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Effect of tillage practices and cropping systems on growth and yield of maize grown in sequence with wheat and chickpea

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Abstract

Field experiments were conducted at New Delhi during the *kharif* season of 2012 and 2013 with maize-wheat/Chickpea cropping systems to evaluate the effect of different tillage and crop establishment techniques, and residue management on performance of the maize grown in sequence with wheat and chickpea in terms of growth and yield. The results revealed that performance of maize in terms of two years mean growth parameters, yield attributes and yields were influenced significantly under different tillage and crop establishment techniques. ZT flat planting with residue retention resulted in significantly higher mean plant height (174.95 cm), dry matter accumulation, leaf area and leaf area index (LAI) than conventional till flat planting of maize. Mean values of days to 50% silking, days to maturity of maize were minimum in zero till flat planting under residue retention with maximum cobs/m^2 (7.75). The mean maize yield attributes *viz*; cob length, cob girth and grain rows/cob were not significantly influenced due to the tillage practices, residue retention and cropping systems, however, the grains/cob was significantly influenced by tillage practices and residue retention. The cob, grain and stover yields are also significantly influenced by tillage practices and residue retention and these were maximum under zero till flat planting with residue retention. The two years mean cob, grain and stover yields of maize were 16.70, 23.37 and 16.17% higher under zero till flat planting with residue retention than to conventional till without residue planting.

Key words: Bed planting, Chickpea, Conventional tillage, Maize, growth, Residue, Zero Tillage, Wheat.

Maize-wheat is one of the predominant cropping systems in India covering an area of 1.13 million hectares mainly in Indo-Gangetic Plains (IGP). Traditionally, maize and wheat are grown either in row geometry or by random broadcasting, mostly after thoroughly tilling the field till the proper tilth is obtained for good crop emergence. The traditional practices of growing of these crops, including running disc harrow two times followed by cultivator two times and application of inadequate and imbalanced nutrients resulting in low productivity and input-use efficiency (Jat *et al.*, 2005). Tillage practices contribute greatly to the cost in any crop production system resulting to lower economic returns (Labios *et al.*, 1997). Intensive tillage results to a decrease in soil organic matter and biodiversity. Reduced or conservation tillage systems are gaining more attention in recent years with the rising concern over natural resource degradation. The efficiency of input use, *viz*; water, fertilizers, herbicides and others depends on tillage and crop establishment practices. It is therefore, essential that the soil environment be manipulated suitably for ensuring a good crop stand and improved resource-use efficiency. Some of the agronomic practices like zero tillage, raised bed planting and residue management are found to be the potential resource conservation technologies (RCT's) which can play an important role to save the scarce natural resources like land and water. In the past weeds were the most culprit to reduce the yields in no tillage but availability of pre and post emergence herbicides made it possible to control weeds in zero tillage conditions. Zero tillage has number of advantages like saving of fuel, energy and time and timely sowing of crops. In India maize is usually cultivated as *kharif* season crop. Generally, this crop is susceptible to water stagnation, experienced during rainy season. Under this situation the bed planting technique of crop establishment is emerged as an important technology which provides favourable environment to the crop. There are many additional benefits including lesser seed and nutrient requirement, opportunity for enhancing diversification and intercropping, moving towards conservation agriculture by using same beds for succeeding crops, reducing cost of cultivation and lesser lodging (Tripathi *et al.*, 2002). The large scale burning of rice straw has created problem of air pollution. Residues, when retained on the soil surface, serve as physical barrier to emergence of weeds, moderate the soil temperature, conserve soil moisture, add organic matter and improve the nutrient-water interactions. Well implemented conservation agriculture systems improve soil quality and production sustainability, although more research is needed about some aspects of the system (Verhulst *et al.*, 2010).

India is witnessing a maize revolution with expansion of area by 1.8%, production by 4.9% and productivity by 2.6% per annum during last ten years in 2003-04 to 2012-13. Maize, an important crop for food and nutritional security in India, is grown in diverse ecologies and seasons of the country on an area of 8.67 million hectares (m ha). Globally, it provides approximately 30% of the food calories to more than 4.5 billion peoples in 94 developing countries, and the demand of maize is expected to double worldwide by 2050 to meet this rising demand, higher maize production is need of the hour (Srinivasan *et al.*, 2004). Succeeding rabi crops in maize sequences *viz.*, wheat and chickpea occupies 30.00 and 8.52 m ha area in the country, respectively during 2012-13 and also meets the nutritional and pulse requirement of the people. All these crops significantly contribute toward the livelihood security for majority of the human population of the country. With the introduction of single cross hybrid (SCH) technology in maize and development of different maturity groups hybrids (extra early, early, medium and late) and expansion of irrigation facilities in north-western plains of India. Productivity of maize however has not increased proportionately and significant yield gaps evident across maize growing areas in the country.

In recent years, owing to declining water availability as well as increasing cost of pumping for rice cultivation Punjab and Haryana states of the region are emphasizing on diversification of rice crop with maize due to its lower water requirement. In western Indo-Gangetic plains maize is/can be grown in sequence with several suitable alternative Rabi (winter) season crops *viz.*, wheat and chickpea. After adoption of maize in place of rice the summer season mungbean and *Sesbania* can be taken up in this region which will help in identifying the alternate cropping system for the region and because of this, the acreage under different maize based systems (maize-wheat and maize-chickpea) have shown increasing trends. Under Indian conditions, assured potential yields and higher returns could be realized by adoption of these maize based sequences especially after introduction SCH, which also improves the resource poor farmer's social status in the region by enhancing farm profitability.

In view of the above considerations, the present study was conducted to adoption the conserving agriculture practices involving zero tillage, raised beds and residue management in conjunction with different maize based cropping systems to improve productivity and profitability and also for efficient utilization of natural resources in maize based cropping systems.

Materials and Methods

The experiment was conducted at the Research Farm of Directorate of Maize Research (DMR), New Delhi, situated at 28°4' N latitude, 77°12'E longitude and 228.6 metres above mean sea level. Soil samples were taken before the start of the experiment which were analysed for physical and chemical properties of the soil. The soil at site was sandy loam in texture with bulk density of 1.57 Mg/m^3, field capacity 16.87% (w/w) and infiltration rate 1.22 cm/hr. It had 0.45 % organic carbon, 158.4 kg $KMnO_4$ oxidizable N/ha, 12.6 kg 0.5 N $NaHCO_3$ extractable P/ha, 248.4 kg 1N NH_4OAc exchangeable K/ha, 7.5 pH and 0.32 dS/m EC at the start of the experiment. The experimental field had an even topography and good drainage system. The field experiment was conducted in split-plot design each having 12 treatment combinations with 3 replications during *kharif* 2012 and 2013. There were six main-plot treatments comprising of different combinations of tillage and crop establishment techniques for both the seasons: Conventional Tillage flat with residue (CTWR); Conventional Tillage flat without residue (CTWOR); Zero Tillage flat with residue (ZTWR); Zero Tillage flat without residue (ZTWOR); Permanent Bed Planting with residue (PBWR); Permanent Bed Planting without residue (PBWOR), while subplot treatments consisted of two cropping systems, viz. Maize-Wheat (MW) and Maize-Chickpea (MC).While it was conducted in randomized block design (RBD) with 3 replications in succeeding wheat and chickpea crops. The maize hybrid 'HQPM 1' was planted on 10^{th} August and 3^{rd} July and harvested on 24^{th} November and 18^{th} October during 2012 and 2013, respectively. The CT consisted of two pass of a disc harrow, followed by two pass of cultivator with planking in the last pass. Permanent raised beds were made with a bed planter which made beds at distance of 67.5 cm from bed to bed with a bed height of 8″. The ZT flat consisted of no-tillage with minimum soil disturbance and one pass of ZT seed drill for sowing of crop. In ZT-beds (permanent beds) one pass of bed planter was made for sowing of crop and shaping of beds. The permanent raised beds were of 67.5 cm width having 37.5 cm top and 30 cm furrow, which was used for irrigation purposes. The maize crop was established at a spacing of 67.5 cm from row to row and 20 cm from plant to plant by dibbling the seeds (20 kg/ha) both for flat and beds. The chopped residue of the previous crop was applied at 5.0 t/ha as per the treatments. Moreover, maize residue was applied to succeeding wheat crop and chickpea and vice-versa. Before sowing, weeds were controlled using tank mix paraquat + glyphosate (each 0.5 kg *a.i.*/ha) in ZT practices. In maize, atrazine (Atrataf 50 WP) as pre-emergence @1.5 kg *a.i.*/ha in 600 litres of water was applied at one day after sowing of crop. Maize crop was given uniform application of 150:80:60 kg/ha of N, P_2O_5 and K_2O. 1/3^{rd} dose of N and full dose of P_2O_5 and K_2O were applied at the time of sowing in furrow opened by pora, Remaining 2/3^{rd} dose of N were applied in two equal splits at eight leaves stage (V8) and tasseling stages. Observations on growth and development parameters were recorded periodically, while on yield attributes and yield of maize was recorded at the time of maturity. The crop was harvested manually 5-7 cm above the ground in every without residue treatment and the entire harvested biomass was removed from the plots of each treatment. While in case of with residue treatment every crop was harvested from 1/3^{rd} height to maintain the residue cover. All the data subjected to analysis of variance (ANOVA) techniques using general linear model (GLM) procedures of the SAS 9.2 software (SAS Institute, 2001) to determine the effect of each treatment. When F ratio was significant, a multiple mean comparison was performed using Fisher's Least Significant Difference Test (0.05 probability level).

Results and Discussion

Growth parameters

The mean plant height, dry matter accumulation and leaf area index (LAI) of maize were influenced significantly due to different tillage and crop establishment techniques at 90 days after sowing (DAS) (Table 1). However, growth parameters of the maize were better during 2013 in comparison to 2012 due to favorable weather conditions during former crop

Table 1. Effect of tillage practices and cropping systems on maize growth parameters, phenological stages and yield attributes (mean of two years).

Treatments	Plant height (cm) at 90 DAS	Dry matter accumulation (g/plant) at 90 DAS	Leaf area index (LAI) at 90 DAS	Days to 50% silking	Days to maturity	Cobs/m^2	100-grain weight (g)	Cob length (cm)	Cob girth (cm)	Grain row/cob	Grains/cob
Tillage practices and residue management											
PBWR	173.92	137.50	3.33	57.09	107.59	7.42	26.97	17.60	13.13	13.30	458.67
PBWOR	166.04	127.25	3.09	57.50	107.50	6.92	27.39	16.98	13.32	13.56	441.00
ZTWR	174.95	138.00	3.19	56.92	107.09	7.75	26.34	17.71	13.05	13.15	474.50
ZTWOR	163.77	124.92	3.04	57.42	107.25	7.09	27.55	17.32	13.17	13.45	450.08
CTWR	171.66	132.75	3.14	58.00	108.67	7.08	27.49	17.29	13.21	13.37	446.59
CTWOR	153.82	120.83	2.84	58.25	108.59	6.42	28.24	16.70	13.55	13.64	405.17
SEm±	4.16	3.16	0.09	0.35	0.46	0.23	0.82	0.31	0.24	0.19	11.87
LSD (P=0.05)	13.13	9.95	0.27	NS	NS	0.72	NS	NS	NS	NS	37.39
Cropping systems											
Maize-Wheat	166.52	128.23	3.03	57.64	107.89	7.09	27.58	17.08	13.27	13.43	442.61
Maize-Chickpea	168.20	132.20	3.17	57.42	107.67	7.14	27.08	17.45	13.20	13.39	449.39
SEm±	2.32	1.90	0.05	0.17	0.23	0.15	0.50	0.30	0.12	0.12	5.68
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

season. In general, crop was grown on beds performed better than the flat planting irrespective of tillage practices and the years. The maximum mean values of these growth parameters were recorded under PBWR followed by ZTWR, while minimum under CTWOR. PB resulted higher values of these growth parameters than CT. However, in all the treatments the residue application recorded better values of growth parameters than without residue application treatments. The mean values of two years of experimentation with respect to plant height, dry matter accumulation and LAI increased by nearly 13.74, 13.34 and 12.32 % at 90 DAS under ZTWR treatment compared with CTWOR planting. There was no further increase in plant height after 90 DAS. There was variation in days to 50 % silking due to different tillage and crop establishment practices. The minimum mean value 56.92 days for 50 % silking under ZTWR while it was maximum of 58.25 days under CTWOR treatment (Table 1).

Yield attributes

The yield attributes like grains/cob, cobs/m2 and cob yield/ha were significantly influence due to different tillage and crop establishment practices while grain row/cob, grains/grain row, cob girth, cob length and 1,00-grain weight were statistically similar (Table 1). In most cases the maximum values of yield attributing traits were recorded under ZTWR than rest of the treatments, while minimum values were obtained under CTWOR treatment. In general, higher values of yield attributes were recorded under ZT than CT. The residue retention with ZT resulted the better mean values of yield attributes than corresponding CT practices.

Yield performance

The two years mean (2012 and 2013) grain, stover and biological yields of maize were differed significantly due to different tillage and crop establishment techniques (Table 2). The grain, stover and biological yields were significantly higher under ZTWR planting than CTWOR planting during study. The minimum values of these traits were registered under CTWOR. Making a comparison of the effect of ZT flat and bed planting vis-à-vis CT planting in three situations, *viz.* permanent bed planting

Table 2. Effect of tillage practices and cropping systems on maize yields and harvest index (mean of two years).

Treatments	Cob yield (t/ha)	Grain yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Tillage practices residue management					
PBWR	6.30	5.21	12.30	18.61	27.97
PBWOR	5.87	4.75	12.06	17.93	26.43
ZTWR	6.64	5.49	12.50	19.14	28.68
ZTWOR	6.20	5.01	11.96	18.15	27.70
CTWR	5.98	4.95	11.69	17.67	28.03
CTWOR	5.69	4.45	10.76	16.45	27.16
SEm±	0.18	0.15	0.30	0.39	0.76
LSD (P=0.05)	0.58	0.46	0.96	1.23	NS
Cropping systems					
Maize-Wheat	6.05	4.95	11.76	17.81	27.77
Maize-Chickpea	6.18	5.00	12.00	18.17	27.56
SEm±	0.08	0.10	0.23	0.24	0.61
LSD (P=0.05)	NS	NS	NS	NS	NS

(PBWR, PBWOR), zero tillage flat (ZTWR, ZTWOR) and conventional tillage (CTWR, CTWOR) revealed that there was 23.37, 16.17 and 16.35 %; increase in mean grain, stover and biological yields during study for the above three situations in ZTWR over CTWOR planting. The increase in ZTWR over to ZTWOR, PBWOR, CTWR, PBWR was recorded to the tune of 9.58 & 5.45, 15.58 & 6.75, 10.91 & 8.32, and 5.37 & 2.85, and in mean grain and biological yields during study. Among all the tillage practices wherever residues was applied, resulted significant increase in mean grain, stover and biological yields during study. In comparison between conservation tillage and conventional tillage (including flat and bed) both resulted in higher mean grain, stover and biological yields which Signifies that conservation tillage may replace unsustainable conventional tillage practices. There was only a marginal non-significant difference in the mean harvest index (HI) of maize under different tillage and crop establishment practices. The interaction effects between continuous tillage and crop establishment techniques, and cropping systems on yield performance of maize were not significant.

Discussion

Growth parameters

The different growth parameters, viz; plant height, dry matter accumulation and leaf area index of maize were influenced significantly due to tillage and crop establishment techniques in both the year of study. The growth parameters of maize were significantly higher under ZT flat and bed planting than conventional till flat planting this might be due better root growth (Aggarwal *et al.*, 2006), which might helped in better soil moisture extraction during dry periods and maintained the plant vigour. Growing maize on beds avoids the adverse effect of short-term water logging during heavy rains and results in more efficient use of irrigation water and nutrients (Singh *et al.*, 2007). Similarly, residue application significantly improved the all the growth parameters than no-residue under all the tillage practices, this might be due to residue application improve the physical environment in the soil; more available soil moisture and nutrients, moderate the soil temperature and reduce the evaporation losses from surface soil. Ram (2006) also reported the higher values of plant height and dry matter accumulation under permanent bed with residue than no-residue under both ZT and CT practices.

Yield attributes

The mean cob length, cob girth, grain rows/ cob and 100-grain weight of maize were recorded similar under different tillage and crop establishment techniques. Ram (2006) and Kaputsa *et al.* (1996) reported similar values of yield attributes of maize under different tillage crop establishment techniques. The other yield attributing characters of maize *viz*; grains/cob, cobs/m^2 and cob yield/ha were influenced significantly under different tillage and crop establishment treatments. The higher mean values of these characters under bed planting might be due to more capture of light, border effect. More LAI might helped in better photosynthesis and assimilation rate which resulted more dry matter and better growth indices, these ultimately gave good performance of crop with regards to yield attributes of maize under bed planting. Behera and Sharma (2009) reported that under heavy rainfall with water logging situation during crop growing season results better performance in bed planting than flat planting. The lower yield attributing characters of maize under CT-flat might be due to more weeds infestation had more competition for water and nutrients, poor root growth, and thus reduced the growth of maize. However, application of residue under all the tillage treatments resulted higher mean values of yield attributes of maize crop, this might be due to maintain good and favourable soil moisture, moderated soil temperature, and improved soil fertility due to constant supply of nutrients through mineralization of these crop residues.

Yield performance

The two years mean grain and stover yields of maize crop were significantly influenced due to different tillage and crop establishment techniques. The better performance of maize under ZT was probably because of no adverse effect of water logging and better anchorage of roots. The increased mean grain yield of 20.8% on ZT beds over flat sowing was reported by Singh *et al.* (2007). Behera and Sharma (2009) reported that under heavy rainfall with water logging situation during crop growing season results better performance under bed planting than flat planting. Maize performed better under ZT than CT practices. The lower yield performance of maize under CTWOR was might be due to more weeds infestation had more competition for water and nutrients, poor root growth, and thus reduced the growth of maize. These results are in the line with Singh *et al.* (2007). The zero tillage resulted higher yields of maize, which might be due to poor crop growth as well as lower mean values of yield attributes. However, management of residue under zero tillage treatments resulted higher mean values of yields of maize crop, this might be due to availability of good and favourable soil moisture, moderated soil temperature, and improved soil fertility and also due to constant supply of nutrients through mineralization of these crop residues. Ram *et al.* (2010) reported higher yields under ZT with residue retension due to the cumulative effects of higher light interception more dry matter production, low soil and canopy temperature, more soil moisture. Improved grain yield due to straw mulch in maize under no-tillage and permanent bed planting was also reported by Kumar *et al.* (2004) and Govaertz *et al.* (2005).

Conclusion

On the basis of present investigations, it can be inferred that :

- Zero till planting with residue retention was found significantly superior in maize for enhancing the two years mean yield to the tune of 22-24 % than conventional till without residue planting and zero-tillage proved superior to conventional tillage in maize with respect to growth and yield attributes as well.

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