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RESEARCH ARTICLE

Tillage and weed management influence on weed growth and yield of summer maize

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ABSTRACT

A field experiment was conducted at AICRP on Weed Management, MRS, Hebbal, Bengaluru during 2020 and 2021 (summer) to study the effect of different conservation tillage and weed management approaches on growth, yield and economics of cultivation of maize. The experiment was laid out in a split-plot design with five main plots of different tillage treatments and three subplots of different weed management practices replicated thrice. The main plot tillage treatments consisted of conventional tillage, zero tillage, minimum tillage, minimum tillage + zero tillage (combination), and permanent raised bed. Among tillage practices, permanent raised bed recorded the least total weed density (64.8 no./m^2) and weed dry weight (21.9 g/m^2) at 60 DAS, compared to other tillage practices and also high kernel yield, stover yield and B: C ratio 3.20 t/ha, 4.10 t/ha and 1.53, respectively due to less weed infestation, good root growth, adequate aeration, and nutrient availability compared to other tillage practices. The subplot weed management practices consisted of recommended herbicides (pendimethalin-750 g/ha (PE) *fb* tembotrione 120 g/ha + atrazine 500 g/ha), integrated weed management (pendimethalin-750 g/ha (PE) + hand weeding at 30 DAS) and unweeded check. Among weed management practices, integrated weed management (pendimethalin-750 g/ha (PE) + hand weeding at 30 DAS recorded the least total weed density and weed dry at 60 DAS compared to unweeded treatment and early 50% tasselling and silking, compared to unweeded treatment and also high kernel yield, stover yield and B: C, 2.94 and 3.49 t/ha, and 1.35 due to less weed infestation, compared to unweeded treatment 1.64 and 2.57 t/ha, and 0.91, respectively.

Keywords: Minimum tillage, Permanent raised bed, Silking, Summer maize, Tasselling, Weed management, Zero tillage

INTRODUCTION

Maize (*Zea mays* L.), popularly known as the queen of cereals, is considered the third most important cereal crop after wheat and rice in the world. India ranks fourth among the maize growing countries in the world with 9.72 mha area, 28.64 MT of production and average productivity of 2.94 t/ha (Anon. 2020). In Karnataka, it occupies 1.40 m ha area, with 3.96 m tonnes production, and average productivity of 2.84 t/ha (Anon. 2020). It contributes to more than half of the coarse cereal production of the country and is widely used as a dual-purpose crop for animal feed as well as industrial raw material in the developed countries, whereas, in the developing countries it is used as a general feed for a human being. In concern to the Indian agricultural scenario, the growth in maize area and production was steady since 1950 but the growth rate in both area and production of maize increased unprecedented in the country during the last ten years due to the adoption of improved production technologies, varieties/ hybrids as well as expansion in non-traditional areas/ states like Andhra Pradesh, Karnataka, Maharashtra, and Tamil Nadu, *etc.* In the years to come, there will be increased pressure on the lands of India's rainfed regions to produce more in order to meet the expanding demands of the human and livestock populations. If preventative actions are not taken, degradation could worsen. To maintain soil quality and increase agricultural output, especially in rainfed locations, it is essential to increase soil organic carbon stock (Srinivasa *et al.* 2011).

The fundamental principles of conservation agriculture are minimising the amount of tillage and increasing the amount of surface cover by keeping crop residues (FAO 2013). It has been widely reported that conservation agriculture (CA), which is viewed as an alternative strategy to maintain and possibly improve agricultural production, reduces soil erosion, improves infiltration, increases soil organic stocks, and improves soil quality in a variety of environments and crops while lowering the risk of soil degradation when grown in rainfed conditions (Vlek and Tamene 2010). Minimizing the intensity of tillage is one of the major conservation agricultural practices which needs to be evaluated under various

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crops and cropping systems for Indian conditions (Veeresh *et al.* 2016). The fundamental principle for all agro-technologies is to maximize the yield by utilizing the soil and other natural resources without making a negative impact on the environment. It is an important strategy for developing a sound long-term weed control program. Weeds tend to compete with crops for similar growth requirements as their own and cultural practices designed to contribute to the crop may also benefit the growth and development of weeds.

MATERIAL AND METHODS

A field experiment was carried out in the summers of 2020 and 2021 to examine the impact of various weed control and tillage practises on weed occurrence, growth characteristics, and yields of maize. The field study was carried out at the AICRP's Main Research Station in Hebbal, Bengaluru, which focuses on weed management. The soil at the experiment site was a sandy loam with a pH of 6.34 and a small amount of organic carbon (0.34%). Three subplots of various weed management practices were replicated three times, while five main plots of various tillage treatments were used in the field experiment. The main plot of tillage treatments consisted of zero tillage, minimum tillage, minimum tillage + zero tillage (combination) and permanent raised bed. The subplot weed management practices consisted of recommended herbicides (pendimethalin-750 g/ha (PE) *fb* tembotrione 120 g/ha + atrazine 500 g/ha), integrated weed management (pendimethalin-750 g/ ha (PE) + hand weeding at 30 DAS) and unweeded treatment.

The maize (*MAH 14-5* hybrid) was sown at a spacing of 60 ³ 30 cm. Fertilizer level of 150 kg N, 75 kg P, and 40 kg K /ha was applied as per the recommendation and all the fertilizers were given as basal dose only. Irrigation was given at intervals of 10–15 days. The pre-emergence (one day after sowing) and post-emergence (20-25 days after sowing) herbicides were applied using a spray volume of 750 and 500 litters per hectare with a knapsack sprayer with nozzle, respectively. The data on species wise weed count in a quadrant of 50 x 50 cm were recorded at 60 DAS (days after sowing). Data were averaged for three replications. The weeds-wise density of sedges, grass and broad-leaf at 60 DAS was taken. In addition, total dry weight was also recorded at 60 DAS. The data on weeds density and dry weight were subjected to the transformation of square root ($\sqrt{x+0.5}$) depending on the variability and weed index calculated by using the formula suggested by Gill and Vijaykumar (1969). Leaf area index was calculated at 60 DAS by using the below formula given by Watson (1947).

$$\text{LAI} = \frac{\text{Leaf area of plant}}{\text{Ground area covered by plant}}$$

The data collected on different traits were statistically analyzed using the standard procedure and the results were tested at a five per cent level of significance as given by Gomez and Gomez (1984). The least significant differences were used to compare treatment means.

RESULTS AND DISCUSSION

Effect of conservation tillage and weed management practices on weeds

The tillage practices did not significantly influence the weed density and weed dry weight at 60 DAS. The interaction effect between tillage and weed management practices was also not significant. *Cyperus rotundus* and *Cynodon dactylon* were the major weeds, which come under sedge and grass.

Weed management practices significantly influenced the weed density and weed dry weight at 60 DAS (**Table 1**). At 60 DAS, integrated weed management practices of pre-emergence application of pendimethalin 750 g/ha followed by hand weeding at 30 DAS recorded significantly lowest total weed density (50.5 no./m^2) in comparison to unweeded control (77.3 no./m^2). Similar results were obtained by Singh *et al.* (2017) that the application of pendimethalin 1.0 kg/ha + two hoeing at 25 DAS and 45 DAS recorded lower weed density and weed dry weight at 60 DAS.

Integrated weed management practices of pre-emergence application of pendimethalin 750 g/ha followed by hand weeding at 30 DAS recorded significantly lower total weed dry weight (12.3 g/m^2) of sedges, grasses, and broad-leaf weeds compared to unweeded control (29.0 g/m^2). Similarly, Rajeshkumar *et al.* (2018) reported that the application of pendimethalin at 0.75 kg/ha followed by one rotary hoeing on 35 DAS recorded the highest weed control efficiency and reduced weed populations and weed dry matter production at 60 DAS. Sanodiya *et al.* (2013) reported that weed control efficiency (WCE) was maximum with pendimethalin 1.0 kg/ha followed by hand weeding at 30 DAS, but the lowest WCE was found with the pre-emergence application of atrazine 1.0 kg/ha alone in fodder maize.

Effect of conservation tillage and weed management practices on growth parameters of maize

The plots imposed with permanent raised bed and conventional tillage numerically recorded the highest leaf area index (2.18), compared to other tillage practices (**Table 3**). Among the weed management practices, the plots treated with pendimethalin 750 g/ha followed by hand weeding at 30 DAS recorded the highest leaf area index (1.85) compared to unweeded control (1.40). Unweeded control recorded the lowest leaf area index due to less effective control of weeds throughout the crop growth period, unweeded control lowered the leaf area as a result of the severe competition of weeds particularly broadleaf weeds and sedges.

Similar results were found by Singh *et al.* (2017). In a long term application of conservation tillage practices resulted in higher values of plant height, dry matter accumulation, LAI, crop growth rate (CGR) and relative growth rate (RGR) under the permanent bed with legume residue than no-residue, and this might be due to better soil health and micro-environment created by the continuous adoption of these resources conserving practice (Memon *et al.*

Table 1. Weed density at 60 DAS in summer maize as influenced by tillage and weed management practices

Treatment	Sedges			Grasses			BLW			Total		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
Tillage practice (T)												
Conventional tillage (CT)	-	-	-	-	-	-		-	-	-	-	-
Zero tillage (ZT)	6.23 (38.9)	6.88 (47.0)	6.56 (42.9)	3.57 (13.4)	3.24 (10.6)	3.41 (12.0)	4.82 (22.9)	5.14 (26.1)	4.98 (24.5)	14.6 (75.2)	15.2 (83.7)	14.9 (79.4)
Minimum tillage (MT)	6.75 (45.8)	7.05 (50.0)	6.90 (47.9)	4.02 (17.1)	3.69 (13.8)	3.86 (15.4)	4.36 (18.7)	4.93 (24.0)	4.65 (21.3)	15.1 (81.6)	15.6 (87.8)	15.4 (84.6)
Zero tillage (ZT) + minimum tillage (MT)	6.64 (44.3)	7.40 (54.7)	7.02 (49.5)	4.13 (18.4)	3.48 (12.0)	3.81 (15.2)	4.59 (20.7)	5.08 (25.4)	4.84 (23.0)	15.3 (83.4)	15.9 (92.1)	15.6 (87.7)
Permanent raised bed (PB)	6.18 (38.7)	6.07 (37.4)	6.13 (38.0)	3.44 (11.8)	3.35 (11.7)	3.40 (11.7)	3.19 (10.1)	4.52 (20.2)	3.86 (15.1)	12.8 (60.6)	13.9 (69.3)	13.3 (64.8)
LSD (p=0.05)	0.954	0.755	0.696	0.649	0.266	0.354	0.479	0.619	0.436	0.779	0.579	0.542
Weed management practice (W)												
Pendimethalin 750 g/ha (PE) *fb* tembotrione 120 g/ha + atrazine 500 g/ha	5.44 (37.5)	5.42 (36.9)	5.43 (37.2)	2.61 (8.20)	2.46 (7.20)	2.54 (7.70)	3.33 (14.3)	3.83 (18.1)	3.58 (16.2)	11.3 (60.0)	11.7 (62.2)	11.5 (61.1)
IWM – pendimethalin 750 g/ha PE + HW at 30 DAS	4.80 (28.9)	4.90 (29.8)	4.85 (29.3)	2.36 (6.60)	2.19 (5.73)	2.28 (6.17)	3.47 (15.2)	3.72 (17.1)	3.60 (15.1)	10.6 (50.7)	10.8 (52.6)	10.7 (50.5)
Unweeded control	5.23 (34.2)	6.12 (46.7)	5.68 (40.4)	4.12 (21.7)	3.60 (15.9)	3.86 (18.8)	3.36 (13.9)	4.25 (22.3)	3.81 (18.1)	12.7 (69.8)	13.9 (84.9)	13.3 (77.3)
LSD (p=0.05)	0.852	0.422	0.584	0.495	0.219	0.308	0.477	0.291	0.338	0.813	0.523	0.608
Interaction (T × W)												
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: (-) = Fallow. The data on weeds density and dry weight were subjected to the transformation of square root $\sqrt{x+0.5}$

Table 2. Weed dry weight (g/m^2) at 60 DAS in summer maize (2020 and 2021) as influenced by tillage and weed management practices

Treatment	Sedges			Grasses			BLW			Total		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
Tillage practice (T)												
Conventional tillage (CT)	-	-	-	-	-	-	-	-	-	-	-	-
Zero Tillage (ZT)	4.79 (24.3)	1.64 (2.30)	3.22 (13.3)	2.37 (5.21)	2.20 (5.09)	2.29 (5.15)	2.61 (6.35)	1.77 (2.73)	2.19 (4.54)	5.90 (35.86)	3.12 (10.1)	4.51 (22.9)
Minimum tillage (MT)	5.23 (28.3)	1.63 (2.22)	3.43 (15.2)	2.61 (6.56)	2.93 (8.42)	2.77 (7.49)	2.60 (6.26)	1.79 (2.74)	2.20 (4.50)	6.35 (41.2)	3.68 (13.3)	5.02 (27.1)
Zero tillage (ZT) + minimum tillage (MT)	5.08 (27.2)	1.66 (2.35)	3.37 (14.7)	2.78 (7.72)	2.79 (8.02)	2.79 (7.87)	2.60 (6.36)	1.96 (3.40)	2.28 (4.88)	6.30 (41.3)	3.68 (13.7)	4.99 (27.4)
Permanent bed (PB)	4.58 (20.6)	1.51 (1.83)	3.05 (11.2)	2.61 (6.47)	2.44 (6.24)	2.53 (6.35)	2.67 (6.67)	1.60 (2.12)	2.14 (4.39)	5.52 (33.7)	3.14 (10.1)	4.33 (21.9)
LSD (p=0.05)	0.472	0.107	0.208	0.433	0.145	0.212	0.119	0.193	0.094	0.576	0.147	0.272
Weed management practice (W)												
Pendimethalin-750 g/ha (PE) *fb* tembotrione 120 g/ha + atrazine 500 g/ha	3.91 (19.0)	1.18 (1.35)	2.55 (10.1)	2.09 (5.08)	2.0 (4.78)	2.05 (4.93)	2.01 (4.63)	1.34 (1.89)	1.68 (3.26)	4.76 (28.7)	2.57 (8.01)	3.67 (18.3)
IWM – pendimethalin 750 g/ha PE + Hand weeding at 30 DAS	3.09 (11.7)	1.09 (1.09)	2.09 (6.40)	1.71 (3.32)	1.36 (2.04)	1.54 (2.68)	2.01 (4.68)	1.32 (1.81)	1.67 (3.25)	3.87 (19.7)	2.04 (4.94)	2.96 (12.3)
Unweeded control	4.81 (29.5)	1.59 (2.78)	3.20 (16.1)	2.43 (7.17)	2.85 (9.84)	2.64 (8.50)	2.27 (6.07)	1.61 (2.89)	1.94 (4.48)	5.82 (42.7)	3.56 (15.5)	4.69 (29.0)
LSD (p=0.05)	0.613	0.076	0.304	0.242	0.225	0.194	0.120	0.131	0.089	0.479	0.192	0.290
Interaction (T × W)												
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: (-) = Fallow. The data on weeds density and dry weight were subjected to the transformation of square root $\sqrt{x+0.5}$

2014). Among weed management treatments, significantly higher number of days were taken for 50% tasseling and silking in unweeded when compared to two other treatments (**Table 3**). Similar results were found by Kommireddy (2018) who reported that among different treatments, the significantly higher number of days taken for 50 per cent tasseling and silking in unweeded control when compared to all other treatments.

Yield parameters and yield

The kernel and stover yields of maize were significantly influenced by different conservation tillage and weed management practices. Permanent raised beds had significantly higher kernel yield, stover yield, and harvest index of maize when compared to zero tillage among different tillage practices (**Table 5**). Significantly higher kernel yield in permanent raised beds was attributed to significantly higher yield parameters as compared to zero tillage (**Table 4**). Conservation tillage, which improves the physical and chemical qualities of the soil, that may greatly impact on root development, is likely to give similar or even higher crop yields than conventional tillage. These findings were in agreement with Sepat and Rana (2013), Choudhary *et al.* (2013) and Parihar *et al.* (2016).

Among the weed management practices, the plots treated with pendimethalin 750 g/ha followed by hand weeding at 30 DAS recorded the highest seed yield compared to the use of only recommended herbicide. Unweeded control recorded the lowest seed yield due to less effective control of weeds throughout the crop growth period. Unweeded control lowered the yield as a result of the severe competition of weeds particularly broadleaf weeds and sedges. Similar results were found by Rajeshkumar *et al.* (2018) when pendimethalin at 0.75 kg/ha was applied followed by one rotary hoeing on 35 DAS resulted. Similarly, a field experiment conducted at Ludhiana (India), found about 25% higher grain yield with a permanent bed planting of maize than flat sowing (Kaur and Mahey 2012) The highest yield in bed planting with the bed was due to increased number of cobs per plant and more grains per cob than flat sowing.

Table 3. Days to 50 per cent tasselling and silking in maize as influenced by different tillage and weed management practices

Treatment	Days to 50% tasseling			Days to 50% silking			leaf area index		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
Tillage practice (T)									
Conventional tillage (CT)	-	-	-	-	-	-	-	-	-
Zero tillage (ZT)	51.4	52.0	51.7	58.2	58.6	58.4	2.08	2.03	2.05
Minimum tillage (MT)	51.8	52.3	52.0	58.5	59.2	58.9	2.04	1.99	2.02
Zero tillage (ZT) + minimum tillage (MT)	51.7	52.6	52.1	58.4	59.5	59.0	1.98	1.93	1.95
Permanent bed (PB)	50.0	50.5	50.2	56.9	57.9	57.4	2.20	2.15	2.18
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	0.301	0.275	0.187
Weed management practice (W)									
Pendimethalin 750 g/ha (PE) *fb* tembotrione 120 g/ha + atrazine 500 g/ha	48.7	51.4	50.0	54.9	58.2	56.5	1.69	1.65	1.67
IWM – Pendimethalin 750 g/ha PE + hand weeding at 30 DAS	47.3	48.9	48.1	53.4	57.6	55.5	1.86	1.83	1.85
Unweeded control	51.3	51.1	51.3	57.3	57.1	57.2	1.42	1.38	1.40
LSD (p=0.05)	0.51	0.60	0.50	0.53	0.63	0.48	0.146	0.151	0.102
Interaction (T × W)									
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. Cob length, cob girth, number of rows per cob and number of kernels per row in maize (summer) as influenced by different tillage and weed management practices

Treatment	Cob length (cm)			Cob girth (cm)			No. of rows per cob			No. of kernels/row		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
Tillage practice (T)												
Conventional tillage (CT)	-	-	-	-	-	-	-	-	-	-	-	-
Zero tillage (ZT)	13.4	13.2	13.3	15.3	15.3	15.3	12.0	12.0	12.0	23.5	24.1	23.8
Minimum tillage (MT)	13.3	13.0	13.1	15.0	15.0	15.0	11.8	11.8	11.8	22.8	23.4	23.1
Zero tillage (ZT) + minimum tillage (MT)	12.9	12.7	12.8	14.0	14.2	14.1	11.6	11.3	11.4	21.9	22.5	22.2
Permanent bed	14.7	14.5	14.6	16.7	16.8	16.7	14.2	13.3	13.8	25.8	26.4	26.1
LSD (p=0.05)	1.39	1.48	0.93	1.57	1.66	1.05	1.68	1.52	1.04	2.42	2.70	1.66
Weed management practice (W)												
Pendimethalin-750 g/ha (PE) *fb* tembotrione 120 g/ha + atrazine 500 g/ha	10.9	10.7	10.8	12.2	12.2	12.2	9.7	9.6	9.7	19.3	19.7	19.5
IWM – pendimethalin 750 g/ha PE + hand weeding at 30 DAS	11.5	11.3	11.4	13.0	13.1	13.0	10.9	10.7	10.8	19.9	20.4	20.2
Unweeded control	10.3	10.1	10.2	11.4	11.5	11.4	9.1	8.8	8.9	17.2	17.7	17.4
LSD (p=0.05)	0.70	0.75	0.50	1.03	1.13	0.74	0.83	0.91	0.60	1.62	1.98	1.24
Interaction (T × W)												
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5. Kernel yield, stover yield, and B:C ratio in summer maize as influenced by tillage and weed management practices

Treatment	Kernal yield (t/ha)			Stover yield (t/ha)			B: C ratio		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
Tillage practice (T)									
Conventional tillage (CT)	-	-	-	-	-	-	-	-	-
Zero tillage (ZT)	2.89	2.88	2.89	3.74	3.79	3.77	1.45	1.36	1.41
Minimum tillage (MT)	2.91	2.92	2.92	3.65	3.90	3.78	1.49	1.38	1.42
Zero tillage (ZT) + minimum tillage (MT)	2.99	3.01	3.00	3.50	3.99	3.75	1.60	1.42	1.46
Permanent bed	3.21	3.18	3.20	4.04	4.16	4.10	1.62	1.45	1.53
LSD (p=0.05)	0.23	0.18	0.18	0.32	0.25	0.25			
Weed management (W)									
Pendimethalin 750 g/ha (PE) *fb* tembotrione 120 g/ha + atrazine 500 g/ha	2.61	2.62	2.62	3.01	3.36	3.19	1.27	1.17	1.22
IWM – pendimethalin 750 g/ha PE + hand weeding at 30 DAS	2.92	2.96	2.94	3.22	3.75	3.49	1.40	1.30	1.35
Unweeded control	1.67	1.61	1.64	2.74	2.39	2.57	0.92	0.90	0.91
LSD (p=0.05)	0.19	0.18	0.16	0.23	0.19	0.18			

Economics

The higher B: C ratio (1.53) was noticed in permanent raised bed, even though there was higher cost of cultivation, still it gave higher gross returns, net returns and B: C due to significantly higher grain and straw yields. The least was recorded in unweeded control (0.91) treatment (**Table 4**).

Conclusion

Permanent raised beds and integrated weed management practice in maize-greengram-maize cropping system under conservation agriculture, realised higher net returns and B: C ratios besides managing agro-ecosystem for improved and sustained productivity than other tillage and weed management practices. Integrated weed management is the most feasible method of weed management strategy for controlling weeds and for sustainable productivity of crops.

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