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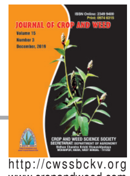

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Initial effect of conservation agriculture on the growth and yield attributes of maize and their correlation behavior with yield

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ABSTRACT

Maize, being a higher yielder than many other competing cereals, can be a potential crop in conservation agriculture practices of the eastern-gangetic plains. However, the benefits of conservation agriculture are time-dependent. To deal with the initial adversities, an extensive study of the microclimatic factors under these systems alone are not sufficient. To understand the scope of existing high yielding varieties of maize under conservation agriculture, a study with five released varieties of maize were conducted under two independent degree of tillage systems, each coupled with residue retention from the preceding kharif season. A significant variations among growth and yield attributes were found across zero and reduced tillage. The highest mean yield was observed under reduced tillage (14.48t ha^{-1}) and the varieties PAC751 and ADV9293 reflected the best performances with respect to yield and other characters. Correlation analysis and path analysis were conducted for each of the treatment conditions to understand the effect of other characters over yield. The yield had a significant positive correlation with plant height (0.930) and root dry weight (0.988) under zero tillage and only with plant height (0.909) under reduced tillage. Leaf area index (0.888) and plant biomass (-0.955) were also found to be the growth characters with a significant positive and negative correlations with yield under reduced tillage. A simple linear regression analysis on each of these combinations of characters under the respective systems revealed their per cent contributions to yield variations, thereby reflecting a better view on their associations. These characters can be used as early selection indices for any longterm breeding programs of maize under the systems of conservation agriculture.

***Keywords*:** Maize, tillage, conservation, residue, selection, yield

Maize, the 'Queen of the cereals', is globally considered to be extremely promising towards food security due to its highest genetic yield potential among all the cereals. Being no exception to Indian agriculture, maize occupies the position of third most important food crop after rice and wheat. It accounts for 10% of the total food grain production in the country (Maize outlook report, 2021). Since the last few decades, the demand for this food crop has been showing a continuous growth. The reasons include rising international prices, increasing numbers of poultry farms all over the country, and increasing popularity of continental corn-based food choices across urban areas Total production of maize in India has been estimated at around 24.51 MMT (Million Metric Tons) in 2020-21 against the annual demand of 25.2 MMT. The projected demand for maize in India will touch 121 MT by the year 2050 (Amarasinghe and Singh, 2008).

Due to the lower yield potential of rain-fed maize cultivation in the country, major interests of farmers accumulate around irrigated maize (CRIDA Annual report, 2013-14). The Indo-Gangetic plains of India are dominated by irrigated cereal-based cropping systems (Timsina *et al.,* 2011). In eastern India, maize is rapidly emerging as a favourable winter crop under rice fallows. The lesser water consumption of winter maize and consequent avoidance of arsenic toxicity compared to boro rice presents maize as a considerable alternative in the Gangetic plains of West Bengal (Ravenscroft *et al.,* 2005). However, the input-output ratio and productivity in these eastern plains of Bengal are not as promising as the western Gangetic plains of India (Jat *et al.,* 2014). The rice-based conventional cultivation methods include heavy water use and intensive tillage potentially damaging the soil quality and fertility. Besides this,the conventional method of cultivation has its own drawback in terms of labour, cost and energy-efficiency (Kumar and Ladha, 2011). These constraints call for an alternative cultivation practice that can be efficient in input use, as well as will sustain the soil health and fertility in the long run.

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Conservation agricultural practices combining minimal or no-tillage with adequate soil cover and crop diversification has arrived as an alternative practice for environmental and agricultural sustainability. Along with resource efficiency, these alternate systems enhance productivity (Gathala *et al.,* 2015), environmental stability (Singh *et al.,* 2016) and labour costs (Parihar *et al.,* 2016). Although conservation agriculture is not a foreign concept to Bengal agriculture, it has been mostly used in rice-wheat cropping systems. Very limited studies and reports speak about the potential of winter maize under conservation agricultural cultivation of rice fallows. It not only resonates a hope for meeting the projected demand for maize in India by the next thirty years but also places a scope for expanding the cultivated land areas by using the unused fallows.

Despite the potential of maize under conservation agriculture, there are yield variations when the crop is exposed to conservation tillage practices. The efficiency of different degrees of tillage and its influence over the soil properties and plant economy has been extensively studied. But the existing variations among the popular maize cultivars and HYVs have not been properly utilized to understand the genotype×tillage effects on the growth and yield characters of maize. To address these less-explored areas, an experiment was conducted in 2019 with five released winter maize varieties in two separate systems of no-tilled and partially tilled residue covered lands. The variation of growth characters was studied and correlated with yield. This study hypothesized that the residue-tillage effect may have altered the contribution of the characters towards yield shaping the final yield variations.

MATERIALS AND METHODS

Experimental location

This experiment was conducted in the Balindi Research Complex, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia in the state of West Bengal. The farm is located on a latitude of 22º95′ N and a longitude of 88º52′ E, around 10 m above mean sea level. The area lies under Southern parts of Bengal, belonging to the eastern Indo-Gangetic plains and the soil type was clayey loam. The experiment was conducted during the winter of 2018-2019.

Weather condition

Weather data was received from the surface weather station of Bidhan Chandra Krishi Viswavidyalaya. The crop received little rainfall of 13.80 mm and 31.50 mm in December and March and a good amount of rainfall in February accounting to 121.90 mm. Maximum temperature varied from 25°C in December to 31.5 °C in March and minimum temperature of 8°C in January to 16°C in March. The crop received a good amount of bright sunshine hours on an average of 7 hr. The monthly rainfall and relative humidity pattern of the winter season of 2018-2019 have been presented in Fig. 1a and Fig. 1b respectively.

Land preparation

The experimental plot was divided into three separate systems of cultivation. The two main treatment plots were subjected to zero tillage (ZT) and reduced tillage(RT) along with the control where the conventional tillage (CT) practices were followed. All three plots were rice fallows, preceded by *kharif* rice and subjected to rice-maize cropping sequence for this experiment. Land of the conventionally tilled plot followed primary tillage by two-pass broad tyne cultivator and secondary tillage by two-pass rotavator. The zero tilled plot had completely undisturbed soil with no manual or mechanical interference. However, the reduced tilled plot followed the same primary tillage with one pass broad tyne cultivator and one pass disc harrow as secondary tillage without the interference of the rotavator.To balance the undesirable initial effects of reduced or zero tillage, the rice plants of the preceding *kharif* season were cut from 15 cm above ground level during harvesting. Half (50%) of the remaining residual rice were retained in the experimental fields as a soil cover to increase organic matter and microbial activities inside the soil. The treatments of the experiment referring to the 'zero' or 'reduced tillage' system in the following sections will, therefore, mean the referred tillage degree combined with rice residue retention.

Treament 1 (T_1): CT: Conventional tillage + 0% rice residue retention

Treatment 2 (T_2): ZT: Zero tillage + 50% rice residue retention

Treatment 3 (T_3): RT: Reduced tillage + 50% rice residue retention

The other 50% residue was discarded to bring out the best effect of tillage and residue on the soil environment with as less interference in the sowing and other cultural practices as possible.

Plant materials and experimental method

Five released varieties of maize including cultivars and high yielders popularly cultivated in various districts of West Bengal were selected for the trial. The varieties were PAC 741, ADV 759, ADV 757, PAC 751 and ADV 9293. The varieties were sown in November 2018 following the split-plot design of experiment. The main plot was divided into three degrees of tillage and each of them was subdivided into subplots with five varieties. The spacing with 60cm row-to-row along with 20cm plant-to-plant distance was maintained in each block.

The sowing operation and fertilization were done with a multi-crop seed cum fertilizer drill. The fertilizer dose was given as per the recommended dose of 140:70:70 NPK kg ha^{-1}. Other regular crop management practices were followed.

Data collection and analysis

Data was recorded from each of the five varieties under the three tillage conditions (Treatments). The observations for each character were taken with three replicates or three individual plants from the middle rows of each plot to eliminate the border effects. The growth characters like plant height in centimeter (PH), leaf numbers (LN), root dry weight in grams (RDW) were recorded at the maximum vegetative stage (60 days from planting). Plant biomass (g) of each plant was taken at harvest maturity. The yield and yield attributes were taken during and after the harvest of each variety.The leaf area was calculated by multiplying the length of the leaf by the maximum width. The obtained value was again multiplied by a constant value of 0.73309 to get the leaf area (Gul *et al.,* 2015). Finally, the leaf area index (LAI) was calculated by dividing the total leaf area per plant by the ground area of each plant which is 1200 sq. cm. The roots were collected from the observed plant very carefully from each plot and they were cleaned with distilled water. All the mud and soil particles were removed from the root samples and they were oven-dried at 60^0C for nine days until the root dry weight was recorded. After the plants were fully matured at each plot, the whole plants including the leaves and stems were harvested. Those plant parts were tagged individually and subjected to oven-drying at 60^0C for around a week following the record of plant biomass (BM) to be taken. The recorded days to reach two important phenological stages were days to 50% silking (FPS) and days to maturity (DM). For recording yield attributes like seed numbers per cob (SNPC) and hundred seed weight in grams (SW), three plants from each plot were separately harvested and subjected to measurements. Three randomly selected areas of one square meter within each plot were selected. The cob numbers per meter square (CNPM) were recorded considering approximate 8 plants in each square meter of the plots.The grain yield from each plot was harvested and sun-dried. The yield per plot was separately taken from three different areas within each plot in kg per meter square and then converted to tonnes ha^{-1}.

The three types of tillage systems being considered as individual treatments were taken as the main factor, while the five varieties were taken as the sub-factor under the main factors. Data were analyzed using the split-plot design (two factor-analysis of variance) and the range of observations along with the mean±SE was compared across the treatments and varieties. The variances were analysed and treatments were compared using the least square difference at a 5% level of significance with the online statistical analysis package “OPSTAT”. The correlation matrices were built using Pearson correlation coefficients (r) between the characters with the help ofthe software “Graph Pad Prism version 8”. The regression analysis was also conducted with the representations of respective coefficients of determinations (R^2) on each association. The path diagrams for the two treatments were built with the help of “R-studio version 1.4.1717” with all the respective co-variances, direct and indirect effects considering yield as the dependent variable.

RESULTS AND DISCUSSION

Analysis of the growth and yield attributes under the three cultivation systems

All the observed growth and yield attributing characters of the five maize varieties were studied under the conventional, zero and reduced tilled systems. The cultivated systems were considered as the main plot treatment conditions exhibiting main effects while the varieties were considered as the sub-plots exhibiting sub-factor effect under the split-plot design. The present study exhibited significant variations for ten recorded growth and yield characters across the varieties and treatments (Table 1) suggesting that they are potential sources of variations and will be responsive to selection. Significant interaction effect between the varieties and treatments (G×T) also suggests useful variations to be found when the five varieties were grown across the three cultivations systems. However, leaf numbers per plant show no significant variations across the treatments, although presenting significant variations at the treatment × genotype interaction effect. The mean ± SE performances of the three treatments for all the characters were compared in Table 2, while the average performances of the five varieties concerning the growth and yield attributes were presented and compared in Table 3.

The average plant height was maximum under both the zero and reduced tillage systems (Table 2) and all the three varieties PAC 751, ADV 759 and ADV 9293 (Table 3) were showing maximum plant height at sixty days after planting. The leaf numbers were highest in ADV 9293 (17.78) and the lowest in ADV 759 (12.44), however, it had no significant variations across the three treatment conditions. Reduced tillage exhibited the highest average leaf area index of 6.00 while the zero tillage had the lowest leaf area index (5.01). Among the five varieties, ADV 9293 had the highest average leaf area index (6.34). Conventional tillage had presented the highest mean value (Table 2) of root dry weight (8.99g). The root dry weight was significantly reduced to 6.22g in zero tillage. Reduced tillage had the minimum average value of root dry weight of 3.10g. PAC 741 (8.57g) and ADV 9293 (7.27g) showing the highest root dry weight among the varieties. Early silking has been observed in zero tillage with the lowest days to fifty percent silking value. The flowering or silking time was also reduced in case of reduced tillage compared to conventional tillage but it was still higher than the zero tillage system. The varieties almost showed simultaneous maturity between conventional and reduced tillage systems. But the zero tillage shortened the average time of the plants to mature. PAC 741 was the earliest to flower as well as mature among the five varieties.From the average yield performances, it is observed that the reduced tillage system had given the highest average yield (14.48 t ha^{-1}) compared to the other two systems. The control plot or on the other term, the conventional system had the lowest yield (9.26 t ha^{-1}). Average cob numbers per meter square were more in the case of both the zero and reduced tillage compared to conventional tillage. The average seed numbers per cob were maximum under reduced tillage and the lowest in zero tillage. Seed weight also reflects the same trend with a maximum mean value under reduced tillage followed by zero tillage. The highest average yield of the three treatments was presented by PAC 751 (13.47 t ha^{-1}), however, based on the least square difference it can be stated that the yields of ADV 9293 (13.40 t ha^{-1}) and ADV 759 (12.35t ha^{-1}) are statistically at par with the highest average yield of PAC 751. Among the five varieties PAC 751, ADV 9293 and ADV 759 had the maximum cobs per meter square across the treatments and only PAC 751 and ADV 9293 had the maximum seed numbers per cob. The seed weight was the highest in the case of PAC 751 and the lowest in the case of the variety PAC 741.

Correlation analysis of the characters under the three systems

Correlation analysis is an important statistical viewpoint to understand the characteristics and degree of association between several selected characters. The analysis was performed on the ten growth and yield characters of the five maize varieties under each of the three treatments which are the three cultivation systems (conventional, zero and reduced tillage). Pearson correlation coefficient was calculated at the respective significance levels. The primary objective of performing correlation analysis under the three systems was to understand if the influence of the characters over each other and ultimately their influence on yield was shifting due to the interference of the treatment conditions.

Correlation under the conventional tillage

Under the conventional tillage (Table 4a), plant height shows a significant positive correlation with days to maturity (r = 0.954) and seed numbers per cob (r = 0.886). Leaf numbers have a significant positive correlation with yield (0.884). The leaf area index has significant positive correlation with days to 50% silking (r = 0.932), days to maturity (r = 0.915), cob numbers per meter square (r = 0.970), seed numbers per cob (r = 0.948) and yield (r = 0.983). The cob numbers per meter square show a significant positive correlation with seed numbers per cob (r=0.993) and both of the characters show a positive correlation with days to 50% silking and days to maturity as well as with seed weight and yield. Plant biomass has a significant negative correlation with all the characters except plant height and root dry weight. Root dry weight shows no significant correlation with any of the characters under conventional tillage. A significant positive correlation exists between seed weight and yield (r = 0.916) while a negative correlation is observed between plant biomass and yield (r = -0.984), and significant negative correlation is found between plant biomass and seed weight (r = -0.948).

Correlation under the zero tillage

Under the Zero tillage (Table 4b), plant height has significant positive correlation with root dry weight (r = 0.976), cob numbers per meter square (r = 0.975), seed numbers per cob (r = 0.975), seed weight (r = 0.973) and yield (r = 0.930). Plant biomass under zero tillage shows a significant negative correlation with leaf area index (r = -0.919) and days to maturity (0.932). Unlike the conventional system, root dry weight under zero tillage shows a significant positive correlation with cob numbers (r = 0.978), seed numbers per cob (r = 0.945), seed weight (r=0.973,) and yield (r = 0.988). Cob numbers per meter square have a positive correlation with seed numbers (r = 0.925), seed weight (r = 0.977) and yield (r = 0.953). Seed numbers per cob do not show any significant correlation with the duration but are correlated with seed weight (r = 0.970) and yield (r = 0.893,). Seed weight, also, is positively correlated (r = 0.945) with yield.

Correlation under reduced tillage

Reduced tillage system shows (Table 4c) significant positive correlation between plant height and leaf area index (r = 0.972), days to 50% silking (r = 0.897), cob numbers per meter square (r = 0.991), seed numbers per cob(r = 0.976), and yield (r = 0.909). Leaf area index has a significant positive correlation with cob numbers per meter square (r = 0.937), seed numbers per cob (r = 0.992) and yield (r=0.888). Root dry weight has no

Table 1: Two-way ANOVA with the mean sum of squares of the eleven characters of the five maize varieties under the three cultivation systems along with the least square differences

Sourcesof Variation	df	PH(cm)	LN	LAI	RDW(g)	FPS	DM	CNPM	SNPC	SW(g)	BM(g)	Yield (t ha^{-1})
Treatment	2	6063.73**	3.62	4.461**	130.15**	217.69**	359.02**	23.489*	40736.68**	131.76**	2934.48**	103.27**
Genotype	4	2902.10**	35.59**	5.07**	30.13**	94.06**	565.08**	28.522**	9706.65**	74.19**	2460.12**	34.74**
Treatment × Genotype	8	1056.00**	10.96**	1.279**	56.7**	22.86**	32.66**	6.489**	2964.54**	14.43**	425.19**	10.99**

[PH=plant height, LN=leaf numbers per plant, LAI=leaf area index, RDW=root dry weight, FPS=days to 50% silking, DM= days to maturity, CNPM=cob numbers per metre square, SNPC=seed numbers per cob, SW=100 seed weight, BM=plant biomass, Treatment= Main factor, Genotype=sub-factor; Treatment × Genotype=interaction effect, Significance level: $^{*}p<0.05$, $^{**}p<0.01$]

Table 2:The mean values of the observed growth and yield attributes across the three cultivation systems

Treatments	PH (cm)	LN	LAI	RDW(g)	FPS	DM	CNPM	SNPC	SW(g)	BM(g)	Yield (t ha^{-1})
CT	112.2	14.33	5.11	8.99	66.27	122.67	11.07	549.20	19.98	369.03	9.26
ZT	145.62	14.13	5.01	6.22	59.20	114.00	12.67	522.05	21.61	351.30	11.37
RT	148.28	15.07	6.00	3.10	65.20	122.27	13.53	622.77	25.73	378.91	14.48
SEm ±	**2.59**	**0.31**	**0.13**	**0.41**	**0.30**	**0.61**	**0.40**	**2.68**	**0.11**	**10.91**	**0.40**
LSD (0.05)	**10.436**	**NS**	**0.50**	**1.63**	**1.20**	**2.48**	**1.62**	**10.81**	**0.44**	**3.65**	**1.63**

[CT=conventional tillage, ZT=zero tillage, RT=reduced tillage, SEm=standard error due to mean, LSD(0.05)=least square difference at 5% level of significance]

Table 3:The mean values of the observed growth and yield attributes across the three cultivation systems

Varieties	PH(cm)	LN	LAI	RDW(g)	FPS	DM	CNPM	SNPC	SW(g)	BM(g)	Yield(t ha^{-1})
PAC 741	113.44	14.11	4.78	8.57	60.00	107.44	10.11	528.93	19.29	383.63	9.15
ADV 759	148.00	12.44	5.40	5.69	65.67	121.33	13.89	580.54	22.81	366.69	12.35
ADV 757	118.50	13.67	4.51	5.01	60.11	116.89	10.89	529.79	19.78	381.97	10.12
PAC 751	151.85	14.56	5.83	3.97	65.33	124.89	13.67	586.18	25.87	351.99	13.47
ADV 9293	145.03	17.78	6.34	7.27	66.67	127.67	13.56	597.92	24.45	347.79	13.40
SEm ±	**2.93**	**0.56**	**0.13**	**0.64**	**0.58**	**0.93**	**0.40**	**4.04**	**0.15**	**2.47**	**0.45**
LSD (0.05)	**8.60**	**1.65**	**0.39**	**1.86**	**1.70**	**2.73**	**1.19**	**11.86**	**0.45**	**7.24**	**1.33**

[LSD(0.05)=least square difference at 5% level of significance]

Table 4: Correlation matrices of the characters under three cultivation systems

(a) Correlation matrix of conventional tillage

	PH	LN	LAI	RDW	FPS	DM	CNPM	SNPC	SW	BM	Yield
PH	1										
LN	0.666	1									
LAI	0.835	0.871	1								
RDW	-0.873	-0.289	-0.488	1							
FPS	0.841	0.721	0.932*	-0.623	1						
DM	0.954*	0.714	0.915*	-0.784	0.964**	1					
CNPM	0.844	0.781	0.970**	-0.575	0.992**	0.957**	1				
SNPC	0.886*	0.739	0.948*	-0.664	0.995**	0.982*	0.993**	1			
SW	0.814	0.777	0.833	-0.670	0.922*	0.913**	0.900*	0.916*	1		
BM	-0.855	-0.914*	-0.949*	0.580	-0.926*	-0.927**	-0.944*	-0.937*	-0.948*	1	
yield	0.833	0.884*	0.983**	-0.526	0.961**	0.933**	0.982**	0.966**	0.916*	-0.984**	1

[Significance level: *$p<0.05$, **$p<0.01$]

(b) Correlation matrix of zero tillage

	PH	LN	LAI	RDW	FPS	DM	CNPM	SNPC	SW	BM	Yield
PH	1										
LN	0.341	1									
LAI	0.836	0.794	1								
RDW	0.976**	0.128	0.697	1							
FPS	0.750	0.731	0.867	0.626	1						
DM	0.782	0.400	0.780	0.727	0.400	1					
CNPM	0.975**	0.216	0.755	0.978**	0.606	0.829	1				
SNPC	0.975**	0.372	0.818	0.945*	0.838	0.643	0.925*	1			
SW	0.973**	0.235	0.746	0.973**	0.697	0.710	0.977**	0.970**	1		
BM	-0.754	-0.685	-0.919*	-0.633	-0.605	-0.932*	-0.728	-0.652	-0.636	1	
Yield	0.930*	-0.028	0.577	0.988**	0.515	0.671	0.953*	0.893*	0.945*	-0.530	1

[Significance level: *$p<0.05$, **$p<0.01$]

(c) Correlation matrix of reduced tillage

	PH	LN	LAI	RDW	FPS	DM	CNPM	SNPC	SW	BM	Yield
PH	1										
LN	-0.727	1									
LAI	0.972**	-0.633	1								
RDW	-0.428	0.824	-0.264	1							
FPS	0.897*	-0.613	0.811	-0.562	1						
DM	0.785	-0.365	0.689	-0.362	0.944*	1					
CNPM	0.991**	-0.789	0.937*	-0.544	0.924*	0.796	1				
SNPC	0.976**	-0.622	0.992**	-0.313	0.869	0.754	0.950*	1			
SW	0.784	-0.324	0.816	-0.232	0.852	0.792	0.765	0.873	1		
BM	-0.990**	0.674	-0.974**	0.412	-0.921*	-0.811	-0.980**	-0.991**	-0.863	1	
Yield	0.909*	-0.561	0.888*	-0.445	0.958*	0.865	0.912*	0.938*	0.955*	-0.955*	1

[Significance level: $*p<0.05$, $**p<0.01$]

significant correlation with any of the characters or with yield under reduced tillage. The days to 50% silking characters shows a positive correlation with yield (r = 0.958). Seed weight is also positively correlated with yield (r = 0.955). However, plant biomass under reduced tillage is negatively correlated with plant height (r = -0.990), leaf area index (r = -0.974), days to 50% silking (r = -0.921), cob numbers (r = -0.980), seed numbers (r = -0.991) and yield (r = -0.955).

Comparison of the three systems for the characters correlated with yield

Under the conventionally cultivated system (Table 4a), the yield is significantly correlated with all the observed characters except plant height and root dry weight. Both of them show no significant correlation with yield. However, under zero tillage (Table 4b), both of these traits have a shifted correlation towards yield having a significant positive correlation coefficient. All the other characters followed an almost similar correlation pattern with yield. The days to 50% silking and plant biomass those are positively and negatively correlated with yield respectively under conventional system shows no yield correlation under zero tillage. Plant height also exhibits a significant positive correlation with yield under reduced tillage, unlike conventional systems. Days to 50% silking follows the zero-tillage pattern and similarly remains uncorrelated with yield under reduced tillage (Table 4c). On the other hand, leaf numbers that shows a significant positive correlation with yield under the conventional system (Table 4a) have no yield correlation under any of the other conservation tillage systems. However, all the other characters have a similar correlation pattern as the conventionally cultivated system.

Path coefficient analysis of yield under the zero and reduced tillage systems

Path coefficient is important for understanding the associations between different factors in yield improvement, even those characters that contain minimum or no direct association with yield (Singh *et al.,*2020). Path coefficient analysis was conducted using yield as the dependent variable with ten growth and yield traits as independent characters. Correlation coefficients of the concerned characters were partitioned into direct and indirect effects. The independent variables were subjected to analysis of their direct and indirect effects on each other as well as yield (Fig. 2) under the two systems. The arrows show the path of direct and indirect effects of the concerned characters reflecting the cause and effect relationships in the model. The double-headed arrows pointing towards two different variables represent the co-variances between the two characters.

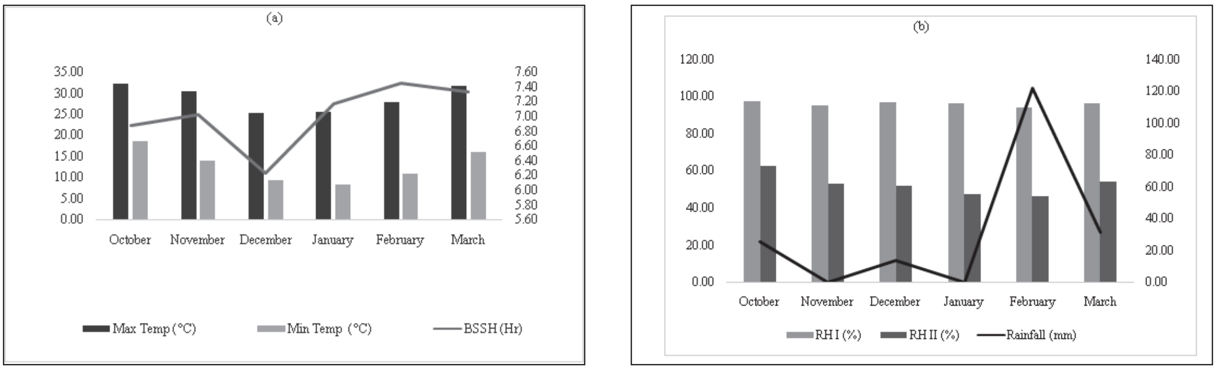

Fig. 1:The weather data of the *rabi* season of 2018-2019 showing (a) monthly rainfall pattern and (b) monthly relative humidity

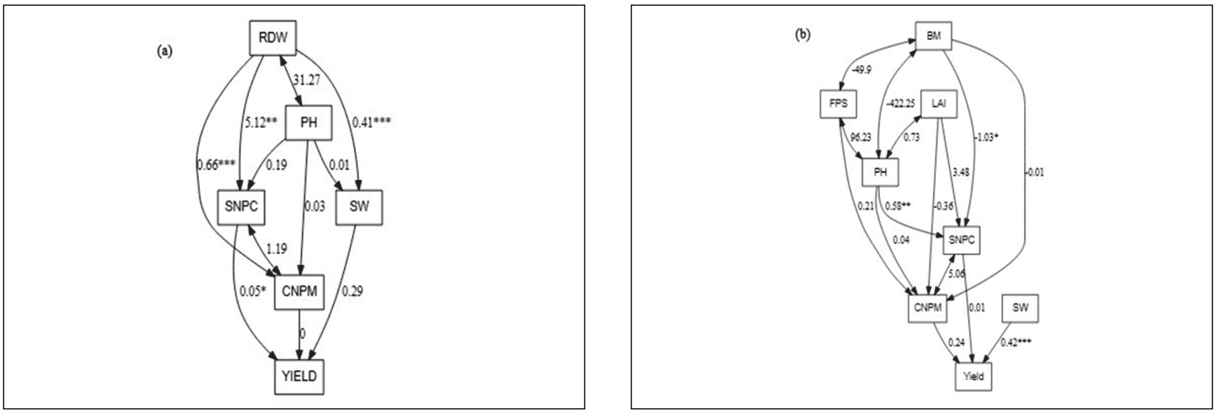

Fig. 2: The individual path diagram using yield as dependent variable under (a) zero (Residual = 0.387) and (b) reduced tillage system (Residual= 0.319); Significance level: ***p<0.01*, ****p<0.001*

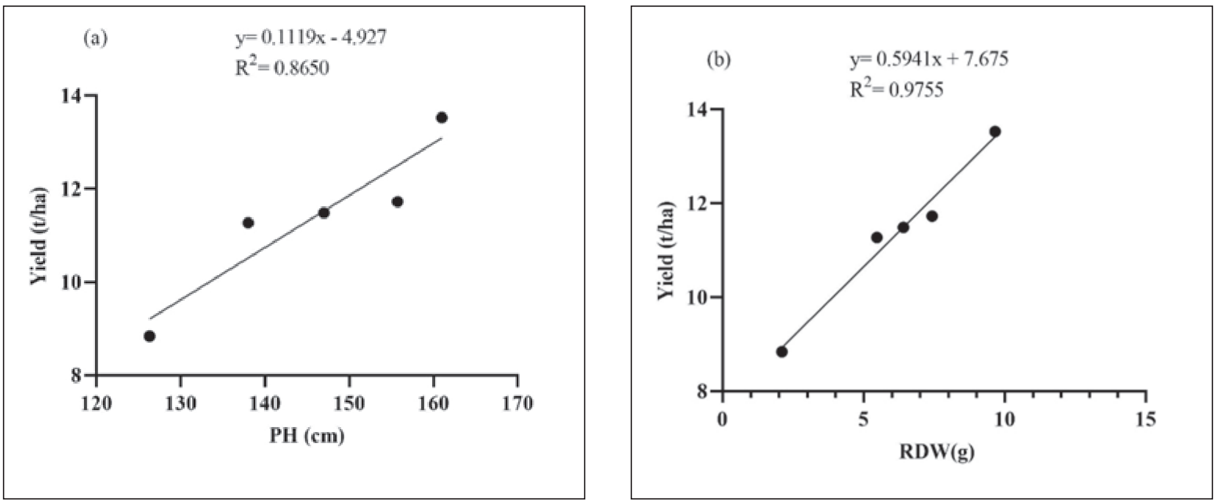

Fig. 3: Simple linear regression of dependent variable yield under zero tillage system against (a) plant height and (b) root dry weight

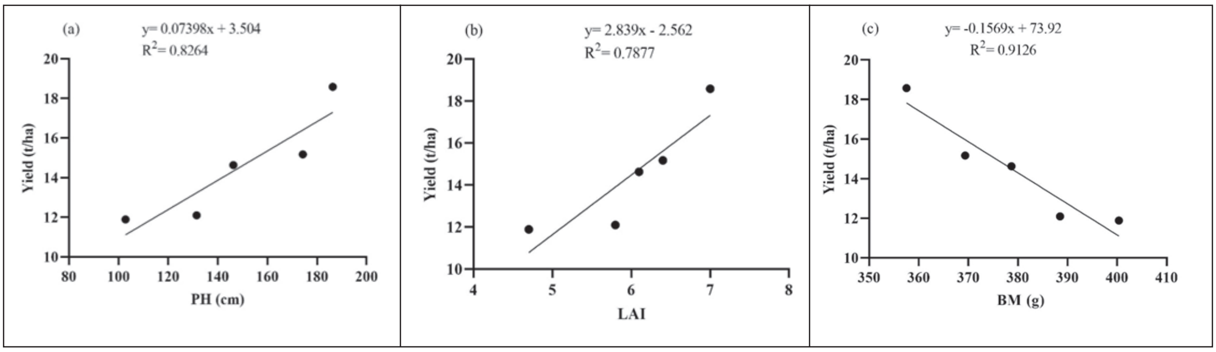

Fig. 4: Simple linear regression of dependent variable yield under reduced tillage system against (a) Plant height and (b) Leaf area index and (c) Plant biomass

From Fig. 2a, it is observed that root dry weight and plant height exhibit the highest amount of covariance together (31.27). Root dry weight has a strong and significant indirect effect on cob numbers per meter square (0.66) while it has a significant indirect effect on seed weight (0.41). A significant positive direct effect is observed between seed numbers per cob and yield (0.05). On the other hand, under reduced tillage (Fig. 2b), seed weight presents a significant positive direct effect (0.42) on yield, but it has no indirect relation to the other variables under the zero-tillage system. Plant height presents a positive indirect effect on seed numbers per cob (0.58). The highest covariance under reduced tillage was observed between plant biomass and plant height (-422.25). Plant biomass also has an indirect negative effect on seed numbers (-1.03). These results suggest plant height and root dry weight under zero tillage can be the potential targets for indirect selection confirming the previous regression models of zero tillage (Fig. 2). Also, under reduced tillage, plant height and biomass offer promising potential for the selection of suitable high yielding varieties. But the pattern between these characters and yield could not be predicted by path analysis.

Regression analysis of the characters under zero and reduced tilled systems

Regression analysis is commonly conducted to understand the association between the response variable and explanatory variable. Linear regression explains the change in the response variable 'y' with respect to the changes in intervention variable 'x' (Hair *et al.,* 2006). The approach helps to predict the response variable with the help of any explanatory variable. In this current study, yield was the major target for assessing the performance of any genotype under the specific cultivation system. However, selection based on yield is time-consuming, particularly for long breeding schemes under the specific tillage system. Therefore, the growth characters over the vegetative periods that have a significant positive or negative correlation with yield can be subjected to quicker selection. The variables taken into consideration for regression analysis were plant height and root dry weight under zero tillage system while plant height, leaf area index and plant biomass under reduced tillage systems. The plant height and root dry weight had previously been observed to have a positive correlation with yield (Table 4b) under zero tillage contrasting their no effect on yield under conventional tillage. The same shift of correlation pattern was found in the case of plant height under reduced tillage (Table 4c). Plant biomass was the only trait negatively correlated with yield under the reduced tillage system. Hence, these characters were picked up and were subjected to simple linear regression to understand their effect on the main dependent variable in this study which was yield.

Yield prediction under zero tillage

The strength of any linear model is usually explained through its R^2 value (Sellam, 2016). The value of R^2 is greater than 0.5 for both plant height (Fig. 3a) and root dry weight (Fig.3b) suggesting their very strong relationships with yield. In simpler terms, with the increase in plant height and root dry weight, the yield will go higher. Variations in plant height can explain the variations in yield upto 86.5% while yield variations can be predicted by root dry weight upto 97.55%.

Yield prediction under reduced tillage

Under the reduced tillage system, all the three characters that are plant height, leaf area index and plant biomass had very high R^2 values (Fig. 4) indicating their strong associations with yield. The plant height and leaf area index had a positive influence on yield predicting the variations up to 82% and 78% respectively. However, it is observed from the association of plant biomass and yield (Fig. 4c) that they negatively influenced one another with a very strong negative association. So, with a steep decrease in plant biomass, yield is expected to be having a major boost.

Therefore, the plant height was a common target of selecting good performing varieties under both the cultivation systems. However, root dry weight under zero tillage alone has distinguished potential to be used as a selection index and leave a considerably good scope for yield improvement beyond the other correlated characters under both the zero and conventional systems. Plant height, leaf area index and biomass all these three characters offers promising potential for the selection of suitable varieties under reduced tillage.

In a study by Govardhanrao and Venkata Ramana (2017), a steady improvement of yield and cropping pattern by maize production was observed under paddy fallow. They also reported a significant increase in cob numbers per plant and grain weight between conventionally cultivated maize and zero tilled maize. These findings stand aligned with the results obtained through this current study which states a 14% increase in the cob numbers per meter square under zero tillage over the conventional tillage and a 22% increase under reduced tillage. The seed weight however was vividly improved under reduced tillage by 28-29%. Meena *et al.* (2015) reported a significant increase in the root biomass under zero tillage, but in this study, only a decreased root dry weight was found under zero tillage. It may be due to the compaction effect of soil and less support from the retained residue under the new-born zero tillage system in this current study. It also throws light on the possible yield reduction in certain genotypes at these initial periods of conservation agriculture due to lower water and nutrient uptake from soil. From the above experiment, hence, it can be concluded that between the two systems of conservation agriculture, reduced tillage has presented better outcomes concerning both yield and growth characters of maize even in the constraining initial seasons. For the grain yield and some other attributes, it was not only better than zero tillage but also better than the performance of conventionally cultivated system. Among the five varieties, ADV 759, PAC 751 and ADV 9293 were the highest yielders and taking into account the other character performances these three varieties, especially PAC 751 and ADV 9293 can be advanced as the potential controls in the long-term research under conservation agriculture. Although the initial effect of conservation agricultural systems may vary over time, these findings are definitely indicators towards the direction or trend of these cultivation systems of maize and crop behaviour under these particular environments. However, further investigations under a gradually maturing conservation agriculture system will confirm the crop and system behaviours. The yield was the final and most important indicator of the performance of maize under the three different cultivation systems. However, for early selection and avoidance of ambiguity due to time, characters, in the above experiment, were investigated for their correlation, degree of association and direct and indirect effects on yield. This study suggests plant height and root dry weight of maize as the most important indicators of fitness and better yield under zero tillage that can erase the need of sole dependence on yield for understanding the crop response to tillage systems. Similarly, under reduced tillage, plant height, leaf area index and plant biomass can be good selection indices and offer the scope of potential improvement beyond the conventional tillage.

In the zero or reduced tillage, the physiology and phenology of the plants vary from the conventional methods. There are significant variations found in the Tillage×Genotype effect of the crop in almost all the characters including yield. The variations among the three tillage systems irrespective of genotypes were also significant suggesting some microclimatic players acting on the crop physiology, flowering time and maturity. These factors may be the prime changes in soil environment when intensity of tillage is dropped, or, the moisture retention, transpiration and cycling in the altered situation. These fluctuations changes the way a plant may yield in a given tillage system. This may be one important reason of the changing correlation patterns among the characters in different tillage systems.

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REFERENCES

Amarasinghe, U.A. and Singh, O.P. 2008. Changing consumption patterns of India: implications on future food demand In: Amarasinghe UA, Shah T, Malik RPS edited. *India's Water Future: Scenarios and Issues*. International Water Management Institute, Colombo, Sri Lanka. pp 131–146.

CRIDA. 2014. Annual Report. Central Research Institute for Dryland Agriculture. Hyderabad, India. pp 197.

Gathala, M., Timsina, J., Islam, M.D., Rahman, M.D., Mahbubur, M.R., Hossain, I., Harun-Ar-Rashid, M.D., Ghosh, A., Krupnik, T., Tiwari, T. and Mcdonald, A. 2014. Conservation agriculture based tillage and crop establishment options can maintain farmers' yields and increase profits in South Asia's rice–maize systems: Evidence from Bangladesh. *Field Crops Res.*, **172**: 85-98.

Govardhanrao, V. and VenkataRamana, P. 2017. Economic performance of zero tillage technology in maize under agency tracts of Andhra Pradesh. *Asian J. Agric. Ext.,***16**(4): 1-4.

Gul, S., Khan, M.H., Khanday, B.A. and Nabi, S. 2015. Effects of sowing methods and NPK levels on growth and yield of rainfed maize (*Zea mays* L.). *Scientifica*, 2015: 1-6.

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E. and Tatham, R.L. 2006. Multivariate data analysis. 6th ed. Pearson Education Inc.

Jat, R.K., Sapkota, T.B., Singh, R.G., Jat, M.L., Kumar, M. and Gupta, R.K. 2014 Seven years of conservation agriculture in a rice–wheat rotation of Eastern Gangetic Plains of South Asia: Yield trends and economic profitability. *Field Crop Res.,* **164**: 199-210.

Kumar, V. and Ladha, J. 2011. Direct seeding of rice, recent developments and future research needs. *Adv. Agron.*, **111**: 297-413.

Maize outlook report. 2021. Agricultural Market Intelligence Centre, ANGRAU, Hyderabad, India.

Meena, J.R., Behera, U.K., Chakraborty, D. and Sharma, A.R. 2015. Tillage and residue management effect on soil properties, crop performance and energy relations in greengram (*Vigna radiata*). *Int. Soil Water Conserv. Res.,* **3**(4): 261-272.

Parihar, C.M., Jat, S.L., Singh, A.K., Kumar, B., Singh, Y., Pradhan, S., Pooniya, V., Dhauja, A., Chaudhary, V., Jat, M.L., Jat, R.K. and Yadav, O.P. 2016. Conservation agriculture in irrigated intensive maize-based systems of north-western India: Effects on crop yields, water productivity and economic profitability. *Field Crops Res.,* **193**: 104-116.

Ravenscroft, P., Burgess, W.G., Ahmed, K.M., Burren, M. and Perrin, J. 2005. Arsenic in groundwater of the Bengal Basin, Bangladesh: distribution, field relations, and hydrogeological setting. *Hydrogeo*, **13**: 727-751.

Sellam, V. and Poovammal, E. 2016. Prediction of crop yield using regression analysis. *Indian J. of Sci. Technol.*, **9**(38):1-5.

Singh, D.P., Singh, H.B. and Prabha, R. 2016. A Book Review on Microbial Inoculants in Sustainable Agricultural Productivity- Vol. II: Functional Application 2.

Singh, S., Habde, S., Singh, D., Khaire, A., Mounika, K. and Majhi, P. 2020. Studies on character association and path analysis studies for yield, grain quality and nutritional traits in F2 population of rice (*Oryza sativa* L.). *Electronic J. Pl. Breed*, **11**:969-975.

Timsina, J., Buresh, R.J., Dobermann, A. and Dixon, J. 2011. Rice-maize Systems in Asia In: Current Situation and Potential. IRRI-CIMMYT joint publication. pp 235.