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RESEARCH ARTICLE

Effect of weed control measures on weeds and yield of *Rabi* (winter) maize

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ABSTRACT

A field study was carried out at AICRP-WM Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, India during two consecutive *Rabi* (winter) seasons of 2019-20 and 2020-21 to assess the effect of weed control measures on weeds and yield of *Rabi* maize. The field experiment was laid out in randomized block design having ten treatments and replicated thrice. The pre-emergence application (PE) of either atrazine + pendimethalin (tank-mix) 500 + 250 g/ha) or early post-emergence application (EPoE) at 10-15 days after seeding (DAS) of topramezone 336 + atrazine 25.2 + 500 g/ha (tank-mix) or tembotrione + atrazine 120 + 500 g/ha (tank-mix) provided effective control of both monocot and dicot weeds with higher yield and benefit cost ratio in winter maize during both the years. However, the mechanical weed control treatments, inter-culturing (IC) + hand weeding (HW) at 20 and 40 DAS provided effective control of weeds with higher grain yield of maize and higher benefit cost ratio during both the study years.

Keywords: Herbicides, Maize, Tembotrione, Topramezone, Weed control efficiency, Weed index, Weed management

INTRODUCTION

Maize (*Zea mays* L.) is the third most important crop among the cereals in India and contributes to the nearly 9% of the national food basket (Jeet *et al.* 2017). Maize is the most versatile crop with highest genetic yield potential, wider adaptability to varied agroecological regions and diverse growing seasons. Maize serves as human food and animal feed and has wide industrial applications. Due to multiple uses, the demand for maize grain is constantly increasing in the global market. In India, maize is grown in an area of 9.18 million hectares with the average productivity of 2960 kg/ha with the production of about 27.23 million tonnes of maize kernels (DES-GOI 2020). Area under winter (*Rabi*) maize is increasing with the introduction of new hybrid varieties.

Due to ample irrigation provided to the winter maize, weeds flourish tremendously. The weed interference is a severe problem in maize, especially in the early stages of the crop growing season due to slow initial growth habit with wider row spacing. Severe competition between weeds and maize at critical growth stages could be reduced both the quality and quantity of maize as weeds compete with the crop for essential resources. Rani *et al.* (2020) observed that critical period of weed competition starts from 17 to 29 days after planting of corn, significantly affect the growth parameters and grain yield of maize. Whereas, Gharde *et al.* (2018) reported that potential yield loss in maize due to weeds ranged from 18-65%. Moreover, higher intensity of weeds increases the cost of cultivation, lowers value of land and curtails the net returns. In order to realize the yield potential of maize, weed management becomes indispensable. Thus, an experiment was conducted to study the effect of weed management treatments in *Rabi* maize in order to identify effective and economical weed management measure.

MATERIALS AND METHODS

A field experiment was conducted during two consecutive *Rabi* (winter) seasons of 2019-20 and 2020-21 at the farm of B. A. College of Agriculture, Anand Agricultural University, Anand. The soil of the experimental field was low in available nitrogen and medium in available phosphorous and high in potassium. Total ten weed management practices, *viz.* pre-emergence application (PE) of atrazine 1.0 kg/ha followed by (*fb*) inter-cultivation (IC) at 30 days after seeding (DAS), pendimethalin 1.0 kg/ha PE *fb* IC at 30 DAS, atrazine + pendimethalin 0.50 +0.250 kg/ha (tank-mix) PE, early post-emergence application (EPoE) of topramezone 25.2 g/ha *fb* IC + hand weeding (HW) at 40 DAS, topramezone + atrazine 25.2 + 500 g/ha (tank-mix) EPoE, tembotrione 120 g/ha EPoE *fb* IC *fb* HW at 40 DAS,

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tembotrione + atrazine 120 + 500 g/ha (tank-mix) EPoE, IC at 20 and 40 DAS, IC + HW at 20 and 40 DAS and weedy check tested. A randomized block design with three replications was used. Maize hybrid GAYMH 3 was sown on 11 and 30 November during 2019 and 2020, respectively keeping distance of 60 x 20 cm by using seed rate of 20 kg/ha. The crop was harvested on 20 and 26 March during 2020 and 2021, respectively. The crop was fertilized with recommended rate of fertilizer *i.e.* 150-60-00 NPK kg/ha wherein, entire quantity of phosphorous in the form of single super phosphate and 25% of recommended dose of nitogen (RDN) in the form of urea was applied at the time of sowing and remaining quantity of nitrogen was applied in three equal split at 4 leaf stage, 8 leaf stage and at tasseling stage during both the years of experimentation. The rest of the recommended package of practices was adopted to raise the crop. Herbicides were applied using knapsack sprayer fitted with flat fan nozzle using 500 litre water/ha as per the treatment. Weed dry weight (biomass) of monocot, dicot and sedges were recorded from randomly selected four spots by using 0.25 m^2 iron quadrat from net plot through destructive sampling method. Weed control efficiency (WCE) was calculated on the basis of dry weight of weeds as per the formula suggested by Maity and Mukherjee (2011). Other observations were also recorded from net plot area. Benefit cost ratio was workout based on the gross realization/total cost of cultivation.

RESULT AND DISCUSSION

Weed species

Fourteen weed species were observed in the experimental field, of which *Eleusine indica* (32.9%), *Dactyloctenium aegyptium* (8.55%), *Digitaria sanguinalis* (6.25%), *Setaria glauca* (4.11%), *Eragrostis major* (3.13%), *Asphodelus tenuifolius* (2.14%), *Commelina benghalensis* (1.32%) were monocot weeds and *Chenopodium album* (14.3%) *Chenopodium murale* (6.58%), *Digera arvensis* (6.58%), *Phyllanthus niruri* (4.44%), *Melilotus alba* (3.62%), *Boerhavia erecta* (1.81%) and *Oldenlandia umbellate* (1.64%) were dicot weeds. In general, monocot weeds were dominant with relative density of 59.9% followed by dicot weed with relative density of 40.1% in the control plot of experimental field.

Effect on weeds

The density and dry biomass of weeds were significantly affected by different weed management practices at 25 DAS during both the years (**Table 1**). IC + HW at 20 and 40 DAS recorded lower density and biomass of monocot, dicot and total weeds while IC alone showed poor control of weeds during both

Table 1. Density and dry biomass of monocot, dicot and total weeds as influenced by weed management practices in *rabi* maize at 25 DAS

Treatment	Weed density (no./m^2)						Weed biomass (g/m^2)					
	Monocot		Dicot		Total		Monocot		Dicot		Total	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Atrazine 1.0 kg /ha PE *fb* IC at 30 DAS	5.36	5.24	1.00	1.00	5.36	5.24	2.74	2.70	1.00	1.00	2.74	2.70
	(28.0)	(26.7)	(0.00)	(0.00)	(28.0)	(26.7)	(6.53)	(6.36)	(0.00)	(0.00)	(6.53)	(6.36)
Pendimethalin 1.0 kg /ha PE *fb* IC at 30	1.63	1.52	3.58	4.57	3.80	4.71	1.20	1.15	1.96	2.13	2.07	2.20
DAS	(1.67)	(1.33)	(12.0)	(20.0)	(13.7)	(21.3)	(0.44)	(0.31)	(2.89)	(3.55)	(3.33)	(3.86)
Atrazine + pendimethalin 500 +250 g/ha	1.52	1.41	1.00	1.00	1.52	1.41	1.14	1.11	1.00	1.00	1.14	1.11
PE (tank-mix)	(1.33)	(1.00)	(0.00)	(0.00)	(1.33)	(1.00)	(0.29)	(0.23)	(0.00)	(0.00)	(0.29)	(0.23)
Topramezone 25.2 g /ha EPoE *fb* IC +	3.20	2.49	3.47	5.36	4.64	5.84	1.86	1.58	2.05	2.44	2.58	2.74
HW at 40 DAS	(9.33)	(5.33)	(12.0)	(28.0)	(21.3)	(33.3)	(2.47)	(1.53)	(3.24)	(5.01)	(5.71)	(6.54)
Topramezone + atrazine 25.2 + 500 g/ha)	2.75	2.24	1.00	1.00	2.75	2.24	1.68	1.46	1.00	1.00	1.68	1.46
EPoE (tank-mix)	(6.67)	(4.00)	(0.00)	(0.00)	(6.67)	(4.00)	(1.84)	(1.13)	(0.00)	(0.00)	(1.84)	(1.13)
Tembotrione 120 g /ha EPoE *fb* IC + HW	4.71	4.99	4.06	7.25	6.14	8.74	2.53	2.70	2.19	3.20	3.19	4.07
at 40 DAS	(21.3)	(24.0)	(16.0)	(52.0)	(37.3)	(76.0)	(5.42)	(6.34)	(3.85)	(9.31)	(9.26)	(15.6)
Tembotrione + atrazine 120 + 500 g/ha	4.57	3.78	1.00	1.00	4.57	3.78	2.48	2.12	1.00	1.00	2.48	2.12
EPoE (tank-mix)	(20.0)	(13.3)	(0.00)	(0.00)	(20.0)	(13.3)	(5.17)	(3.49)	(0.00)	(0.00)	(5.17)	(3.49)
IC at 20 and 40 DAS	5.93	4.57	5.11	3.58	7.80	5.74	3.63	3.17	2.69	2.41	4.42	3.86
	(34.7)	(20.0)	(25.3)	(12.0)	(60.0)	(32.0)	(12.3)	(9.07)	(6.31)	(4.84)	(18.6)	(13.9)
IC + HW at 20 and 40 DAS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Weedy check	11.7	15.1	11.2	11.0	16.1	18.7	7.66	8.27	5.52	4.82	9.40	9.52
	(136)	(228)	(124)	(120)	(260)	(348)	(57.9)	(67.6)	(29.6)	(22.3)	(87.5)	(89.9)
LSD (p=0.05)	0.98	1.01	0.98	0.83	1.18	0.85	0.48	0.41	0.39	0.30	0.53	0.46

Note: Data subjected to $(\sqrt{x+1})$ transformation. Figures in parentheses are means of original values; PE = pre-emergence application; EPOE = early post-emergence application; IC = inter cultivation, HW = hand weeding, DAS = days after seeding, *fb* = followed by the years. Among herbicidal treatments, significantly lower density and dry biomass of weeds was observed with atrazine + pendimethalin 500 +250 g/ ha PE (tank-mix). Among pre-emergence herbicides, pendimethalin 1.0 kg/ha and atrazine 1.0 kg/ha showed poor control of dicot and monocot weeds, resulting in increased total density and dry biomass. Among post-emergence herbicide, the efficacy of topramezone and tembotrione was poor on monocot and dicot weed but complete control of dicot weed was achieved when applied as tank mix with atrazine. Triveni *et al*. (2017) also observed better weed control with pre-and post-emergence herbicides during critical period of crop weed competition.

At harvest, lower density of weeds was recorded with atrazine + pendimethalin 500 +250 g/ha (tank-mix) PE and it was at par with IC + HW at 20 and 40 DAS, pendimethalin 1.0 kg /ha PE *fb* IC at 30 DAS and tembotrione + atrazine 120 + 500 g/ha (tank-mix) EPoE during both the years of experimentation. Martin *et al.* (2011) also observed effective control of individual weed species, by 5 to 45%, with application of tank-mix of tembotrione with atrazine 31 + 370 g/ha at four to five-collar leaf stage of corn. Significantly lower dry biomass of monocot, dicot and total weeds was observed with atrazine + pendimethalin 500 +250 g /ha (tank mix) PE, pendimethalin 1.0 g/ha PE *fb* IC at 30 DAS, topramezone 25.2 g /ha EPoE *fb* IC + HW at 40 DAS, tembotrione 120 g/ha EPoE *fb* IC + HW at 40 DAS and IC + HW at 20 and 40 DAS during both the years (**Table 2**).The higher weed control might be due to the enhanced efficacy of tank-mix application which effectively controlled the dicot weeds. Atrazine + pendimethalin 500 + 250 g/ha (tank-mix) PE recorded 65.5 and 82.4% weed control efficiciency while IC + HW carried out at 20 and 40 DAS recorded 90.0 and 79.6%, during 2019-20 and 2020-2021, respectively. Triveni *et al.* (2017) also recorded higher weed control efficiency with tank-mix formulation of tembotrione 50 g/ha+ atrazine 0.5 kg/ha at 15-20 DAS followed by hand weeding twice at 20 and 40 DAS. As the weed control efficiency is directly related with the weed dry biomass observed under respective treatments wherein, lower weed dry biomass was recorded under above said treatment might have reflected in higher weed control efficiency. The effectiveness of tank mix application of herbicide in maize (Gharsiram 2022) was also documented.

Effect on crop

The grain and stover yield of maize were significantly affected due to different weed management practices during both the years (**Table 3**). Significantly higher grain yield (9.09 and 8.91 t/ ha) was recorded under IC + HW at 20 and 40 DAS as well as topramezone 25.2 g/ha EPoE *fb* IC + HW at 40 DAS during 2019-20 and 2020-2021, respectively. The higher grain yield might be due to effective control of weeds during critical crop weed

Table 2. Density and dry biomass of monocot, dicot and total weeds as influenced by weed management practices in *Rabi* (winter) maize at harvest

Treatment	Weed density (no./m^2)						Weed biomass (g/m^2)						WCE (%)	
	Monocot		Dicot		Total		Monocot		Dicot		Total			
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Atrazine 1000 g/ha PE *fb* IC at 30 DAS	4.71 (21.3)	5.11 (25.3)	5.08 (25.3)	3.20 (9.33)	6.86 (46.7)	5.95 (34.7)	7.92 (61.7)	7.08 (49.5)	7.83 (60.4)	5.02 (24.4)	11.1 (122)	8.63 (73.9)	58.4	59.2
Pendimethalin 1.0 kg/ha PE *fb* IC at 30 DAS	2.49 (5.33)	2.95 (8.00)	5.24 (26.7)	3.93 (14.7)	5.74 (32.0)	4.84 (22.7)	4.05 (15.5)	3.87 (14.5)	8.02 (64.4)	5.85 (34.0)	8.97 (79.9)	6.97 (48.5)	72.7	73.2
Atrazine + pendimethalin (500 +250 g./ha) PE (tank-mix)	2.95 (8.00)	2.49 (5.33)	4.96 (24.0)	3.20 (9.33)	5.70 (32.0)	3.95 (14.7)	5.97 (34.9)	3.39 (10.9)	8.16 (65.9)	4.67 (20.9)	10.1 (101)	5.71 (31.8)	65.5	82.4
Topramezone 25.2 g /ha EPoE *fb* IC + HW at 40 DAS	2.49 (5.33)	3.37 (10.7)	6.06 (36.0)	3.90 (14.7)	6.50 (41.3)	5.08 (25.3)	3.83 (13.8)	4.65 (21.4)	7.71 (58.5)	5.79 (32.7)	8.56 (72.3)	7.38 (54.1)	75.3	70.1
Topramezone + atrazine (25.2 + 500 g/ha) EPoE (tank-mix)	5.22 (26.7)	3.20 (9.33)	5.11 (25.3)	3.73 (13.3)	7.27 (52.0)	4.85 (22.7)	8.36 (69.1)	4.73 (21.5)	9.00 (80.1)	5.40 (28.9)	12.3 (149)	7.13 (50.4)	49.1	72.2
Tembotrione 120 g/ha EPoE *fb* IC + HW at 40 DAS	2.49 (5.33)	3.87 (14.7)	5.72 (32.0)	3.73 (13.3)	6.18 (37.3)	5.29 (28.0)	4.02 (15.2)	5.36 (29.5)	8.31 (68.4)	4.77 (21.9)	9.18 (83.6)	7.15 (51.3)	71.5	71.7
Tembotrione + atrazine (120 + 500 g/ha) EPoE (tank-mix)	3.75 (13.3)	3.78 (13.3)	4.24 (17.3)	3.58 (12.0)	5.60 (30.7)	5.12 (25.3)	9.07 (81.9)	4.98 (24.0)	9.31 (85.9)	5.13 (25.5)	13.0 (168)	7.08 (49.5)	42.7	72.7
IC at 20 and 40 DAS	5.26 (26.7)	4.43 (18.7)	5.91 (34.7)	3.90 (14.7)	7.86 (61.3)	5.83 (33.3)	10.1 (101)	7.08 (49.5)	9.64 (92.0)	6.50 (41.6)	13.9 (193)	9.60 (91.1)	34.1	49.7
IC + HW at 20 and 40 DAS	3.40 (10.7)	3.20 (9.33)	4.10 (16.0)	3.73 (13.3)	5.24 (26.7)	4.84 (22.7)	3.16 (8.97)	4.29 (17.6)	4.60 (20.2)	4.49 (19.5)	5.49 (29.2)	6.16 (37.0)	90.0	79.6
Weedy check	6.50 (41.3)	6.28 (38.7)	6.94 (48.0)	5.38 (28.0)	9.48 (89.3)	8.20 (66.7)	12.2 (149)	10.1 (102)	12.0 (144)	8.95 (79.2)	17.1 (293)	13.5 (181)	-	-
LSD (p=0.05)	0.89	0.96	1.20	1.01	1.07	1.08	1.3	1.58	1.16	1.08	1.37	1.48	-	-

Note: Data subjected to $(\sqrt{x+1})$ transformation. Figures in parentheses are means of original values., PE = pre-emergence application; EPOE = early post-emergence application; IC = inter cultivation, HW = hand weeding, DAS = days after seeding, *fb* = followed by

Table 3. Grain and stover yield as well as weed index of maize as influenced by weed management practices in *Rabi* maize

Treatment	Grain yield (t/ha)		Stover yield (t/ha)		Weed index (%)		B:C	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Atrazine 1.0 g/ha PE *fb* IC at 30 DAS	7.62	8.24	8.27	9.91	5.8	7.5	2.56	2.78
Pendimethalin 1.0 kg/ha PE *fb* IC at 30 DAS	7.85	8.03	8.60	9.93	3.0	9.9	2.63	2.70
Atrazine + pendimethalin (500 +250 g/ha) PE (tank- mix)	7.68	8.33	8.36	9.68	5.1	6.5	2.67	2.89
Topramezone 25.2 g/ha EPoE *fb* IC + HW at 40 DAS	7.94	8.91	8.91	9.86	1.9	-	2.42	2.70
Topramezone + atrazine (25.2 + 500 g/ha) EPoE (tank-mix)	7.34	8.90	8.19	9.82	9.3	0.1	2.38	2.85
Tembotrione 120 g/ha EPoE *fb* IC + HW at 40 DAS	7.89	8.78	8.87	9.80	2.5	1.5	2.41	2.67
Tembotrione + atrazine (120 + 500 g/ha) EPoE (tank-mix)	7.32	8.75	8.07	9.71	9.5	1.8	2.43	2.87
IC at 20 and 40 DAS	7.37	8.31	7.59	9.80	8.9	6.7	2.51	2.83
IC + HW at 20 and 40 DAS	8.09	8.69	9.29	10.48	-	2.5	2.43	2.60
Weedy check	6.73	6.76	7.82	8.59	16.8	24.1	2.44	2.46
LSD (p=0.05)	0.61	1.15	0.77	0.69	-	-	-	-

PE = pre-emergence application; EPoE = early post-emergence application; IC = inter cultivation, HW = hand weeding, DAS = days after seeding, *fb* = followed by

competition period which lead to increase the availability of resources which reflected in better growth of the crop thereby higher grain yield. Similar line of results was also observed by Saimaheswari *et al*. (2022). Whereas, significantly higher stover yield (9.29 and 10.48 t/ha) of *Rabi* maize was achieved under IC + HW at 20 and 40 DAS during both the years. Among all the weed management practices, significantly lower grain and stover yield was recorded under weedy check but it was at par with IC carried out at 20 and 40 DAS. The minimum yield reduction due to weeds was observed with topramezone 25.2 g /ha EPoE *fb* IC + HW at 40 DAS and topramezone + atrazine 25.2 + 500 g /ha (tank-mix) EPoE followed by tembotrione 120 g /ha EPoE *fb* IC + HW at 40 DAS during 2019-20 and 2020-2021, respectively. The highest yield reduction was observed under weedy check (16.8 and 24.1% during 2019-20 and 2020-2021, respectively).

Economics of different treatment indicated that maximum benefit cost ratio of 2.67 and 2.89 was observed with atrazine + pendimethalin 500 +250 g / ha (tank-mix) PE during 2019-20 and 2020-21, respectively. The higher B:C might be due to higher grain and stover yield achieved under these treatments as a result of better control of weeds. Barla *et al*. (2016) also observed that tank-mix application of atrazine + pendimethalin PE was cost effective weed control measure in maize. The results are in accordance with the results of Kakade *et al*. (2020).

It was concluded that tank mix application of atrazine + pendimethalin 500 +250 g /ha PE or early post-emergence (10-15 DAS) application of topramezone + atrazine 25.2 + 500 g /ha or tembotrione + atrazine 120 + 500 g /ha EPoE effectively controlled the weeds in winter maize.

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