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Optimizing Establishment Methods and Weed Management Practices on Growth, Yield and Economics of Maize under Irrigated Condition

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

To study the performance of different crop establishment techniques and weed management practices on growth, yield attributes, yield and economics of maize hybrid, field experiment was conducted during *Summer* 2023 season.The treatment comprised of different sowing methods *viz*.,

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pneumatic precision planter, manual rotary dibbler and manual dibbling and these treatments were compared with varied weed management practices such as pre-emergence (PE) application with atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS + power weeding at 20 and 40 DAS, pre-emergence (PE) application with atrazine 50 % WP @ 0.75 $kgha^{-1}$ at 3 DAS + hand weeding at 20 and 40 DAS and pre-emergence (PE) application with atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS + early post-emergence (EPoE) application with topramezone 33.6 % SC @ 25.2 g ha^{-1} at 20 DAS. The results revealed that manual dibbling under conventional levelled ridges and furrows and pre-emergence application of atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS through drone followed by power weeding at 20 and 40 DAS recorded the highest vigour index, root length, volume and biomass. Early field emergence was noticed with manual dibbling under ridges and furrows which wasfollowed by pneumatic precision planter. However, higher LAI was recorded under manual rotary dibbler followed by pneumatic precision planter. Pre-emergence application of atrazine 50 % WP @ 0.75 $kgha^{-1}$ at 3 DAS + hand weeding at 20 and 40 DAS had significantly less weed density and dry weight and the next best treatment was pre-emergence application with atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS + power weeding at 20 and 40 DAS. Significantly higher grain and stover yieldwas obtained under manual rotary dibbler treatment which was at par with pneumatic precision planter. Highest net returns and benefit cost ratio were observed with manual rotary dibbler followed by atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS + power weeding at 20 and 40 DAS.

Keywords: Vigour; crop establishment; mechanization; yield; economics.

1. INTRODUCTION

Maize (*Zea mays L*.) is one of the most versatile and multifaceted crop which has wider adaptability under varied agro-climatic conditions. Globally, maize is known as the queen of cereals owing to its highest genetic yield potential. Currently, 1147.7 million tonnes of maize produced across 170 countries in an area of 193.7 million ha with an average productivity of 5.75 t ha^{-1} [1]. In India, maize is cultivated in an area of 9.9 million ha with a production of 31.5 million tonnes [2]. In Tamil Nadu, maize is grown in an area of 4.0 lakh ha with a production of 2.56 million tonnes during 2020-21 with an average productivity of 6.41 t ha^{-1}. Maize is the most resource-use efficient, high yielding crop and is extensively used in livestock sector thus, it could be best integrated with livestock and poultry components ensuring doubling the farmer's income under integrated farming system. Therefore, demand of maize is rising every year in Tamil Nadu and in future also its requirement would be higher due to progressive growth in poultry sector. Consequences of this, area under maize cultivation in Tamil Nadu is increasing exponentially both in rainfed and irrigated situations.

Farm mechanization and crop productivity have positive correlation, as farm mechanization saves time, labour, reduces drudgery and cut down production cost in the long run, which reduces post-harvest losses, boosts crop output and farm income. According to World Bank, half of the Indian population would live in urban areas by the year 2050 and therefore, it is estimated that percentage of agricultural workers in total work force would drop from 58.2% in 2001 to 25.7% by 2050 [3]. This shows the need to enhance the level of farm mechanization in the country.

Mehta et al., [4] reported that high adoption level of farm mechanization in different field operations in maize cultivation in the order of seed bed preparation (60%), planting (40%) weeding, plant protection (30%), harvesting and threshing (30%). Maize seeds are relatively bolder in size and normally sown at wider spacing which facilitated easy weeding and inter cultural operations through implements. Moreover, maize cobs are placed well above the ground is amenable to harvesting mechanically [5]. Spraying plant protection chemicals through manual sprayer is laborious, time consuming and cumbersome. Now a days, spraying costs towards application of herbicides, insecticides and fungicides are higher than the chemical cost owing to escalation of labour wages. Moreover, non-availability and shortage of labours during pest outbreak period further worsen the problem. Under these circumstances, drone would be the one of the viable proposition against labour drudgery. Better crop establishment and subsequent crop stand are critical requirements for obtaining higher crop productivity [6]. In maize, weeds considered to be an important factor which influence the crop productivity and among the different weed management options, chemical weed management combined with

cultural practices are turning out to be more reliable owing to its labour efficiency, time saving and economic weed suppression [7].

Weed infestation particularly during critical period of crop growth is a significant barrier to the production of maize and reduced maize yield by 24-83 percent [8,9]. Considering all these facts, field trial was carried out to develop technology capsule for mechanization in maize for crop establishment and weed control for enhancement of productivity, profitability and drudgery reduction.

2. MATERIALS AND METHODS

Field experiment was conducted during *Summer* 2023 season at *Field No. 37, Eastern Block,* Central Farm Unit, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, India to find out suitable crop establishment techniques and weed management method in maize for higher productivity and profitability. The Experiment consisted of the following treatments *viz*., M_1 - sowing by pneumatic precision planter under laser levelled plot, M_2 - sowing by manual rotary dibbler under laser levelled plot, M_3 - manual dibbling under conventional levelled ridges and furrows as main plot treatments and S_1 – pre-emergence (PE) application of atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS followed by power weeding at 20 and 40 DAS, S_2 - pre-emergence (PE) with atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS followed manual weeding at 20 and 40 DAS and S_3 - pre-emergence (PE) with atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS and early post-emergence (EPoE) application with topramezone 33.6 % SC @ 25.2 gha^{-1} at 20 DAS as sub-plot treatments. The trial was conducted in split plot design with three replications. The soils of experimental field represent the clay loam type. The available nutrient status of the field was low in N (246 kg ha^{-1}), medium in phosphorus (19 kg ha^{-1}) and high in potash (353 kg ha^{-1}) and determined in laboratory [10,11,12]. The seeds of short duration maize hybrid CO (H) M 8 were utilized for this study. Tractor drawn pneumatic precision planter and manual operated rotary dibbler were used for sowing operation under laser levelled plots and these sowing methods were compared with manual dibbling in ridges and furrows method of land configuration under conventionally levelled plot. Pre-emergence herbicide (atrazine) was applied on 3 DAS while early post-emergence herbicide (topramezone) was sprayed on 20 DAS and these operations were carryout by drone. Battery driven (16000 mAh, 25.4 V) Agricultural Drone Sprayer (Model Hexa-copter) with 10 litre tank capacity, 4 T-JET nozzles and flying speed of 4 m/sec was utilized for spraying pre-emergence and early post-emergence herbicides. Seed rate under different crop establishment techniques in this study revealed that 21.0 kg, 24.0 kg and 20.0 was used in pneumatic precision planter, manual rotary dibbler and manual dibbling, respectively. Required plant population was maintained by thinning and gap filling at 10 days after sowing (DAS). Recommended doses of organic manure such as FYM @ 12.5.0 t ha^{-1} including inorganic fertilizers (250:75:75 kg NPK ha^{-1}) were applied along the planting rows as urea and single super phosphate and muriate of potash and covered with top soil. Nitrogen was applied in three splits *viz*., 25 % N as basal and 50 % N at 25 DAS and remaining 25 % of N at 45 DAS, whereas, entire dose of phosphorus and muriate of potash were applied as basal. All other plant protection measures were adopted as prophylactic measures to check the incidence of major pests. During the cropping period a total of 178.9 mm was received with 15 rainy days. No rainfall was received at the time of sowing to peak vegetative period. Whereas, a continuous dry spell of 7 days during cob formation and 15 days at grain filling stages was noticed. During the dry period, totally 15 irrigation was given through drip (half an hour per day with a capacity of 9 LPH) to maintain soil moisture at field capacity and as a result, 375 mm of water was given to maize hybrid through drip system. In total, 553.9 mm of water was supplied through rainfall and supplemental irrigation during crop life cycle. Root length, was recorded with a scale at 25, 45 and 65 DAS and expressed in cm. Similarly, root volume was measured with a measuring cylinder at 25, 45 and 65 DAS by water displacement method and expressed in cc. Likewise, root samples taken at 25, 45 and 65 DAS were oven dried for three days at 60-70°C to get a constant weight and expressed in g $plant^{-1}$. After measuring the root and shoot length of maize seedlings on 8 DAS, seedling vigour index was determined by adding mean of root and shoot length and then multiplied with germination per cent [13]. LAI was calculated at vegetative, tasseling and grain filling stage by multiplying length and width of index leaf (third fully opened leaf from the top) and No. of leaves $plant^{-1}$with corrector factor (0.796) and the cumulative values were divided with plant spacing [14]. Predominant weeds species such as *Trianthema portulacastrum, Cynodon dactylon, Digeria*

arvensis were found and weed dry weight of dominant weeds were counted and recorded at 25 and 45 DAS in both crop establishment and weed management plots. Number of grain rows cob^{-1}, grains row^{-1} and shelling per cent were recorded from randomly selected five cobs obtained from the tagged plants in net plot area. Cobs from the net plot was harvested separately, sun dried, shelled and cleaned. The grains were further sun dried to bring the moisture content to 12 percent then weighed and expressed in t ha^{-1}. After the cobs were harvested, stover weight from each plot was weighed separately after drying and expressed in t ha^{-1} and finally statistical analysis was done [15].

3. RESULTS AND DISCUSSION

Effect of crop establishment methods and weed management practices on vigour index and field establishment: Manual dibbling under conventional levelled ridges and furrows method had recorded highest vigour index of 2172 which was followed by sowing with manual rotary dibbler under laser levelled plot (1822). The lowest vigour index of 1540 was observed with pneumatic precision planter under laser levelled plot. Ridges and furrow method of land configuration favoured deep penetration of radicle and early emergence of plume which reflected on higher vigour index envisaged in the experimental study. Weed management practices significantly altered vigour index at 8 DAS and the highest vigour index of 1952 was registered in pre-emergence application of atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS followed by power weeding at 20 and 40 DAS. The results on field establishment recorded at 6 DAS indicated that early field emergence was noticed with manual dibbling sowing under ridges and furrows method of land configuration (4.5 days) which was followed by pneumatic precision planter (5.0 days). Sowing with manual rotary dibbler took 5.4 days to emerge plume which might be due to deeper placement of seeds. However, field establishment rate was not significantly influenced by weed management practices.

Effect of crop establishment methods and weed management practices on root parameters of maize: Root length was significantly altered by sowing methods at all the stages of observation and manual dibbling under conventionally levelled ridges and furrows recorded highest root length. However, weed management practices did not differ significantly for root parameter. Similar results were obtained by Khan et al., [16] the ridges offer loose fertile soil that is more aerated and mechanically compacted less, allowing the roots to develop extensively.

Crop establishment methods greatly influenced root volume at all the stages of observation and significantly higher root volume (9.67, 44.6 and 58.9 cc at 25, 45 and 65 DAS, respectively) was recorded in manual dibbling under ridges and furrows which was followed by pneumatic precision planter at 45 and 65 DAS. Similar results were found by Khan et al., [16] in maize crop under ridge method of planting. Similar to root length and volume, manual sowing under ridges and furrows had exhibited higher root biomass at 45 and 65 DAS.

Effect of crop establishment methods and weed management practices on LAI of maize: In contrast to this, significantly higher plant height at vegetative, tasseling and grain filling stage was registered in sowing with pneumatic precision planter which was at par with manual rotary dibbler. However, weed management practices did not significantly alter plant height at all the stages of crop growth. These results tend to support the results of Rajaiah et al., [17]. Significantly higher leaf area index (LAI) was observed with manual rotary dibbler at vegetative and tasseling stage and LAI was not significantly influenced by weed management practices at tasseling and grain filling stage, which coincides with the findings of Raihan et al., [18] that non-significant differences in LAI was found and maximum LAI was recorded in ridge planting method followed by line sowing and broadcast planting methods. Pre-emergence application with atrazine 50 % WP @ 0.75 $kgha^{-1}$ at 3 DAS + hand weeding at 20 and 40 DAS controlled the weeds effectively and recorded less weed density and dry weight and created weed free environment at critical stages of crop growth. The next best treatment was pre-emergence application with atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS + power weeding at 20 and 40 DAS. Similar results are in accordance with the findings of Abdullah et al., [19]. As compared to hand weeding and power weeder weeding, highest weed density and dry weight at 25 and 45 DAS was noticed with pre-emergence application of atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS + early post-emergence (EPoE) application with topramezone 33.6 % SC @ 25.2 g ha^{-1} at 20 DAS through drone.

Table 1. Effect of mechanization practices on growth characters of hybrid maize CO (H) M 8 during *summer* 2023 season

Treatments	Vigour Index	Field establishment (days)	Root length (cm)			Root volume (cc)		
			25 DAS	45 DAS	65 DAS	25 DAS	45 DAS	65 DAS
Main Plot (Sowing methods)								
M_1 - Pneumatic Precision Planter *	1540	5.0	20.4	27.2	34.7	8.72	36.4	55.0
M_2 - Manual rotary dibbler *	1822	5.4	23.9	26.1	29.8	9.39	30.6	48.3
M_3 - Manual Dibbling **	2172	4.5	24.5	28.0	34.8	9.67	44.6	58.9
SEd	58.2	0.29	0.67	0.53	1.2	0.67	1.75	1.32
CD (p=0.05)	162	0.81	1.85	1.48	3.2	1.88	4.86	3.67
Subplot (Weed management)								
S_1 - PE with Atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS+ Power Weeding at 20 & 40 DAS•	1952	4.9	23.3	27.3	33.4	9.56	37.8	57.2
S_2 - PE with Atrazine 50 % WP @ 0.75 kgha^{-1} at 3 DAS + Hand weeding at 20 & 40 DAS•	1795	5.1	22.2	27.1	33.1	8.83	36.5	53.3
S_3 - PE with Atrazine 50 % WP @ 0.75 kgha^{-1} at 3 DAS + EPoE with Topramezone 33.6 % SC@25.2 gha^{-1} at 20 DAS•	1787	5.0	23.3	27.0	32.8	9.39	38.8	51.7
SEd	106	0.17	0.80	0.95	1.3	0.36	1.06	3.71
CD (p=0.05)	233	0.37	1.73	2.07	2.8	0.79	2.31	8.09
Interaction								
MxS								
S Ed	162	-	1.31	-	-	0.85	2.31	-
CD (p=0.05)	365	NS	3.05	NS	NS	2.18	5.82	NS

**M_1 and M_2 – Sowing under laser levelled flatbed followed by earthing up using intercultural implement*

***M_3 – Sowing under conventional levelled ridges and furrows*

•S_1, S_2, S_3-Spraying of PE and EPoE herbicides will be done through drone

Table 2. Effect of mechanization practices on growth characters of hybrid maize CO (H) M 8 during *summer* 2023 season

Treatments	Root Biomass (g)			Plant Height (cm)			Leaf Area Index		
	25 DAS	45 DAS	65 DAS	Vegetative	Tasseling	Grain Filling	Vegetative	Tasseling	Grain Filling
Main Plot (Sowing methods)									
M_1 - Pneumatic Precision Planter *	1.1	20.5	33.0	68.1	177.9	226.8	0.86	2.27	4.52
M_2 - Manual rotary dibbler *	1.5	22.4	30.4	70.7	182.0	222.1	1.13	2.51	4.95
M_3 - Manual Dibbling **	1.0	22.5	33.1	60.4	170.9	207.9	0.72	2.00	4.47
SEd	0.02	0.39	0.61	1.70	1.84	3.3	0.03	0.06	0.13
CD (p=0.05)	0.07	1.07	1.69	4.74	5.11	9.1	0.07	0.18	0.37
Subplot (Weed management)									
S_1 - PE with Atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS+ Power Weeding at 20 & 40 DAS•	1.1	21.9	32.1	69.03	177.3	217.3	0.94	2.34	4.73
S_2 - PE with Atrazine 50 % WP @ 0.75 kgha^{-1} at 3 DAS + Hand weeding at 20 & 40 DAS•	1.4	22.3	33.2	67.06	176.8	220.7	0.97	2.30	4.45
S_3 - PE with Atrazine 50 % WP @ 0.75 kgha^{-1} at 3 DAS + EPoE with Topramezone 33.6 % SC@25.2 gha^{-1} at 20 DAS•	1.0	21.3	31.2	63.12	176.8	218.8	0.80	2.13	4.77
SEd	0.04	0.82	1.12	3.50	1.56	5.3	0.04	0.11	0.26
CD (p=0.05)	0.09	1.79	2.45	7.53	3.39	11.6	0.09	0.25	0.57
Interaction MxS									
S Ed	0.07	1.22	1.70	-	-	-	0.07	-	-
CD (p=0.05)	0.14	2.74	3.84	NS	NS	NS	0.15	NS	NS

**M_1 and M_2 – Sowing under laser levelled flatbed followed by earthing up using intercultural implement*

***M_3 – Sowing under conventional levelled ridges and furrows*

•S_1, S_2, S_3-Spraying of PE and EPoE herbicides will be done through drone

Table 3. Effect of mechanization practices on weed parameters of hybrid maize (CO (H) M8 during *summer* 2023 season

Treatments	Weed density (No. m^{-2})		Weed dry weight (g)	
	25 DAS	45 DAS	25 DAS	45 DAS
Main Plot (Sowing methods)				
M_1- Pneumatic Precision Planter *	2.55	3.01	1.50	2.04
	(7.67)	(10.78)	(1.99)	(4.38)
M_2- Manual rotary dibbler *	2.63	3.07	1.61	2.68
	(8.11)	(11.44)	(2.60)	(8.46)
M_3 - Manual Dibbling **	2.63	3.04	1.36	2.24
	(7.67)	(10.89)	(1.46)	(5.36)
Sed	0.15	0.16	0.04	0.10
CD (p=0.05)	0.42	0.45	0.11	0.24
Subplot (Weed management)				
S_1 - PE with Atrazine 50 % WP@ 0.75 kg ha^{-1} at 3DAS+ Power Weeding at 20 & 40 DAS•	2.85	3.29	1.61	2.82
	(7.78)	(10.44)	(2.10)	(7.58)
S_2 - PE with Atrazine 50 % WP@ 0.75 kgha^{-1} at 3 DAS + Hand weeding at 20 & 40 DAS•	1.03	1.11	0.85	0.89
	(0.67)	(0.78)	(0.25)	(0.30)
S_3 - PE with Atrazine 50 % WP@ 0.75 kgha^{-1} at 3 DAS +EPoE with	3.92	4.72	2.01	3.25
Topramezone 33.6 % SC@25.2 gha^{-1}at 20 DAS•	(15.00)	(21.89)	(3.71)	(10.32)
Sed	0.18	0.16	0.06	0.08
CD (p=0.05)	0.40	0.34	0.14	0.18
Interaction				
MxS				
Sed	-	-	0.11	0.14
CD (p=0.05)	NS	NS	0.24	0.31

 # Figures in parenthesis are original values (Analysis by $\sqrt{x+0.5}$ transformation)

**M_1 and M_2 – Sowing under laser levelled flatbed followed by earthing up using intercultural implement*

***M_3 – Sowing under conventional levelled ridges and furrows*

•S_1,S_2, S_3-Spraying of PE and EPoE herbicides will be done through drone.

Table 4. Effect of mechanization practices on yield characters of hybrid maize CO (H) M 8 during *summer* 2023 season

Treatments	Number of grain rows cob^{-1}	Number of grains row^{-1}	Shelling %	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})
Main Plot (Sowing methods)					
M_1 - Pneumatic Precision Planter *	14.78	36.00	76.34	7.10	10.09
M_2 - Manual rotary dibbler *	14.44	34.33	77.50	7.33	10.89
M_3 - Manual Dibbling **	15.00	31.22	73.69	6.40	9.31
SEd	0.24	0.62	1.14	0.13	0.19
CD (p=0.05)	0.67	1.72	3.16	0.37	0.54
Subplot (Weed management)					
S_1 - PE with Atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS+ Power Weeding at 20 & 40 DAS$^{\bullet}$	14.78	34.33	76.20	6.93	10.06
S_2 - PE with Atrazine 50 % WP @ 0.75 kgha^{-1} at 3 DAS + Hand weeding at 20 & 40 DAS$^{\bullet}$	14.89	34.00	76.11	7.03	10.21
S_3 - PE with Atrazine 50 % WP @ 0.75 kgha^{-1} at 3 DAS + EPoE with Topramezone 33.6 % SC@25.2 gha^{-1} at 20 DAS$^{\bullet}$	14.56	33.00	75.23	6.87	10.02
S Ed	0.36	0.55	1.63	0.24	0.35
CD (p=0.05)	0.78	1.19	3.56	0.53	0.77

**M_1 and M_2 – Sowing under laser levelled flatbed followed by earthing up using intercultural implement*

***M_3 – Sowing under conventional levelled ridges and furrows*

$^{\bullet}S_1$, S_2, S_3-Spraying of PE and EPoE herbicides will be done through drone

Table 5. Influence of different cultivation practices on economics of maize during *summer* 2023 season

Treatments	No. of man days ha^{-1}	Cost of Cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	Benefit Cost Ratio
M_1S_1	16	47115	169200	122085	3.59
M_1S_2	75	65115	172800	107685	2.65
M_1S_3	17	50365	167400	117035	3.32
M_2S_1	17	48350	175140	126790	3.62
M_2S_2	76	66350	177300	110950	2.67
M_2S_3	18	51600	174420	122820	3.38
M_3S_1	40	51070	154440	103370	3.02
M_3S_2	99	69070	155700	86630	2.25
M_3S_3	41	54320	152100	97780	2.80

Effect of crop establishment methods and weed management practices on yield attributing characters of maize: No significant difference among establishment methods and weed management was observed on number of grain rows cob^{-1}. Nevertheless, higher yield attributing characters such as number of grains $row^{-1}$and shelling per cent were recorded with manual rotary dibbler which was observed to be on par with pneumatic precision planter. The lowest values of these parameters were noticed under manual dibbling. The influence of weed management practices on yield attributing characters were also significant and highest values were noticed with pre-emergence application with atrazine 50 % WP @ 0.75 $kgha^{-1}$ at 3 DAS + hand weeding at 20 and 40 DAS.

Effect of crop establishment methods and weed management practices on grain yield and economics of maize: Significantly higher grain of 7.33 t ha^{-1} and stover yield 10.89 of t ha^{-1} was obtained under manual rotary dibbler treatment which was at par with crop establishment by pneumatic precision planter (7.10 t $ha^{-1}$and 10.09 t ha^{-1}, respectively). The lowest grain and stover yield were registered in manual dibbling method of sowing. These results are in line with the finding of Rajaiah et al., [17] due to precise seed placement, better crop establishment and efficient utilization of resources at all stages of crop growth.

Higher cost of cultivation (Rs. 69070 ha^{-1}) and labour utilization of 99 man days ha^{-1}were incurred in manual sowing with pre-emergence with atrazine 50 % WP @ 0.75 $kgha^{-1}$ at 3 DAS + hand weeding at 20 and 40 DAS which was followed by manual rotary dibbler and pre-emergence with atrazine 50 % WP @ 0.75 $kgha^{-1}$ at 3 DAS + hand weeding at 20 and 40 DAS. Similar finding of Manjulatha et al., [20] which revealed that cost of production under conventional method is higher than mechanized plot which might be due to more farm labour utilization.

Though the treatment consisted of pre-emergence with atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS + hand weeding at 20 and 40 DAS had recorded significantly higher grain yield of 7.4 t ha^{-1} and gross returns of Rs. 177300 ha^{-1} over other treatments, it failed to realize higher net returns and benefit cost ratio owing to higher cost of cultivation (Rs.66350 ha^{-1}) and more labour utilization (76 man days ha^{-1}). This is supported by Chinnappa et al., [21] stated that mechanization results in cost saving and increased profit due to intensive mechanized farms compared to low mechanized farms which could reduce dependence on human labour. Highest net returns of Rs.126790 ha^{-1} and B:C ratio (3.62) were observed with manual rotary dibbler followed by pre-emergence with atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS + power weeding at 20 and 40 DAS. The next best treatment was manual rotary dibbler with pre-emergence with atrazine 50 % WP @ 0.75 kg ha^{-1} at 3 DAS + early post-emergence (EPoE) application with Topramezone 33.6 % SC @ 25.2 g ha^{-1} at 20 DAS. Similar results by Manjulatha et al., [20] revealed that the variable costs are high in conventional method than mechanization due to higher labour requirement and lack of timely operations, better tillage practices and even depth of sowing.

4. CONCLUSION

From this study, it could be concluded that sowing by manual rotary dibbler along with pre emergence application of atrazine @ 0.75 kg a.i ha^{-1}at 3 DAS followed by power weeder weeding at 20 and 40 DAS (M_2S_1) recorded higher productivity, monetary returns, benefit cost ratio. Hence this treatment paved the way for reducing the drudgery and enhancing the profitability.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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ANNEXURE I

Summary table on cost of items under different crop establishment methods and weed management practices in hybrid maize during *Summer* 2023 season

S. No.	Details of Common field operations	Treatments		
A	**Crop establishment techniques**	**M_1**	**M_2**	**M_3**
1	Preparatory land cultivation	5560	5560	5560
2	Seed cost	11410	13044	10870
3	Sowing	1250	850	5740
4	Urea - 550 kg	3000	3000	3000
5	Single Super Phosphate (SSP) - 470 kg	3700	3700	3700
6	Muriate of Potash (MoP) - 125 kg	2000	2000	2000
7	Atrazine Herbicide - 1.5 kg	750	750	750
8	Cost of plant protection chemical	3700	3700	3700
9	1st top dressing with Urea at 25 DAS	1950	1950	1950
10	2nd top dressing with Urea at 45 DAS	1950	1950	1950
11	Hiring charges of Drone for spraying PP chemicals	4950	4950	4950
12	Harvesting	3080	3080	3080
	Total	**43300**	**44534**	**47250**
B	**Weed management****	**S_1**	**S_2**	**S_3**
	Total	**3815**	**21815**	**7065**

**M_1: Pneumatic precision planter*
**M_2: Manual rotary dibbler*
**M_3: Manual dibbling*
***S_1: Pre-emergence herbicide + power weeder weeding at 20 and 40 DAS*
***S_2: Pre-emergence herbicide + manual weeding at 20 and 40 DAS*
***S_3: Pre-emergence and early post-emergence herbicide at 20 DAS*

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