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Influence of tillage practices and crop diversification on productivity and soil health in maize (*Zea mays*)/soybean (*Glycine max*) based cropping systems

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ABSTRACT

A field experiment was conducted at New Delhi during 2010–12 to find-out the influence of tillage practices and cropping systems on crop productivity and soil health in maize (*Zea mays* L.)/soybean (*Glycine max* L.) based cropping systems. Results revealed that minimum tillage with crop residue mulch improved the yield of component crops by 5–22% as well as system productivity by 5.4–7.1% in current study. The effect of minimum tillage on crop yields was more pronounced among summer season crops followed by winter season crops. Soil organic carbon (SOC) and available NPK as well as S exhibited marked improvement due to minimum tillage over conventional tillage. Soil pH and soil physical properties revealed favourable effects of minimum tillage over initial status. On an average, maize/soybean grown after summer greengram observed about 10–12% increase in yield than grown after spring sunflower. Winter season wheat, coriander, fenugreek, vegetable pea and potato exhibited 10.4, 6.9, 3.8, 6 and 11% higher yield after soybean compared to their respective yields after maize. Yield of spring sunflower in soybean–vegetable pea–sunflower system was 18 and 11% higher than its yield in maize–potato–sunflower and maize–vegetable pea–sunflower systems, respectively. The productivity of soybean based cropping systems was higher than that of maize based systems. With intervention of vegetable pea and potato during winter and sunflower during spring; the productivity of maize/soybean–vegetable pea/potato–sunflower systems was enhanced by 128% over maize/soybean–wheat–greengram systems. Similarly, replacement of wheat with coriander in maize/soybean–wheat–greengram system also improved the system productivity markedly. Diversified soybean–fenugreek/wheat/coriander–greengram systems also led to a marked improvement in SOC over initial status. Intervention of legumes also improved the available N, while cropping systems without non–legumes showed a decline in available N over initial status.

Key words: Maize/soybean based cropping systems, Soil health, System productivity, Tillage

Continuous cereal-cereal based production systems coupled with conventional cultivation practices has led to numerous production vulnerabilities in Indian agriculture (Paul *et al.* 2014). Thus, in order to sustain the soil and crop productivity, the minimum soil disturbance, organic soil cover and crop diversification assume great importance (Rana *et al*. 2004, Gangwar *et al*. 2006). Crop diversification through intervention of legumes as well as integrated crop, soil, nutrient and pest management are some of the viable options to cope up the emerging challenges in Indian agriculture. In the recent past, there is sizeable increase in maize acreage (about 33% from 2000 to 2011) and soybean as well in India (about 97% from 2000 to 2011). At present, maize–wheat (1.8 million ha) and soybean–wheat (4.5 million ha) are the predominant cropping systems in India (SOPA 2013). These crops have emerged as alternative options for replacing rice in cereal based cropping systems in water scarcity areas of north–western India besides those areas where sowing of wheat is delayed after rice (Gupta *et al.* 2002). Soybean being a legume, leaves 45 to 60 kg residual N/ha to the succeeding crop and creates favourable soil physico–chemical environment to the crop growth. It is also instrumental in sustaining soil organic matter status through substantial recycling of foliage/rhizosphere root biomass. The traditional practices of growing these crops have some limitations with respect to sustaining crop and soil productivity. Lower cropping intensity of maize/soybean based cropping systems is also an issue of major concern. Zero/minimum tillage with residue covers is being advocated for soil, organic matter, water, hydrothermal regulation and energy management over traditional tillage practices (Gangwar *et al.* 2006, Gill and Jat 2007). But, information on the comparative performance of intensive diversified maize and soybean–based cropping systems having 300% cropping intensity coupled with minimum/conventional tillage and crop residue cover, is very meager.

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Table 1 Agronomic practices followed in different crops

Agronomic practices	Crops								
	Kharif			*Rabi*			Summer		
	Maize	Soybean	Wheat	Potato	Pea	Fenugreek	Coriander	Sunflower	Green gram
Varieties/hybrid	PEHM–2	PUSA –9712	HD–2894	K. Badshah	Pusa Prabhat	AM–1	ACR–1	KBSH–1	Pusa Vishal
Seed rate (kg/ha)	20	75	100	200	80	25	15	4	20
Spacing (cm)	60×20	30×10	22.5×10	50×25	30×10	30×10	30×10	60×30	30×10
Fertilizers (N:P:K kg/ha)	120:60:80	20:40:20	120:60:40	120:60:80	20:40:20	20:40:20	60:30:20	60:90:60	20:30:20
No. of irrigations									
2010–11	2	2	4	5	4	3	3	4	4
2011–12	3	4	6	5	4	4	4	5	4
2012–13	3	4							
Crop duration (Days)	87,83,90	112,120,118	153, 154	113, 116	116,115	133,127	127,132	88,90	70,71

Thus, keeping in view above facts, the present study was undertaken to find out the effect of tillage practices and crop diversification through legumes/non legumes on the system productivity and soil physico-chemical properties in Indo-Gangetic plains region of north India.

MATERIALS AND METHODS

A field experiment was conducted during 2010–12 and at the Research Farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi (28°40' N latitude, 77°12' E longitude and an altitude of 228.6 m amsl). The mean annual rainfall of Delhi is 650 mm and more than 80% generally occurs during the south-west monsoon season (July–September). The soils of experimental field was sandy-loam in texture having 212 kg/ha N, 13.5 kg/ha available P, 240 kg/ha K and 0.35% organic carbon. The pH and EC of soil were 7.5 and 0.30 dS/m, respectively.The experiment was laid out in three times replicated split–plot design, assigning two tillage practices (i) conventional tillage (ii) minimum tillage with mulching of crop residues @ 5 tonnes/ha in each crop in main–plot and cropping systems (maize/soybean–wheat–greengram, maize/soybean–coriander–greengram,maize/soybean–fenugreek–greengram,maize/soybean–vegetable pea–sunflower and maize/soybean–potato–sunflower) in sub–plots. In the conventional tillage treatment, the tillage operations were carried out as per requirement of each crop. In minimum tillage treatment, one ploughing with planking was done followed by sowing of crop on flatbed except maize and potato where ridge were made at 60 cm spacing and there after dibbling was done as per plant to plant spacing. After the sowing of crop, mulching was done in minimum tillage treatment, where crop residues of preceding crops was used on succeeding crops @ 5 t/ha. Plant analysis of crop residues was carried out and nutrient added through mulching are given in Table 2. Input used such as varieties, fertilizers, irrigation, herbicides/pesticides and cultural practices followed in each crop are given in Table 1. In case of no rainfall, a pre–sowing irrigation was given to ensure timely sowing of the crop and thereafter irrigations were scheduled based on recommended IW/CPE ratio for each crop. The weight of grain/seed yield of maize, soybean, wheat, coriander, fenugreek, greengram and sunflower from net plot in each treatment after threshing was weighed and weight was expressed in t/ha. In potato, tubers of net plot area were dug out. After removing of soil adhering to tubers, weight of the tubers of each plot was recorded, separately. The values were finally expressed in t/ha. The weight of green pods recorded from each plots over different picking was added and expressed as t/ha. For comparison of cropping systems, maize grain equivalent yield was calculated considering the prevailing market prices (average): maize grain (10×10^3 ₹/tonne), soybean seed (20×10^3 ₹/tonne), wheat grain (12×10^3 ₹/tonne), coriander seed (50×10^3 ₹/tonne), fenugreek seed (40×10^3 ₹/tonne), vegetable pea (12×10^3 ₹/tonne), potato tubers (7×10^3 ₹/

Table 2 Nutrient concentration and addition through crop residues (2010–11 and 2011–12)

Crops	Applied season	Nutrient concentration (%)						Nutrient added (kg/ha)					
		N		P		K		N		P		K	
		2010–11	2011–12	2010–11	2011–12	2010–11	2011–12	2010–11	2011–12	2010–11	2011–12	2010–11	2011–12
Green gram	*Kharif*	0.94	0.94	0.11	0.13	0.89	0.91	47.1	47.3	5.42	6.51	44.5	45.5
Soybean	Winter	0.88	0.96	0.16	0.17	2.02	2.11	44.0	48.0	8.31	8.50	101.4	105.6
Wheat	Summer	0.50	0.53	0.03	0.04	1.21	1.21	25.0	26.5	1.72	1.82	60.4	60.8

Crop residues were applied @ 5.0 tonnes/ha dry matter tonne), greengram grain (35×10^3 ₹/tonne) and sunflower seed (25×10^3 ₹/tonne). The system productivity was calculated by adding the maize grain equivalent yields of all the crops treatment and replication–wise. For estimation of residual soil fertility, soil samples were taken after harvest of 2012 rainy season maize and soybean crops from a depth of 0–15 cm and analyzed for different physico-chemical properties as per the standard procedures. All the data pertaining to crop yields, system productivity and soil properties were statistically analysed using the *F*–test as per the procedure given by Gomez and Gomez (1984). LSD values at P=0.05 were used to determine the significance of difference between treatment means.

RESULTS AND DISCUSSION

Effect of tillage practices on crop yields

Results showed that minimum tillage with mulching @ 5 tonnes/ha recorded marked improvement in yield of component crops over conventional tillage. Favourable effects of minimum tillage + mulching on yield over conventional tillage were also found to vary across the seasons and crops within the same season (Tables 3, 4 and 5). The effect of mulching accumulated over the years and the gap in yield was more in second year than the first year. In *kharif* season, maize yield under minimum tillage with mulching was 10.7% higher in first year, which increased to 20.5% in the third year. Similar trend was observed in soybean too. In the winter season crops, fenugreek, coriander, wheat, vegetable pea and potato recorded 8.6, 5.5, 13.4, 8.6 and 12.5% increase in seed and grain yield in first year and 15.8, 5.1, 12.9. 11.2 and 13.9% in the second year, respectively owing to favourable effect of minimum tillage with mulching over conventional tillage. Favourable effect of minimum tillage + mulching was more pronounced in summer season, resulting in 15.5 and 22.4% increase in seed/grain yield of sunflower and greengram in first year, respectively. Corresponding increase in yield for the second year was 14.9% for sunflower and 31.4% for greengram. Favourable effect of minimum tillage with mulching over conventional tillage may be attributed to optimum soil moisture regime, weed suppression and availability of more nutrients due to decomposition of mulches, improvement in soil properties and soil temperature regulation. Similar favourable effects of minimum tillage + mulching on crop productivity due to improvement in moisture, heat and air regime, restriction on evaporation and weed suppression were also reported by Bu *et al*. (2002) and Kumar *et al.*(2013). Choudhary and Kumar (2014) also reported 18–35% higher productivity of sequential crops with mulch application. These results are expected as addition of organic material along with inorganic can bring about equilibrium between degenerative and restorative activities in the soil profile. This practice also found in arresting the decline trend in soil health and productivity through the correction of marginal deficiencies of some secondary and micronutrients and micro–flora and fauna and their beneficial influence on physical, chemical and biological properties of soils (Ramesh *et al.* 2009).

Effect of preceding crop on the yield of succeeding crops

Effect on kharif crops: In different cropping systems, marked effects of preceding crops were observed on succeeding crops. Maize recorded the highest productivity in the second and third year of experiment in maize–fenugreek–greengram followed by maize–coriander–greengram sequence. Maize yield of these two sequences was significantly higher than the maize yield recorded in maize–potato–sunflower sequence (Table 3). On an average, grain yield of maize in maize–fenugreek–greengram sequence was 12.8% higher than the maize yield recorded in maize–potato–sunflower sequence. These variations in maize yield may be ascribed to favourable effect of preceding legume on succeeding non–legume crop as compared to sunflower, which is very exhaustive crop and also carry allelopathic effect. At IARI New Delhi, Rana *et al.* (2004), Babu *et al*. (2013) and Babu *et al.* (2014) reported that sunflower as preceding crop caused considerable reduction in yield of succeeding crops and adverse affects were more pronounced on legume crops as compared to cereals and oilseed crops. Similar effect of legume and non–legume was reported by Tirumala (2012) and Sharma *et al.* (2014). Similar to maize, soybean yield also recorded marked variation due to cropping systems (Table 3). Soybean seed yield in soybean–coriander–greengram and soybean–fenugreek–greengram sequence was conspicuously higher than the seed yield recorded in soybean–potato–sunflower and soybean–vegetable pea–sunflower crop sequence, during both the year. Based on two years average, soybean yield in soybean–fenugreek–greengram sequence was 11% higher than the seed yield of soybean–potato–sunflower sequence. This variation in grain/seed yield of maize/ soybean crop may be attributed to favourable effects of legume crop on the succeeding crop and adverse effect of sunflower on succeeding crop. Similar favourable effects of legume on succeeding crop and unfavourable effects of sunflower has also been reported by Rana *et al*. (2004), Prakash *et al.* (2004) and Babu *et al.* (2013).

Effect on rabi crops: All the winter season crops recorded markedly higher economic yield after soybean than maize. On an average economic yields of wheat (grain), fenugreek (seed), coriander (seed), pea (green pods) and potato (tubers) after soybean was 10.4, 3.8, 6.9, 6 and 11% higher than yields of these crops after maize (Table 3). This improvement in yield may be attributed to legume effect of soybean in term of N–fixation, soil microbiological properties and improvement in physical properties as reported by Tirumala (2012).

Effect on summer crops: Over the years, the highest productivity of sunflower was recorded in soybean–vegetable pea–sunflower sequence, which was statistically at par with soybean–potato–sunflower, but significantly superior to maize–potato/vegetable pea–sunflower cropping systems. On an average, sunflower yield in soybean–

Table 3 Effect of tillage practices and cropping systems on productivity *kharif* season crops

Treatment	Maize grain yield (tonnes/ha)			Soybean seed yield (tonnes/ha)		
	2010–11	2011–12	2012–13	2010–11	2011–12	2012–13
Tillage practices						
Conventional tillage	2.32	2.54	2.70	1.27	1.42	1.52
Minimum tillage with crop residue mulch	2.57	2.80	3.22	1.40	1.56	1.69
SEm±	0.02	0.03	0.05	0.01	0.02	0.03
LSD (*P*=0.05)	0.17	0.18	0.29	0.07	0.13	0.16
Cropping systems						
Maize–Potato–Sunflower		2.50	2.80			
Maize–Pea–Sunflower		2.60	2.84			
Maize–Wheat–Greengram		2.64	2.87			
Maize–Coriander–Greengram		2.80	3.12			
Maize–Fenugreek–Greengram		2.81	3.17			
Soybean–Potato–Sunflower					1.41	1.52
Soybean –Pea–Sunflower					1.43	1.53
Soybean –Wheat–Greengram					1.51	1.62
Soybean –Coriander–Greengram					1.54	1.66
Soybean –Fenugreek–Greengram					1.56	1.68
SEm±		0.07	0.09		0.03	0.04
LSD (*P*=0.05)		0.22	0.27		0.10	0.11

Table 4 Effect of different tillage practices and cropping systems on productivity of *rabi* season crops

Treatment	Fenugreek (tonnes/ha)		Wheat (tonnes/ha)		Coriander (tonnes/ha)		Green pea (tonnes/ha)		Potato (tonnes/ha)	
	2010–11	2011–12	2010–11	2011–12	2010–11	2011–12	2010–11	2011–12	2010–11	2011–12
Tillage practices										
Conventional tillage	1.61	1.64	3.80	3.96	1.64	1.70	12.21	12.99	24.67	25.58
Minimum tillage with crop residue mulch	1.75	1.90	4.01	4.16	1.86	1.92	13.26	14.45	27.77	29.13
SEm±	0.02	0.05	0.02	0.02	0.02	0.03	0.13	0.20	0.16	0.34
LSD (*P*=0.05)	0.11	0.28	0.13	0.13	0.12	0.20	0.80	1.19	0.99	2.05
Cropping systems										
Maize–Fenugreek–Greengram	1.62	1.65								
Soybean–Fenugreek–Greengram	1.74	1.86								
Maize–Wheat–Greengram			3.84	3.99						
Soybean–Wheat–Greengram			3.97	4.13						
Maize–Coriander–Greengram					1.69	1.75				
Soybean–Coriander–Greengram					1.81	1.87				
Maize–Pea–Greengram							12.32	13.37		
Soybean–Pea–Greengram							13.16	14.07		
Maize–Potato–Greengram									24.93	25.88
Soybean–Potato–Greengram									27.50	28.83
SEm±	0.03	0.04	0.03	0.03	0.02	0.02	0.09	0.13	0.33	0.37
LSD (*P*=0.05)	0.10	0.17	0.11	0.12	0.07	0.08	0.37	0.50	1.28	1.47

vegetable pea–sunflower system was 18.3 and 11.3% higher than maize–potato–sunflower and maize–vegetable pea–sunflower system, respectively. Effect of preceding crops like wheat, fenugreek and coriander was not observed on the grain yield of summer greengram both in maize and soybean cropping systems. The highest seed yield of green gram was recorded in soybean–fenugreek–greengram system which was significantly superior to greengram seed yield in maize based cropping systems (Table 5). Results confirm the finding of Tirumala (2012) and Sharma *et al.* (2014).

System productivity

Effect of tillage practices: While comparing the total productivity of cropping systems in terms of maize grain equivalent yield (MEY) under different tillage practices, it

Table 5 Summer season crops yield and maize grain equivalent system productivity as influenced by different tillage practices and cropping systems

Treatment	Sunflower seed (tonnes/ha)		Greengram seed (tonnes/ha)		System productivity (Maize grain equivalent yield) (tonnes/ha)	
	2010–11	2011–12	2010–11	2011–12	2010–11	2011–12
Tillage practice						
Conventional tillage	1.74	1.94	0.49	0.51	15.11	16.69
Minimum tillage with crop residue mulch	2.01	2.23	0.60	0.67	15.93	17.93
SEm±	0.02	0.02	0.01	0.01	0.05	0.06
LSD (*P*=0.05)	0.11	0.13	0.06	0.05	0.24	0.31.
Cropping systems						
Maize–Potato–Sunflower	1.71	1.93			22.52	23.94
Maize–Pea–Sunflower	1.82	2.04			22.73	24.78
Maize–Wheat–Greengram			0.49	0.52	11.57	11.57
Maize–Coriander–Greengram			0.51	0.54	13.93	14.66
Maize–Fenugreek–Greengram			0.53	0.54	12.04	12.56
Soybean–Potato–Sunflower	1.92	2.11			24.52	26.30
Soybean –Pea–Sunflower	2.04	2.26			24.12	26.39
Soybean –Wheat–Greengram			0.56	0.61	11.49	12.42
Soybean –Coriander–Greengram			0.58	0.66	14.66	15.68
Soybean –Fenugreek–Greengram			0.61	0.69	12.71	14.02
SEm±	0.06	0.07	0.02	0.04	0.06	0.07
LSD (*P*=0.05)	0.17	0.22	0.06	0.10	0.18	0.23

was observed that tillage practices influenced the system productivity significantly during both the seasons. Over the experimental period, system productivity was higher in the second season than the first season. Minimum tillage with mulching recorded 5.4% higher system productivity than conventional tillage during 2010–11, which increased to 7.4% in 2011–12. This behaviour of system productivity may be traced to favourable effects of minimum tillage with mulching on the productivity of individual crop of cropping system by virtue of improvement in soil properties as given in Table 6. Similar favourable effects of minimum tillage + mulching on system productivity were also reported by Bu *et al.* (2002) and Kumar *et al.* (2013).

Effect of cropping systems: On an average, soybean based systems were found more productive than maize based systems during both the crop seasons. Maximum total productivity was recorded in maize/soybean–vegetable pea–sunflower cropping system closely followed by maize/soybean–potato–sunflower cropping system (Table 5). Maize–vegetable pea–sunflower system produced 96 and 114% higher system productivity during 2010–11 and 2011–12, respectively than conventional system (maize–wheat–green gram). With respect to maize–potato–sunflower system, the increase was 94 and 107% in respective season over maize–wheat–green gram system. Replacement of wheat with spices (coriander and fenugreek) in maize–wheat–greengram cropping system also improved the system productivity over conventional system and advantage in productivity was more with coriander than the fenugreek. Similar results were also observed in soybean based cropping systems. The lowest system productivity was recorded in soybean–wheat–green gram cropping system, which was 110 and 112% lower than the soybean–vegetable pea–sunflower system. Chitale *et al.* (2011) and Sharma *et al.* (2014) also recorded improvement in the system productivity with the intervention of vegetables and spices in the conventional cropping systems. This improvement in productivity may be attributed to higher biological yield of vegetable crops and higher market values of the spices.

Soil properties

Effect of tillage practices on soil properties: On completion of two cropping cycles, a significant increase in soil organic carbon (SOC) and available NPK and S were recorded due to tillage practices (Table 6). Minimum tillage with mulching recorded 8.5, 7.7, 8.4 and 15.8% increment in SOC and available NPK over conventional tillage. This improvement in SOC and available NPK and S is very much expected under minimum tillage + mulching, as each crop of the system was mulched @ 5 tonne/ha of crop residues and its incorporation in the soil after harvest of each crop, which contributed additional amount of SOC and NPK as compared to conventional tillage (Table 6). The results confirm the findings of Ramesh *et al.* (2009). Soil properties such as pH, electrical conductivity (EC), bulk density (BD), field capacity (FC) and permanent wilting point (PWP) were not found to vary statistically due to tillage practice; as the effect of tillage practices on these properties become visible in long–term study only.

Effect of cropping systems on soil properties: Among the cropping systems, the highest SOC was recorded in

Table 6 Soil organic carbon (%) available N, P, K and S (kg/ha), pH, eclectic conductivity (EC)*, bulk density (BD), field capacity (FC) and permanent wilting point (PWP) at the end of experiment as influenced by different tillage practices and cropping systems

Treatment	SOC	N	P	K	S	pH	EC	BD	FC	PWP
Tillage practices										
Conventional tillage	0.350	206	13.5	219.7	13.6	7.50	0.31	1.42	17.0	5.77
Minimum tillage with crop residue mulch	0.380	230	15.0	254.6	14.2	7.43	0.30	1.43	17.2	6.15
SEm±	0.004	1.84	0.26	4.53	0.11	0.02	0.00	0.004	0.05	0.17
LSD (*P*=0.05)	0.023	11.21	1.60	27.55	NS	NS	NS	NS	NS	NS
Cropping systems										
Maize –Potato–Sunflower	0.326	203	12.5	231.5	13.1	7.40	0.31	1.43	17.3	6.47
Maize –Pea–Sunflower	0.339	212	13.9	236.3	14.2	7.44	0.31	1.41	17.5	6.10
Maize– Wheat–Greengram	0.367	216	13.8	239.2	15.0	7.45	0.31	1.43	16.3	5.55
Maize– Coriander–Greengram	0.367	215	13.7	239.4	15.3	7.38	0.31	1.43	17.3	5.83
Maize –Fenugreek–Greengram	0.370	221	14.2	240.5	15.6	7.58	0.30	1.41	17.2	6.07
Soybean–Potato–Sunflower	0.366	221	14.0	233.2	12.9	7.40	0.30	1.42	17.2	5.88
Soybean –Pea–Sunflower	0.372	223	14.5	236.5	12.3	7.44	0.31	1.43	16.8	6.02
Soybean–Wheat–Greengram	0.378	224	15.2	238.5	13.1	7.51	0.30	1.43	17.5	5.87
Soybean– Coriander–Greengram	0.374	221	19.1	236.4	14.0	7.47	0.30	1.42	16.8	5.97
Soybean –Fenugreek–Greengram	0.391	227	20.1	239.8	14.7	7.58	0.30	1.43	16.8	5.87
SEm±	0.006	3.83	0.42	4.68	0.16	0.07	0.005	0.01	0.38	0.16
LSD (*P*=0.05)	0.017	10.99	1.21	13.41	0.45	NS	NS	NS	NS	NS
Initial values	0.358	212	13.5	240	13.8	7.50	0.30	1.41	17.1	5.88

*EC: mmhos/dS; BD: Mg/m^3; FC & PWP in %.

soybean–fenugreek–greengram system, followed by soybean–wheat–greengram and soybean–coriander–greengram system and the SOC in these systems was higher than the initial status. Maize–potato–sunflower and maize–pea–sunflower system showed negative impact on SOC as compared to initial value (Table 6). Soybean based cropping system had positive impact on available N while maize based systems had negative impact except maize–fenugreek–greengram system over initial value of available N. Soybean–fenugreek–greengram system recorded the highest value of available N, which was 5% higher than initial value. In contrast, maize–potato–sunflower recorded the lowest value of available N, which was 10.9% lower than initial value. In case of available P also, soybean based cropping systems have positive impact, while there is not much change in maize based cropping system. In all the cropping systems negative impact was observed on available K over initial status. In soybean based cropping systems, available S was found to decline over initial values while in maize based system available S remained around initial value except maize–fenugreek–greengram system. Soil pH, EC, BD, FC and PWP remained unaffected due to cropping systems. Higher SOC in soybean based cropping systems and positive balance of SOC and available N and P over initial values in soybean based systems may be attributed to more litter fall and root biomass contribution due to closer spacing as compared to maize, N fixation by soybean, addition of higher dose of P to legume and favourable effect of underground root biomass of legumes in increasing P availability. Similar results were also reported by Dhiman (2010) and Sharma *et al.* (2014).

It is therefore concluded that minimum tillage with crop residue mulching is not only a viable replacement for the conventional tillage but has great potential in improving the soil and crop productivity in a sustainable manner. Thus, there is a dire need to select appropriate crop combinations in the cropping systems for enhancing the crop productivity and soil health. Intervention of spices, vegetables and sunflower in maize/soybean–wheat–greengram system also assume great potential in enhancing the system productivity of conventional cropping systems.

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