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Co-implementation of tillage and precision nutrient management practices on crop yield of *kharif* maize (*Zea mays*)

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ABSTRACT

Our accustomed agricultural practices of tilling the soil continuously and excessive fertilizer applications caused not only a decrease in organic carbon content and soil degradation but also disturbed environmental harmony. With this backdrop, current study was carried out during rainy (*kharif*) seasons of 2018 and 2019 at the research farm of Trihut College of Agriculture, Dholi, Pusa, Bihar to evaluate the effect of different tillage and nutrient management practices on maize (*Zea mays* L.). The experiment was laid out in split-plot design with tillage as the main plot and nutrient management as the sub-plot. The results showed significantly superior maize grain yield in PB (6.1, 6.2 mg/ha) and 60% RDN+GSGN (6.0, 5.9 mg/ha) over CT (4.9, 5.0 mg/ha) and RDF (5.1, 5.4 mg/ha) during 2018 and 2019. Similar trend was followed in stover yield, net returns and B:C ratio. Among path analysis, harvest index and no of grains/cob observed largest direct path coefficient of yield attributes to determine the maize grain yield and stover yield respectively. The results suggest that the adoption of conservation tillage and precise nutrient management practices will help in the realization of better yield with maximum profit by way of reducing the input capital apart from improving soil health thereby sustaining natural resources for future generations.

Keywords: Conservation tillage, Precision nutrient management, Permanent bed, Path analysis, Yield enhancement

In recent decades, agriculture is under vulnerable due to blooming population, intensive cultivation and fall in yield gain constituting about 31% of major cereal crops (Grassini *et al*. 2013, Garai *et al*. 2019). Concurrently, farming people are trying to decrease the adverse environmental impacts, viz. land degradation, ground water contamination and climate change (Kar *et al*. 2021). In addition, adaption and practicing of rice-wheat cropping system in Indo-Gangetic plains lead to deterioration of soil by practicing heavy tillage operation, faulty fertilizer application and continuous lifting of ground water to meet the water requirements for rice crop which drastically depleted ground water table (Humphreys *et al*. 2010, Sharma *et al*. 2012). All these depleted soil resources to the extent that future production in these areas unsustainable. This indicates that agriculture systems needs a combination of new technologies that are capable to knock new sources of production growth and are of more sustainable.

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In this scenario, Conservation agriculture (CA) is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. Hence, more emphasis was focused on sustainable agriculture production system for efficient soil and natural resource management in eco-friendly manner. Long term adoption of CA practices has been reported; to increase the factor productivity and crop yields, to enhance agricultural sustainability, ensure timeliness of cropping practices, and improved ecosystem services.

In India, maize (*Zea mays* L.) performed to be one of the most emerging-crop for the farmers being suitably fitted in rice-based systems (Jat *et al.* 2019). Maize, versatile cereal crop, has recorded highest growth rate among all food grains in the last one decade because of emerging food habit as well as enhanced industrial requirements. In present day scenario, maize production and utilization have changed due to gaining importance of crop in commercial sector and rising demand in diversified end users. Srinivasan *et al*. (2004) suggested that enhancing maize production is need for the hour to meet the rising demand.

All these above-mentioned facts represent that the conservation practices can improve the soil health and yield of maize. In this context, the present study was designed with conservation tillage and nutrient management to boost up growth with proficient use of serviceable resources.

MATERIALS AND METHODS

A field experiment was conducted during rainy (*kharif*) seasons of 2018 and 2019 with the 3 sets of tillage and nutrient management practices at the research farm of Trihut College of Agriculture, Dholi, Pusa (25° 99' N and 85° 60' E and at an elevation of 52.18 m MSL), Bihar. The mean average rainfall of the experiment site was 869.8 mm. Before start of the experiment, the soil samples in triplicate were collected from 0–15 cm soil depth using soil auger. The soil of experiment site is sandy loam with 1.3 g/cm^3 BD, 29.84% water holding capacity (WHC), medium in organic carbon, available phosphorus, available potassium and low available nitrogen in soil. The experiment was laid out in spilt-plot design with 3 tillage practices [zero tillage (ZT), conventional tillage (CT) and permanent bed (PB)] as main-plot and 3 nutrient management practices [recommended dose of fertilizer (RDF), site-specific nutrient management (SSNM) and recommended dose of nitrogen 60% (RDN) + green seeker guided N application (GSGN)] as sub-plot and replicated thrice. The total area of the experiment site was 450 m, each experiment unit size was 4.0 m × 4.2 m with 6 inter-rows and 21 intra-rows.

In CT plots, heavy tillage operations were followed according to the local farmer practices. The primary tillage operation like tractor driven plough and secondary tillage operations like disking and planking were done. While in case of ZT, no tillage operations were done and in PB reshaping of beds were practiced every season before sowing. The quality protein maize (QPM) shaktiman-5 hybrid was sown with a seed rate of 20 kg/ha during first fortnight of July in 2018 with a row spacing of 67 cm and plant to plant distance at 15 cm. Line sowing method was followed in ZT and PB.

Among the nutrient management practices, 120-26-42 kg N-P-K ha was applied in RDF and in SSNM the fertilizer dose was calculated by using Nutrient Expert software application developed by International plant nutritional institution (IPNI). According to Nutrient Expert software recommendation during two years was 90-18-38 kg N-P_2O_5-K_2O/ha and 103-17-44 kg N-P-K/ha, respectively. However, in all nutrient management treatments full dose of P and K was applied as basal. Whereas, nitrogen application was done 3 times one at basal dose of 50% and remaining 50% was in 2 split doses at knee height stage and tasseling stage. In RDN 60% + GSGN treatment, maize crop was fertilized with 60% of nitrogen, viz. 72 kg/ha as basal dose of application and remaining dose of fertilizer was applied according to the requirement of the crop by taking the readings of NDVI with green seeker instrument.

Description of green seeker NDVI sensor instrument: NDVI (Normalized Difference in Vegetation Index) sensors or green seeker crop sensing is a handy tool which helps in efficient and precise management of crop inputs. Green seeker uses optical sensors that emits two bands of light, viz. Red light and Near Infra-Red light and measures the amount of reflectance. The value reported from these indices is termed as Normalized difference vegetative index (NDVI)

$$\text{NDVI} = \frac{\text{NIR reflectance} - \text{Red reflectance}}{\text{NIR reflectance} + \text{Red reflectance}}$$

Calculation of N rates from NDVI values (OSU Algorithm) (Gupta 2006):

$$Y_{po} = 1291 \times (\text{Exponential of NDVI reading taken/ Sum of GDD} \times 2649.9)\ V_8 \text{ to } V_{12}$$

(NDVI of stage which reading is taken)

$$\text{RI} = \text{NDVI N Rich strip/NDVI farmers practice}$$

$$Y_{PN} = Y_{po} \text{ X RI}$$

$$\text{N Rate} = (Y_{PN} - Y_{PO}) \times 0.0125/\text{Expected FUE}$$

where GDD = $\{(T_{Max} + T_{Min})/2\} - T_{Base;}\ T_{Bsse} = 10^oC$; Y_{po} = yield potential; RI = Response index; Y_{PN} = predicted attainable yield; V8 = flag leaf visible stage; V9 = ligule of last leaf just visible; V10 = boot stage; V11-V12 = Heading and ripening.

Across the weed management practices, glyphosate was sprayed @1.0 l a.i/ha 30 days before sowing to kill perennial and grassy weeds in ZT and PB. Atrazine @2.0 kg/ha was applied in all the treatments as pre-emergence herbicide and one manual weeding was done with hand hoe at 35th days after planting.

The cobs were harvested when the cob sheaths turned brown in colour and grains became hard. Net plot area was considered for harvesting by leaving one row on each side and two intra-rows of each plot. The cobs were manually plucked in the standing crop and stover was harvested later. The harvested cobs were kept in gunny bag for each experiment unit and dried in the sun to ensure optimum moisture level i.e. 25% for shelling. The shelling of cobs was done manually with the hand and weighed separately for each experiment unit. The stover was cutted 30 cm above ground level and remaining was left in the field as residue. After the harvest of the crop, soil samples were collected from three different places at a depth of 0–15 cm in every treated plot. The collected samples were air dried at room temperature. After which, the soil samples were processed by grinding and passing through 2 mm sieve. The processed samples were taken in polythene bags and used for further analysis.

The recorded data for different parameters, viz. growth stages, yield attributes and yield were analyzed with the help of ANOVA technique by Gomez and Gomez (1984) for spilt-plot design using excel work book. The LSD test was used to reduce the effect of treatments at 5% level of significance (P=0.05). The critical difference (CD) values for pair-wise comparison among the treatment effect were computed. Path analysis was performed to assess the relationships between crop yields and yield attributes with AMOS SPSS 16.0 (Statistical package for the social sciences 16.0).

RESULTS AND DISCUSSION

Effect of tillage and nutrient management practices on crop yield: Conservation tillage and precision nutrient management practices resulted significant effect on crop yield during both the years (Table 1). The higher grain yield was observed in permanent raised bed (PB) with 22.7 and 22.9% compared to conventional tillage (CT). Concomitantly, zero tillage (ZT) resulted 12.2 and 14.1% more crop yields compared to CT practices. Among the nutrient management practices 60% recommended dose of nitrogen + green seeker guided nitrogen application (RDN+GSGN) resulted 17.4 and 9.8% significantly superior yields over recommended dose of fertilizer (RDF). Site specific nutrient management (SSNM) was statistically at par with 60% RDN+GSGN and observed 7.9 and 4.1% higher yields compared to RDF. Similarly, stover yield was significantly more under PB with 14.1 and 16.3% over CT. Among nutrient management practices, 60% RDN+GSGN resulted more yields with 15.1 and 8.9% compared to RDF. Higher stone yield was resulted in PB with 22.6 and 13.9% followed by ZT (19.4 and 7.1%) over CT. Across nutrient management practices, 60% RDN+GSGN (5.1 and 11.6%) and SSNM (3.6 and 6.5%) resulted higher yields compared to RDF.

The higher crop yield in PB and ZT was due to addition of previous crop residue which serves as the potential sources for crop nutrients through mineralization process and leads to slower and continuous release of nutrients to plants. Further, it also favours temperature moderation thereby helps in better crop growth (Verhulst *et al.* 2011, Gathala *et al.* 2011, Jat *et al.* 2013, Parihar *et al.* 2016). In addition to this, precise application of fertilizers may have combined effect of additional nutrients (Blanco-Canqui and Lal 2009, Kaschuk *et al.* 2010) to crop. The presences of higher amount of organic matter resulted in increase the chelation with the nutrients applied through fertilizers, which reduces the loss of nutrients and making it available to the crop (Naik *et al.* 2022). Added crop residues will positively influence the soil physico-chemical properties (bulk density, water holding capacity and aggregate stability etc.) that could help in better root proliferation and nutrient uptake apart from improving biological properties (Jat *et al.* 2013) like microbial activity which in turn enhances nutrient transformation and availability. On the other hand, lower yields with conventional tillage might be attributed to negative influence on soil physical, chemical and biological properties, destruction of soil structure and lower water holding capacity of the soil (Prabhamani and Babalad 2018).

RDN 60%+GSGN nutrient management is based on the real time nitrogen demand unlike SSNM. NDVI values obtained from green seeker showed direct correlation with chlorophyll content and plant growth. It also ensures that the required nutrients are supplied in appropriate rate and ratio when crop needed which leads to higher crop yields (Majumdar *et al*. 2012).

Effect of tillage and nutrient management practices on economics: In contrast to tillage practices, PB showed more net returns and B: C ratio during both the years i.e. 43.0, 42.9 and 45.3, 44.7%, respectively over CT (Table 1). Whereas, ZT was statistically at par with PB and resulted significantly more (27.3, 28.0 and 30.2, 30.8%, respectively) compared to CT. Concomitantly, in nutrient management practices 60% RDN+GSGN resulted more net returns and B: C ratio (33.9, 16.6 and 36.0, 16% respectively) compared to RDF. However, SSNM was statistically at par with 60% RDN + GSGN.

The monetary returns and B: C ratio was resulted more with PB and 60% RDN+GSGN treatment, which might be due to reduced mechanization and fertilizer rates coupled with increased in crop yields. While, permanent raised beds and double no tillage systems use, reduced inputs,

Table 1 Effect of tillage and nutrient management practices on crop yield

Treatment	Gain yield (mg/ha)		Stover yield (mg/ha)		Stone yield (mg/ha)		Net returns (₹/ha)		B:C ratio	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Tillage treatment										
ZT	5.6 ± 0.63^{a}	5.7 ± 0.68^{b}	9.0 ± 0.94^{a}	8.6 ± 0.85^{b}	2.2 ± 0.58	2.3 ± 0.25	59435 ± 11525^{a}	65988 ± 12158^{b}	1.55 ± 0.30^{a}	1.61 ± 0.30^{b}
CT	4.9 ± 0.48^{b}	5.0 ± 0.35^{c}	7.9 ± 0.95^{b}	7.4 ± 0.62^{c}	1.8 ± 0.45	2.2 ± 0.20	46665 ± 8952^{b}	51535 ± 6461^{c}	1.19 ± 0.24^{b}	1.23 ± 0.15^{c}
PB	6.1 ± 0.27^{a}	6.2 ± 0.35^{a}	9.7 ± 0.88^{a}	9.2 ± 0.57^{a}	2.2 ± 0.43	2.5 ± 0.21	66763 ± 11782^{a}	73669 ± 6504^{a}	1.73 ± 0.31^{a}	1.78 ± 0.17^{a}
Nutrient management treatment										
RDF	5.1 ± 0.59^{b}	5.4 ± 0.76^{b}	8.2 ± 0.95^{b}	8.0 ± 1.10^{b}	2.0 ± 0.56	2.2 ± 0.18	48734 ± 10325^{b}	58309 ± 14016^{b}	1.22 ± 0.26^{b}	1.38 ± 0.33^{b}
SSNM	5.5 ± 0.54^{ab}	5.6 ± 0.69^{ab}	8.9 ± 1.10^{ab}	8.3 ± 1.01^{ab}	2.1 ± 0.47	2.3 ± 0.27	58851 ± 10023^{a}	64849 ± 12832^{a}	1.59 ± 0.28^{a}	1.63 ± 0.33^{a}
RDN 60% + GSGN	6.0 ± 0.87^{a}	5.9 ± 0.51^{a}	9.5 ± 1.23^{a}	8.8 ± 0.86^{a}	2.1 ± 0.56	2.4 ± 0.24	65278 ± 14864^{a}	68034 ± 9980^{a}	1.66 ± 0.38^{a}	1.61 ± 0.24^{a}

ZT, Zero tillage; CT, Conventional tillage; PB, Permanent raised bed; RDF, Recommended dose of fertilizer; SSNM, Site specific nutrient management; RDN 60% + GSGN, Recommended dose of nitrogen 60% + green seeker guided nitrogen application.

labour and energy, providing potentially more economic benefits (Ram *et al*. 2011). Singh *et al*. (2014) and Pal and Bhatnagar (2014) also noticed similar results. Parihar *et al.* (2016) observed similar cost of cultivation in permanent bed (PB) under different crops of maize based system. Jat *et al.* (2012) noticed significantly higher net returns and benefit: cost ratio under minimum tillage compared to normal tillage. Similarly, under nutrient management net returns and B: C ratio were observed highest by Kumar *et al.* (2013), Prasanth *et al*. (2014), Anand *et al*. (2017) and Pramanick *et al.* (2022).

Evaluation of yield attributes and association with crop yields: Path analysis was conducted to quantify the effect of yield attributes on grain yield and stover yield during 2018–2019 (Table 2, 3 and Fig 1). The results showed that harvest index and no of grains/cob has largest direct path coefficient of yield attributes to determine the maize grain yield and stover yield, respectively. Among grain yield, except test weight and days to 50% flowering all other attributes, viz. plant height, length of cob, girth of cob, no of cobs/plant and no of grains/cob has indirectly contributing the grain yield by predominately associating to harvest index, and their indirect path coefficients through harvest index were the highest among all path coefficients and further larger than their corresponding path coefficients. In contrast to stover yield except plant height and test weight all other attributes, viz. length of cob, girth of cob, no of cobs/plant, days to 50% flowering and no of grains/cob were indirectly contributing the stover yield by predominately associating with no of grains/cob, and their indirect path coefficients through no of grains/cob were the highest among all path coefficients and further larger than their corresponding path coefficients.

Further, regression studies showed 92% of R^2 in association with yield attributes to grain yield. Similarly, 79% of R^2 was observed in association with stover yield to yield attributes (Supplementary Fig 1).

It can be concluded that conservation tillage practices, viz. permanent bed and zero tillage (22.71, 22.94% and 12.21, 14.10%) along with real time nutrient management practices like green seeker guided nitrogen application (GSGN) helps to improve the crop performance to 17.47 and 9.83% compare to conventional maize farming. Hence, it is found over than all sustainable yields with conservation and precision nutrient management practices. However, the relationship between yield attributes to crop yields

Table 2 Path analysis relating grain yields to selected yield attributes (pooled mean values was taken and analysed)

	X_1 yield	X_2 yield	X_3 yield	X_4 yield	X_5 yield	X_6 yield	X_7 yield	X_8 yield
X_1	0.094	-0.035	**0.311**	0.083	0.004	0.071	0.216	-0.004
X_2	0.047	-0.070	**0.261**	0.072	0.005	0.056	0.185	0.001
X_3	0.046	-0.029	**0.629**	0.040	0.006	0.044	0.117	-0.002
X_4	0.045	-0.035	**0.179**	0.143	0.004	0.026	0.165	-0.002
X_5	0.031	-0.025	**0.311**	0.044	0.014	0.033	0.113	0.000
X_6	0.074	-0.043	**0.309**	0.092	0.005	0.091	0.197	-0.005
X_7	0.071	-0.045	**0.261**	0.083	0.005	0.063	0.283	-0.002
X_8	0.036	0.009	**0.158**	0.036	-0.000	0.043	0.069	-0.011

The data with an underline represent direct path coefficients, and those in bold represent the most important path coefficients that determine grain yields; X_1, Plant height; X_2, Test weight; X_3, Harvest index; X_4, Length of cob; X_5, Girth of cob; X_6, No of cobs/plant; X_7, No of grains/cob; X_8, Days to 50% flowering.

Table 3 Path analysis relating stover yields to selected yield attributes (pooled mean values was taken and analysed)

	X_1 yield	X_2 yield	X_3 yield	X_4 yield	X_5 yield	X_6 yield	X_7 yield	X_8 yield
X_1	-0.015	-0.131	0.259	0.061	-0.000	0.205	**0.369**	-0.063
X_2	-0.007	-0.261	0.217	0.063	-0.000	0.162	**0.315**	0.022
X_3	-0.007	-0.108	0.523	0.036	-0.000	0.128	**0.200**	-0.041
X_4	-0.007	-0.131	0.149	0.126	-0.000	0.169	**0.282**	-0.042
X_5	-0.005	-0.093	0.259	0.039	-0.001	0.097	**0.193**	0.001
X_6	-0.011	-0.162	0.257	0.081	-0.000	0.261	**0.337**	-0.079
X_7	-0.011	-0.170	0.217	0.073	-0.000	0.182	**0.483**	-0.040
X_8	-0.005	0.035	0.131	0.032	0.000	0.124	**0.118**	-0.166

The data with an underline represent direct path coefficients, and those in bold represent the most important path coefficients that determine stover yields; X_1, Plant height; X_2, Test weight; X_3, Harvest index; X_4, Length of cob; X_5, Girth of cob; X_6, No of cobs/plant; X_7, No of grains/cob; X_8, Days to 50% flowering.

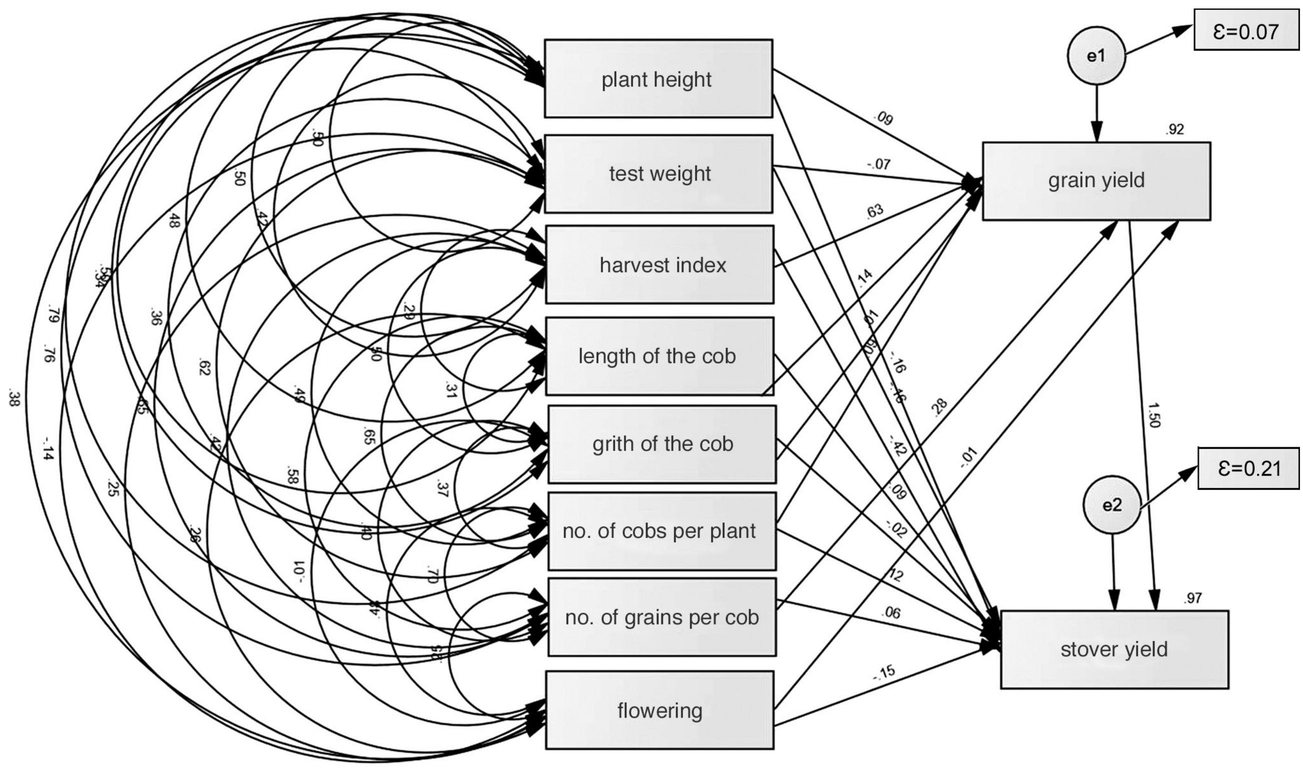

Fig 1 Path diagram for evaluating relationship between yield attributes and crop yields (using AMOS SPSS Software).

were quantified by using path analysis and results showed highest path coefficient in harvest index and no of grains/ cobs under grain yield and stover yield, respectively. Further regression studies, explained 92% and 79% R^2 in relationship with grain yield and stover yield to yield attributes. Hence, conservative approach can be particularly suitable for lower gangetic plains where downward spiraling of resources is being evidenced because of continuous rice-wheat rotation under intensive cropping.

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