

Performance of Planters Under Different Tillage Practices on Growth, Yield, Energy Use Efficiency and Economics of Rabi Maize (*Zea mays L.*)

Comment [WU1]: In what geo edaphic condition???

Comment [WU2]: Ecology of study???

Comment [WU3]:

ABSTRACT

Aim: To evaluate the performance of planters under different tillage practices on growth, yield, energy use efficiency and economics of *rabi* maize.

Study design: Split-plot

Place and Duration of Study: Maize Research Centre, ARI, Rajendranagar between November 2021 and April 2022.

Methodology: A field experiment was conducted at Maize Research Centre, ARI, Rajendranagar, Hyderabad, Ranga Reddy (District) during *rabi* 2021-22 to evaluate the performance of planters under different tillage practices on growth, yield, energy use efficiency and economics of *rabi* maize in sandy clay loam soils. The experiment was assigned in fifteen treatments, laid out in split-plot design with three replications. Treatments included were three tillage practices, (i)M₁=Conventional tillage, (ii)M₂=Reduced tillage and (iii)M₃=Zero-tillage in main plots and evaluated 5 planters viz., (i)S₁=Multi-crop vacuum planter (ii)S₂=Mechanical planter, (iii)S₃=Seed-cum-fertiliser drill, (iv)S₄=Bullock drawn plough and (v)S₅=Manual sowing were randomly placed in sub-plots of the main plot.

Results: Interaction between planters and tillage practices realized significantly higher grain yield (10283 kg ha⁻¹) when the *rabi* maize was sown with Multi-crop vacuum planter under conventional tillage practice compared to bullock drawn plough. However, it was comparable with Mechanical planter and manual sowing under conventional tillage as well as under reduced tillage practices. Irrespective of the planters significantly lower grain yield was obtained under zero-tillage practice. Overall, the cost of cultivation was high with conventional sowing practices (bullock drawn plough/manual sowing compared to mechanical sowing with improved planters. Higher net returns were observed with multi-crop vacuum planter under conventional tillage practice (Rs.1,43,179 ha⁻¹)

Conclusion: In case of labour shortage, sowing with multi-crop vacuum planter or Mechanical planter instead of sowing with conventional practices like bullock drawn plough and manual sowing can save time, labour, reduce drudgery as well as production costs. Thus, we can effectively carry out important field operations viz., sowing, weeding and harvesting in time without much delay through mechanization in maize.

1. INTRODUCTION

Maize is the miracle crop grown in varied climatic conditions for food, fodder, feed and industrial purpose. Worldwide, maize is cultivated nearly 185 m ha area with a production of 1070 mt and an average productivity of 5.6 t ha⁻¹. In India, it is being cultivated in 9.2 m ha with 27.8 mt production and having an average productivity of 2.96 t ha⁻¹,

(Directorate of Economics and Statistics, Gol 2020). In Telangana State, it is cultivated in a total area of 6.35 l ha, out of which 3.86 l ha during *kharif* under rainfed and around 2.491 ha during *rabi* under irrigated conditions (2019-20). In Telangana State, the rainfed maize realizing low yield levels of 4.9 t ha⁻¹, where in winter maize under irrigated conditions realizes 7.0 t ha⁻¹. Majority of the farmers in our State are small or marginal and constitute 80 % of total holdings. Conventional practices are followed for most of farm operations in maize, viz., seed bed preparation, sowing, inter cultivation, harvesting and threshing which consume maximum time, energy, cost as well as drudgery to the growers. High labour 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. 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. Use of improved implements has potential to increase productivity up to 30% and reduce cost of cultivation up to 20%. Estimated percentage of agricultural workers in total work force would drop to 25.7% by 2050 from 58.2% in 2001. Average farm power availability for the cultivated areas of the country has been increased from 0.295 kW ha⁻¹ in 1971 to 2.02 Kw ha⁻¹ in 2017 (Manpreet *et al.* [8]).

Besides, Farm mechanization, Conservation agriculture practices including zero-tillage and minimum tillage reduce operational costs that include machinery, labour, fuel while increasing yields and better utilizing natural resources. 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. On long term, Zero-till maize-based crop rotation reported a increase in the soil organic matter content through efficient management of crop residue and improves soil biological properties, microscopic bio-diversity and enzyme activity (Aikins *et al.* [1]) Minimum tillage involves considerable soil disturbance, though to a much lesser extent that associated with conventional tillage. Minimum tillage is aimed at reducing tillage to the minimum necessary for ensuring a good seed bed, rapid germination, a satisfactory crop stand and favorable growing conditions (Choudhary and Behera [3]).

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. Currently, there are various types of planters which have different types of seed metering mechanisms are available, to evaluate the suitability of the planters along with weeding, harvesting and threshing machines in maize. 60-70% of the farmers in in some districts of Telangana State are using bullock drawn ploughs for sowing maize. Hence, the present Research project has under taken with an objective to study the feasibility of different planters under different tillage practices on growth, yield, energy requirement, labour saving and cost economics of *rabi* maize.

2. MATERIAL AND METHODS

A field experiment was conducted during *rabi* season of 2021-22 at Maize Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad with fifteen treatments, laid out in split-plot design with three replications. The soil of experimental site was Sandy clay loam in texture and slightly alkaline in reaction (pH 7.94), high in organic carbon (0.98%), medium in available nitrogen (290.5 kg ha⁻¹) and available Phosphorus (40.5 kg ha⁻¹) and high in available Potassium (400.8 kg ha⁻¹) with Electrical Conductivity of 0.21 ds m⁻¹. Treatments included were three Tillage practices (i) M₁ = Conventional Tillage, (ii) M₂ = Reduced Tillage and (iii) M₃ = Zero -Tillage as main plot treatments of and five Planters S₁ - Multi-crop vacuum planter, S₂ - Mechanical planter, S₃ - Seed- cum- fertiliser drill, S₄ - Bullock drawn plough and S₅ - Manual sowing randomly placed in sub-plots of the main plot.

Comment [WU4]: Role of zero tillage in conservation of micro fauna % & flora of that soil

Comment [WU5]: Impact on organic matter???

Comment [WU6]: Some back ground of research???

Comment [WU7]: Problem statement???

Comment [WU8]: Hypothesis of study???

Comment [WU9]: Objective of study???

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 x 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 maize crop under irrigated conditions during *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 in net plot basis. (Benefit: Cost ratio) were calculated by dividing the gross returns with cost of cultivation. Finally, Input and out energy involved in maize production was calculated to arrive energy ratio as well as energy productivity. The saving of labour and time for different farm operations. in both mechanized and conventional practices were also assessed.

$$\text{B:C ratio} = \frac{\text{Gross returns (Rs ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs ha}^{-1}\text{)}}$$

3. RESULTS AND DISCUSSIONS

3.1 Growth parameters

The data presented in (Table 1) revealed that, Conventional and reduced tillage practices had shown significant difference among growth parameters of maize compared to Zero-tillage practice. The M₁ Conventional tillage treatment recorded significantly higher plant height (193.80 cm), Leaf area (398.06 cm²) and dry matter production (15622 kg ha⁻¹). Among the different types of planters sowing with multi crop vacuum planter has recorded significantly higher plant height (199.77 cm), leaf area (413.55 cm²) and dry matter production (15701 kg ha⁻¹). The increase in plant height in conventional tillage maize could be ascribed to reduced crop weed competition, better aeration, soil moisture, nutrient availability and in turn better root growth resulted in significantly higher values of all the parameters of crop growth. Similar findings were reported by Anjum *et al.* (2) and Karki *et al.* (6) Even though the crop growth parameters were comparable with manual sowing, Multi crop vacuum planters provide accurate and precise rate of seed placement and saving in seed rate compared to conventional methods. The planter was able to correct the 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.* (5) and Manjeet *et al.* (7).

3.2 Yield attributes and yield

The conventional tillage has recorded Significantly higher number of plants ha⁻¹ (79094), number of cobs ha⁻¹ (76028.27), number of grain rows cob⁻¹ (15.60), number of grains row⁻¹ (36.13), test weight (36.58 g), cob length (19.36 cm), cob girth (15.89 cm) was observed in Conventional tillage practice (M₁) followed by Reduced tillage practices (M₂). (Table 2&3). However, it is superior over zero-tillage. Among sub-plots S₁= multi crop vacuum planter recorded significantly higher yield (9046.89), number of plants ha⁻¹ (77015), number of cobs ha⁻¹ (77855), number of grain rows cob⁻¹ (15.55), number of grains row⁻¹ (36.77), test weight (37.75 g), cob length (20.44 cm), cob girth (15.85 cm) (Table 2 & 3) However, the maize grain yield is statistically on par with manual sowing (8877 kg ha⁻¹). The interaction effect due to tillage practices and planters on grain yield (kg ha⁻¹) was significant. Maize crop sown with Multi-crop vacuum planter (S₁) under Conventional tillage (M₁) practice produced significantly higher grain yield (10283 kg ha⁻¹). Interaction effect might be due to the fact that good pulverization of soil under conventional tillage contributed to better crop establishment with optimum plan population, efficient utilization of resources including available soil moisture, nutrients and solar energy at all stages of crop growth and lower weed infestation. and finally has realized increase in grain yield. Similar findings were reported by Anjum *et al.* (2). Multi crop vacuum planters provide accurate and precise rate of seed placement. The

Comment [WU10]: Nature of soil???

Comment [WU11]: Soil texture % & structure??

Comment [WU12]: No of irrigation % & amount of water in each irrigation???

Comment [WU13]: Need each parameter more discussion with comparison with past review

planter was able to correct the problems associated with conventional practices of seed planting such as poor seed placement, poor spacing efficiency, and serious farm drudgery. Similar findings were reported by Elijah *et al.* (5) and Manjeet *et al.* (7).

3.3 Harvest index

The data presented in (Table 3) visualize that the tillage practices did not have a conspicuous effect on harvest index, but the harvest index was influenced significantly by planters. The higher harvest index was noted with planters under S1,S2,S3 treatments might be ascribed due to mechanical harvesting of the crop has realized lower stover yields. In contrary, due to manual harvesting, higher stover yields were realized under S4 and S5 treatments and hence, the noted lower harvest index.

3.4 Economics

Conventional tillage (M_1) registered higher net returns (Table 3) and least net returns and B:C ratio was observed with Zero tillage (M_3) among the tillage practices. Among sub-plots significantly higher net returns, B:C ratio was observed with multi-crop vacuum planter treatment. The least net returns were observed in Bullock drawn plough treatment (S_4) due to higher missing index, multiple index there by registered less plant population and over all yield. Maize under conventional tillage coupled with multi crop vacuum planter recorded significantly higher gross returns, net returns and B:C ratio due to vigorous plant growth, higher nutrient uptake improving translocation of photosynthates for elevated yield components production and higher seed yields resulting in higher monetary returns and B:C ratio. These results tend to support the results of Manjeet *et al.* (7) and Anjum *et al.* (2).

3.5 Energy Use Efficiency

Interms of Energy requirement, the higher total input energy (22599 MJ ha^{-1}) in maize production was in mechanized practice than in Conventional practice(20952 MJ ha^{-1}) where in higher total out put energy was in conventional practice due to higher stover yields and hence, realized higher energy ratio(11.31%) and energy productivity(0.42 kgMJ^{-1})(Table 6). The increased use of inputs such as fertilizer, irrigation water, diesel, plant protection chemicals, electricity etc. demands more energy in the form of human, animal and machinery. Diesel and fertilizers contribute more than 50% of total energy input. These results tend to support the results of Sefeedpari *et al.* (10)

Table 1. Growth parameters of maize as influenced by tillage practices and planters.

Treatments	Plant height (cm)				Leaf area (cm ²)				Dry matter production (kg ha ⁻¹)			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
Tillage practices												
M ₁	25.06	145.80	178.66	193.80	96.77	216.29	382.06	398.06	558.26	3837.06	14487.33	15622.00
M ₂	23.98	139.93	172.53	187.33	95.55	209.73	363.53	377.73	523.20	3606.20	13778.07	14772.60
M ₃	22.48	135.33	166.66	181.33	89.86	188.04	354.53	368.06	508.73	3471.40	13261.93	14530.33
SE(m)±	0.46	1.69	1.85	2.30	0.87	4.53	4.70	1.83	8.31	42.68	213.13	205.21
CD (P=0.05)	1.87	6.84	7.47	9.27	3.53	18.29	18.97	7.38	33.51	60.36	859.29	827.35
Planters												
S ₁	26.56	151.33	180.11	199.77	99.78	219.88	396.00	413.55	600.11	3951.44	14186.78	15701.78
S ₂	22.11	130.11	169.77	178.77	92.46	192.41	347.88	352.11	482.77	3427.88	13656.33	14530.78
S ₃	23.18	141.33	172.88	184.66	93.55	210.33	367.55	382.55	524.55	3604.88	13899.33	14828.56
S ₄	21.50	129.55	163.00	176.88	89.22	187.55	338.00	349.44	462.55	3322.55	13363.89	14314.89
S ₅	23.58	149.44	177.33	197.33	95.28	213.26	384.55	408.77	580.33	3884.33	14105.89	15498.89
SE(m)±	0.66	2.58	3.34	3.60	2.13	4.14	6.76	7.16	18.37	99.76	180.03	264.62
CD (P=0.05)	1.94	7.58	9.82	10.58	6.25	12.15	19.87	21.03	53.95	141.08	528.62	776.99
Interaction												
SE(m)±	1.12	4.34	5.50	6.03	3.14	7.85	11.94	11.25	18.58	160.34	351.02	458.45
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SE(m)±	1.03	3.79	4.14	5.14	1.96	10.14	10.52	4.09	29.65	95.44	476.59	458.87
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: M₁ = Conventional tillage, M₂ = Reduced tillage, M₃ = Zero tillage, S₁ = Multi crop vacuum planter, S₂ = Mechanical planter, S₃ = Seed cum fertilizer drill, S₄ = Bullock drawn plough, S₅ = Manual sowing, cm- centimeter, DAS-Days after sowing, NS- Non significant

Table 2. Effect of tillage practices and planters on yield attributes of maize.

Treatments	No. of Plants ha ⁻¹	No. of cobs ha ⁻¹	No. of grain rows cob ⁻¹	No. of grains row ⁻¹	Test weight (100 seed) (g)	Cob length (cm)	Cob girth (cm)
Tillage practices							
M ₁	79094	76028.27	15.60	36.13	36.58	19.36	15.89
M ₂	73217	72251	15.20	34.73	35.17	18.16	15.43
M ₃	65914	64724	13.33	32.80	30.93	17.33	13.94
SE(m)±	1852	1647	0.308	0.36	0.29	0.35	0.36
CD (P=0.05)	7470	6643	1.24	1.48	1.18	1.44	1.47
Planters							
S ₁	77015	82107	15.55	36.77	37.75	20.44	15.85
S ₂	72213	65684	14.22	34.00	30.89	17.22	14.76
S ₃	73767	70981	15.11	34.77	35.11	17.96	15.07
S ₄	64844	60593	13.33	32.33	29.88	16.80	14.18
S ₅	75870	75639	15.33	34.88	37.50	19.01	15.55
SE(m)±	1553	1893	0.51	0.92	0.53	0.34	0.25
CD (P=0.05)	4562	5559	1.50	2.72	1.55	1.00	0.74
Interaction							
SE(m)±	3037	3364	0.85	1.48	0.87	0.63	0.53
CD (P=0.05)	10157	10762	NS	NS	2.67	NS	NS
SE(m)±	4143	3684	0.68	0.82	0.65	0.80	0.81
CD (P=0.05)	8999	10491	NS	NS	2.81	NS	NS

Note: M₁ = Conventional tillage, M₂ = Reduced tillage, M₃ = Zero tillage, S₁ = Multi crop vacuum planter, S₂ = Mechanical planter, S₃ = Seed cum fertilizer drill, S₄ = Bullock drawn plough, S₅ = Manual sowing, g- grams, cm- centimeter, NS- Non significant

Table 3. Effect of tillage practices and planters on yield and economics of maize.

Treatments	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Harvest index (%)	Cost of cultivation (Rs ha ⁻¹)	Gross returns (Rs ha ⁻¹)	Net returns (Rs ha ⁻¹)	B:C ratio
Tillage practices							
M ₁	9519.73	6840.73	58.45	62110.00	186777.20	124667.20	2.36
M ₂	8697.26	6738.47	56.74	59610.00	170640.40	111030.40	2.22
M ₃	7759.60	6611.33	54.48	54410.00	152243.30	97833.36	2.16
SE(m)±	247.63	119.61	1.03	-	4857.98	4858.40	0.08
CD (P=0.05)	998.37	NS	NS	-	19585.60	19587.31	NS
Planters							
S ₁	9046.89	5913.89	60.22	55186.00	177500.00	122314.00	2.53
S ₂	8512.22	5510.00	60.58	54866.00	167009.80	112143.80	2.37
S ₃	8705.11	5397.67	61.68	53226.00	170794.30	117568.30	2.54
S ₄	8152.89	8305.33	49.43	60286.00	159959.70	99673.68	1.99
S ₅	8877.22	8524.00	50.87	69986.00	174171.10	104185.10	1.81
SE(m)±	176.91	137.12	0.63	-	3470.86	3470.92	0.06
CD (P=0.05)	519.42	400.17	1.84	-	10191.08	10191.25	0.17
Interaction							
SE(m)±	369.36	237.50	1.09	-	7246.55	7246.91	0.12
CD (P=0.05)	1266.40	NS	NS	-	24844.77	24846.25	NS
SE(m)±	553.72	267.46	2.35	-	10862.78	10863.73	0.18
CD (P=0.05)	1050.54	NS	NS	-	20611.12	20611.70	NS

Note: M₁ = Conventional tillage, M₂ = Reduced tillage, M₃ = Zero tillage, S₁ = Multi crop vacuum planter, S₂ = Mechanical planter, S₃ = Seed cum fertilizer drill, S₄ = Bullock drawn plough, S₅ = Manual sowing, kg ha⁻¹ - Kilogram per hectare, Rs ha⁻¹ - Rupees per hectare, NS- Non significant

Table 4. Interaction effect of tillage and planters on grain yield (kg ha⁻¹) of maize

Tillage practices	Planters					
	S ₁ - Multi-crop vacuum planter	S ₂ - Mechanical planter	S ₃ - Seed- cum- fertiliser 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	8511	8697
M ₃ - Zero –Tillage	7479	7469	8051	7788	8010	7759
Mean	9046	8512	8705	8152	8877	
	SE(m)±			CD (P=0.05)		
Tillage practices (M)	247			998		
Planters (S)	176			519		
Sub (S) at same main (M)	553			1050		
Main (M) at same or different sub (S)	369			1266		

Note: M₁ = Conventional tillage, M₂ = Reduced tillage, M₃ = Zero tillage, S₁ = Multi crop vacuum planter, S₂ = Mechanical planter, S₃ = Seed cum fertilizer drill, S₄ = Bullock drawn plough, S₅ = Manual sowing, kg ha⁻¹- Kilogram per hectare, Rs ha⁻¹- Rupees per hectare, NS- Non significant

Table 5. Interaction effect of tillage and planters on test weight of maize

Tillage practices	Planters					
	S ₁ -Multi-crop vacuum planter	S ₂ -Mechanical planter	S ₃ -Seed- cum-fertiliser drill	S ₄ - Bullock drawn plough	S ₅ - Manual sowing	Mean
M ₁ -Conventional Tillage	39.43	33.53	37.96	33.60	38.40	36.58
M ₂ -Reduced Tillage	38.36	32.97	35.16	31.23	38.13	35.17
M ₃ -Zero –Tillage	35.46	26.16	32.21	24.83	35.96	30.93
Mean	37.75	30.89	35.11	29.88	37.50	
	SE(m)±		CD (P=0.05)			
Tillage practices (M)	0.29		1.18			
Planters (S)	0.53		1.55			
Sub (S) at same main (M)	0.65		2.81			
Main (M) at same or different sub (S)	0.87		2.67			

Note: M₁ = Conventional tillage, M₂ = Reduced tillage, M₃ = Zero tillage, S₁ = Multi crop vacuum planter, S₂ = Mechanical planter, S₃ = Seed cum fertilizer drill, S₄ = Bullock drawn plough, S₅ = Manual sowing, kg ha⁻¹ - Kilogram per hectare, Rs ha⁻¹ - Rupees per hectare, NS- Non significant

Table 6: Energy utilization in maize production under different tillage practices and planters

Treatments	Total Input energy (MJ ha ⁻¹)	Total output energy (Mjha ⁻¹)	Energy ratio (%)	Energy productivity (kgMJ ⁻¹)
Main plots: Tillage practices				
M ₁	21999.52	225449.30	10.29	0.43
M ₂	21959.26	212080.70	9.45	0.38
M ₃	21891.09	196707.80	9.03	0.34
SEm±	-	2985.43	0.19	0.012
CD (P=0.05)	-	12036.19	0.74	0.05
Sub-plots: Planters				
S ₁	22584.24	206912.90	9.17	0.40
S ₂	22591.41	194004.70	8.59	0.37
S ₃	22599.21	195436.00	8.65	0.38
S ₄	21022.21	223664.10	10.24	0.37
S ₅	20952.72	237045.20	11.31	0.42
SE(m)±	-	3353.78	0.20	0.009
CD (P=0.05)	-	9847.28	0.59	0.028
Interaction				
SE(m)±	-	5992.29	0.35	0.019
CD (P=0.05)	-	NS	NS	NS
SE(m)±	-	6675.64	0.42	0.027
CD (P=0.05)	-	NS	NS	NS

Note: M₁ = Conventional tillage, M₂ = Reduced tillage, M₃ = Zero tillage, S₁ = Multi crop vacuum planter, S₂ = Mechanical planter, S₃ = Seed cum fertilizer drill, S₄ = Bullock drawn plough, S₅ = Manual sowing, kg MJ⁻¹- Kilo gram per mega joules, MJ ha⁻¹- Mega joules per hectare, NS- Non significant, %- percentage

Table7: Requirement of Man days and time in Mechanized vs Conventional practices

	Field operations	Machinery used	Mechanized practice		Conventional practice	
			Man days (ha ⁻¹)	Time taken (hr ha ⁻¹)	Man days (ha ⁻¹)	Time taken (hr ha ⁻¹)
A	Sowing	Planters	1	2.5-3.0	--	--
		Bullock drawn	--	--	3	5
		Manual	--	--	16	8
B	Weeding	Power weeder	3	5	--	--
		Mini tractor drawn inter rcultivator	2	3.5	--	--
		Manual	--	--	24	12
C	Harvesting	Single row maize grain harvester	4	5	-	--
		Manual	--	--	24	8
D	Threshing and Shelling	Maize Dehusker-cum sheller	6	1.5	--	--
		Manual	--	--	18	10
	Total(A+B+C+D)		16	18	85	43
E	Common field operations(Bunds and channels formation, Irrigation, Spraying of herbicide and pesticide(two times),fertilizer application (4 times)		20	20	20	20
F	Post-harvest operations(cleaning,bagging and transport)		16	12	16	12
	GrandTotal(A+B+C+D+E+F)		52	50.0	121	75.0

Note One man day =6 hrs

3.6 Time and Man days

The data presented in Table(7) indicated that, there was a saving of 69 man days ha⁻¹(81%) and 25 hours (58%) time with mechanized practices compared to conventional practices. Further, overall saving of 57% in man days and 33.3% in time was observed in mechanized practices compared to conventional practices in maize production. These results tend to support the results of Muhieldeen *et al.* (9)

4. CONCLUSION AND RECOMMENDATIONS

Sowing with multi-crop vacuum planter or mechanical planter can save time, labour, seed rate, reduce drudgery and overall production costs. Hence, Mechanization with planters along with other mechanical interventions for weeding, harvesting and shelling is a viable option for maize cultivation

ETHICAL APPROVAL

No ethical issues were reported during the research work.

REFERENCES

1. Aikins KA, Diogenes LA, Jensen TA, John B. Advances in residue management mechanisms of zero-tillage planters. An ASABE Meeting Presentation. 2020;Paper No: 1700449.
2. Anjum SA. Morphological and phenological attributes of maize affected by different tillage practices and varied sowing methods. *American Journal of Plant Sciences*. 2014;5: 1657-1664.
3. Choudhary RL, Behera UK. Conservation agriculture and nitrogen management in maize–wheat cropping system: effect on growth, productivity and economics of wheat. *International Journal of Chemical Studies*. 2020;8(2): 2432-243.
4. Clarke LJ. Strategies for agricultural mechanization development: the roles of the private sector and the government. Agricultural Support Systems Division,FAO Publication, 2000; Rome, Italy.
5. Elijah AA, Adejoke DA, Bernard O. Development of a self propelled multi crop two rows precision planter: a new design concept for the metering mechanism. *International Journal of Mechanical Engineering and Technology*. 2018;9(10): pp.349-358.
6. Karki TB, Nirmal G, Jiban S. Systems optimization through tillage and residue management and cropping system in maize based system. *International Journal of Current Microbiology and Applied Sciences*. 2014. Volume 3: pp.990-1002.
7. Manjeet S, Mahesh K, Apoorv P, Karun S, Pramod KM. Comparative field performance of pneumatic planters for planting of maize crop. *Agricultural Engineering Today*. 2018; Vol. 42(3).
8. Manpreet J, Bhathla S, Ramanjit K.Improved technologies for higher maize production, maize Production. 2019; (<https://www.intechopen.com>).
9. Muhieldeen OA, Eldin S, Mohamed A, Yousif E. Comparision of different planting machines with manual sowing for sorghum crop in central of sudan. *International Journal of Engineering Research and Technology*. 2020; 2278-0181.
10. Sefeedpari P, Shahin R, Seyyed HPK, Mohammad G. A source-wise and operation-wise energy use analysis for corn silage production, a case study of Tehran province, Iran. *International Journal of Sustainable Built Environment*. 2012; 1, 158-166.

Comment [WU14]: Tally each refrence with text

Comment [WU15]: Reference formate is according to journal????