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Effect of conservation tillage and nutrient management on maize in maize-pigeon pea intercropping system

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Abstract
Conservation agriculture is the effective way of utilization of natural resources and sustainable crop production. In CA practices we use in this experiment maize+pigeon pea intercropping that increase the crop intensification that lead to increase crop production. This experiment on "Effect of conservation tillage and nutrient management on maize in maize-pigeon pea intercropping system" was conducted during 2019-2020 at TCA research farm, Dholi (Dr. RPCAU, Pusa). The experiment was laid out in split plot design with 4 main plot treatment *viz.*, T_1: Permanent bed (PB), T_2: Zero tillage (ZT), T_3: Fresh bed (FB) and T_4: Conventional tillage (CT) and 3 sub-plot treatment *viz.*, N_1: 100% Recommended dose of fertilizer (RDF), N_2: 120% Recommended dose of fertilizer (RDF) and N_3: 80% Recommended dose of fertilizer (RDF) which were replicated thrice. The result indicated that the parameters of growth, yield attributes and yield of maize crop was affected by tillage and nutrient management. The plant height and LAI of maize were significant influenced by tillage and nutrient management and it were higher in PB and 120% RDF application and it at par with ZT and 100% RDF application which were compared to CT and 80% RDF application. The higher growth under these treatments were also associated with yield attributing character of maize *viz.*, length of cob, number of rows per cob, number of grains per row, test weight. Maize grown under PB tillage recorded (58.9 q/ha) of grain yield being at par with grown under ZT (56.4 q/ha) compared to CT (49.0 q/ha) while, under the nutrient management practices recorded highest yield with 120% RDF application in maize (58.1 q/ha). Harvest index of maize was higher in PB and 120% RDF applications which was closely followed by ZT and 100% RDF application.

Keywords: Conservation tillage, fresh bed, intercropping system, nutrient management, permanent bed, zero tillage

Introduction
Today, intercropping with legume is our need for sustaining food production, reduce the nutritional insecurity of growing population and enhance the production from per unit area because culturable area suitable for crop production remains fixed or is decreasing, yet farmers have to face the duty of growing production demands. In addition, legumes have well-established role in restoring soil fertility, cereals are the staple food for humans and legumes and are also important for protein-rich food, feed and fodder. Therefore, the beans are described as "unique jewels of the Indian crop". Intercropping mean grow two or more crops on the same piece of land within the same year to encourage their interaction and this maximizes the potential for productivity by avoiding necessity on only one crop (Sullivan, 2003) [38].

Globally, maize (*Zea mays* L.) is grown for nutrition, forage, nutritious sanctuary and industrial crop. Being grown in diverse seasons and ecosystems with highest production and productivity among the cereals. Globally maize is growing on 184 m ha, with 872 MT of production and 5519 kg/ha of productivity (Directorate of Economics and Statistics 2016). While, in India, 9.75 m ha area covered (Indian Agristat, 2017) with 28.88 million tonnes of production (Agricoop, 2018). In Bihar, it is grown throughout the year with 0.24 m ha area and 0.62 MT of production during the *kharif* season and 0.28 m ha area with 2.13 MT of production during *Rabi* season and in summer season 0.19 m ha with 1.08 MT of production (DES, 2017). The productivity in India of maize is 2965 kg ha^{-1} (Indian Agristat, 2019). This is by far below 5.51 t ha^{-1} the world's productivity (Directorate of Economics and Statistics 2016). Maize consumption in India has grown up to 19 million tonnes (USDA, 2013-14), it is used as a source of poultry (51 per cent), human food (23 per cent), cattle feed (12 per cent), starch (12 per cent), food processing, brewery & others (2 per cent) and it is basic raw material for the various industries *viz*., bio-fuel, food sweeteners, cosmetics and alcoholic beverages (IMA, KPMG Analysis 2012-13) and with highest productivity make unique that place as "Queen of Cereals".

Material and Method

A field experiment was examined at TCA, research farm Dholi under Dr. RPCAU, Pusa (Bihar during the *kharif* seasons of 2019-20. The experiment was laid in split plot having net plot size of 8.44 m x 4.20 m with thrice replications. The main treatment was tillage practices like T1 = Zero tillage (ZT), T2 = Permanent bed (PB), T3 = Fresh bed (FB) and T4 = Conventional tillage (CT) with sub plot nutrient management treatment *viz*., N1 = 100% RDF, N2 = 120% RDF and N3 = 80% RDF. Maize variety 'P3322' was sown on 3rd week of June. On the third week of October maize was harvested. Both crops were grown together in 2:2 ratio with 67/20x20 cm row/row x plant geometry. For maintaining plant population thinning was done at 15 days after sowing. Since this experiment on nutrient management, the dose of fertilizers was applied according to treatment with RDF *i.e.*, maize (120:60:50 NPK Kg/ha). Basal dose of fertilizers was applied of half dose nitrogen and total phosphorus and potassium to maize and remaining nitrogen was top dressed in two equal splits *i.e.*, 1/4th at knee-high and 1/4th at tasseling stage of the crop according to the plan in each plot. The remaining crop cultivation practices like weed management, insect-pest management were done same in all plot. The data of growth parameters, yield attributes and yields of maize crop recorded at different stage of growth and analysed as per standard by statistical method (Gomez and Gomez, 1984) [10].

Result and Discussion

Growth parameters

Growth parameters *viz*., plant height, plant population, leaf area index, days to 50% Silking and days to 50% tasseling and days to maturity varies differentially by tillage and nutrient management practices while, plant height at 25 days after sowing (DAS) not affected, but at harvest it was significantly influenced by tillage practices. Permanent bed showed significantly superior plant height at harvest which was at par with zero tillage over the fresh bed and conventional tillage. Highest plants height was observed in permanent bed (PB) at harvest with values of 173.0 cm which was over the FB (164.3 cm) and CT (157.4 cm). The different growth characters like plant height at harvest, LAI and ear height were significantly influenced by different tillage and nutrient management treatments. Whereas plant height at 25 DAS and plant population significantly not differed by both tillage and nutrient management practices. (Karki *et al.*, 2015) [21] found the similar results. The maximum value of all the growth parameters at various growth stages were recorded in permanent bed (PB), whereas the lowest values were recorded in conventional tillage (CT) (Table 1). which might be due to growing of plants on raised beds leading to escaping of adverse effects of waterlogging during kharif season. Minimum tillage makes available well gases exchange in the rooting-zone, easily oxidation of organic matter and also, provides pore space for air-water movement and water retention and release (Kassam and Friedrich, 2009) [23]. In addition to this, growing of plants on PB forms decrease the bulk density, enhanced soil water storage and loose soil structure, so that roots can penetrate deep in to the soil and extract more amount of nutrients from deeper layers. Further, continuous addition of organic matter over the years as crop residue to soil led to increase in microbial population thereby enhancing mineralization and making available to plants. (Singh *et at*., 2012) [35] recorded maximum plant height under PB over to ZT and CT. (Hossain *et al.*, 2014 and Singh, 2003) [15, 37] reported meaningfully advanced crop growth in residue retention with PB treatments than CT. He *et al.* (2012) [14] found that higher crop growth due to increase the soil water storage capacity in PB than other tillage. Ram (2006) also found higher LAI under PB than ZT and CT. Yadav *et al.* (2005) also found the same result.

Among the nutrient management practices, 120% RDF noted maximum plant height at harvest (170.4 cm) witch at par with 100% RDF (167.2 cm) as compared to and 80% RDF (161.0 cm) respectively. Across the treatments plant population showed no significant difference among tillage and nutrient management practices either in initial (or) final stage. However, in initial stage under permanent bed (PB) maximum plant population (56981) was noticed followed by ZT (56752), FB (56732) and CT (56737). Similarly, the plant population at harvesting stage recorded no statistically differed by tillage and nutrient management practices. However, at harvest maximum plant population was observed in permanent bed (53893) followed by zero tillage (53795), FB (53596) and conventional tillage (53527). Like tillage practice, nutrient management also showed no significant difference among the treatments. Leaf area index and ear height showed significant difference across the both treatments (Table 1). In tillage practice, highest leaf area index (3.9) and ear height (67.8 cm) was noticed in PB which was at par with ZT (3.4 and 64.2 cm) and over with FB (2.8 and 62.9 cm) and CT (2.8 and 60.3 cm). Similarly, in nutrient management maximum leaf area index was observed in RDF 120% (3.5) which was at par with 100% RDF (3.2) and over the 80% RDF (2.9) respectively, and ear height was observed maximum in 120% RDF 67.2 cm which was significantly higher from 100% RDF (63.1 cm) and 80% RDF (61.4 cm).

In our study under nutrient management, higher values of growth parameters were noticed in 120% RDF and 100% RDF treatment over 80% RDF. Maize crop requires higher amount of nutrients to achieve higher productivity and to attain higher yields balanced and timely supply of nutrients is needed. (Taterwal *et al.*, 2011 and Sampath kumar and Pandian 2010) [39, 31] similar finding reported that maize crop responded well to fertigation and application of nutrients up to 150 per cent of RDF and maximized the grain yield. (Singh *et al.*, 2019) [33, 36] found the maximum LAI in balanced supply of fertilizer.

Yield attributes

Yield assigning parameters *viz.*, days to 50% Silking, day to 50% tasseling, days to maturity, length of cob, girth of cob, no. of rows cob^{-1}, no. of cobs plant^{-1}, no. of grains row^{-1} and test weight are described in Table 2. Among the tillage practices not a significant difference was found in days to 50% Silking, day to 50% tasseling and days to maturity. However, in case of days to 50% tasseling and days to 50% Silking PB and ZT showed a smaller no. of days to flowering as compare to FB and CT. Whereas, in days to maturity CT advanced by one day over ZT and PB respectively. Similarly, nutrient management practice did not affect days to 50%

Silking, days to 50% tasseling and days to maturity. However, 80% RDF nutrient management showed reduced days to 50% Silking and days to 50% tasseling and maturity compared to 100% RDF and 120% RDF.

Effect of Permanent bed and zero tillage practices lead to enhancement in yield accrediting characters *viz.*, length of cob, no. of cobs plant^{-1}, no. of rows cob^{-1}, no. of grains row^{-1} and test weight over conventional tillage in maize (Table 2). At the same time, the other yield attributing characters were not differed by tillage practices like days to 50% tasseling and silking, days to maturity and girth of cob because they are varietal characters which were more bounded to genetic (or) breeding approaches. To change these genetic characters, modifications in breeding/genetic approaches should be done. Hence, in our findings the augmentation in cob length, no. of cobs plant^{-1}, no. of rows cob^{-1}, no. of grains row^{-1} and test weight were recorded, as these characters are more easily changed by adaptation of conservation performs (PB and ZT) for more productivity of maize. The higher values of these yield attributes characters might be due to more availability of soil moisture, nutrients, healthier growth of crop that led to translocation more of photosynthates to sink from source under PB and ZT practices. (Govaerts *et al.*, 2005, Ahmad *et al.*, 2010 and Jat *et al.*, 2018) [11, 3, 20] that reported length of cob, no. of grains row^{-1} and test weight were significantly more under permanent bed over the CT. (Bakht *et al.*, 2006 and Sandhu *et al.*, 2019) [4, 32] found that more cob length and 1000-kernels weight with residue left in field than without residues. (Singh and Singh, 2019) [33, 36] found that bed planting and ZT higher no. of cobs plant^{-1} and test weight compared to flat planting. (Karki *et al.*, 2015) [21] reported similar finding that no. of rows cob^{-1}, no. of grains row^{-1} were higher under no till condition than CT.

The length of cob, no. of rows cob^{-1}, no. of cobs plant^{-1}, no. of grains row^{-1} and 100 grains test weight were significantly affected by tillage and nutrient management treatments. However, no significant effect was observed on girth of cob in either of treatments. In tillage practices, length of cob was higher in PB (14.6 cm) which was at par with ZT (14.5 cm) over FB (13.0 cm) and CT (11.9 cm). Among the nutrient management treatments 120% RDF (13.9 cm) observed maximum length of cob and at par with 100% RDF (13.6 cm) as related to 80% RDF (13.0 cm). while tillage and nutrient management treatments did not affect the girth of the cob and maximum girth of cob was found in PB (13.1 cm) and 120% (13.4 cm) followed by ZT (12.9 cm), 100% RDF (12.8 cm), FB (12.8 cm) and CT (12.4 cm), 80% RDF (12.2 cm). Among the tillage practices, no. of cobs plant^{-1} and no. of grains row^{-1} was maximum in PB (1.20 cobs plant^{-1}, 33.6 grains row^{-1}) which was statistically at par with ZT (1.17 cobs/plant and 32.3 grains/row) as compared to FB (1.12 cobs/plant, 30.3 grains/row) and CT (1.09 cobs/plant, 29.3 grains/cob). Similarly, in nutrient management 120% RDF significantly highest no. of cobs per plant (1.19 cobs/plant) and no. of grains per row (32.8 grains/row) were found at par with 100% RDF (1.14 cobs/plant and 31.5 grains/row) followed by 80% RDF (1.11 cobs/plant and 29.7 grains/row) treatment. Tillage practices significantly affected the no. of rows cob^{-1} and maximum no. of rows cob^{-1} was found in PB (16) witch at par with ZT (16) and over the FB (14) and CT (14). But nutrient management was not significantly influenced the no. of rows cob^{-1} however higher no. of rows cob^{-1} was found in 120% RDF (15.1) *fb* 100% RDF (15) and 80% RDF (14). Tillage and nutrient management practices did significantly affect the 100 grains test weight (seed index) was significantly influenced by, maximum test weight was observed with PB (28.6 g) at par with ZT (27.6 g) and 120% RDF (28.7 g) followed by FB (26.4 g), CT (26.3 g), 100% RDF (26.9 g), 80% RDF (26.2 g).

Across the nutrient management practices, length of cob, no. of cobs plant^{-1}, no. of grains row^{-1} and test weight were superior in 120% RDF treatment and 100% treatments over 80% RDF and days to 50% tasseling and silking and days to maturity were not affected by nutrient management practices because in over-all silking and tasselling arises after the accumulation of approximately 1135 growing degree units (GDU) (aganytime.com). Other parameter affected might be due to appropriate application of nutrients in required quantity, higher NUE and a better crop growth environment that helped to transport the assimilates / photosynthates from source to sink. Higher biomass buildup per unit area with enhance the ferritization. (Jaidka *et al*., 2018 and Imran *et al*., 2015) [17, 16] reported that N fertilization positively corelated with maize cob weight, grain weight per cob and cob girth that increase the grain yield of maize.

Crop yields

Both tillage and nutrient management practices did significantly affect the grain, Stover and biological yield of maize while Stone yield and harvest index did not significantly influence by these treatments (Table 3). Across tillage practices the grain yield in PB (58.9 q ha^{-1}) which was statistically at par with ZT (56.4 q ha^{-1}) and were significantly higher yields followed by FB (52.1 q ha^{-1}) and CT (49.0 q ha^{-1}). Stover and biological yield differed significantly with tillage practices. Highest yields were found in PB (90.4 and 168.2 q ha^{-1}) which was significantly superior over ZT (83.5 and 158.6 q ha^{-1}) and FB (76.6 and 144.8 q ha^{-1}) and CT (73.8 and 136.8 q ha^{-1}). However, stone yield higher in PB (18.7 q ha^{-1}) and 120% RDF (18.7 q ha^{-1}) *fb* ZT (18.7 q ha^{-1}) FB (17.1 q ha^{-1}), CT (16.9 q ha^{-1}) and 100% RDF (18.0 q ha^{-1}) and 80% RDF (17.0 q ha^{-1}). Similarly, harvest index (HI) was higher in PB (37.1%) *fb* ZT (35.6%), FB (35.6%) and CT (35.0%).

Conservation tillage practices over the years help to enhance the crop yields of maize at fixed site but harvest index (HI) not affected. It shows that genetic parameters. Whereas, grain, Stover and biological yield meaningfully differed by tillage and nutrient management treatments (Table 3). In our findings grain yield was 20.31%, 13.17% and 4.44% higher in PB as related to CT, FB and ZT respectively. Stover yield and biological yield were 22.53%,17.92%, 8.31%, 22.95%, 16.16% and 6.05% respectively, higher in PB over CT, FB and ZT the reason behind higher yield attributing characters under PB was photosynthates movement potential higher from source to sink that leads to increase in yield attributing characters. (Board *et al.*,1992) [6] reported that at vegetative and early reproductive periods of plant growth increase light interference by narrow row spacing (0.5 m) related to the wide row spacing (1 m). Similarly, (Zhang *et al.*, 2008) observed that the higher distribution of light is recorded in narrow strip systems. And also, continuous addition of crop residue to the field helps to increase in microbial population which leads to enhance more micropores and ultimately improves the water retention capacity, aggregate stability and easy assimilation of nutrients from soil to plants. Reduced tillage helps to decrease the soil compactness and improves the root growth which helps to uptake water and nutrients from deeper layers. All the above cumulative improvement results in enhance the better crop growth and development ultimately leading to increase in crop yields of maize. Moreover, the higher reproductive period was noticed in PB compare to CT and FB practices helped in proper grain filling of crop. (Aggarwal *et al.*, 2006) [1] also noticed significantly higher growth parameters under PB as compared to CT practice. Growing of kharif maize on beds helps to avoid temporary water logging due to heavy rains resulting in increased water use efficiency (Singh *et al.*, 2007) [34]. Reason behind more yields of maize under conservation agriculture is combination effects of further applied nutrients (Kaschuk *et al.*, 2010 and Blanco-Canqui and Lal, 2009) [22, 5] improved soil moisture regimes (Govaerts *et al.*, 2009) [12], check weed growth that reduced the competition for nutrients, light and water (Chauhan *et al.*, 2007 and Ozpinar, 2006) [7] and with maximum aeration related to CT. (Rashid *et al.*, 2019, Gathala *et al.*, 2015, Govaertz *et al.*, 2005, Hassan *et al.*, 2005 and Kumar *et al.* 2004) [30, 18, 11, 13] increased maize yield in permanent bed due to straw mulch and residues retention, this result also supported by (Chaudhary, 2011, Jat *et al.*, 2013, Pal and Bhatnagar, 2014 and Kumar *et al.*, 2019) [19, 27].

Among the nutrient management practices, grain yield was significantly superior in 120% RDF (58.1 q/ha) and was statistically over 100% RDF (54.3 q/ha) and 80% RDF (50.0 q/ha). Stover yield was significantly higher in 120% RDF (84.8 q/ha) which was at par with 100% RDF (80.7 q/ha) as compared to 80% RDF (77.6 q/ha). However, higher harvest index was found in 120% RDF (36.0%) *fb* 100% RDF (35.4%) and 80% RDF (34.5%) respectively.

Conservation tillage with ideal nutrient management significantly affected the grain yield, Stover yield and biological yield. Grain yield improved by 16.1 and 8.6% under 120% RDF and 100% RDF treatments as compared to 80% RDF. Similarly, Stover yield and biological yield were also increased under 120% RDF and 100% RDF (14.7, 8.0% and 11.7, 5.3%) over 80% RDF treatment. These indicates that the placement of nutrients just near the base of plant became quite useful as there was no leaching loss and (Jat *et al.*, 2013) [19] Split applications of N at as a starter dose @ 30 kg ha^{-1} and then after at knee high stage and flowering stage improved the N uptake system and the optimum soil moisture helps in better utilization of applied nutrients (Sampath kumar and Pandian 2010) [31], that leads to increase in biological yields and also incorporation of residue in the field leads to significant increase in organic carbon, soil protein and microbial population that ultimately helped to mineralize organic matter and slowly release the nutrients in the soil and make available to the plants. (Ram *et al.*, 2009 and Kumar *et al.*, 2005) [29, 24] release of adequate amount of nutrient at different stages performed the higher grain yield also found the same results. (Ahmad *et al.*, 2009 and Singh and Singh, 2019) [2, 33, 36] found that enhance the N at 150 Kg/ha found higher yield due to better vegetative growth.

Table 1: plant population, LAI and days to maturity of maize affected by tillage and nutrient management practices.

Treatments	Plant population ha^{-1}		Leaf area Index	Days to 50% Tasselling	Days to 50% Silking	Days to maturity
	25 DAS	At harvest	(50 DAS)			
Tillage practices						
Zero Tillage	56752	53795	3.4	56	59	104
Permanent Bed	56981	53893	3.9	56	59	104
Fresh Bed	56732	53596	2.8	57	62	103
Conventional tillage	56737	53527	2.	57	62	103
S.Em±	515.6	215.5	0.14	0.63	0.82	0.38
LSD (p =0.05)	NS	NS	0.5	NS	NS	NS
Nutrient management						
100% RDF	56955	53586	3.2	57	60	104
120% RDF	56721	53956	2.5	57	61	104
80%RDF	56725	53567	2.9	56	60	103
S.Em±	367.30	169.3	0.11	0.91	0.43	0.41
LSD (p =0.05)	NS	NS	0.4	NS	NS	NS
LSD (p=0.05) (T×N Interaction)	NS	NS	NS	NS	NS	NS

Table 2: yield attributes of maize affected by tillage and nutrient management practices.

Treatment	Length of cob (cm)	Girth of cob (cm)	Number of cobs per plant	Number of rows per plant	Number of grains per row	Test weight (g)
Tillage practices						
Zero Tillage	14.5	12.9	1.17	16	32.3	27.6
Permanent Bed	14.6	13.1	1.20	16	33.6	28.6
Fresh Bed	13.0	12.8	1.12	14	30.3	26.4
Conventional tillage	11.9	12.4	1.09	14	29.3	26.3
Sem±	0.35	0.45	0.02	0.49	0.85	0.37
LSD (p =0.05)	1.2	NS	0.07	2	2.9	1.3
Nutrient management						
100% RDF	13.6	12.8	1.14	15.0	31.5	26.9
120% RDF	13.9	13.4	1.19	15.1	32.8	28.7
80%RDF	13.0	12.2	1.11	14.0	29.7	26.2
Sem±	0.15	0.36	0.007	0.27	0.75	0.52
LSD (p =0.05)	0.5	NS	0.02	NS	2.3	1.6
LSD (p=0.05) (T×N Interaction)	NS	NS	NS	NS	NS	NS

Table 3: Yield and harvest index of maize crop affected by tillage and nutrient management practices

Treatments	Grain yield (q/ha)	Stone yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Harvest index
	Tillage practices				
Zero Tillage	56.4	18.7	83.5	158.6	35.6
Permanent Bed	58.9	18.7	90.4	168.2	37.1
Fresh Bed	52.1	17.1	76.6	144.8	35.6
Conventional tillage	49.0	16.9	73.8	136.8	35.0
S.Em±	1.78	0.50	1.84	1.52	1.01
LSD (p =0.05)	6.2	NS	6.4	5.2	NS
	Nutrient management				
100% RDF	54.3	18.0	80.7	152.0	35.4
120% RDF	58.1	18.5	84.8	160.1	36.0
80%RDF	50.0	17.0	77.6	143.3	34.5
S.Em±	1.10	0.48	1.45	1.96	0.61
LSD (p =0.05)	3.3	NS	4.4	5.8	NS
LSD (p=0.05) (T×N Interaction)	NS	NS	NS	NS	NS

Summary and Conclusion

Conservation tillage significantly affected the growth character, yield attributes and yields of both crops compared to fresh bed and conventional tillage practices. Permanent bed and zero tillage practices performed better in yield maximization of maize in maize – pigeon pea intercropping system. As well as 120% RDF practices gave the maximum growth and yield attributes character and yields of both crops compared to 80% RDF treatments.

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