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Original Research Article

Reduced tillage and use of organics: A progressive manoeuvre towards conservation of resources and improvement in soil intrinsic properties

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A B S T R A C T

More recently, conservational tillage practices are being contemplated as an effective management practice to restore intrinsic physical soil fertility and overall soil health. An experiment was conducted at AICRPDA farm Indore, in kharif season 2017-18, in this study we used a combination of reduced tillage and organic materials namely, compost, straw and Glyricidia green leaves to assess their effect on soil properties. The design used in the experiment was RBD with soybean crop with eight treatments and each of them was randomized and replicated four times. Application of the different organic materials and reduction in the tillage intensity in different treatment plots connoted exaltation in different soil physical properties. Treatment T3in which reduced tillage was adopted with 4t ha^{-1}straw+ Hand Weeding depicted the foremost soil physical and chemical properties. Augmentation in available N, P, K and S after harvest was found in treatment T3.Also, in treatment T3 pH, EC and BD was found decreased whereas WHC and Porosity of the soil was found increased. Result showed that adoption of reduced tillage and application of different organics improved the nutrient status and physicochemical properties of the soil.

Introduction

Escalating global demand for food led to intensification of agricultural practices Ineffectual management practices with intensive agricultural practices during the last few decades has resulted in degradation of arable soils worldwide including breakdown of soil structure, accelerated oxidation, consequent loss of soil organic carbon (SOC) content and release of carbon dioxide to the atmosphere. Excessive disturbance of the top soil through intensive tillage operations and removal of residues in conventional tillage systems result in loss of soil fertility and hampers soil health. Soil health (Döring *et al.*, 2015) loss as a result of agricultural intensification is a global concern (Tittonell, 2014). Soil fertility is an important form of renewable natural capital (Sanchez *et al.*, 1997). The loss in fertility of the soil of farming land has become a major cause of poor yield of the crops. A fertile soil which is productive results most often in yield increase giving profit to farmers (Fresco and Kroonenberg, 1992). Intensive and conventional tillage led to a loss of soil fertility and reduction of soil water holding capacity and soil structural stability, by facilitating erosion by water and wind, and is reflected in a constant increase in the rates of fertilizers used by farmers to maintain crop productivity (Du Preez *et al.*, 2001; Roldán *et al.*, 2003; D´Haene *et al.*, 2008). With the loss in productivity farmers tend to use chemical fertilizers indecorously which leads to the pollution and depletion of natural properties of the soil. In present scenario, there is a need of astute management of the available resources by accepting practices that curtail the soil disturbance. A difference in management practices often result in differences in biological, chemical and physical properties of soil which in turn, result in changes in functional quality of soil(Islam and Weil, 2000; Aziz *et al.*, 2009; Derpsch *et al.,* 2010; Wolfarth *et al.,* 2011; Celik *et al.,* 2011; Ding *et al.,* 2011). Conservation agriculture (CA) is being considered as a potential system having the capability of improving soil quality and providing stable yields. More recently, conservation agriculture has been promoted to restore intrinsic physical soil fertility and overall soil health. All internal and interrelated properties of soil (biological, chemical and physical) are significantly affected by reducing soil tillage (Thomas *et al.*, 2007). In order to improve soil health, a range of practices such as improved crop rotations, reduced tillage, green manures (GM) and organic amendments may be used for different agro-ecosystems (Larkin, 2015; Turmel *et al.,* 2014; van Bruggen and Semenov, 2015).

Studies conducted under a wide range of climatic conditions, soil types, and crop rotation systems showed that soils under no-tillage and reduced tillage have significantly higher SOC contents compared with conventionally tilled soils (Alvarez, 2005). Reduced tillage and no-tillage favored the surface accumulation of organic C and total N in the soil, as well as that of available K and Mg (Małecka *et al.,* 2012), higher levels of soil organic C, microbial biomass C and N, potential N mineralization, total N, and extractable P were directly related to surface accumulation of crop residues promoted by conservation tillage management (Shokati and Ahanga, 2014) Similarly, soil bulk density is modified under conservation tillage (Lal *et al.,* 1994). McGarry *et al.,* (2000) have found the no tillage (NT) as an effective practice for clay soils to minimize sub-soil compaction and to induce natural structure formation through shrink-swell cycles.

Materials and Methods

A long-term study on the impact of reduced tillage and effect of different organics with either hand weeding or application of herbicide on soybean production was carried out at AICRPDA, Indore, during 2017-18. The location has semi-arid (Hot moist) climate and is situated in Malwa Plateau in MP hence, summer season is dry and the temperature may rise upto 44^0C or even higher during April-May. In winter season the temperature is generally normal and may descend upto 10^oC during December and January. From sowing to harvesting 16 Standard Meteorological weeks were recorded. The highest maximum and minimum temperatures recorded were 34.7^0 C and 27.36^0 C respectively. The total rainfall of 636.50 mm was recorded during the SMW.

Results and Discussion

The various treatments had significant effect on soil properties:

Physical Properties

Various treatments posed different effects on soil physicochemical properties such as soil bulk density, porosity and water holding capacity, it was observed that after harvesting, reducing tillage intensity in the soil decreased BD and simultaneously increased porosity and WHC in treatments in which organics were added.

After the experiment it was concluded that organics had positive effect on soil physical properties, after harvesting results showed that addition of organics and reduction in the tillage intensity reduced the bulk density and increased porosity and water holding capacity. The lowest value of bulk density (1.21 Mgm^{-3}) was recorded in case of treatment T3- RT + 4 t ha^{-1} straw + HW followed by T5 and T8, it clearly depicts that the organics resulted in the lowering of bulk density. The porosity ranged from 50.20 to 53.98 % in different treatments and was highest in the treatment T3- RT + 4 t ha^{-1} straw + HW. Similarly, WHC was also found highest (52.93%) in Treatment T3- RT + 4 t ha^{-1} straw + HW.

Chemical Properties

In the experiment conducted, Available Nitrogen, Phosphorus, Potassium and Sulphur are determined. Different treatments resulted in different effects on soil EC, pH, OC, available N, P_2O_5 and K_2O, which revealed that the treatments involving organics resulted in a considerable build-up of soil nutrients particularly available N, P and organic carbon content in plough layer. Result before sowing and after harvesting of crop is shown in following Table C and D. Table A and B shows the effects of reduced tillage and organics on soil physical properties. Table A shows the physical properties of experimented soil before the sowing of soybean crop.

After the completion of experiment it was observed that the best result was discovered in T3- RT+4 t ha^{-1}straw + HW followed by T5 and T8. It was observed that all the plots in which organics were applied showed increase in pH and decrease in EC. OC increased from 0.80% to 0.81%, pH increased from 7.66 to 7.67, EC decreased from 0.58 dSm^{-1} to 0.32 dSm^{-1}, available N increased from 308.30 kg ha^{-1} to 310.83 kg ha^{-1}, available P_2O_5 increased from 13.88 kg $ha^{-1}$to 14.80 kg ha^{-1}, available K_2O increased from 694.85 kg $ha^{-1}$to 702.93 kg $ha^{-1}$and available S increased from 18.20 kg $ha^{-1}$to 18.70 kg ha^{-1} followed by T5 in which the available N increased from 303.80 kg ha^{-1} N to 305.83 kg ha^{-1} N, available P_2O_5 increased from 13.25 kg ha^{-1} P_2O_5 to14.40 kg ha^{-1} P_2O_5, available K_2O increased from 551.83kg $ha^{-1}$to 670.80 kg $ha^{-1}$and available S increased from 18.09 kg ha^{-1} to 18.56 kg ha^{-1}. and T8 in which available N increased from 304.78 kg ha^{-1} to 302.83 kg ha^{-1}, available P_2O_5 increased from 13.53 kg ha^{-1} P_2O_5 to14.23 kg ha^{-1}, available K_2O increased from 651.20 kg $ha^{-1}$to 656.08 kg $ha^{-1}$and available S increased from 18.02 kg $ha^{-1}$to 18.54 kg ha^{-1}.

These three treatments were statistically at par and were found to be superior to the other treatments. From the experiment we delineated that adding organics in the soil results in alleviating the nutrient status of the soil, from this long term experiment this can be clearly stated that inclusion of organic materials not only increases the soil fertility but also helps in maintaining it in the long run and can be accepted as an efficacious way to fed the increasing population without deteriorating soil health and conserving resources simultaneously.

Salinas-Garcia *et al.* (1997) found that conservation tillage management altered the depth distribution and concentration of crop residue, organic C, microbial biomass C and N, C: N ratio, potential nitrogen mineralization, inorganic N, total N and extractable P. Higher level of soil organic carbon, microbial biomass C and N, inorganic and total N and extractible P were directly related to the surface accumulation of crop residues which further promoted by conservation tillage management.

Mupangwa *et al.* (2013) in there study assessed effects of reduced tillage and mulching on soil organic carbon, bulk density, infiltration and maize yield. Treatments consisted of three tillage methods (conventional ploughing, ripping and planting basins) combined factorially with mulch levels (0, 0.5, 1, 2, 4, 8 and 10 t ha ^{1}). Soil organic carbon increased with time in all tillage systems and more SOC gained in planting basins. Soil bulk density decreased with time in all tillage systems irrespective of mulch quantity applied. Ripping loosened the soil much deeper than the other tillage methods. Total infiltration in all treatments was similar over the four seasons. Soil structural changes resulted in increased unsaturated hydraulic conductivity and sorptivity of the clay loam soil.

Hati *et al.* (2014) in his experiment consummated that the SOC content up to 15 cm soil depth were significantly higher in NT, RT and MB where wheat residues were left after harvest, than that in CT system. The SOC in MB were significantly higher than CT in 15-30 cm soil layer. Soil water retention at 4 cm and at air entry potential (50 cm suction) was significantly higher in NT, MB and RT treatments than in CT. Soil physical properties *viz.*, infiltration rate, bulk density, mean weight diameter and water stable aggregation also improved under NT and RT. The SOC and aggregate stability were higher in $N_{150\%}$ as compared to $N_{50\%}$. Soil water retention did not vary among the N levels. However, yields of both the crops were similar under the tillage systems.

Rusu *et al.* (2014) concluded that the implementation of minimum and no-tillage soil systems has increased the organic matter content from 2% to 7.6% and water stable aggregate content from 5.6% to 9.6%, at 0–30 cm depth, as compared to the conventional system. Accumulated water supply was higher (with 12.4%–15%) for all minimum and no-tillage systems and increased bulk density values by 0.01%–0.03% (no significant difference) While the soil fertility and the wet aggregate stability have initially been low, the effect of conservation practices on the soil characteristics led to a positive impact on the water permeability in the soil. Availability of soil moisture during the crop growth period led to a better plant watering condition. Subsequent release of conserved soil water regulated the plant water condition and soil structure. International Soil and Water Conservation.

Mohanty *et al.* (2015) reported that practice of MT decreased the soil BD (from 1.29 to 1.24 Mg m-3), increased SOC (+20.1%) and macro-aggregates (+12.6%) with concomitant decrease in proportion of micro-aggregates (-23.5%) over CT systems. Inclusion of cover crops in the tillage practices enhanced the SOC (+9.4%) over NCC (fallow). Elevation of SOM due to residue inputs and its protection under MT systems accelerated the formation of macro-aggregates through an increase in biomass content in the soils under this rainfed agro-ecosystem.

Sheehy *et al.* (2015) procured that the aggregate size decreased in the order of NT > RT > CT at all study sites. In addition to increased mean weight diameter (MWD) under NT, a general trend of redistribution of SOC into these formed macroaggregates was found at all study sites, i.e., the LM fraction gained SOC. However SOC was lost in other fractions under NT compared to CT at some sites and none of the sites showed any significant changes in bulk soil SOC content under NT or RT. Also our hypothesis that there would be more SOC incorporated in mM fraction in NT and RT compared to CT was corroborated only at site 4 under NT. Thus, although the potential to accumulate SOC under NT or RT compared to CT seems to be limited in boreal agroecosystems, the redistribution of SOC to the more stable conditions within the aggregates indicates positive impacts of no-till practice.

Zuber *et al.* (2015) in his experiment found thatafter 15 years, bulk density (BD) under NT was 2.4% greater than under CT. Water aggregate stability (WAS) was 0.84 kg kg–1 under NT compared to 0.81 kg kg–1 under CT. Similarly, soil organic carbon (SOC) and total nitrogen (TN) were greater under NT than under CT with SOC values for 0 to 60 cm of 96.0 and 91.0 Mg ha–1 and TN values of 8.87 and 8.40 Mg ha–1 for NT and CT, respectively.

Treatment details

Sym.	Treatments	Treatments Details
T_1	CT + RF (-OT) + HW	Conventional tillage + RDF + No off-season Tillage + Hand Weeding
T_2	CT + RF (+OT) + HW	Conventional tillage + RDF + With off-season Tillage + Hand Weeding
T_3	RT + 4 t ha^{-1} straw + HW	Reduced tillage + 4 tonne ha^{-1} Straw + Hand Weeding
T_4	RT + 4 t ha^{-1} straw + Hb	Reduced tillage + 4 tonne ha^{-1} Straw + Herbicide
T_5	RT + 4 t ha^{-1} compost + HW	Reduced tillage + 4 tonne ha^{-1} Compost + Hand Weeding
T_6	RT + 4 t ha^{-1} compost + Hb	Reduced tillage + 4 tonne ha^{-1} Compost + Herbicide
T_7	RT + 4 t ha^{-1} Glyricidia green leaves + Hb	Reduced tillage + 4 tonne ha^{-1} Glyricidia green leaves + Herbicide
T_8	RT + 4 t ha^{-1} Glyricidia green leaves + HW	Reduced tillage + 4 tonne ha^{-1} Glyricidia green leaves + Hand Weeding

Table A. Physical properties of experimental soil before sowing

Sym	Treatments	Physical properties soil before sowing		
		BD (Mg m^{-3})	**Porosity (%)**	**WHC (%)**
T1	CT + RF (-OT) + HW	1.31	49.80	48.90
T2	CT + RF (+OT) + HW.	1.30	51.35	50.98
T3	RT+4 t ha^{-1} straw + HW.	1.21	52.46	51.08
T4	RT + 4 t ha^{-1} straw + Hb.	1.28	50.27	49.07
T5	RT+ 4 t ha^{-1}compost +HW	1.24	52.52	51.56
T6	RT+ 4 t ha^{-1} compost + Hb.	1.30	51.35	50.99
T7	RT + 4 t ha^{-1} Glyricidia green leaves + Hb.	1.26	50.46	49.94
T8	RT + 4 t ha^{-1}Glyricidia green leaves+ HW.	1.24	51.23	50.37

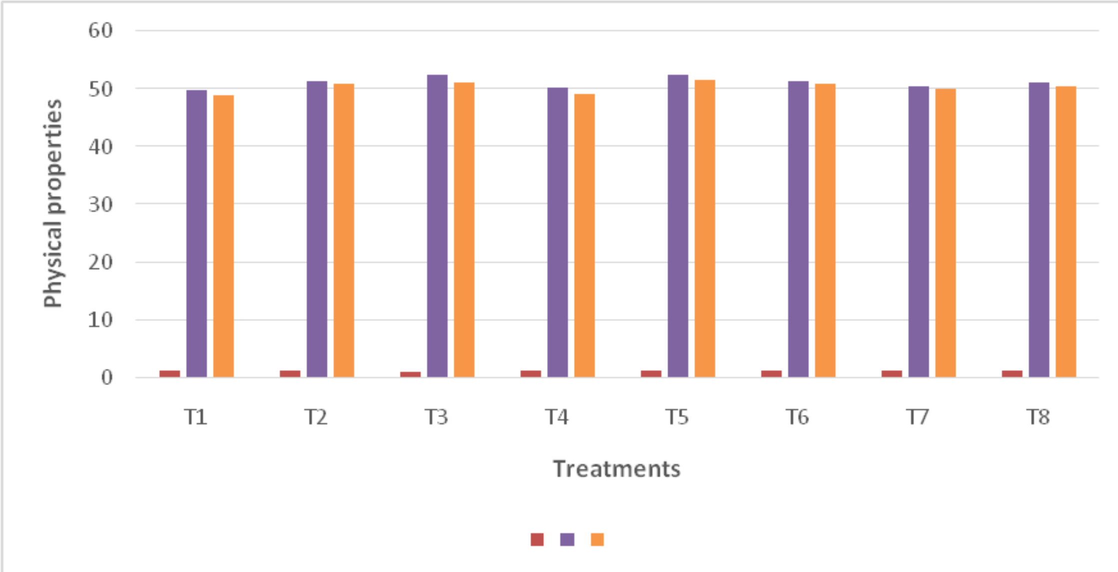

Fig. A Physical properties of experimental soil before sowing [BD (Mg m^{-3}), Porosity %, WHC%].

Table.B Physical properties of experimental soil after harvesting

Sym	Treatments	Physical properties of soil after harvesting		
		BD(Mg m^{-3})	Porosity (%)	WHC (%)
T1	CT + RF (-OT) + HW	1.32	50.20	50.01
T2	CT + RF (+OT) + HW.	1.31	50.95	49.75
T3	RT+4 t ha^{-1}straw + HW.	1.20	53.98	52.33
T4	RT + 4 t ha^{-1}straw + Hb.	1.27	51.91	50.95
T5	RT+ 4 t ha^{-1} compost+ HW	1.23	53.28	52.97
T6	RT+4 t ha^{-1} compost + Hb.	1.29	52.26	51.37
T7	RT + 4 t ha^{-1} Glyricidia green leaves + Hb.	1.25	51.35	50.98
T8	RT + 4 t ha^{-1}Glyricidia green leaves+ HW.	1.23	52.56	51.86

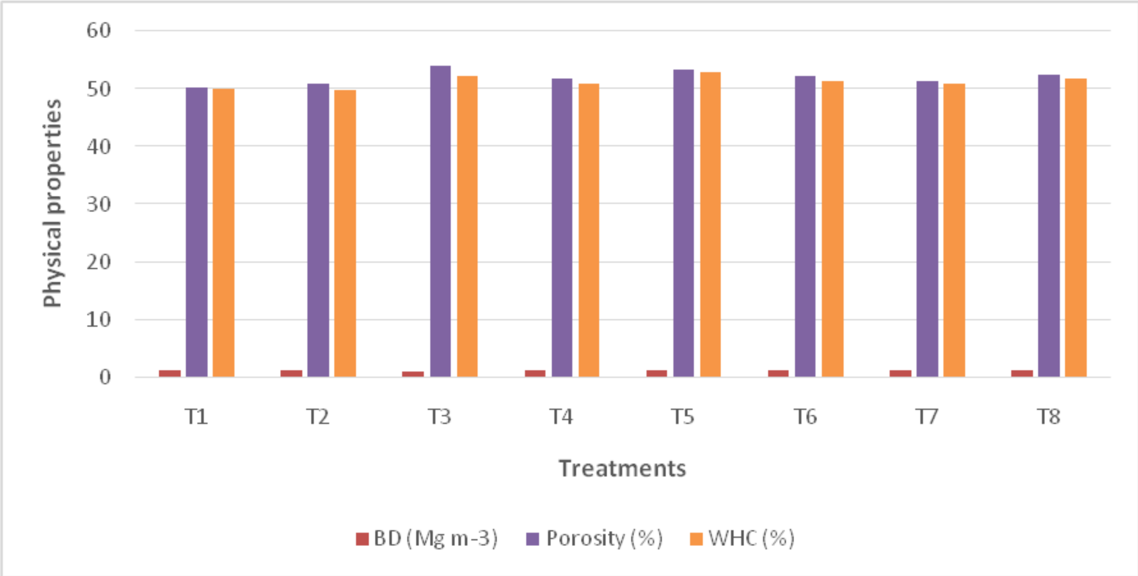

Fig.B Physical properties of experimental soil after harvesting [BD (Mg m^{-3}), Porosity %, WHC%].

Table.C Chemical properties of experimental soil before sowing of soybean

Sym	Treatments	Before sowing of soybean						
			Kg ha^{-1}				EC	pH
		OC%	N	P_2O_5	K_2O	S	dSm^{-1}	(2:1)
T1	CT + RF (-OT) + HW	0.44	235.83	9.95	542.60	10.03	0.52	7.51
T2	CT + RF (+OT) + HW.	0.40	212.15	9.75	531.70	9.80	0.53	7.53
T3	RT+4 t ha^{-1}straw + HW.	0.80	308.30	13.88	694.85	18.20	0.58	7.66
T4	RT + 4 t ha^{-1}straw + Hb.	0.68	252.83	11.68	640.48	16.08	0.54	7.62
T5	RT+ 4 t ha^{-1} compost+ HW	0.78	303.80	13.25	551.83	18.09	0.55	7.65
T6	RT+4 t ha^{-1} compost + Hb.	0.66	256.63	11.63	557.98	16.25	0.52	7.63
T7	RT + 4 t ha^{-1} Glyricidia green leaves + Hb.	0.69	263.83	11.75	560.23	16.45	0.52	7.63
T8	RT + 4 t ha^{-1}Glyricidia green leaves+ HW.	0.74	302.83	13.53	651.20	18.02	0.55	7.64

Table.D Chemical properties of experimental soil after harvesting of soybean.

Sym	Treatments	After harvesting of soybean						
			Kg ha^{-1}				EC dSm^{-1}	pH (2:1)
		OC%	N	P_2O_5	K_2O	S		
T1	CT + RF (-OT) + HW	0.43	228.70	10.87	540.28	9.43	0.33	7.50
T2	CT + RF (+OT) + HW.	0.40	205.08	10.65	528.95	8.43	0.31	7.52
T3	RT+4 t ha^{-1}straw + HW.	0.81	310.83	14.80	702.93	18.70	0.32	7.67
T4	RT + 4 t ha^{-1}straw + Hb.	0.68	255.93	12.02	559.35	17.08	0.33	7.63
T5	RT+ 4 t ha^{-1} compost+ HW	0.79	305.83	14.40	670.80	18.56	0.31	7.66
T6	RT+ 4 t ha^{-1} compost + Hb.	0.67	258.75	12.03	563.98	17.40	0.32	7.64
T7	RT + 4 t ha^{-1}Glyricidia green leaves + Hb.	0.70	265.75	12.13	564.78	17.46	0.32	7.64
T8	RT + 4 t ha^{-1}Glyricidia green leaves+ HW.	0.75	304.78	14.23	656.08	18.54	0.31	7.65

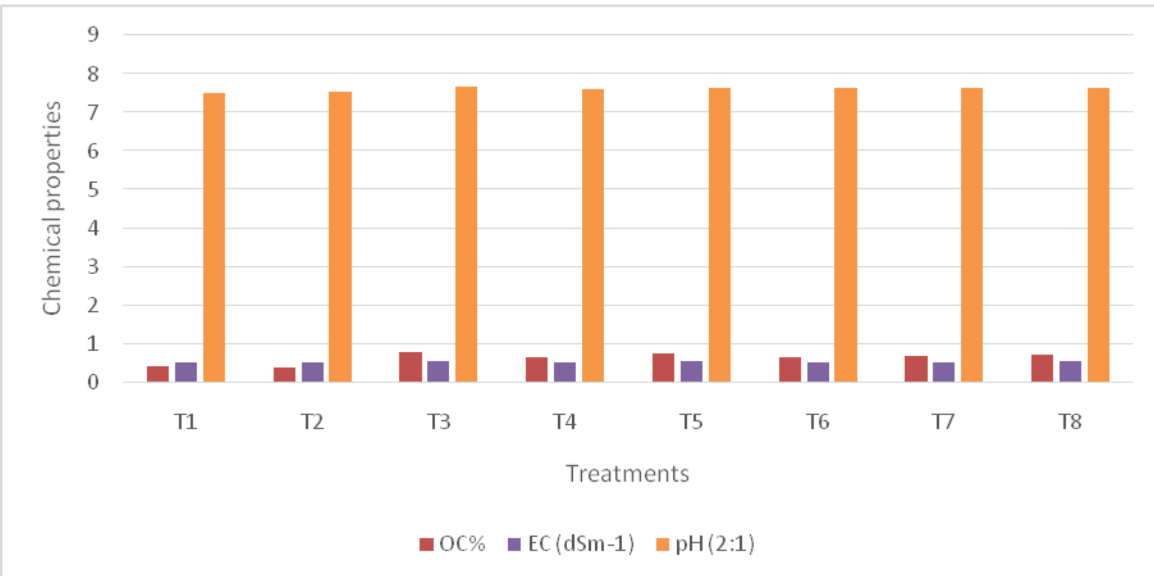

Fig.C EC, pH and OC of soil before sowing of Soybean

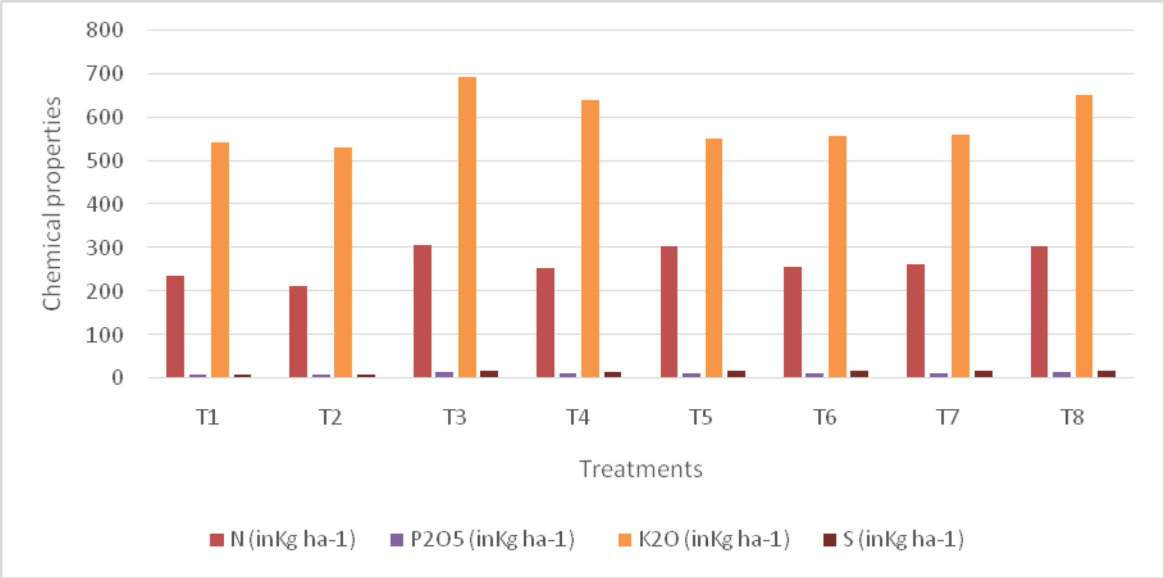

Fig.D Available N, P_2O_5, K_2O and S before sowing of soybean

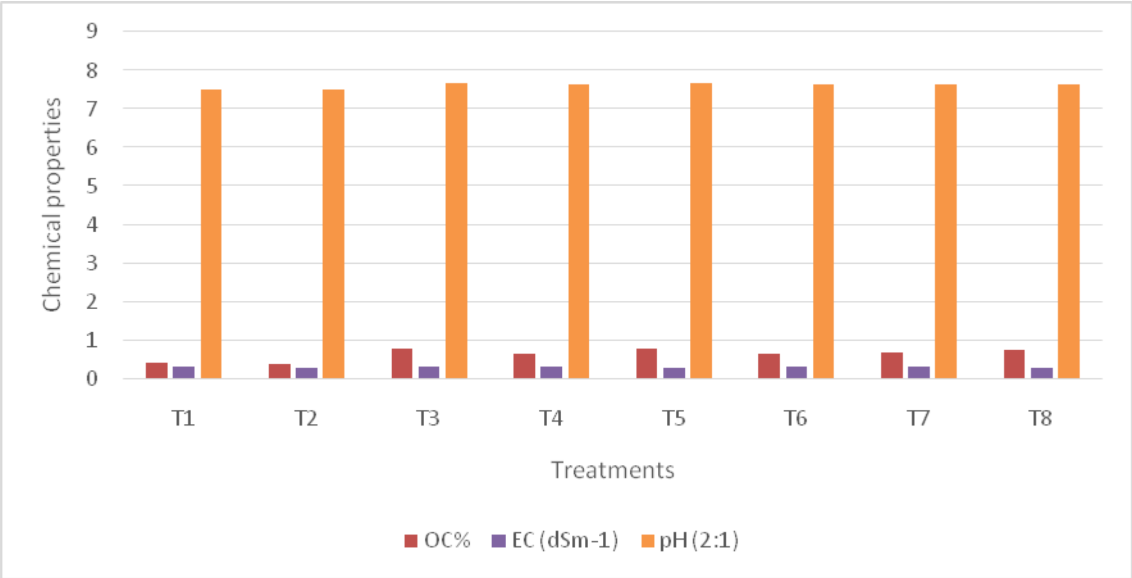

Fig.E EC, pH and OC of soil after harvesting of Soybean

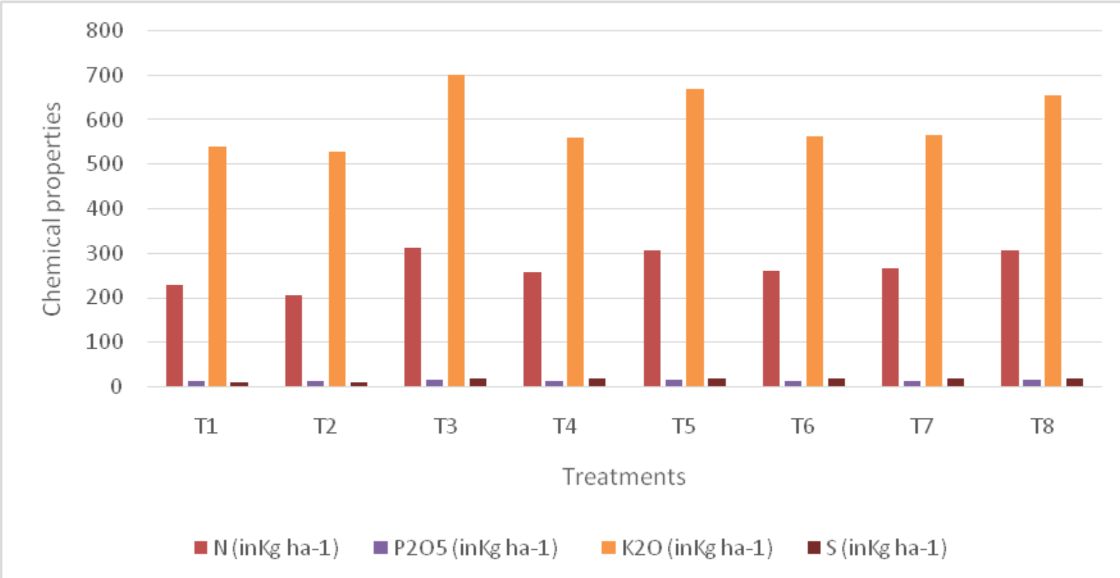

Fig.F Available N, P_2O_5, K_2O and S after harvesting of soybean.

Less intensive tillage practice with inclusion of organics resulted in good soil fertility status and soil health. Treatment T3 which is applied with Reduced tillage + 4 tonne ha^{-1} Straw + Hand Weeding performed higher in comparison to other treatments. All the treatments in which organics were applied showed better soil physico-chemical properties than conventional tillage. In T3 status of Available N, P, K and S after harvest found increased, the pH was a bit higher as compared to its value before sowing, BD of the soil was found decreased, WHC and Porosity was found increased. Result showed that application of organics with reduced tillage improves the soil nutrient status as well as physico-chemical condition.

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