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Soil health under maize-wheat cropping system influenced by tillage options and summer green manuring

Sunil Kumar, RN Meena and MP Singh

Abstract
A field experiment was conducted in 2016-17 and 2017-18 during *kharif* and *rabi* season at agricultural research farm of BHU, Varanasi to study the effect of different tillage options and green manuring on soil health under maize-wheat based cropping system. The experiment was laid out in split plot design consisting of 20 treatments. The four different tillage options were assigned to main plot and five summer green manuring treatments were kept in sub plots. ZTM – ZTW and CTM – CTW remained statistically at par with each other and showed higher uptake than the other tillage practices. The treatment *dhaincha* followed by sunnhemp recorded significantly higher N, P and K uptake by grain and stover over the other green manuring practices. Tillage options and summer green manuring slightly improve the soil bulk density, pH and EC but it was not up to the level of significance under maize-wheat based cropping system. The treatment ZTM – ZTW registered significantly higher value of organic carbon content during second year, after harvest of each crop. The significantly highest primary nutrient availability was recorded in treatment ZTM – ZTW after harvest of maize crop but it was not significant in case of P and K during first year of experimentation. Whereas, ZTM – ZTW resulted significantly highest available nutrient status of soil after harvest of the experimental wheat crop as compared to other tillage Options. Among summer green manuring, *dhaincha* followed by sunnhemp recorded significantly higher organic carbon during second year after harvest of each maize and wheat crop over other green manuring practices. The highest N, P and K availability was recorded significant in *dhaincha* after harvest of maize crop but it was not significant in case of P and K in case of maize crop during first year of investigation. Whereas, *dhaincha* and sunnhemp resulted significantly the highest available N, P and K of soil after harvest of wheat crop as compared to other green manuring practices. It is recommended that ZT maize and summer green manure *dhaincha* residue mulching should be followed to improve soil physio-chemical properties of soil.

Keywords: clusterbean, conservation tillage, cowpea, *Dhaincha*, Sunnhemp green manures, maize-wheat system

Introduction
Maize and wheat are two important cereals contributing to food and nutritional security at the global level. Maize-wheat cropping system is followed in upland irrigated ecologies of the Indo-Gangetic Plains (IGP) of India. Tillage and nutrients are the most crucial monetary inputs for crop production. Intensive tillage, continuous over mining of nutrients from soil and imbalanced use of fertilizers lead to deterioration of soil health and decrease in productivity of maize-wheat system in long run (Ghosh *et al.*, 2015) [8]. Conservation agriculture is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with sustained production, while concurrently conserving the environment. Conservation agriculture is characterized by three interlinked principles, namely continuous minimum mechanical soil disturbance, permanent organic soil cover and diversification of crop species grown in sequence or associations (FAO, 2010) [7]. The advantages of minimum or no tillage, retention of crop residues in field and diversifying rotation to improve soil health and productivity are fast popularizing.
In the present day agriculture, emphasis is being laid on the maximization of agricultural productivity per unit area per unit time through multiple cropping systems. But this approach of continuous cropping exhausts the nutrients from the soil. Good yield on a sustainable basis can be obtained, provided soil quality and health is maintained with adequate supply of macro and micronutrients. Green manuring being a low cost practice is an alternate way to improve soil fertility status.

Mulch enhanced root and increased maize grain yield by increasing plant N-uptake efficiency, falling N discharge losses and improving nutrient preservation over unmulched plots (Aulakh *et al*., 2000) [1]. In addition to the nutrient benefits, legume crops have many other positive effects on subsequent crops, such as decreased plant diseases, decreased weed density, improved soil structure (Goyal *et al*., 1999) [9] and exudation of beneficial compounds, such as auxins, gibberellins and cytokinins.

Soil fertility management at an adequate level is one of the most important factors affecting crop production. This objective can be achieved if appropriate soil and crop management practices are adopted. Use of organic manures, including green manuring, is an important strategy to maintain and/or improve soil fertility for sustainable crop production. Green manuring can increase cropping system sustainability by reducing soil erosion, by increasing nutrient retention, improving soil fertility (Fageria and Baligar, 2005) [6], and by reducing global warming potential. The complexities with residue management in zero-till systems indicate the need for more research for improved and efficient utilization of crop residues.

Materials and Methods

The trial was carried out during *kharif* and *rabi* season of 2016-17 and 2017-18 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (India). The experimental site was fairly uniform in topography and well drained in nature. The soil was sandy clay loam in texture having pH (7.72), electrical conductivity (0.30 dS/m at 25 ºC) and moderate fertility with 0.41% organic carbon, 146.80 kg ha^{-1} available N, 18.35 kg ha^{-1} available P and 175.60 kg ha^{-1} available K. The experiment was laid out in split plot design consisting of 20 treatments with three replications. The four different tillage practices *viz*. Conventional tillage maize — Conventional tillage wheat (CTM — CTW), Minimum tillage maize — Minimum tillage wheat (MTM — MTW), Minimum tillage maize —Zero tillage wheat (MTM — ZTW) and Zero tillage maize — Zero tillage wheat (ZTM — ZTW) were assigned to main plot and five summer green manuring treatments *viz.* Summer fallowing, Dhaincha (*Sesbania aculeata*), Sunnhemp (*Crotalaria juncea*), Clusterbean (*Cyamopsis tetragonoloba*) and Cowpea (*Vigna sinensis*) were kept in sub plots. All the summer green manure crops were incorporated or cut at 45 DAS. In T_1, T_2, and T_3 treatments, the different green manure crops were incorporated into the soil according to main plot tillage practices. In T_4 treatment, the biomass of different green manures were cut to ground level and the material was then chopped to 10 to 15 cm size pieces particularly in case of dhaincha and sunnhemp and was spread in same sub plots uniformly (mulching) and maize crop was sown without any tillage operation.

In Zero tillage wheat (ZTW) plots, the crop was established without any preparatory tillage. In Conventional tillage wheat (CTW) and Minimum till wheat (MTW), the field was tilled according to main plot treatments in same layout during *rabi* season. The recommended dose of fertilizer 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} (maize) and 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} (wheat) were applied through Urea, DAP and MOP, respectively. One third recommended dose of nitrogen and full doses of P and K were applied as basal and rest two splits of nitrogen was top dressed through urea at knee high and tassel emergence stage (maize) and at first irrigation and second irrigation (wheat). In soil physio-chemeical parameters *viz.* bulk density, pH, EC, organic carbon, available N, P and K observations were analyzed after harvest of each crop.

Results and Discussion

Nutrient uptake

Significant improvement in N, P and K uptake by grain and Stover/straw of maize and wheat was observed with each increment of N, P and K up to 101.01, 29.99 and 74.55 kg ha^{-1} in maize and 92.62, 17.48 and 23.82 kg ha^{-1} in wheat, respectively (Table 1&3). ZTM – ZTW and CTM – CTW remained statistically at par with each other and showed higher uptake than the other tillage practices. The treatment dhaincha followed by sunnhemp recorded significantly higher N, P and K uptake by grain and stover over the other green manuring practices during both years of the investigation. This might be due to fact that summer green manures residue applications (ZTM) on soil surface (mulching) suppress the growth of weeds, increase the moisture availability and moderate the soil temperature. Thus, it increased the biomass accumulation of maize which ultimately increased the grain and stover yield of crop and resulted in higher uptake of N, P and K. Similar result was also reported by Patra *et al*. (2004) [14].

The higher mean total N, P and K uptake under zero till maize might be due to better root growth, leading to more extraction of nutrient from soil, lower weed infestation and better performance of crops particularly by maize under water logging condition, thus all these factors might have contributed to higher uptakes of nutrients under ZTM. The addition of nutrients through residue, improved physical environment favorable for better microbial activity that might helped in mineralization resulting better availability of nutrients to maize crop and thus increased the uptake under zero tillage (Behera *et al*., 2007) [2]. Conservation tillage practices brought significant differences in the nutrient uptake by the maize-wheat cropping system Parihar (2014) [13].

Soil physico-chemical properties

Tillage practices and summer green manuring slightly improve the soil bulk density, pH and EC but it was not up to the level of significance in two years experiment under maize-wheat cropping system. Whereas, the lower bulk density, pH and EC recorded with different green manuring crops than the summer fallowing but its value was not up to the significant level during both the years of investigation (Table 5). The treatment ZTM – ZTW registered significantly higher value of organic carbon content during second year, after harvest of each crop (Table 2&4). The significantly highest primary nutrient availability was recorded in treatment ZTM – ZTW after harvest of maize crop but it was not significant in case of P and K during first year of experiment. Whereas, ZTM – ZTW resulted significantly highest available nutrient status (N, P and K) of soil after harvest of the experimental wheat crop as compared to other tillage practices during both the years of experimentation (Table 2&4). Among different summer green manuring treatments, dhaincha followed by sunnhemp recorded significantly higher organic carbon during second year after harvest of each maize and wheat crop over other green manuring practices. The highest N, P and K availability was recorded significant in treatment dhaincha after harvest of maize crop but it was not significant in case of P and K in case of maize crop during first year of experiment.

Whereas, dhaincha and sunnhemp resulted significantly highest nutrient status (available N, P and K) of soil after harvest of wheat crop as compared to other green manuring practices during both the years of experimentation.

Lower bulk density in zero till maize plots is expected as the level of compaction itself is an indication of the pressure on microorganisms in the soil causing their death. Intensive soil cultivation which may increase soil bulk density is intimately connected with reduced porosity and the alteration of pore size distribution. Lower soil bulk density under residue mulch or organic manure application than in residue removal has been also observed by others (Mandal *et al*., 2013 and Kuotsu *et al*., 2014) [12, 11].

All the examined summer green manures mulching increased the content of SOC relative to the conventional and minimum tillage. As green manure residues are principal source of C, so increase in SOC due to addition of summer green manures as mulching material is expected. The organic mulch eventually breaks down and becomes a part of the soil and is added to SOC pool and soil available nutrient reserves (Gruber *et al.*, 2008). The SOC concentrations under ZT relative to CT were higher in the soil (Das *et al*., 2017). Mulching can increase SOC by influencing the soil water regime through the interception of precipitation (Sun *et al*., 2013), and by generating specific microclimate conditions that affect chemical, biochemical and biological processes (Di Bene *et al*., 2011). Summer green manures mulching (ZTM) increased concentration of soil available N, P and K. Increase in soil nutrient status due to continuous mulching has been also indicated by others (Kuotsu *et al*., 2014) [14]. No-till treatments have higher P, K and organic carbon concentrations in the superficial 0-2.5 cm soil layer and in runoff sediments than CT (Betrol *et al*., 2007) [3].

It is observed that ZT maize – ZT wheat and summer green manure dhaincha residue mulching should be followed for improving soil physico-chemical properties in maize-wheat cropping system.

Table 1: Effect of different tillage practices and green manuring on yield attributes of maize (pooled data of 2 years)

Treatment	Cobs/ plant	Cob length (cm)	Cob girth (cm)	Per cob weight (g)	Kernels weight/ cob (g)	Kernels/ cob	Test weight (g)	Cobs weight (kg/plot)
Tillage practices								
CTM-CTW	1.24	16.61	10.44	98.0	77.8	369.8	237.4	6.86
MTM-MTW	1.23	16.16	9.98	93.0	73.4	346.0	236.9	6.55
MTM-ZTW	1.21	15.81	9.67	91.9	71.9	340.4	236.7	6.45
ZTM-ZTW	1.28	17.11	10.99	103.3	82.0	383.9	238.9	6.96
SEm±	0.01	0.14	0.13	1.1	0.9	5.0	0.3	0.07
CD (P=0.05)	NS	0.43	0.40	3.6	2.9	15.5	1.1	0.22
Summer green manuring								
Summer fallowing	1.22	15.62	9.49	88.5	69.3	330.6	236.7	6.36
Dhaincha	1.25	17.18	11.04	102.5	81.8	386.1	238.1	6.99
Sunnhemp	1.25	16.89	10.75	100.8	80.0	376.6	237.8	6.85
Clusterbean	1.24	16.30	10.12	96.4	75.7	357.1	237.5	6.68
Cowpea	1.23	16.12	9.94	94.5	74.6	349.6	237.4	6.65
SEm±	0.01	0.14	0.14	1.1	0.9	4.2	0.2	0.07
CD (P=0.05)	NS	0.41	0.41	3.1	2.6	11.8	0.6	0.20
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

Details of treatments are given under Materials and Methods; CTM-CTW, conventional tillage maize-conventional tillage wheat; MTM- MTW, minimum tillage maize-minimum tillage wheat; MTM-ZTW, Minimum tillage maize-zero tillage wheat; ZTM–ZTW, zero tillage maize-zero tillage wheat

Table 2. Effect of different tillage practices and green manuring on yield of maize (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Tillage practices				
CTM-CTW	5.48	6.57	12.05	45.4
MTM-MTW	5.20	6.26	11.46	45.3
MTM-ZTW	5.10	6.18	11.28	45.1
ZTM-ZTW	5.59	6.61	12.20	45.7
SEm±	0.06	0.07	0.13	0.18
CD (P=0.05)	0.20	0.22	0.41	NS
Summer green manuring Summer fallowing	5.01	6.12	11.13	44.9
Dhaincha	5.62	6.64	12.26	45.8
Sunnhemp	5.49	6.55	12.04	45.5
Clusterbean	5.31	6.37	11.69	45.4
Cowpea	5.28	6.34	11.62	45.3
SEm±	0.06	0.06	0.12	0.17
CD (P=0.05)	0.18	0.18	0.33	NS
Interaction	NS	NS	NS	NS

Details of treatments are given under Materials and Methods; CTM-CTW, conventional tillage maize-conventional tillage wheat; MTM- MTW, minimum tillage maize-minimum tillage wheat; MTM-ZTW, Minimum tillage maize-zero tillage wheat; ZTM–ZTW, zero tillage maize-zero tillage wheat

Table 3: Effect of different tillage options an d green manuring on N P K uptake (kg ha^{-1}) in grain and stover of maize under maize-wheat based cropping system

Treatments	N uptake in grain		N uptake in stover		P uptake in grain		P uptake in stover		K uptake in grain		K uptake in Stover	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Tillage Options												
T1: CTM – CTW	95.38	98.50	33.79	34.62	27.42	28.44	25.17	25.97	69.57	71.94	111.13	113.84
T2: MTM – MTW	90.01	92.96	31.86	32.71	25.97	26.95	23.72	24.49	65.62	68.28	104.60	107.93
T3: MTM – ZTW	89.32	89.22	31.42	31.54	25.62	25.50	23.39	23.27	64.72	64.40	103.13	103.91
T4: ZTM – ZTW	97.31	101.01	34.63	35.66	28.63	29.99	25.79	26.74	72.51	74.55	113.72	116.44
SEm ±	1.67	1.83	0.57	0.57	0.38	0.48	0.45	0.49	0.97	0.79	1.80	2.43
CD (P=0.05)	5.78	6.34	1.98	1.97	1.31	1.68	1.56	1.71	3.36	2.73	6.22	8.41
Summer green manuring												
M1: Summer fallowing	87.50	87.38	30.77	31.43	24.75	24.72	22.86	22.93	62.78	63.87	101.07	103.13
M2: Dhaincha	97.79	101.62	34.90	35.91	28.88	30.39	26.00	27.02	73.05	75.37	114.61	117.57
M3: Sunnhemp	95.55	98.74	34.34	35.14	28.18	29.37	25.58	26.45	71.29	73.18	112.80	115.41
M4: Clusterbean	92.56	95.10	32.38	32.97	26.49	27.16	24.13	24.69	66.98	68.52	106.35	108.68
M5: Cowpea	91.61	94.27	32.24	32.71	26.26	26.96	24.02	24.50	66.41	68.03	105.90	107.86
SEm ±	1.67	1.83	0.52	0.46	0.41	0.49	0.49	0.40	1.04	0.80	1.62	2.00
CD (P=0.05)	4.81	5.26	1.49	1.33	1.18	1.42	1.40	1.16	3.00	2.30	4.67	5.75
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4: Effect of different tillage options and green manuring on chemical properties of soil after harvest of maize under maize-wheat based cropping system

Treatments	Organic carbon (per cent) after harvest of maize		Available N (kg ha^{-1}) after harvest of maize		Available P (kg ha^{-1}) after harvest of maize		Available K (kg ha^{-1}) after harvest of maize	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Tillage Options								
T1: CTM – CTW	0.43	0.42	156.76	157.48	19.01	18.86	182.76	183.66
T2: MTM – MTW	0.43	0.42	154.34	153.97	18.46	18.54	180.50	180.44
T3: MTM – ZTW	0.43	0.40	153.88	153.55	18.37	18.43	179.20	179.25
T4: ZTM – ZTW	0.44	0.45	164.49	171.27	19.55	20.14	189.04	194.83
SEm ±	0.01	0.01	2.23	2.47	0.30	0.28	2.95	2.77
CD (P=0.05)	NS	0.02	7.70	8.55	NS	0.97	NS	9.60
Summer green manuring								
M1: Summer fallowing	0.42	0.40	146.84	144.88	18.38	18.08	178.32	174.47
M2: Dhaincha	0.44	0.45	166.74	171.17	19.31	19.62	187.46	192.06
M3: Sunnhemp	0.44	0.44	164.01	167.42	19.21	19.50	186.45	190.98
M4: Clusterbean	0.43	0.42	156.26	158.41	18.67	18.90	181.17	182.70
M5: Cowpea	0.43	0.42	152.99	153.47	18.65	18.88	180.98	182.51
SEm ±	0.01	0.01	2.28	2.65	0.25	0.23	2.40	2.25
CD (P=0.05)	NS	0.02	6.57	7.63	NS	0.66	NS	6.47
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

Table 5: Effect of different tillage options and green manuring on N P K uptake (kg ha^{-1}) in grain and straw of wheat under maize-wheat based cropping system

Treatments	N uptake in grain		N uptake in straw		P uptake in grain		P uptake in straw		K uptake in grain		K uptake in straw	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Tillage Options												
T1: CTM – CTW	84.37	88.73	31.27	32.34	15.14	16.25	4.24	4.25	23.52	24.21	87.53	87.65
T2: MTM – MTW	79.37	83.47	29.54	30.49	14.37	15.03	4.02	3.96	22.18	22.47	82.66	83.21
T3: MTM – ZTW	76.94	76.14	28.82	28.48	13.82	13.89	3.90	3.72	21.45	21.25	80.65	79.61
T4: ZTM – ZTW	84.76	92.62	31.60	33.48	15.77	17.48	4.40	4.54	23.82	25.75	88.44	92.93
SEm ±	1.67	1.76	0.56	0.53	0.31	0.27	0.07	0.09	0.44	0.43	1.64	1.21
CD (P=0.05)	5.79	6.08	1.92	1.84	1.06	0.94	0.26	0.32	1.52	1.48	5.67	4.17
Summer green manuring												
M1: Summer fallowing	75.80	75.78	28.30	28.22	13.44	13.80	3.79	3.64	21.13	20.50	79.20	76.78
M2: Dhaincha	85.72	93.40	32.08	33.83	16.03	17.31	4.48	4.57	24.13	26.09	89.79	94.56
M3: Sunnhemp	84.27	90.04	31.22	32.80	15.53	16.64	4.34	4.42	23.49	25.01	87.37	91.14
M4: Clusterbean	81.22	84.03	30.15	30.71	14.52	15.33	4.07	4.00	22.64	22.85	84.37	83.67
M5: Cowpea	80.03	82.95	29.79	30.44	14.35	15.25	4.03	3.97	22.31	22.64	83.36	83.09
SEm ±	1.86	1.65	0.58	0.57	0.31	0.26	0.08	0.09	0.44	0.36	1.63	1.18
CD (P=0.05)	5.36	4.75	1.67	1.65	0.89	0.74	0.23	0.25	1.25	1.04	4.70	3.41
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4: Effect of different tillage options and green manuring on chemical properties of soil after harvest of wheat under maize-wheat based cropping system

Treatments	Organic carbon (per cent) after harvest of wheat		Available N (kg ha-1) after harvest of wheat		Available P (kg ha-1) after harvest of wheat		Available K (kg ha-1) after harvest of wheat	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Tillage Options								
T1: CTM – CTW	0.43	0.42	154.88	158.48	18.75	18.79	179.79	181.12
T2: MTM – MTW	0.43	0.41	151.57	154.97	18.33	18.52	178.63	179.94
T3: MTM – ZTW	0.42	0.40	151.17	153.55	18.25	18.35	177.56	178.03
T4: ZTM – ZTW	0.45	0.45	167.22	172.36	19.85	20.19	191.50	196.77
SEm ±	0.01	0.01	2.58	2.47	0.28	0.34	2.97	3.06
CD (P=0.05)	NS	0.02	8.93	8.55	0.96	1.18	10.28	10.58
Summer green manuring								
M1: Summer fallowing	0.42	0.39	143.05	145.65	18.20	17.94	171.32	173.08
M2: Dhaincha	0.44	0.44	167.62	171.95	19.30	19.65	189.31	191.19
M3: Sunnhemp	0.44	0.43	164.28	168.19	19.19	19.53	188.06	190.10
M4: Clusterbean	0.43	0.41	155.10	159.18	18.65	18.85	180.46	182.82
M5: Cowpea	0.43	0.41	150.99	154.24	18.63	18.83	180.18	182.63
SEm ±	0.01	0.01	2.65	2.65	0.24	0.27	3.02	2.65
CD (P=0.05)	NS	0.02	7.63	7.63	0.68	0.77	8.70	7.62
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

References

1. Aulakh MS, Khera TS, John WD, Singh K, Singh B. Yields and nitrogen dynamics in a rice-wheat system using green manure and inorganic fertilizer. Soil Science Society of American Journal. 2000;64:1867-1876.
2. Behera UK, Sharma AR, Pandy HN. Sustaining productivity of wheat-soybean cropping system through integrated nutrient management practices on the Vertisols of central India. Plant and Soil 2007;297:185-199.
3. Betrol I, Engel FL, Mafra AL, Betrol OJ, Ritter SR. Phosphorus, potassium and organic carbon concentrations in runoff water and sediments under different soil tillage systems during soybean growth. Soil & Tillage Research. 2007;94:142-150.
4. Das A, Ghosh PK, Lal R, Saha R, Ngachan S. Soil quality effect of conservation practices in maize-rapeseed cropping system in eastern Himalaya. Land Degradation & Development. 2017;28:1862-1874.
5. Di Bene C, Pellegrino E, Tozzini C, Bonari E. Changes in soil quality following poplar short-rotation forestry under different cutting cycles. Italian Journal of Agronomy. 2011;6:28-30.
6. Fageria NK, Baligar VC. Role of cover crops in improving soil and row crop productivity. Communications in Soil Science and Plant Analysis 2005;36:2733-757.
7. FAO. What is conservation?, 2010. Available at: ⟨http://www.fao.org/ag/ca.Ia.html⟩.
8. Ghosh BN, Dogra P, Sharma NK, Bhattacharyya R, Mishra PK. Conservation agriculture impact for soil conservation in maize–wheat cropping system in the Indian sub-Himalayas. International Soil and Water Conservation Research. 2015;3:112-118.
9. Goyal S, Chander K, Mundra MC, Kapoor KK. Influence of inorganic fertilizers and organic amendments on soil organic matter and soil microbial properties under tropical conditions. Biology and Fertility of Soils. 1999;29:96-200.
10. Gruber S, Acharya D, Claupein W. Wood chips used for weed control in organic farming. Journal of Plant Disease and Protection. 2008;21:395-400.
11. Kuotsu K, Das A, Lal R, Munda GC. Ghosh PK and Ngachan SV, Land forming and tillage effects on soil properties and productivity of rainfed groundnut (*Arachis hypogaea* L.)– rapeseed (*Brassica campestris* L.) cropping system in north eastern India. Soil & Tillage Research. 2014;142: 15–24.
12. Mandal S, Chakraborty D, Tomar RK, Singh R, Garg RN, Aggarwal P, *et al*. Tillage and residue management effect on soil hydro-physical environment under pigeonpea (*Cajanus cajan*)–wheat (*Triticum aestivum*) rotation. Indian Journal of Agricultural 2013;83:502-507.
13. Parihar MD. Studies on greenhouse gas emissions and carbon sequestration under conservation agriculture in maize based cropping systems. Ph.D. Thesis, Chaudhary Charan Singh Haryana Agricultural University, Hisar, 2014.
14. Patra AK, Chhonkar PK, Khan MA. Nitrogen loss and wheat (*Triticum aestivum*) yields in response to zero-tillage and sowing time in a semi-arid tropical environment. Journal of Agronomy and Crop Science 2004;190:324-331.
15. Sun X, Wang G, Lin Y, Liu L, Gao Y. Intercepted rainfall in Abiesfabri forest with different-aged stands in Southwest China. Turkish Journal of Agriculture and Forestry. 2013;37:494-504.