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Chemical weed management in maize using pre and post emergence herbicides

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Abstract
A field experiment was conducted during *kharif* 2018-19 College of Agriculture, Latur to find out the effective herbicides for control of weeds in maize (*Zea mays* L.). The experiment comprises of ten treatment combinations and were compared with weed free and weedy check and laid out in randomized block design and replicated three times. Application of pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i. ha^{-1} (PoE) was significantly superior in reducing weed density and dry weight of weeds. Weed free check, pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i ha^{-1}.(PoE), pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* tembotrione 120 g a.i. ha^{-1} (30 DAS) and atrazine 1000 g a.i. ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i. ha^{-1} (PoE) registered 6335, 6099, 5549 and 5230 kg ha^{-1} kernel yield respectively as against the seed yield of weedy check, 2737 kg ha^{-1}.

Keywords: Maize, weed management, new chemicals, pre-emergence and post-emergence

Introduction
Maize (*Zea mays* L.) or Indian corn is an essential crop which highly contributes to the world agriculture and more importantly to the world's food basket. In India, maize covers 9.28 m ha area with the productivity of 2.82 MT ha^{-1} during 2018-19 (Ministry of Agriculture, India). Maize occupies importance as a human food (25%), poultry supplement (49%), animal supplement (12%), and industrial products such as starch (12%). Maize also contains maximum genetic yield potential, therefore maize is known as "Queen of cereals" (India Maize Summit, 2018). Weeds usually reduces crop yield up to 31.5% (22.7% in *rabi* and in *kharif* 36.5%). But as farmers adopt some kind of weeding on their crop field, a conservative estimate of 10% loss in crop yields may be taken as more realistic, hand weeding is most effective if done in time, though it is costly and time consuming. Apart from this, labourers are not available for weeding owing to other agricultural operation going on simultaneously. Additionally, manual method of weed control cannot be put into practice until weeds have achieved certain heights. In *kharif* maize, problem of severe weed infestation level combined with various species of weeds. Almost every type of weeds namely grassy, broad leaved and sedges infest the maize fields. As they compete for moisture, nutrients, space, light, shelter for many diseases and pest ultimately disturbs the growth of the plants, reduce the yield and also deteriorates the quality of crop. Sharma *et al*., (2000) [5] reported that the reduction (33-50%) in grain yield due to weed infestation. The higher loss in crop yield due to weed competition and it is evaluated that during the 1st 3-6 weeks (Shad *et al*., 1997) [4]. Therefore, there is a need for some alternate herbicides or sequential application of herbicide, which gives broad spectrum and season long control of weeds during the critical period in *kharif* maize, without affecting the crop growth and crop yield.

Materials and methods
A field experiment was conducted during *kharif* 2018-19 College of Agriculture, Latur to find out the effective herbicides for control of weeds in maize (*Zea mays* L.). The experiment comprises of ten treatment combinations and three replications under randomized block design with the net plot area (16.56 m^2).The soil of experimental site was medium and black in color with good drainage and low in available nitrogen (125.3 kg ha^{-1}), medium in available phosphorous (18.20 kg ha^{-1}) and very high in available potassium (498.58 kg ha^{-1}). The soil was moderately alkaline in reaction having pH (7.7). Maize *'Mahabeej-Uday'* was sown on 02

August 2019 at 60 cm row to row and 30 cm plant to plant spacing using 15 kg ha^{-1}seed rate and was harvested on 01 December 2019. Recommended dose of fertilizers (150 kg N + 75 kg P + 75 kg, kg ha^{-1}) was applied. The doses of herbicides were computed as per treatments. The stock solution of desired concentration was prepared as per treatment for each plot and the herbicides were applied with knap sack sprayer. The pre-emergence herbicides were applied 24 hours after sowing and in case of post-emergence herbicides they were applied as per the treatments. Treatments were as follows, T_1- Weedy check, T_2- Weed free check, T_3- Atrazine 1000 g a.i.ha^{-1} (PE) *fb* Halosulfuron-methyl 90 g a.i. ha^{-1} (PoE), T_4- Atrazine 1000 g a.i. ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i. ha^{-1} (PoE), T_5- Pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* halosulfuron-methyl 90 g a.i. ha^{-1} (PoE), T_6- Pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* tembotrione 120 g a.i. ha^{-1} (30 DAS), T_7- Pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i. ha^{-1} (PoE), T_8- Halosulfuron-methyl 90 g a.i. ha^{-1} (PoE), T_9- Tembotrione 120 g a.i. ha^{-1} (PoE), T_{10}- 2,4-D amine 1000 g a.i. ha^{-1} (PoE) (*fb- Followed by*). The observations on weed population was recorded at 30, 45 and 60 DAS and weed dry weight were recorded at harvest and data was analyzed using square root transformation (X + 0.5). The yield recorded at net plot basis converted to hectare and expressed in kg ha^{-1}. The data was statistically analyzed by adopting Fishers methods of analysis of variance as outlined by Gomez and Gomez (1984) [3].

Results and discussion

Weed dynamics

The experimental field was infested with *Commelina benghalensis L., Acalypha indica L., Amaranthus viridis, Euphorbia spp., Parthenium hysterophorun, Corchorus fascicularis L., Abutilon hirtum (Lam.), Boerhavia coccinea, Phyllanthus niruri, Argemone Mexicana L., Euphorbia geniculata Orteg., Achyranthus aspera L., Cardiospermum helicacabum L., Xanthium strumarium L., Celosia argentea L.* under broad leaved weeds followed by grasses *Sorghum halepense L., Cynodon dactylon L. Pers., Eriochloa spp. and* sedges *Cyperus rotundus L.* At 30 DAS, significant reduction in total weed density was recorded under herbicidal treatment Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE), which was at par with Atrazine 1000 g a.i.ha^{-1} (PE) *fb* Halosulfuron-methyl 90 g a.i.ha^{-1} (PoE), Atrazine 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) and Pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS) but significantly superior over other herbicidal treatments. At 45 DAS, minimum total weed density was observed in Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) which was at par with Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS) and found significantly superior over other herbicidal treatments. At 60 DAS, significant reduction in total weed density was recorded under herbicidal treatment Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE), which was at par with Atrazine 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) and Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS) and found significantly superior over rest of the herbicidal treatments. Although, Weed free check showed lowest total weed density. Whereas highest total weed density was observed in Weedy check. Total dry weight of weeds was significantly reduced under Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) followed by Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS) as compared to other herbicidal treatments. It might be due to two fold action of this combination and sequential application that affected both grasses as well as broad leaf weeds. The greater effectiveness of Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) has also been reported by Biswas *et al*. (2018) [2] and Barua S. (2019) [1], who observed least total weeds dry weight under these combination. Maximum weed index was observed in Weedy check, followed by Halosulfuron-methyl 90 g a.i.ha^{-1} (PoE), Tembotrione 120 g a.i.ha^{-1} (PoE) and Atrazine 1000 g a.i.ha^{-1} (PE) *fb* Halosulfuron-methyl 90 g a.i.ha^{-1} (PoE). Whereas, minimum weed index was found in Weed free check followed by Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE), Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS), Atrazine 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE). Higher weed control efficiency and herbicide efficiency index among herbicidal treatments was noticed in Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) followed by Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS) (Table 1).

Table 1: Effect of weed control treatments on density and dry weight of weeds, weed control efficiency (%), weed index (%), herbicide efficiency index (%), kernel yield (kg ha^{-1}) and stover yield (kg ha^{-1})

Treatment	Weed density (1m^2)			Weed dry weight (g/net plot*)	Weed control efficiency (%)	Weed index (%)	Herbicide efficiency index (%)
	30 DAS	45 DAS	60 DAS				
Weedy check	6.19** (37.83)	6.57 (42.67)	6.81 (45.94)	96.17 (9250.06)	0.00	131.42	0.00
Weed free check	2.81 (7.44)	1.87 (3.00)	1.52 (1.84)	23.51 (552.63)	94.03	0.00	22.00
Atrazine 1000 g a.i.ha^{-1} (PE) *fb* Halosulfuron-methyl 90 g a.i.ha^{-1} (PoE)	2.67 (6.66)	3.38 (10.98)	3.06 (8.88)	40.02 (1601.36)	82.69	50.91	3.08
Atrazine 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE)	2.67 (6.66)	2.68 (6.70)	1.96 (3.35)	33.97 (1153.46)	87.53	21.12	7.30
Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* halosulfuron-methyl 90 g a.i.ha^{-1} (PoE)	3.05 (8.83)	3.1 (9.11)	2.75 (7.11)	35.37 (1250.96)	86.48	39.72	4.85
Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS)	2.49 (5.72)	2.05 (3.71)	1.75 (2.57)	30.95 (957.73)	89.65	14.15	9.92
Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE)	2.35 (5.04)	1.91 (3.16)	1.74 (2.56)	27.32 (745.9)	91.94	3.86	15.23
Halosulfuron-methyl 90 g a.i.ha^{-1} (PoE)	5.24 (27.00)	3.73 (13.44)	3.93 (15.00)	61.82 (3821.43)	58.69	79.85	0.69
Tembotrione 120 g a.i.ha^{-1} (PoE)	5.29 (27.58)	2.96 (8.27)	2.90 (7.93)	60.5 (3660.9)	60.42	56.42	1.21
2,4-D amine 1000 g a.i.ha^{-1} (PoE)	5.22 (26.83)	2.91 (8.00)	2.30 (4.79)	34.07(1160.36)	87.46	30.37	6.18
SE ±	0.72	0.48	0.58	98.13	-	-	-
CD 5%	2.14	1.43	1.74	291.52	-	-	-

*16.56 m^2, ** data in parenthesis (original value) was subjected to $\sqrt{X + 0.5}$ transformation.

Effect on yield

Data regarding cob yield (Table 2) showed that, statistically higher cob yield (kg ha^{-1}) was observed in Weed free check i.e. 7940 kg ha^{-1}, which was at par with Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) having cob yield 7888 kg ha^{-1} and Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb*

tembotrione 120 g a.i.ha^{-1} (30 DAS) having cob yield 7257 kg ha^{-1}, but significantly superior over other herbicidal treatments. Of all the treatments Weedy check showed the lower cob yield (kg ha^{-1}) i.e. 4434 kg ha^{-1} as compared to any other treatments. Among all the treatments, statistically higher kernel yield (kg ha^{-1}) was observed in Weed free check i.e. 6335.23 kg ha^{-1}, which was at par with Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) having kernel yield 6099.73 kg ha^{-1} and Pendimethalin 1000 g a.i. ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS) having kernel yield 5549 kg ha^{-1}, but significantly superior over other herbicidal treatments. Of all the treatments Weedy check showed the lowest kernel yield (kg ha^{-1}) i.e. 2737 kg ha^{-1} as compared to any other treatments. Data indicated that the statistically higher stover yield (kg ha^{-1}) was observed in Weed free check i.e. 11207.03 kg ha^{-1}, which was at par with Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE) having stover yield 9878.97 kg ha^{-1} and Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS) having stover yield 9091 kg ha^{-1}, but significantly superior over other herbicidal treatments. Of all the treatments Weedy check showed the low stover yield (kg ha^{-1}) i.e. 6767 kg ha^{-1} as compared to any other treatments. The yield (grain and stover) is the function of cumulative effect of yield attributes and the growth characters. The grain yield of maize positively influenced by cob length, cob girth, number of rows cob^{-1}, number of kernels row^{-1} and test weight. Yield attributes of maize were significantly influenced by adapting different weed management practices and higher value were noticed under treatments which had lower weed density and their dry weight and as a result of minimum weed competition. The reduction in weed competition in maize by the application of herbicides not only favored the crop plants with more availability of space, light, moisture and nutrients but also minimized weed interference, facilitating vigorous growth of crop plants. These results are found to be in close conformity with Biswas *et al.,* (2018) [2] and Barua S. (2019) [1].

Table 2: Effect of weed control treatments on yield (kg ha^{-1})

Treatment	Cob Yield kg ha^{-1}	Kernel Yield kg ha^{-1}	Stover Yield kg ha^{-1}
Weedy check	4434	2737	6767
Weed free check	7940	6335	11207
Atrazine 1000 g a.i.ha^{-1} (PE) *fb* Halosulfuron-methyl 90 g a.i.ha^{-1} (PoE)	5980	4198	7846
Atrazine 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE)	6933	5230	8216
Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* halosulfuron-methyl 90 g a.i.ha^{-1} (PoE)	6343	4534	8077
Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* tembotrione 120 g a.i.ha^{-1} (30 DAS)	7257	5549	9091
Pendimethalin 1000 g a.i.ha^{-1} (PE) *fb* 2,4-D amine 1000 g a.i.ha^{-1} (PoE)	7888	6099	9878
Halosulfuron-methyl 90 g a.i.ha^{-1} (PoE)	4884	3522	7217
Tembotrione 120 g a.i.ha^{-1} (PoE)	5764	4050	7302
2,4-D amine 1000 g a.i.ha^{-1} (PoE)	6434	4859	8117
SE ±	392	288	456
CD 5%	1165	856	1355

Conclusion

Based on the result it can be inferred that application of Pendimethalin 1000 gm a.i. ha^{-1} (PE) *fb* 2,4-D amine 1000 gm a.i. ha^{-1} (PoE) is proved to be most effective in controlling weeds, gave higher yield, although hand weeding is the best.

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