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Efficacy of pre and post emergence herbicide on weed control in *kharif* maize (*Zea mays* L.)

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Abstract
An experiment was conducted at Agronomy Main Research Station, OUAT, and Bhubaneswar during *kharif, 2016.* The experiment was laid out in randomized block design with ten treatments and three replications. The soil of the experimental field was sandy loam in texture, acidic in reaction (pH 4.68) and available nitrogen (233.0 kg/ha), phosphorus (23.2 kg/ha) and potassium (153.1kg/ha). The results of experiment revealed that the experimental site was infested with broad leaved weeds (69.66 to 91.69 %) being higher than the grasses (7.48 to 28.10%) and sedge (0.83 to 3.19%). Amongst broad leaved weeds, *Luduwigia parviflora* was the dominant while in grasses, *Digitaria sanguinalis* was most prevalent and only one sedge weed *Cyprus rotundus* occurred. Hand weeding performed at 20 and 40 DAS remarkably reduced the density of grasses, sedge and broadleaved weeds along with total weed population and weed dry weight thereby improving the weed control efficiency at all the growth stages of the crop. It was comparable with herbicide combination of atrazine @ 750 g/ha+ pendimethalin @ 750 g/ha as PE at 1 DAS, pendimethalin @ 1.0 kg/ha as PE at 1 DAS with sequential application of atrazine @ 750 g/ha + 2, 4-D amine salt @ 400 g/ha as PoE at 25 DAS and atrazine @ 1.0 kg/ha as PE at 1 DAS followed by tembotrione @ 120 g/ha as PoE at 25 DAS. The crop growth and yield attributes and grain (7.0 t/ha) and Stover yield (7.57) of hybrid maize were enhanced with herbicide combination of atrazine @ 750 g/ha+ pendimethalin @750 g/ha as PE at 1 DAS. It was followed by atrazine @1.0 kg/ha as PE at 1 DAS with sequential application of tembotrione @ 120 g/ha as PoE at 25 DAS being comparable with hand weeding at 20 and 40 DAS.

Keywords: efficacy of herbicide, combination of herbicide, hand weeding, sequential application, soil reaction

Introduction
Maize (*Zea mays* L.) is one of the most versatile emerging crop having wider adaptability under varied agro climatic conditions. In India, maize is the third most important food crops after rice and wheat. In India, it is cultivated over an area of 8.69 m ha with production of 21.80 m tonnes and productivity is 2509 kg ha^{-1} in 2015-16 (AICRP on maize 2016) [1]. In Odisha, it is grown in an area of 0.26 million hectare with a production of 0.6 million tonnes. The potentiality of maize crop can be fully exploited by adopting suitable agronomic practices. Among them, weed management plays a significant role in enhancing the crop yield. Generally, weeds reduce crop yields by competing for light, nutrients, water and carbon dioxide as well as interfering with harvesting and increasing the cost of cultivation. Management of weeds is considered to be an important factor for achieving higher productivity as weed problem is more severe during continuous rains in early stages of maize growth which cannot be controlled by traditional and cultural practices alone due to too much wetness.Initial slow growth of maize is more sensitive to weed competition during its early growth period. Wider row spacing of the crop provide enough opportunity for the weeds to emerge and offer severe competition. The growth of maize plants in the first three to four weeks is rather slow and during this period weeds establish rapidly and take competitive advantage (Srividya *et al.,* 2011). Use of pre and post emergence herbicides at temporal variation may help in avoiding the problem of weeds throughout the growth stages. The choice of weed control methods largely depend on effectiveness and economics.

Materials and Methods
The experimental was conducted in the Agronomic Main Research Farm of Orissa University of Agriculture and Technology, Bhubaneswar. The soil of the experimental field was sandy loam in texture, acidic in reaction (pH 4.68) and available nitrogen (233.0 kg/ha), phosphorus

(23.2 kg /ha) and potassium (153.1kg /ha). The experiment was laid out in randomized block design with ten treatments and three replications. Total rainfall of 841 mm was received during cropping period July, August, September and October 2016.The rainfall received during July and October were 222.2 and 132.8 mm, respectively. Mean normal relative humidity for morning and afternoon were 91.9% and 80.3% respectively.

Design	Randomized Block Design (RBD)
No. of treatment	10
No. of replications	3
Total no. of plot	30
Net Plot size	3.8m x 3.0m = 11.4 m^2
Gross plot size	5 m x 4.2 m = 21 m^2
Variety	Hishell hybrid
Spacing	60cm x 20 cm

Treatment Details

T1	Control (weedy check)
T2	Hand weeding at 20 and 40 DAS
T3	Atrazine @ 1.0 kg/ha as pre-emergence at 1 DAS
T4	Atrazine @ 750 g/ha+ pendimethalin @ 750 g/ha as pre-emergence at 1 DAS
T5	Atrazine @ 750 g/ha + 2,4-D amine salt @ 400 g/ha as post emergence at 25 DAS
T6	Halosulfuron @ 60 g/ha at 25 DAS as post emergence
T7	Atrazine @ 1.0 kg/ha as pre-emergence at 1 DAS followed by halosulfuron @60 g/ha as post emergence at 25 DAS
T8	Tembotrione @120 g/ha at 25 DAS as post emergence
T9	Pendimethalin @1000 g/ha (PE) at 1 DAS followed by atrazine @ 750 g/ha + 2,4-D amine salt @ 400 g/ha as post emergence at 25 DAS
T10	Atrazine @1.0 kg ha as pre-emergence at 1 DAS followed by tembotrione @120 g/ha as post emergence at 25 DAS

Result and discussion

1. Weed density

1.1 Total weed population

The total weed population presented in (Table 1) showed the significant difference between the treatments at all the growth stages of crop. At 25 DAS, total weed population was significantly the lowest in hand weeding at 20 and 40 days after sowing recording the density of 5.31 (28.00/m^2). It was followed by atrazine @ 750 g/ha + pendimethalin @750 g/ha at 1 DAS as pre-emergence, atrazine @ 1.0 kg/ha at 1 DAS as pre-emergence followed by tembotrione @120 g/ha at 25 DAS (POE) and pendimethalin @1.0 kg/ha at 1 DAS (PE) followed by atrazine @ 750 g/ha + 2, 4-D amine salt @ 400 g/ha at 25 DAS (POE). During 50 DAS, the minimum broad leaved weed population of 4.77 (25.33 /m^2) was recorded in hand weeding at 20 and 40 DAS which was at par with pendimethalin @1.0 kg/ha at 1 DAS (PE) followed by atrazine @750 g/ha + 2,4-D amine salt @ 400 g/ha at 25 DAS (POE) and atrazine @750 g/ha + 2,4-D amine salt @ 400 g/ha at 25 DAS as post emergence (POE).The total weed population of 10.73 (114.67 /m^2) was recorded in hand weeding at 20 and 40 DAS that remained at par with pendimethalin @1.0 kg/ha at 1 DAS (PE) followed by atrazine @ 750 g/ha + 2,4-D amine salt @ 400 g/ha at 25 DAS (POE) at Harvest. At this stage the next best result was recorded in atrazine @750 g/ha + 2,4-D amine salt @ 400 g/ha at 25 DAS as post emergence (POE) and atrazine @750 g/ha + pendimethalin @750 g/ha at 1 DAS as pre-emergence.

1.2 Dry weight of total weeds

The data on total weed dry weight depicted in (Table 1) revealed that the weed management treatment exerted the significant effect at all the crop growth stages. At 25 DAS the lowest total weed dry weight of 2.19 (4.56 g/m^2) was recorded in hand weeding at 20 and 40 days after sowing. It was at par with all the pre emergence application of herbicidal treatments such as atrazine @ 1.0 kg/ha at 1 DAS as pre-emergence(PE), atrazine @ 750 g/ha + pendimethalin @750 g/ha at 1 DAS as pre-emergence, atrazine @1.0 kg/ha at 1 DAS (PE) followed by halosulfuron @ 60 g/ha at 25 DAS (POE), pendimethalin @ 1.0 kg/ha at 1 DAS (PE) followed by atrazine @ 750 g/ha + 2,4-D amine salt @ 400 g/ha at 25 DAS (POE) and atrazine @ 1.0 kg ha at 1 DAS as pre-emergence followed by tembotrione @ 120 g/ha at 25 DAS (POE). The lowest total weed dry weight of 3.56g (12.27 g/m^2) was recorded in atrazine @750 g/ha + pendimethalin @ 750 g/ha at 1 DAS as pre-emergence which was at par all the treatments excepting halosulfuron @ 60 g/ha at 25 DAS as post emergence, tembotrione @ 120 g/ha at 25 DAS as post emergence and weedy check at 50 DAS. At the harvest, the lowest weed dry weight of 3.75 g (13.75 g/m^2) was observed in hand weeding which remained at par with pendimethalin @ 1.0 kg/ha at 1 DAS (PE) followed by atrazine @ 750 g/ha + 2,4-D amine salt @ 400 g/ha at 25 DAS (POE) and atrazine @ 1.0 kg ha at 1 DAS as pre-emergence followed by tembotrione @ 120 g/ha at 25 DAS (POE). The total weed dry weight was the highest in weedy check treatment through the growth stages of the crop.

1.3 Weed control efficiency (WCE)

The WCE computed at 25, 50, and harvest are presented in Table 1. At 25 DAS, the maximum WCE was recorded in hand weeding at 20 and 40 days after sowing (95.23%) followed by atrazine @ 750 g/ha + pendimethalin @ 750 g/ha at 1 DAS as pre-emergence (93.56%). During 50 DAS, atrazine @ 750 g/ha + pendimethalin @ 750 g/ha at 1 DAS as pre-emergence gave the highest WCE (89.26%). After it, the next best result was obtained in hand weeding at 20 and 40 DAS. During harvest, hand weeding at 20 and 40 DAS gave the highest WCE (87.46%) followed by atrazine @750 g/ha + 2, 4-D amine salt @ 400 g/ha at 25 DAS as post emergence (POE).

Table 2: Effect of weed control treatments on weed count, weed dry weight and weed control efficiency (WCE) in maize crops

Treatment	25 DAS			50 DAS			Harvest		
	Weed count (0.25m^2)	**Weed** dry weight **(g)**	**WCE (%)**	**Weed count (0.25m^2)**	**Weed dry weight (g)**	**WCE (%)**	**Weed count (0.25m)**	**Weed dry weight (g)**	**WCE (%)**
Weedy check	34.46 (1191.0)	9.78 (95.67)	0.00	32.62 (1085.4)	10.63 (113.60)	0.00	30.96 (962.7)	10.49 (109.6)	0.00
Hand weeding at 20 and 40 days after sowing (DAS)	5.31 (28.0)	2.19 (4.56)	95.23	4.77 (25.4)	3.78 (14.00)	87.68	9.96 (98.67)	3.75 (13.7)	87.46
Atrazine @ 1.0 kg/ha as pre-emergence (PE) at 1 DAS	14.53 (211.0)	2.88 (8.03)	91.61	26.69 (720.0)	4.93 (24.93)	78.05	23.41 (552.0)	5.7 (31.2)	71.51

Atrazine @ 750 g/ha + pendimethalin @ 750 g/ha as pre-emergence at 1 DAS	9.30 (86.7)	2.57 (6.16)	93.56	14.00 (201.4)	3.56 (12.27)	89.20	18.06 (340.0)	5.3 (26.9)	75.39
Atrazine @ 750 g/ha + 2,4-D Amine salt @ 400 g/ha as post emergence (PoE)at 25 DAS	32.59 (1062.7)	9.04 (81.29)	15.05	10.02 (100.7)	3.86 (14.40)	87.32	13.46 (180.7)	4.4 (18.6)	82.98
Halosulfuron @ 60 g/ha(PoE) at 25 DAS	31.89 (1021.0)	9.60 (93.69)	2.07	27.59 (766.0)	7.87 (62.87)	44.66	29.02 (866.7)	6.7 (44.4)	59.46
Atrazine @ 1.0 kg/ha at 1 DAS (PE) followed by halosulfuron @ 60 g/ha (PoE) at 25 DAS	13.37 (183.33)	2.49 (5.79)	93.95	24.68 (610.7)	4.36 (19.60)	82.75	25.31 (653.3)	5.2 (26.9)	75.44
Tembotrione @ 120 g/ha (PoE) at 25 DAS	30.07 (1093.6)	9.13 (95.65)	0.02	28.46 (809.4)	7.66 (58.29)	48.69	27.24 (782.7)	8.1 (64.8)	40.85
Pendimethalin @ 1.0 kg/ha at 1 DAS (PE) followed by atrazine @ 750 g/ha + 2,4-D amine salt @ 400 g/ha (PoE) at 25 DAS	12.32 (152.00)	3.26 (10.15)	89.39	8.19 (72.0)	4.33 (18.53)	83.69	12.01 (144.0)	4.5 (20.00)	81.76
Atrazine @ 1.0 kg/ha at 1 DAS (PE) followed by tembotrione @ 120 g/ha (PoE) at 25 DAS	12.17 (147.67)	2.74 (7.15)	92.53	22.93 (525.4)	4.09 (16.27)	85.68	21.16 (458.7)	4.6 (20.7)	81.12
SE(m)±	0.92	0.87	-	1.56	0.53	-	0.96	0.30	-
CD (P = 0.05)	2.72	2.58	-	4.62	1.56	-	2.84	0.88	-

Table 2: Effect of weed control treatments on plant dry weight, yield and economics of maize

Treatment	Dry weight of plant 45 DAS	Dry weight of plant At harvest	Grain yield (t/ha)	Harvest index (%)	Weed index (%)	B:C ratio
Weedy check	229.92	556.65	4.49	43.79	35.89	2.21
Hand weeding at 20 and 40 days after sowing (DAS)	319.23	824.00	6.47	46.97	7.57	2.51
Atrazine @ 1.0 kg/ha as pre-emergence (PE) at 1 DAS	293.56	760.80	5.85	45.38	16.45	2.76
Atrazine @750 g/ha + pendimethalin @750 g/ha (PE) at 1 DAS	335.83	920.51	7.00	48.03	0.00	3.15
Atrazine @750 g/ha + 2,4-D Amine salt @ 400 g/ha as post emergence (PoE) at 25 DAS	319.92	824.01	6.57	47.00	6.14	3.07
Halosulfuron @ 60 g/ha (PoE) at 25 DAS	289.06	721.37	4.77	41.19	31.80	2.00
Atrazine @1.0 kg/ha at 1 DAS (PE) followed by halosulfuron @60 g/ha (PoE) at 25 DAS	299.67	792.08	6.10	46.42	12.92	2.47
Tembotrione @120 g/ha (PoE) at 25 DAS	294.50	759.19	5.03	42.60	28.13	2.19
Pendimethalin @1.0 kg/ha at 1 DAS (PE) followed by atrazine @ 750 g/ha + 2,4-D amine salt @ 400 g/ha (PoE) at 25 DAS	300.96	800.57	6.26	45.76	10.57	2.77
Atrazine @1.0 kg ha at 1 DAS (PE) followed by tembotrione @120 g/ha(PoE) at 25 DAS	328.11	885.03	6.74	47.20	3.72	2.84
SE(m)±	14.46	28.57	0.35	1.34	-	-
CD (P = 0.05)	42.95	84.88	1.05	3.99	-	-

2.1 Plant dry weight (m^2)

The plant dry matter production of 45 DAS was the highest in atrazine @ 750 g/ha + pendimethalin @ 750 g/ha at 1 DAS as pre-emergence (335.83 g/m^2) that remained at par with atrazine @ 1.0 kg ha at 1 DAS as pre-emergence followed by tembotrione @ 120 g/ha (POE) at 25 DAS (328.11 g/m^2). The highest dry matter accumulation was observed in atrazine @ 750 g/ha + pendimethalin @ 750 g/ha at 1 DAS as pre-emergence followed by atrazine @ 1.0 kg/ha at 1 DAS as pre-emergence in sequence of tembotrione @ 120 g/ha (POE) at 25 DAS which were at par with hand weeding at 20 and 40 DAS during harvest.

2.2 Grain yield

Weed management treatments exerted the significant effect in increasing the grain yield over un-weeded control (Table 24). Pre-emergence application of atrazine @ 750 g/ha + pendimethalin @ 750 g/ha at 1 DAS recorded the highest grain yield (7.00t/ha). It was at par with atrazine @1.0 kg/ha (PE) at 1 DAS followed by tembotrione @ 120 g/ha (POE) at 25 DAS (6.74 t/ha) and atrazine @ 750 g/ha + 2,4-D amine salt @ 400 g/ha at 25 DAS as post emergence (6.57 t/ha), hand weeding at 20 and 40 days after sowing (6.47 t/ha), pendimethalin @ 1.0 kg/ha (PE) at 1 DAS followed by atrazine @ 750 g/ha + 2,4-D amine salt @ 400 g/ha (PoE) at 25 DAS (6.26 t/ha) and atrazine @ 1.0 kg/ha (PE) at 1 DAS followed by halosulfuron @ 60 g/ha (POE) at 25 DAS (6.10 t/ha). The grain yield obtained among the herbicidal treatments was the lowest in halosulfuron @ 60 g/ha as PoE. Weedy check treatment recorded the lowest grain yield of 4.49 t/ha.

2.3 Harvest Index

Data on harvest index presented in Table 24 indicated that the maximum harvest index was obtained in **a**trazine @ 750 g/ha + pendimethalin @ 750 g/ha as pre-emergence at 1 DAS (48.03%) which was at par with all other treatment except post emergence application of halosulfuron @ 60 g/ha at 25 DAS and tembotrione @ 120 g/ha at 25 DAS and weedy check treatment. The second highest harvest index (47.20%) was observed in atrazine @ 1.0 kg/ha at 1 DAS (PE) followed by tembotrione @120 g/ha (POE) at 25 DAS.

2.4. Weed Index

Data pertaining to weed index computed on the basis of maximum grain yield as presented in Table 24 showed that un weeded control recorded the maximum yield loss of 35.89 %. Minimum yield loss was observed in atrazine @ 1.0 kg /ha(PE) at 1 DAS followed by tembotrione @ 120 g/ha (POE) at 25 DAS (3.72%) and atrazine @750 g/ha + 2,4-D Amine salt @ 400 g/ha at 25 DAS as post emergence (6.14%) as compared with hand weeding at 20 and 40 days after sowing (7.57%).

2.5 Economics

The economics of cultivation of maize calculated basing upon

the prevailing market price of input and output are depicted in Table 2. The data revealed that the pre emergence application of atrazine @750 g/ha+ pendimethalin @750 g /ha at 1 DAS registerd the highest B:C ratio (3.15).

Conclusion

It is concluded that herbicide combination of atrazine @750 g/ha + pendimethalin @750 g/ha as pre-emergence at 1 DAS effectively controlled the weeds as comparable with hand weeding at 20 and 40 DAS. The same treatment produced the highest grain (7.0 t/ha).

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