil layer (Table 2). Maximum Fe and Mn availability of 8.44 and 4.97 mg/kg was recorded in maize-wheat-green gram cropping system and the lowest in cowpea-cauliflower-potato system. The lowest Fe availability in vegetable system it might be due to more chelating of Fe with organic matter because this system produced more biomass than the other systems. It was evident from the data that highest amount of Fe and Mn micronutrients are maintained under maize-wheat-green gram cropping system. The highest Zn availability was observed in cowpea-cauliflower-potato (2.73 mg/kg) whereas least availability was observed in fruit-vegetable system (1.31 mg/kg). The highest availability in vegetable system was mainly because Zn is less tightly bound with organic compounds than Fe. Available Zn and Cu also showed the similar trend. Cu availability was maximum in cowpea-cauliflower-potato cropping system (1.77 mg/kg), while rice-wheat cropping system exhibited the least value (Table 2).

Soil carbon stock was highest in sorghum-barseem (Fig. 2) followed by maize-wheat-green gram and least in cowpea-cauliflower-potato in surface soil (0-15 cm depth) this may be due to higher biomass production under sorghum-berseem system as compared to other cropping system. Similarly Basak et al., (2015) reported the higher values of pools of organic C in soils under Inceptisols which produce higher biomass and yield compared to soils under Entisols and Alfisols.

Conclusion

In the silty loam soils of IGP, maize-wheat-green gram cropping system may be an alternative to rice-wheat cropping system to sustain the soil quality as it contains higher SOC (0.56%), N (172.1 kg/ha), P (48.8kg/ha) and K (178.3 kg/ha) than any grain production system. Fodder (sorghum-berseem) based cropping system was more pronounced in terms of available N (221 kg/ha) and SOC (0.59%) than any other system. Availability of secondary nutrients status under different cropping system varied as per the crop demand and left over crop residues in the soil. The soil quality depends on the duration of the leguminous crops grown under the different cropping system as it was evidenced that fodder based cropping system had recorded highest soil quality parameters followed by maize-wheat-green gram cropping system.

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