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Impact of tillage practices and planters on productivity, soil parameters, nutrient uptake and economics in *rabi* maize (*Zea mays* L.)

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ABSTRACT: As the world's population grows, agriculture is facing an increasing demand for productivity, efficiency, and sustainability to ensure food security. It is the need of the hour and a challenge to change the agricultural strategy for increasing crop yields through appropriate mechanization to meet the food grain requirement of the ever increasing population. High labor demands in peak period of each operation adversely affect the timeliness of operations there by reducing the crop yield. In any agricultural operation, timeliness of operations is one of most important factors which can only be achieved if an appropriate machine is engaged. Seed planting is a major step in crop production stages that requires timeliness of operation. It is tedious, less efficient and time-consuming especially when done manually. Modernization of agriculture necessitates appropriate machinery for enhancing resource use efficiency and productivity in agriculture especially the more precise the planting operation, the better the quality and quantity of crop harvested. Further, conservation agriculture holds tremendous potential for all sizes of farms and agro-ecological systems, but its adoption is perhaps most urgently required by small holder farmers, especially those facing acute shortage of labour. Further, recycling of crop-residues in the soil is a promising option for replenishing soil fertility, improving physico-chemical properties, and enhancing/sustaining crop yield. In this regard, present investigation was set to study the Impact of tillage practices and planters on productivity, soil parameters, nutrient uptake and economics in *rabi* maize (*Zea mays* L.). The experiment was carried out at Maize Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad, Telangana State in spilt plot design with 3 main treatments of tillage practices *viz.*, conventional, reduced and zero-tillage and 5 sub treatments of different planting options of planters *viz.*, multi-crop vacuum planter, mechanical planter, seed-cum-fertilizer drill and convention planting options of bullock drawn plough and manual sowing and replicated thrice in clay loam soils during *rabi* 2021-22. The study revealed that, significantly higher productivity and nutrient uptake was observed in *rabi* maize sown with multi-crop vacuum planter under conventional tillage practice rather than reduced and zero-tillage practices. Zero-tillage practice shown promise for better soil aggregation and organic carbon content with reduced energy inputs. In general, mechanical methods of sowing incurred lower costs than conventional methods. Over all, higher B:C ratio recorded with conventional tillage practice compared to reduced and zero-tillage treatments.

Keywords: Multi-crop vacuum planter, soil penetration resistance, organic carbon, bullock drawn plough, conventional tillage, zero tillage.

INTRODUCTION

Maize is a miracle crop grown in varied climatic conditions for food, fodder, feed and industrial purpose. Worldwide, maize is cultivated in nearly 185 m ha area with a production of 1070 m t and average productivity of 5.6 t ha^{-1}. It is cultivated in 9.2 m ha with 27.8 mt production and average productivity of 2.96 t ha^{-1}, (Directorate of Economics and Statistics, GoI 2020). In Telangana State it is cultivated in a total area of 6.35 lakh ha, out of which 3.86 lakh ha during *kharif* under rain fed and around 2.491akh ha during *rabi* under irrigated conditions (2019-20). Most of our state farmers are small or marginal and constitute 80% of total holdings. Conventional practices are followed for most of maize farms *viz*., seed bed preparation, sowing, inter-cultivation, harvesting and threshing which consume maximum time, energy, cost and drudgery to the growers. High labour demands in each operations in peak period adversely affect the timeliness of operations by reducing the crop yield. In any agricultural operation, timeliness of operations is one of the most critical factors which can only be achieved if an appropriate machine is engaged. Although the maize production in 2021 is 28.5 mt, the demand is increasing in our country; and hence, there is a need for mechanization. Using improved implements can increase productivity up to 30 % and reduce the cost of cultivation up to 20 %. The estimated percentage of agricultural workers in the total work force would drop to 25.7 % by 2050 from 58.2 % in 2001. Average farm power availability for the country's cultivated areas has increased from 0.295 Kw ha^{-1} in 1971 to 2.02 Kw ha^{-1} in 2017 (Manpreet *et al.,* 2019).

Besides, Farm mechanization, Conservation agriculture practices including zero- tillage and minimum tillage reduce operational costs that including machinery, labour and fuel while increasing yields and better utilizing natural resources. Conservation agriculture holds tremendous potential for all sizes of farms and agro-ecological systems, Still, its adoption is perhaps most urgently required by small holder farmers, especially those facing an acute labor shortage. In the long term, Zero-till maize-based crop rotation reported an increase in the soil organic matter content through efficient management of crop residue and improved soil biological properties, microscopic bio-diversity, soil is enhanced by soil micro fauna which includes bacteria, fungi, nematodes, and enzyme activity (Aikins *et al*., 2020) Minimum tillage involves considerable soil disturbance, though much less than that associated with conventional tillage (Choudhary and Behera 2020).

The growing population and reducing land available for agriculture is insisting mechanised agriculture to meet the food demand. The higher energy requirements of modern agricultural implements and the increasing cost of energy is making farmers look for implements/machines that have lower energy demand to reduce the overall cost of production (Bovas *et al*., 2022). Modernization of agriculture necessitates appropriate machinery for enhancing resource use efficiency and productivity, especially the more precise the planting operation, the better the quality and quantity of crop harvested. The problems associated with manual sowing are no control over the depth of seed placement, no uniformity in the distribution of seed placement, loss of seeds, no proper germination of seeds, during sowing placement of seeds at uneven depth may result in poor emergence, more labour and time required for sowing can be overcome by mechanical precise planting (Ahmed *et al*., 2021). Improved efficiency in planting. increased yielding and reliability in crop. During *kharif* sowing, placement of seeds at uneven depth may result in poor emergence because subsequent rains bring additional soil cover over the seed and affect plant emergence. Proper compaction over the seeds is provided (Rajavel *et al*., 2018).

Proper use of mechanized inputs into agriculture has a direct and significant effect on production, productivity and profitability on agriculture farms, along with labor productivity and quality of life of people engaged in agriculture (Clarke, 2000). For tilled land with flat surface and appropriate planting condition, high-efficiency and high-speed precision planters are usually applied. As for no/minimum-tilled land, because of the existence of residue, anti-blocking devices are necessarily mounted on planters to cut or clean residue (Yang *et al*, 2016). Currently, various planters which have different types of seed metering mechanisms are available, to evaluate the suitability along with weeding, harvesting and threshing machines in maize. 60-70% of the farmers in some districts of Telangana State are using bullock drawn ploughs for sowing maize. Sowing with planters saves 91.80 % time compared to maize sown with traditional methods (Narang *et al*., 2015). Hypothesis of the present study is with the use of various machines in conservation, reduced, zero tillage lowers production cost enhances the productivity, precision, timeliness and efficient use of various crop inputs and improves farm income. Hence, the present Research project has taken with an objective to study the feasibility of different planters under different tillage practices on productivity, soil parameters and nutrient uptake of *rabi* maize.

MATERIALS AND METHODS

A field experiment was conducted during the *rabi* season of 2021-22 at Maize Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad with fifteen treatments, laid out in a split-plot design with three replications. The soil of the experimental site was clay loam in texture and slightly alkaline in reaction (pH 7.94), low in organic carbon (0.45 %), low in available nitrogen (228 kg ha^{-1}), high in available Phosphorus (86 kg ha^{-1}) and available Potassium (370 kg ha^{-1}) with Electrical Conductivity of 0.21 ds m^{-1}. As it was *rabi* crop, seven irrigations were provided during the crop duration. Treatments included were three Tillage practices (i) M_1 = Conventional tillage, (ii) M_2= Reduced tillage and (iii) M_3 = Zero-tillage as main plot treatments and five Planters S_1- Multi-crop vacuum planter, S_2-Mechanical planter, S_3 - Seed- cum- fertilizer drill, S_4- Bullock drawn plough and S_5 - Manual sowing randomly placed in sub-plots of the main plot.

A medium duration (105 days) Maize hybrid DHM-121 was sown in the field with a seed rate of 20 kg ha^{-1}, maintaining 60 cm × 20 cm as spacing at a depth of 2-5 cm. A short- duration green gram crop was raised as a bulk during *kharif* season and followed by a maize crop under irrigated conditions during the *rabi* season after practicing different tillage treatments. The crop was fertilized with 240:80:80 kg (100 % RDF) of Nitrogen, Phosphorus and Potassium ha^{-1} in the form of Urea, DAP and MOP and all the recommended package was adopted for plant protection. Besides planters for sowing operation other mechanical interventions were also adopted for weeding (power weeder and pre and post-emergence herbicides), inter cultivation (Mini tractor drawn inter cultivator), harvesting (Single row maize grain harvester) and threshing and shelling (Dehusker-cum-sheller). The growth and yield parameters were recorded as per the procedure on a net plot basis. (Benefit: Cost ratio) was calculated by dividing the gross returns by the cost of cultivation.

RESULTS AND DISCUSSION

A. Soil Parameters

Conservation tillage systems that leave crop residues on the soil surface stabilized the soil moisture and temperature, an improvement of aggregate stability and an increase in soil organic matter.

i) Soil penetration resistance. The data pertaining to soil parameters *viz*., penetration resistance, soil aggregates, organic carbon content and post-harvest soil available nutrients presented in Table 1. Tillage practices significantly influenced soil penetration resistance. The zero- tillage treatment recorded significantly highest soil penetration resistance (1.93 milli pascals) compared to conventional tillage treatment (1.05 milli pascals). Planters influenced the soil penetration resistance significantly. As general principle that, the soil penetration resistance vary in accordance with depth of sowing (Abbas *et al*., 2022). Accordingly, crop sown with bullock drawn plough was recorded significantly highest soil penetration resistance (1.83 milli pascals) might have due to higher depth of sowing compared to other mechanical planters. The interaction effect due to tillage practices and planters on soil penetration resistance was non-significant.

The lower growth of maize in zero- tillage may be ascribed to greater soil bulk density and soil penetration resistance which adversely affects the root growth resulting less nutrients removal from soil and high crop-weed competition. Low emergence count in zero tillage might be due to more compact soil and less soil-seed contact.

ii) Soil aggregates. The tillage practices influenced the soil aggregates significantly with highest soil aggregates (>0.25 mm %) of 43.95 % was observed with maize under zero- tillage treatment. Further, planters influence the percent soil aggregates significantly and highest soil aggregates % was recorded in maize sown with multi- crop vacuum planter (43.43 %) which is on par with manual sowing (41.53 %). Lowest soil aggregates % was recorded in plots sown with bullock drawn plough (35.84 %).

Table 1: Influence planters under different tillage practices on soil parameters.

Treatments	Soil penetration resistance (milli pascals)	Soil aggregates (>0.25 mm %)	Organic carbon content (%)	Soil Available N (kg ha^{-1})	Soil Available P (kg ha^{-1})	Soil Available K (kg ha^{-1})
Main-plots: Tillage practices						
M_1- Conventional Tillage	1.05	35.89	0.45	231.33	86.06	356.53
M_2- Reduced Tillage	1.43	38.65	0.46	232.20	86.80	357.33
M_3- Zero -Tillage	1.93	43.95	0.48	233.06	87.73	357.46
SE(m)±	0.05	0.65	0.01	0.22	0.22	0.16
CD (P=0.05)	0.21	2.63	0.023			
Sub-plots: Planters						
S_1- Multi-crop vacuum planter	1.28	43.43	0.48	230.44	86.11	356.33
S_2- Mechanical planter	1.39	39.32	0.45	232.77	86.33	357.00
S_3- Seed-cum- fertiliser drill	1.53	37.35	0.46	232.66	87.22	357.33
S_4- Bullock drawn plough	1.83	35.84	0.44	234.22	88.00	358.11
S_5- Manual sowing	1.33	41.53	0.47	230.88	86.66	356.77
SE(m)±	0.10	1.18	0.01	0.53	0.32	0.21
CD (P=0.05)	0.30	3.48	NS	1.55	0.94	0.62
Interaction						
Sub treatment at same level of main treatment						
SE(m)±	0.16	1.95	0.015	0.49	0.49	0.36
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Main treatment at same/different level of sub treatment						
SE(m)±	0.11	1.46	0.016	0.49	0.49	0.36
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Lowest soil aggregates % was recorded in plots sown with bullock drawn plough (35.84 %). However, the interaction effect between planters and tillage practices on percent soil aggregates was found to be non-significant. Similar findings reported by Çelik *et al*. (2011).

iii) Post-harvest available nutrients. The post-harvest available soil nutrients (N, P_2O_5 and K_2O) were influenced by tillage practices and planters. Tillage practices did not showed conspicuous change in soil available nutrients however, zero-tillage treatment recorded marginally higher available soil nitrogen, phosphorus and potassium and followed by reduced tillage compared to conventional tillage.

Planters influence the available nutrients at harvest significantly. Among planters bullock drawn plough treatment recorded significantly higher soil available nitrogen, phosphorus and potassium respectively and lower with multi- crop vacuum planter treatment.

Overall, the post-harvest soil data indicated that, there was marginal increase with a tune of 4-5 kg in available phosphorus and potassium. Whereas decrease in available nitrogen status compared to initial soil nutrient status, which might due to exhaustive nature of maize crop.

iv) Organic carbon content. Perusal of the data indicated that tillage practices influence organic carbon content significantly. Among tillage practices zero-tillage treatment recorded significantly higher organic carbon content (0.48 %) and lower in conventional tillage treatment (0.45 %). Planters could not influence the available soil organic carbon content significantly. The interaction effect due to tillage practices and planters on soil organic carbon was non- significant. Zero-tillage resulted in higher organic carbon content, better aggregation, C content and N availability in soil, and reduced the energy inputs. Similar findings reported by Meena *et al*. (2015).

B. Yield

Effect of tillage practices significantly influenced the grain yield (Table 2). Among, different tillage practices, the conventional tillage treatment recorded significantly highest grain yield (9519 kg ha^{-1}) which was on par with reduced tillage treatment (8697 kg ha^{-1}) and out yielded zero-tillage treatment (7759 kg ha^{-1}). Planters influenced the maize grain yield significantly. Among different planters evaluated, maize sown with improved multi- crop vacuum planter realized highest grain yield (9047 kg ha^{-1}) which was on par with manual sowing treatment (8877 kg ha^{-1}) and mechanical planter (8705 kg ha^{-1}). However, lowest grain yield was recorded with bullock drawn plough under conventional method of sowing (8153 kg ha^{-1}). The interaction effect due to tillage practices and planters on grain yield was found to be significant (Table 3). Irrespective of planters, maize sown under conventional tillage realized significantly higher grain yield compared to reduced and zero-tillage practices. Irrespective of tillage practices maize sown with multi-crop vacuum planter recorded higher grain yield compared to mechanical planter, seed-cum-fertilizer drill and conventional methods *viz*., bullock drawn plough. In turn, mechanical planter and seed-cum-fertilizer drill registered on par grain yields under reduced and zero-tillage practices. In contrast, under zero-tillage the conventional method of sowing recorded higher grain yield compared to mechanical sowing. The significantly higher grain yields were observed with multi-crop vacuum planter (10283 kg ha^{-1}) sown under conventional tillage practice. This could be ascribed that, the fine soil tilth and perfect land levelling were pre-requisite for better germination and establishment and ultimately final grain yield. Interaction effect might be due to the fact that efficient utilization of resources including available soil moisture, nutrients and solar energy at all stages of crop growth and lower weed infestation under conventional tillage practice resulted in better plan growth, maximum dry matter accumulation and higher yield attributes. These results are in conformity with the findings of Kumar *et al*. (2018), Anjum *et al*. (2014) and Karki *et al*. (2014). Further, sowing maize with improved planters was provided accurate and precise rate of seed placement with considerable reduction in problems associated with the manual methods of seed planting such as poor seed placement, poor spacing efficiency, and serious farm drudgery. Similar findings reported by Elijah *et al*. (2018) and Manjeet *et al.* (2018).

C. Nutrient Uptake

Nutrient uptake by crop is an important factor that determines the yield. Nitrogen is an essential nutrient required for vegetative growth of the crop which determines the dry matter production as well as the final yield. The tillage practices influenced the total nitrogen uptake at harvest significantly (Table 1) and highest nitrogen uptake at harvest recorded in conventional tillage practice (101.62 kg ha^{-1}) and lower uptake in zero-tillage practice (89.76 kg ha^{-1}). Nitrogen uptake at harvest was significantly influenced by planters and significantly highest nitrogen uptake at harvest recorded in maize sown with multi-crop vacuum planter (100.50 kg ha^{-1}) which is on par with manual sown plots (98.54 kg ha^{-1}). It was in tune with final yield and lowest in bullock drawn plough plots (90.43 kg ha^{-1}).

Highest phosphorus uptake at harvest recorded in conventional tillage practice (32.04 kg ha^{-1}) and lower in zero- tillage practice (27.70 kg ha^{-1}). In similar trend as with nitrogen uptake, significantly higher phosphorus uptake at harvest recorded with multi- crop vacuum planter sown plots (31.31 kg ha^{-1}) followed by mechanical planter (28.54 kg ha^{-1}) and lower phosphorus uptake in bullock drawn plough plots (25.15 kg ha^{-1}).

Potassium plays major role in regulation of water in plants, activation of enzymes, protein and starch synthesis and imparts drought resistance to plants. As similar as nitrogen and phosphorus uptake, the highest potassium uptake at harvest also recorded in conventional tillage (97.80 kg ha^{-1}) and lower potassium uptake at harvest recorded in zero-tillage treatment (86.53 kg ha^{-1}). Planters influenced the total potassium uptake at harvest significantly. Highest potassium uptake at harvest recorded with multi-crop vacuum planter (99.00 kg ha^{-1}) followed by mechanical planter (90.33 kg ha^{-1}) and lower phosphorus uptake at harvest recorded with bullock drawn plough (85.77 kg ha^{-1}). Zero-tillage resulted in higher organic carbon content, better aggregation, C content and N availability in soil, and reduced the energy inputs. Similar findings reported by Meena *et al*. (2015).

C. Economics

The planters and tillage practices adopted should also be economically reasonable for a farmer in order to reduce their input cost without sacrificing yields. The data with respect to cost of cultivation, gross return, net return and benefit cost ratio of maize are presented in Table 2.

In general, mechanical methods of sowing incurred lower costs than conventional methods. It has been reported that planters provide desired plant population with uniform plant spacing and depth of operation, which results in uniform crop stand and hence, reduced cost of cultivation is achieved due to elimination of thinning operation as well as savings of seed and fertilizer. Higher cost of cultivation incurred in conventional tillage practice (Rs. 62110 ha^{-1}) compared to zero-tillage practice (Rs. 54410 ha^{-1}). Among planters higher cost of cultivation incurred in conventional sowing methods by manual (Rs. 69986 ha^{-1}) and bullock drawn plough (Rs. 60286 ha^{-1}) with higher labour cost. Similar results were reported by Manjeet *et al*. (2018).

Gross returns related economic yield and prevailing market price, higher yields in conventional tillage practice along with multi- crop vacuum planter, manual sowing treatments recorded higher gross returns. Similar results reported by Anjum *et al*. (2014).

Net returns, depends on gross returns and cost of cultivation. Higher gross returns along with lower cost of cultivation leads to higher net returns. Higher gross returns, lower cost of cultivation observed in mechanical sowing treatments which in turns gives higher net returns. These results tend to support the results of Manjeet *et al*. (2018).

Over all, higher B:C ratio recorded with conventional tillage practice (2.36) compared to reduced and zero-tillage treatments. Among planters higher B:C ratio recorded with seed- cum- fertilizer drill (2.54) which is followed by multi-crop vacuum planter (2.53) and mechanical planter treatment (2.37).

Table 2: Influence planters under different tillage practices on grain yield, nutrient uptake and economics in *rabi* maize.

Treatments	Grain yield (kg ha^{-1})	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	Cost of cultivation (Rs.ha^{-1})	Gross returns (Rs.ha^{-1})	Net returns (Rs.ha^{-1})	Benefit: Cost ratio
Main-plots: Tillage practices								
M_1- **Conventional Tillage**	9519	101.62	32.04	97.80	62110	186777	124667	2.36
M_2- **Reduced Tillage**	8697	94.49	31.02	91.93	59610	170640	111030	2.22
M_3- **Zero –Tillage**	7759	89.76	27.70	86.53	54410	152243	97833	2.16
SE(m)±	337	1.60	0.76	0.56	--	--	--	--
CD (P=0.05)	998	6.47	3.06	2.29	--	--	---	--
Sub-plots: Planters								
S_1- **Multi-crop vacuum planter**	9047	100.50	31.31	99.00	55186	127500	122314	2.53
S_2- **Mechanical planter**	8705	94.46	28.54	90.33	54866	167009	112143	2.37
S_3- **Seed- cum- fertiliser drill**	8512	92.51	27.49	89.66	53226	170794	117568	2.54
S_4- Bullock drawn plough	8153	90.43	25.15	85.77	60286	159959	99673	1.99
S_5- Manual sowing	8877	98.54	30.23	95.66	69986	174171	104185	1.81
SE(m)±	177	1.87	0.71	1.65	--	--	---	---
CD (P=0.05)	519	5.49	2.09	4.89	--	--	---	--
Interaction								
Sub treatment at same level of main treatment								
SE(m)±	398	3.31	1.70	2.62				
CD (P=0.05)	1266	NS	NS	NS				
Main treatment at same/different level of sub treatment								
SE(m)±	553	3.50	1.30	1.27				
CD (P=0.05)	1050	NS	NS	NS				

Table 3: Interaction effect of tillage practices and planters on grain yield (kg ha^{-1}) of maize.

Treatments	Planters					
Tillage practices	Grain yield (kg ha^{-1})					
	S_1-Multi-crop vacuum planter	S_2-Mechanical planter	S_3-Seed- cum-fertilizer drill	S_4-Bullock drawn plough	S_5-Manual sowing	Mean
M_1- **Conventional Tillage**	10283	9538	9273	8393	10110	9519
M_2- **Reduced Tillage**	9378	8529	8790	8277	8512	8697
M_3-**Zero -Tillage**	7479	7469	8052	7788	8010	7759
Mean	9047	8512	8705	8153	8877	
	SE(m)±			CD (P=0.05)		
Tillage practices (M)	337			998		
Planters (S)	177			519		
Sub treatments (S) at same main treatments (M)	554			1050		
Main treatments (M) at same or different sub treatments (S)	369			1266		

CONCLUSION

Based on the present investigation, it can be concluded that maize sown with multi-crop vacuum planter under conventional tillage realized significantly higher grain yield, nutrient uptake and benefit cost ratio. Further, Zero-tillage resulted in higher organic carbon content, better aggregation, C content and N availability in soil, and reduced the energy inputs.

FUTURE SCOPE

The planters and harvesting machines has to be fine tuned for their suitability in small land holdings. More emphasis has to be given to develop planters suitable for reduced and zero-tillage conditions to cut down the cost of cultivation in view of saving time, energy and labour.

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