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Research Paper

Productivity and profitability of maize (*Zea mays*) as influenced by tillage practices and green manuring under Eastern Uttar Pradesh conditions

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) and winter (*rabi*) seasons of 2016–17 and 2017–18 at Varanasi, Uttar Pradesh, to study the effect of different tillage practices and green manuring on productivity and profitability of maize (*Zea mays* L.)–wheat (*Triticum aestivum* L.) cropping system. The experiment was laid out in a split-plot design, consisting of 20 treatments. Four different tillage practices, viz. T_1, conventional tillage maize–conventional tillage wheat; T_2, minimum tillage maize–minimum tillage wheat; T_3, minimum tillage maize-zero tillage wheat; and T_4, zero tillage maize–zero tillage wheat, were assigned to main plot and 5 summer green-manuring treatments, viz. M_1, summer fallowing; M_2, *dhaincha* [*Sesbania bispinosa* (Jacq.) W. Wight)]; M_3, sunnhemp (*Crotalaria juncea* L.); M_4, clusterbean (*Cyamopsis tetragonoloba* (L) Taub.]; and M_5, cowpea [*Vigna unguiculata* (L.) Walp.], were kept in subplots. The treatment T_4 and T_1 remaining at par with each other, registered higher yield-attributing characters, grain and stover yields, quality and benefit: cost (B:C) ratio. In case of summer green manuring, M_2 recorded higher yield-attributing characters, grain (5.59 t/ha) and stover (6.61 t/ha) yields, quality, gross returns, net returns and B : C ratio over other treatments, but it was at par with M_3. Thus, ZT maize and summer green manure *dhaincha* residue mulching may be followed to achieve higher yield and profitability in Uttar Pradesh conditions.

***Kew words*:** Green manures, Maize, Tillage, Wheat

Shortage of water, labour and energy resources, together with inappropriate crop management practices and the adverse effects of conventional tillage on the carbon-based sustainability index, as well as declines profit margins, are forcing to farmers of IGP to switch over to conservation agriculture (CA) practices. Tillage and nutrients are the most crucial monetary inputs for crop production. The conventional practice of excessive tillage, involving 6–8 tillage operations for maize and wheat, consumes a high proportion (25–30%) of the total operational energy in maize and wheat production (Sidhu *et al*., 2004). Tillage practices contribute greatly to the energy and labour cost in any crop production system resulting in lower economic returns (Kumar *et al*., 2013). 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).

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The complexities with residue management in zero-till systems indicate the need for more research for improved and efficient utilization of crop residues. Several authors have documented that future of sustainable agriculture is dependent on recycling of on-farm crop residues to maintain soil fertility (Singh *et al*., 2012). Although CA shows great promise in many agro-ecological environments, there is continuing debate about its practical feasibility under certain farmer circumstances, especially for small holders in mixed crop/ livestock systems in tropical regions, where there is competition for crop residues between their uses as animal feed as opposed to soil retention (Valbuena *et al*., 2012). Removal of crop residues recorded significantly higher net returns as well benefit: cost (B: C) ratio over soil application of crop residues. This is mainly due to the cost of residues and that involved in their application (Jat *et al*., 2012).

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. It has received a new impetus in recent years with an urgent need for increased food production in the country (Virdi *et al*., 2005). Since, limited information is available on the influence of tillage and green manuring for the maize–wheat system on crop productivity, soil quality and economics, there is an urgent need to reduce the cost of cultivation and increase profitability by developing and adopting reduced tillage technologies.

MATERIALS AND METHODS

The trial was carried out during the rainy (*kharif*) and winter (*rabi*) season of 2016–17 and 2017–18 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, (25°18' N, 83°03' E, 76 m from mean sea-level in the Northern Gangetic Alluvial plains), Uttar Pradesh. The experimental site was fairly uniform in topography and well-drained in nature. The soil was sandy clay loam having *p*H (7.72), electrical conductivity (0.30 dS/m at 25°C) and moderate fertility with 0.41% organic carbon, 146.80 kg/ha available N, 18.35 kg/ha available P and 175.60 kg/ha available K. The experiment was laid out in a split-plot design, consisting of 20 treatments with 3 replications. Four different tillage practices, viz. T_1, conventional tillage maize-conventional tillage wheat (CTM-CTW); T_2, minimum tillage maize- minimum tillage wheat (MTM-MTW); T_3, minimum tillage maize-zero tillage wheat (MTM-ZTW); and T_4, zero tillage maize-zero tillage wheat (ZTM–ZTW), were assigned to main plot and 5 summer green-manuring treatments, viz. M_1, summer fallowing; M_2, *dhaincha*; M_3, sunnhemp; M_4, clusterbean; and M_5, cowpea were kept in subplots. All the summer green-manure crops were incorporated or cut at 45 days after sowing (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.

RESULTS AND DISCUSSION

Yield attributes, yield and quality

The tillage practices exhibited marked improvement in the yield attributes of maize, i.e. cob length (cm), cob girth (cm), per cob weight (g), kernels weight/cob (g), kernels/cob, cob weight (kg/ha). Among different tillage practices, ZTM-ZTW and CTM-CTW revealed higher values but statistically at par with each other. Overall the effect of tillage practices on maize yield and yield-attributing characters were in the order of $T_4 > T_1 > T_2 > T_3$. Summer green-manuring treatments had also a significant effect on yield attributes of maize. *Dhaincha* recorded significantly higher yield attributing characters which was at par with sunnhemp than the remaining green-manuring treatments. Cobs/plant and test weight (g) were not influenced significantly due to different green-manuring treatments during both the years.

Significant difference in cob weight was recorded due to different tillage practices and summer green manuring during both the years (Table 1). Among the different tillage practices, ZTM-ZTW recorded significantly highest cobs weight which remained statistically at par with CTM-CTW and was significantly superior to MTM-MTW and MTM-ZTW. Treatment MTM-ZTW recorded the lowest cob weight during both the years. Further, maximum cob weight was recorded during the second year as compared to the first year. Summer green-manuring practices resulted in significantly maximum cob weight over summer fallowing. Among the summer green-manuring treatments, *dhaincha* recorded significantly maximum cob weight over the other green-manuring practices and it was at par with sunnhemp during both the years. Overall the cob weight obtained from different green manuring treatments was in the order of $M_2 > M_3 > M_4 > M_5 > M_1$. Interaction of different tillage practices and summer green manuring on cob weight was non-significant.

Among the tillage practices, ZTM-ZTW resulted in significantly highest grain yield over MTM-MTW and MTM-ZTW and it was statistically at par with CTM-CTW during both the years. Overall the effect of tillage practices on maize grain yield was in the order of $T_4 > T_1 > T_2 > T_3$. Data further revealed that amongst green manures, the highest grain yield (5.62 t/ha) was recorded with *dhaincha* over the other treatments, viz. clusterbean, cowpea and summer fallowing and it was statistically at par with sunnhemp during both the years. Overall, the grain yield of maize obtained from different summer green-manuring treatments was in the order of $M_2 > M_3 > M_4 > M_5 > M_1$. The interaction effect between different tillage practices and summer green manuring on grain yield was found non-significant during both the years.

The treatments MTM-ZTW and ZTM-ZTW had lowest and highest stover yield, respectively, during both the year. The ZTM-ZTW treatment recorded comparatively higher stover yield than CTM-CTW during both the years. Among the summer green-manuring practices, *dhaincha* recorded significantly maximum stover yield compared with the other green-manuring practices and it was at par with sunnhemp during both the years. Among the tillage practices, ZTM-ZTW recorded significantly highest biological yield over MTM-MTW and MTM-ZTW and it was statistically at par with CTM-CTW during both the years. Overall, the effect of tillage practices on maize biological yield was in the order of $T_4 > T_1 > T_2 > T_3$. Amongst the green manures, the highest biological yield was recorded with *dhaincha* over the other treatments, viz. clusterbean, cowpea and summer fallowing and it was statistically at par with sunnhemp during both the years.

However, cobs/plant, test weight (g), harvest index (per cent), shelling percentage, protein and starch content (per cent) did not show the level of significance during both the years. The higher values of yield attributes, viz. cob length, cob girth, weight/cob, kernels weight/ cob, kernels/ cob and test weight and yield recorded under zero till maize and remained at par with conventional till maize, but it was significantly superior to the minimum tillage (MTM-MTW and MTM-ZTW). This might be owing to more leaf-area index which might helped in better photosynthesis and assimilation rate that resulted in more dry matter and better growth indices, thus ultimately gave good performance of crop.

Retention of green manures residue under zero tillage maize (ZTM-ZTW) resulted higher values of yield attributes of the maize crop than residue incorporation; this might be owing to maintenance of good and favourable soil moisture, moderate soil temperature and improved soil fertility because of constant supply of nutrients through mineralization of summer green manures residues. The cut biomass of green manures provided a good cover on the soil surface in maize crop and checked further weed growth (Dogra *et al.*, 2002), conserved rainwater and might have supplied N to the maize plants after mineralization during grand growth period owing to its narrow C : N ratio (Sharma and Behera, 2010). Singh *et al.* (2014) reported that, the biomass of green manures along with the associated weeds should be cut at 35–40 days of growth and spread as mulch in between the inter-row spaces of maize which is helpful in conserving moisture and nutrients for the following winter season wheat. Zero tillage and residue conservation are considered as means of reducing soil erosion, leaching and run-off of agricultural chemicals (Uri *et al.*, 1998).

Legume mulching was beneficial in improving the growth and yield attributes of maize over no-mulching (Sharma and Behera, 2010). Beneficial effects of mulching in maize were largely owing to enhanced moisture conservation and weed control (Mastana, 1988), and through additional nutrient supply (Sharma and Acharya, 2000). Similarly, mulch increases soil moisture and nutrients availability to plant roots in turn, leading to maize growth, development and yield (Agber *et al.,* 2017).

The higher values of yield attributes and yield recorded under zero till maize and remained at par with conventional till maize. The cob/m^2 and kernels/cob were maximum under ZT than CT, as reported by Devkota *et al.*

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

(2013). Ram *et al.,* (2010) and revealed that yield attributes (cobs/plant, kernels/cob and 1,000-grain weight) and yield performance of maize under different conventional and zero tillage practices were observed statistically similar. Similarly, Singh *et al.* (2007) reported relatively higher maize grain yield under zero tillage than conventional tillage. Grain yield of maize was the highest under PB or ZT than CT (Naresh *et al*., 2012; Devkota *et al.,* 2013).

Economics

The treatment ZTM-ZTW resulted in higher gross returns, net returns, benefit: cost the other tillage practices. Highest gross returns, net returns and benefit: cost ratio were obtained with the *dhaincha* summer green manuring, being a par with sunnhemp and superior to rest of the treatments. Among the tillage practices ZTM-ZTW resulted in the highest wheat-equivalent yield (WEY) of the system which was at par with CTM-CTW and both were significantly better than MTM-MTW and MTM-ZTW (Table 3). Among the summer green manuring, *dhaincha* recorded the maximum WEY over the other summer green-manuring practices, but it was statistically at par with sunnhemp.

Zero-till maize (ZTM) recorded lower cost of cultivation and higher gross returns, net returns, B : C ratio than CTM and MTM. However, the cost of production of zero-till maize was higher in 2016 than that of 2017. This may be due to increased cost of harrowing before sowing of summer green manures but in next year under ZTM plot there was no-tillage operation before sowing of green manures. The sowing of summer green-manures was done with the help of zero-ferti seed drill in ZTM plots. Lower cost of production under ZT than CT practices due to no-tillage operations, except planting of crops, saving of money in weed-control practices due to herbicide application, which were less costly than manual weeding and labour-cost saving involved in various cultural operations. Among the tillage practices, zero tillage saves irrigation water through the combined effect of maize that allowed to be planted without pre-irrigation and shortening the duration of the first irrigation, as surface irrigation water flows faster across non-tilled plots. Apart from reducing cultivation costs, zero tillage increases maize harvests, facilitates timely maize sowing which results in many benefits like better crop establishment of maize as heavy rainfall occurs in the month of July, early sowing of wheat which prevents from terminal heat stress and price advantage due to earliness in marketing. The cost saving towards irrigation, land preparation for sowing and weed control makes zero tillage profitable and is the main driver behind its spread. The use of ZT significantly reduces energy costs, mainly by reducing tractor costs associated with conventional methods (Erenstein and Farooq, 2009). Jat *et al*. (2005) also reported that, cost of cultivation was the lowest under ZT and the highest under CT maize crop mainly through saving in cost for tillage practices. The higher gross and net returns under ZTM treatments owing to greater yield performance of the crops, whereas the lowest B : C ratios were recorded under CTM treatment

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 practices and green manuring on shelling percentage, quality, system wheat-equivalent yield (WEY) and economics of maize of 2016 and 2017 (pooled data of 2 years)

Treatment	Shelling (%)	Protein content (%)	Starch content (%)	System wheat equivalent yield (t/ha)	Cost of cultivation (×10³ ₹/ha)	Gross returns (×10³ ₹/ha)	Net returns (×10³ ₹/ha)	Benefit: cost ratio
Tillage practices								
CTM-CTW	79.9	11.0	60.2	9.40	43.6	101.1	57.5	1.32
MTM-MTW	79.5	11.0	59.9	8.93	38.2	96.0	57.8	1.51
MTM-ZTW	79.1	10.9	59.6	8.49	38.2	94.4	56.1	1.47
ZTM-ZTW	80.2	11.1	60.4	9.57	36.2	102.7	66.6	1.84
SEm±	0.42	0.04	0.23	0.11				
CD (P=0.05)	NS	NS	NS	0.35				
Summer green manuring								
Summer fallowing	78.8	10.9	59.4	8.48	35.7	92.9	57.1	1.60
Dhaincha	80.4	11.1	60.3	9.63	40.0	103.3	63.3	1.58
Sunnhemp	80.2	11.0	60.2	9.37	39.9	101.2	61.3	1.53
Clusterbean	79.6	11.0	60.1	9.04	39.6	98.0	58.4	1.48
Cowpea	79.4	11.0	60.0	8.97	39.9	97.4	57.5	1.44
SEm±	0.38	0.03	0.19	0.11	–	–	–	–
CD (P=0.05)	NS	NS	NS	0.31	–	–	–	–
Interaction	NS	NS	NS	NS	–	–	–	–

due to higher cost of cultivation. Tillage practices contributed greatly to the labour cost in any crop-production system resulting in lower economic returns. Visalakshi and Sireesha (2015) reported that, zero tillage maize cultivation reduces the number of field operations from an average of 4; farmers can save 25 litres of fuel/hectare of land over conventional maize cultivation. Zero tillage was originally perceived as potentially generating higher yields at a lower production cost, while being an environmentally friendly practice that saves water and soil (Hobbs and Gupta, 2003).

Based on our results it is recommended that ZT maize and summer green-manure *dhaincha* residue mulching should be followed to achieve higher yield and net returns in maize under eastern Uttar Pradesh conditions.

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