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Shweta Kumari
Department of Agronomy, Bihar Agricultural University, Sabour, Bihar, India

Sanjay Kumar
Department of Agronomy, Bihar Agricultural University, Sabour, Bihar, India

Suman Agrawal
Department of Agronomy, Bihar Agricultural University, Sabour, Bihar, India

Chandini
Department of Agronomy, Bihar Agricultural University, Sabour, Bihar, India

SK Dutta
Department of Agronomy, Bihar Agricultural University, Sabour, Bihar, India

YK Singh
Department of Soil Science and Agricultural Chemistry, BAU, Sabour, Bihar, India

Amit Pradhan
Department of Soil Science and Agricultural Chemistry, BAU, Sabour, Bihar, India

Subrat Keshori Behera
Department of Statistics Mathematics and Computer Application, BAU, Sabour, Bihar, India

Corresponding Author:
Shweta Kumari
Department of Agronomy, Bihar Agricultural University, Sabour, Bihar, India

Effect of conservation agriculture-based tillage practices on growth and productivity potential of rabi crops

Shweta Kumari, Sanjay Kumar, Suman Agrawal, Chandini, SK Dutta, YK Singh, Amit Pradhan and Subrat Keshori Behera

Abstract
Tillage a pivotal practice for seed bed preparation, soil moisture conservation and weed control which ultimately leads to greater crop production. The present study was a long-term maize-based conservation agriculture field experiment which was established in 2013-14 at experimental farm of Bihar Agricultural University, Sabour, Bhagalpur. It was devised to compare the effect of zero tillage, permanent beds and the conventional tillage on growth and yield of the fifth year *rabi* season crops. In the split plot design, three tillage practices *viz.* zero tillage (ZT), conventional tillage (CT) and permanent bed (PB) were kept in main plot and four rabi crops *viz.* wheat, *rabi* maize, mustard and chickpea were kept in sub plot and the treatment combination were replicated thrice. The results revealed that higher grain yield of wheat was recorded under PB (5488 kg ha^{-1}) over ZT and CT while, the higher grain yield of rabi maize (11279 kg ha^{-1}), mustard (970 kg ha^{-1}) and chickpea (1936 kg ha^{-1}) was recorded in ZT over CT. Conservation agriculture-based tillage practices *viz.* zero tillage and permanent bed along with residue retention resulted in significant increase in plant height, biomass production and productivity of rabi crops as compared to conventional tillage practice.

Keywords: Zero tillage, conventional tillage, permanent bed, conservation agriculture

Introduction
Tillage is an important agro-technique, performed to achieve favourable soil environment for crop growth and development. It is the mechanical manipulation of the soil for the purpose of seed bed preparation significantly affecting the soil characteristics such as soil water conservation, soil temperature, infiltration and evapotranspiration processes. However, in some situations tillage can also lead to soil degradation which results into development of compacted soil having low soil organic carbon and poor drainage. This suggests that tillage exerts impact on the soil purposely to produce crop and consequently affects the environment. Indo Gangetic Plains is a home for almost 20% of the world population [18, 7]. Bihar is one of the most important states in the Eastern India and Middle Indo Gangetic Plains in terms of crop production. Unlike the North Western part of India, the North Eastern part has comparatively smaller land holdings and with the synchronous occurrence of drought and flood every year renders the state with limited resources for enhancing the production and productivity of crops. In Bihar, the *rabi* crop is generally grown after the harvest of predominant *kharif* rice or *kharif* maize. The distribution of the monsoon determines the sowing and harvest of the rice crop which renders the field for the next season *rabi* crop. However, sometimes due to delayed monsoon or due to long duration rice cultivars, the harvesting of the rice gets delayed and as a result the sowing of the next crop getsfurther delayed due to the conventional land preparation practice by the farmers. With the growing population the food demand is also increasing thus generating the need of more land for crop production and increased per unit productivity. But they earning for yield increase is to meet growing demand must be done in a way that soil degradation is minimal and the soil is prepared to serve as a sink rather than a source of atmospheric pollutants. Thus, conservation tillage (*viz.* zero tillage and bed planting) along with some complimentary practices such as soil cover and crop diversification [10] has emerged as a viable option to ensure sustainable food production and maintain environmental integrity. Zero tillage increases soil moisture retention capacity, minimizes soil temperature fluctuations, and decreases soil erosion by wind and water, enhances organic matter content in soil with time, improves soil micro-organisms activity, resulting in increased crop growth and yield [31, 6, 20, 15, 42]. The traditional practice of opening and turning the soil greatly contributes towards the quick oxidation of organic matter

in the soil [21], quantitative loss of residual soil moisture and high labour and energy input thereby resulting in the poor economic returns for the farmers [2]. Thus, conservation tillage not only reduce the cost of cultivation but also leads to uniform and early crop establishment. It also improves the soil properties by providing better conditions for growth and development of crop, therefore the zero tillage and permanent bed may be a viable alternative to conventional tillage.

Instead of intensive cropping, diversified cropping is another alternative strategy to sustain soil fertility and crop productivity [43]. Crop sequences modify the soil moisture content and water infiltration rate [36]. The quantity and quality of crop residues as well as the fallow time period are determined by the cropping sequence, which in turn modify the soil structure [14]. Adoption of suitable cropping sequences and conservation tillage may positively affect the soil organic carbon (SOC) concentration and improve the soil quality of degraded hilly soils [12, 30].

The practice of growing cereal after cereal coupled with use of intensive tillage led to decline in factor productivity [17], stagnation in crop yield and depression in farm income which in bulk posing a serious threat to food security of IGP region [1]. In nutshell, traditional RWCR needs to be replaced by location-specific diversified cropping systems so as to sustain the farm livelihoods, conserve natural resource-base, and reduce farm and environmental risks in the IGP region [1]. Therefore, there is a dire need to diversify rice-wheat crop rotation (RWCR) while shifting some area to oilseeds, pulses and other suitable grain crops other than rice and wheat. Crop diversification provides lot of opportunities in fulfilling the basic needs and regulating farm income, ensuring balanced food supply, conserving natural resources and creating employment opportunity [23]. Considering present market externalities, environmental concerns, there are opportunities for diversifying the RWCR using suitable legumes, oilseeds and cereals other than rice and wheat [33]. In this context maize is viable options to replace rice in rainy season. The other major drivers for replacing of rice with maize are (i) better adaptability of maize to diverse ecologies because of its C4 nature, (ii) increasing demand of maize for poultry, piggery and fishery sectors, (iii) narrowing export market for rice [13], (iv) higher productivity potential with more palatable fodder [38]. Increasing demand for oilseeds and pulses has further prompted farmers to diversify RWCR using legume and oilseeds as an alternative to wheat during *rabi* season [37]. Overall, crop diversification in cereal-cereal based production systems is the need of the hour in IGP both through location-specific cereal replacement and crop-intensification as well [39]. Thus, the current study was undertaken to access the impact of long term tillage practices and legume intensified maize based production systems in relation to enhance productivity, profitability and soil health; besides ameliorating the production vulnerabilities that rice wheat rotation has broughtso far.

Materials and Methods

The present experiment was carried out at research farm of Bihar Agricultural University, Sabour during 2017-18 rabi season, to evaluate the effect of long-term conservation agriculture practices like zero tillage and permanent beds on growth, development and productivity of the fifth year rabi season crops as compared to their performance against the conventional tillage for different rabi crops. The experimental plots had uniform topography. The sequences of crops grown during the preceding four years in the experiment were maize in kharif season followed by wheat, *rabi* maize, mustard and chickpea in *rabi* season. The experimental site is situated at longitude 87º2'45" East and latitude 25º15'4" North at an altitude of 37.19 meters above mean sea level. The climatic condition of this place is tropical to subtropical and somewhat semi-arid in nature and is characterized by very dry summer, moderate rainfall and very cold winter. The data on weather parameters were recorded from meteorological observatory of Bihar Agricultural University, Sabour during the crop season. The average rainfall is about 1407 mm (10-years average) which is unimodal type mostly precipitating during middle of June to middle of October, where potential evapo-transpiration is lower than the rainfall. The minimum and maximum day temperature is 18 ºC and 35 ºC during summer season whereas 15 ºC and 25 ºC during winter season. During the crop season there was cool and bright climate prevailed throughout the dry season.

The experiment was laid out in split plot design with 12 treatment combinations comprising of three tillage treatments; T_1 -zero tillage (ZT), T_2- conventional tillage (CT) and T_3-permanent bed (PB) in main plot, four rabi crops viz. C_1-Wheat (var. HD 2967), C_2- *Rabi* Maize (var. P 3396), C_3-Mustard (var. Rajendra Suphlam) and C_4-Chickpea (var. JG 14) in sub plots. The fertilizer dose was 120:60:40,150:75:50, 80:40:40, 20:50:0 (N: P_2O_5: K_2O kgha^{-1}), in wheat, *rabi* maize, mustard and chickpea respectively. In wheat and rabi maize nitrogen was applied in three splits, half as a basal dose at the time of sowing, one fourth before first irrigation and one fourth before third irrigation while full dose of P_2O_5 and K_2O were applied as basal. In mustard total amount of P_2O_5 and K_2O with 50% of N were applied as a basal, while the left over N was top dressed at the time of first irrigation. In chickpea, total amount of 20:50 kg of N: P_2O_5 ha^{-1} were applied at the time of sowing. After sowing of crops in the plots a uniform application of pre emergence herbicide – Pendimethalin @ 3L a.i. ha^{-1} was sprayed for management of weeds within two days after sowing.

In zero tillage, crops were grown on zero tilled plots without disturbing the soil except for seed or fertilizer placement, with 30 per cent maize residue retained in the plots from the *kharif* maize crop in rotation. The conventional tilled plots were ploughed with two passes of tractor drawn disc plough followed by two ploughing with cultivator and one planking. The field was uniformly leveled to the specified plot dimension and in permanent bed**;** crops were grown on permanent bed plots without disturbing the soil except for seed or fertilizer placement, with 30 per cent maize residue retained in the plots from the earlier maize crop in rotation. The width of the beds (mid-furrow to mid-furrow) was 67 cm, with 37 cm wide flat tops, and 30 cm furrow width.

To interpret the effect of different treatments, the data collected in course of experiment were analyzed statistically by applying the analysis of variance techniques laid down by Cochran and Cox (1967), Panse and Sukhatme (1978) and Gomez and Gomze (1984) [11, 34, 24]. Tukey's honest significant difference (HSD) test was used as a post hoc means separation test (p<0.05) for attributes of individual crops for comparison of tillage methods. Relevant data were statistically analyzed separately to interpret the results and the mean data for each parameter has been presented. For comparison of 'F' values and for determination of critical difference at 5% level of significance, Fischer and Yates Table (1963) [19] were consulted.

Results and Discussion

Effect of different tillage practices on growth and development of different *rabi* crops

Crop growth response comprises of changes in growth and development which can be quantified through changes in height, dry matter production and yield. We have compared Conventional tillage (CT) which basically represents current farmers' practices with the resource efficient tillage practices such as zero tillage (ZT) and permanent bed (PB).

The plant height and total biomass production gradually increased from 30 days after sowing (DAS) to harvest and showed variable response in different crops due to alteration in tillage practices. At harvest the plant height was significantly higher in ZT maize (201.8 cm) followed by PB (197.7 cm) and CT (188.2 cm) (Table 1). In chickpea the maximum plant height was recorded at the time of harvest under ZT (36.4 cm) which was statistically at par with PB (35.6 cm) but significantly higher over CT chickpea (33.7 cm). The significant effect of tillage on dry matter was found only for wheat and maize crop at different growth stages which has been presented in Table 2. The maximum dry matter production of wheat and maize were observed at harvest. Wheat recorded 14.9% and maize recorded 12.2% higher biomass under PB and ZT respectively than CT. Dry matter production at 30 and 60 DAS was recorded highest in PB (336 g m^{-2}) & (656 g m^{-2}) followed by ZT (302 g m^{-2}) & (617 g m^{-2}) which were found to be statistically at par with CT (230 g m^{-2}) & (537 g m^{-2}) respectively in wheat. At 90 DAS, dry matter of wheat crop was significantly higher in PB (907 g m^{-2}) compared to CT (750 g m^{-2}) while the dry matter in ZT wheat (846 g m^{-2}) was statistically at par with both PB and CT which was similar to the dry matter production of wheat at harvest where PB (1413 g m^{-2}) recorded significantly higher dry matter as compared to CT (1202 g m^{-2}) while dry matter in ZT wheat (1334 g m^{-2}) was statistically at par with both PB and CT. In contrary, maize did not have any significant effect of tillage on dry matter production up to 90 DAS, however tillage practices had significant influence on dry matter production at the time of harvest. The maximum dry matter of maize was recorded with ZT (2536g m^{-2}) which was significantly higher over CT maize (2226 g m^{-2}). The dry matter of maize in PB (2379 g m^{-2}) at harvest was found to be statistically at par with ZT and CT.

The above results can be explained as, the growth and development of a plant can be manifested from the changes in different plant physiological parameters as well as its dry matter accumulation which determine the size of the photosynthetic structure. Timely sowing under zero tillage and permanent bed condition resulted in early establishment of the crop and consecutive higher dry matter accumulation. This could mainly be attributed to the fact that the residual soil moisture utilized in the establishment of *rabi* crops under ZT and PB was not available with CT practice due to the quick evaporation of surface soil moisture induced a result of tillage operations. The reduction in tillage usually results in a progressive change in the total porosity of soil. Porosity and water holding capacity of the soil is increased with ZT and PB as a result the plant can utilize the major proportion of soil moisture for its growth and development. Under conservation agriculture based practices substantial amount of crop residue is recycled rendering stabilization of soil organic carbon [40] as soil organic matter [26, 9]. In contrast removal of crop residues under conventional tillage practices results in low levels of soil organic carbon [3] which indirectly negatively impacts the crop growth and productivity under CT system [21].

Effect of tillage practices on grain yield of different *rabi* crops

In wheat due to tillage practices biological yield was significantly higher in PB over CT. The maximum biological yield was recorded in PB (14132 kg ha^{-1}) which was significantly higher as compared to CT (12017 kg ha^{-1}) but biological yield in ZT wheat (13339 kg ha^{-1}) was at par with both PB and CT. In maize biological yield in ZT (25359 kg ha^{-1}) was significantly higher with CT (22262 kg ha^{-1}) and biological yield in PB (23786 kg ha^{-1}) was statistically at par with ZT as well as CT. In mustard there was no significant effect of tillage practices on biological yield. The maximum biological yield was recorded in CT (4255 kg ha^{-1}) which was statistically at par with ZT (3906 kg ha^{-1}) and PB (3875 kg ha^{-1}). Similarly, in chickpea also there was no significant effect of tillage practices on biological yield. However, the maximum biological yield was recorded in ZT (5194 kg ha^{-1}) which was statistically at par with CT (5020 kg ha^{-1}) and PB (4822 kg ha^{-1}).

In wheat the maximum grain yield was recorded in PB (5488 kg ha^{-1}) which was significantly higher as compared to CT (4442kg ha^{-1}) and statistically at par with ZT grain yield (5463 kg ha^{-1}). The grain yield was 19.1% and 18.7% higher in PB and ZT as compared to CT plots respectively. In maize the grain yield was significantly higher with ZT (11279 kg ha^{-1}) over CT (9427 kg ha^{-1}). The grain yield of maize in PB (10863 kg ha^{-1}) was found statistically at par with ZT. The grain yield was 16.4% and 13.2% higher in ZT and PB as compared to CT plots respectively. In mustard there was no significant effect of tillage on grain yield. However, maximum grain yield was recorded in ZT (970 kg ha^{-1}) which was statistically at par with PB (955 kg ha^{-1}) and CT (931 kg ha^{-1}). The grain yield was 4.0% and 2.5% higher in ZT and PB as compared to CT plots respectively. In chickpea there was significant effect of ZT on grain yield as compared to PB and CT. The maximum grain yield was recorded in ZT (1936 kg ha^{-1}) which was significantly higher over PB (1790 kg ha^{-1}) and CT (1705 kg ha^{-1}). The PB and CT crops produced almost similar yields while ZT plots produced 8% and 13% higher yield over PB and CT plots respectively.

Significantly higher grain yield of wheat was observed in the PB as compared with CT, which might be attributed to the higher spike density, and other yield attributes of wheat crop in PB than CT. The present findings are well supported by Dhillon *et al.*, 2000 and Hobbs and Gupta (2003) [16, 27] who also reported higher yields of wheat in bed planted wheat than flat-planted wheat. The significantly higher yield of chickpea and maize in ZT system might be due to the compound effects of additional essential nutrients [4, 29], lesser population of weed [32, 8], better soil physical health [28, 37], improved water regimes [25] and enhanced nutrient use efficiency as compared to CT [41]. In addition to all these factors, the root growth was found to be better under CA compared to CT due to lesser compaction [35, 5]. Zero tillage had a significant influence in increasing the crop yield followed by permanent bed.

The results showed that conservation agriculture-based Zero tillage and permanent bed tillage practices along with residue retention resulted insignificant increase in growth, dry matter accumulation and yield of *rabi* crops than conventional tillage.

Table1: Plant height of *rabi* crops as influenced by different tillage methods

Plant Height (cm)				
Rabi crops / Tillage	**30 DAS**	**60 DAS**	**90 DAS**	**At Harvest**
Wheat				
Zero Tillage	24.0 a	52.5 a	88.9 a	103.2 a
Conventional Tillage	24.1 a	53.6 a	86.5 a	100.2 a
Permanent Bed	22.6 a	48.3 a	86.5 a	101.5 a
Maize				
Zero Tillage	27.9 a	92.3 a	184.2 a	201.8 a
Conventional Tillage	26.8 a	82.0 a	161.7 a	188.2 c
Permanent Bed	23.5 a	83.9 a	181.1 a	197.7 b
Mustard				
Zero Tillage	41.5 a	86.2 a	179.2 a	186.1 a
Conventional Tillage	41.4 a	87.3 a	176.3 a	184.6 a
Permanent Bed	44.9 a	94.4 a	185.3 a	191.2 a
Chickpea				
Zero Tillage	18.1 a	28.4 a	34.8 a	36.4 a
Conventional Tillage	16.6 a	26.9 a	32.3 b	33.7 b
Permanent Bed	17.4 a	27.6 a	34.4 a	35.6 a

Means followed by a similar lowercase letter within a column are not significantly different (at $P<0.05$) according to Tukey's HSD test.

Table 2: Dry matter accumulation of rabi crops as influenced by different tillage methods

Dry Matter (g m^{-2})				
Rabi crops / Tillage	**30 DAS**	**60 DAS**	**90 DAS**	**Harvest**
Wheat				
Zero Tillage	302 a	617 a	846 ab	1334 ab
Conventional Tillage	230 b	537 b	750 b	1202 b
Permanent Bed	336 a	656 a	907 a	1413 a
Maize				
Zero Tillage	83.6 a	543.6 a	1366.2 a	2536 a
Conventional Tillage	68.2 a	480.6 a	1301.4 a	2226 b
Permanent Bed	79.2 a	525.6 a	1350.0 a	2379 ab
Mustard				
Zero Tillage	66 a	226 a	320 a	469 a
Conventional Tillage	71 a	349 a	354 a	511 a
Permanent Bed	65 a	227 a	322 a	465 a
Chickpea				
Zero Tillage	21 a	139 a	357 a	467 a
Conventional Tillage	19 a	134 a	344 a	452 a
Permanent Bed	19 a	130 a	325 a	434 a

Means followed by a similar lowercase letter within a column are not significantly different (at $P<0.05$) according to Tukey's HSD test.

Table 3: Biological yield, grain yield, straw yield and harvest index of rabi cropsas influenced by tillage methods

Rabi crops/ Tillage	**Biological Yield (kg ha^{-1})**	**Grain yield (Kg ha^{-1})**	**Straw/ Stover yield (kg ha^{-1})**	**Harvest Index (%)**
Wheat				
Zero Tillage	13339 ab	5463 a	7876 ab	41 a
Conventional Tillage	12017 b	4442 b	7575 b	37 b
Permanent Bed	14132 a	5488 a	8644 a	39 ab
Maize				
Zero Tillage	25359 a	11279 a	14080 a	45 a
Conventional Tillage	22262 b	9427 b	12835 a	42 a
Permanent Bed	23786 ab	10863 a	12923 a	46 a
Mustard				
Zero Tillage	4687 a	970 a	3718 a	21a
Conventional Tillage	5106 a	931 a	4175 a	18 b
Permanent Bed	4650 a	955 a	3695 a	21 a
Chickpea				
Zero Tillage	5194 a	1936 a	3259 a	37 a
Conventional Tillage	5020 a	1705 b	3314 a	34 b
Permanent Bed	4822 a	1790 b	3032 a	37 a

Means followed by a similar lowercase letter within a column are not significantly different (at $P<0.05$) according to Tukey's HSD test.

Conclusion

Based on the result of the experiment, "effect of different tillage methods on growth and productivity of rabi crops" it can be concluded that the conservation agriculture-based zero tillage and permanent bed tillage practices along with residue retention and crop diversification resulted in significant increase in growth, biomass production and productivity of rabi crops than conventional tillage and traditional rice-wheat based cropping system. Zero tillage and permanent bed gave enhanced produce of different rabi crops due to early crop establishment, less pest damage and greater soil health benefits along with less water requirement. This suggests that, zero tillage and other conservation agriculture-based tillage practices along with partial residue retention can be adopted for sustainable and profitable cropping in this region.

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