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# Comparative study on weed control efficacy of different pre-and post-emergence herbicides in *Kharif* maize

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**ABSTRACT**

A field experiment was conducted at Research Farm of Punjab Agricultural University, Ludhiana during *Kharif* 2016 and 2017 to find out the best chemical weed management practices in maize. Ten treatments were evaluated in a randomized block design with three replications. Treatments consisted of pre-emergence (PE) and post-emergence (PoE) herbicide applications along with weed-free check and weedy check. Experimental results indicated that pendimethalin 1.0 kg/ha as PE *fb* atrazine 0.75 kg/ha + 2,4-D amine 0.4 kg/ha at 25 DAS as PoE recorded lowest weed index (4.9 and 3.9% respectively, during *Kharif* 2016 and 2017) followed by treatment atrazine 1.5 kg/ha as pre-emergence *fb* tembotrione 120 g/ha as PoE at 25 DAS (5.6 and 4.4%, respectively). Grain yield was significantly higher (6.71 and 6.67 t/ha, respectively) with treatment weed-free than all other treatments however, it was statistically at par with treatment pendimethalin 1.0 kg/ha as PE *fb* atrazine 0.75 kg/ha + 2,4-D amine 0.4 kg/ha at 25 DAS as PoE (6.38 and 6.41 t/ha, respectively during *Kharif* 2016 and 2017) followed by atrazine 1.5 kg/ha as PE *fb* tembotrione 120 g/ha as PoE at 25 DAS (6.34 and 6.37 t/ha, respectively).

## INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereals of the world and has attained a commercial crop status and also has scope to increase the present yield. Maize, which is mostly grown during *Kharif* rainy season, faces a formidable weed problem competing severely for growth resources resulted in yield losses from 33 to 50% Sharma *et al.* (2000). Maximum yield loss due to weed competition occurs during the first 3-6 weeks, *i.e.*, before the canopy has developed thick enough to smother the weeds (Shad *et al.* 1993). Wider row spacing and initial slow crop growth (Nagalakshmi *et al.* 2006) makes maize highly sensitive to weed competition up to 6 weeks growth period. Thus, to realize optimum yield, thorough weed management is considered critical during the initial 6 weeks of crop growth to minimize crop-weed competition.

Management of weeds is considered to be an important factor for achieving higher productivity. Due to increased cost and non availability of manual labour in required number for timely hand weeding, the role of herbicide is a significant preposition. Herbicides not only control the weeds timely and effectively, but also offer great scope for minimizing the cost of weed control irrespective of the situation. Use of pre- and post-emergence application of herbicides would make herbicidal weed control more acceptable to farmers. Usage of PE herbicides assumes greater importance in the view of their effectiveness from initial stages. Pre-emergent application of herbicides will control the weeds up to 25 days and after that PoE application is given so that further growth of weeds can also be controlled. Pre- and post-emergence herbicides will be an ideal means for controlling the weeds in view of economics and effectiveness in maize. Keeping above in view, an study was carried out to study the sequential application of pre-emergence and post-emergence herbicides in maize during *Kharif* 2016 and 2017.

## MATERIALS AND METHODS

A field experiment was conducted at the Research Farm of Punjab Agricultural University, Ludhiana during *Kharif* 2016 and 2017. The soil of the experimental field was loamy sand in texture, low in available nitrogen (132.5kg/ha), medium in available phosphorus (20.4 kg/ha) and potash (183.5 kg/ha). The experiment was laid out in a randomized block design (RBD) with the following treatments *viz.* control (weedy check), weed-free, atrazine 1.5 kg/ha as pre-emergence (PE), atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha as PE, atrazine 1.5 kg/ha + 2,4-D amine 0.4 kg/ha at 25 days after sowing (DAS)

as post-emergence (PoE), halosulfuron 90 g/ha at 25 DAS, atrazine 1.5 kg/ha as PE followed by (*fb*) halosulfuron 90 g/ha at 25 DAS, tembotrione 120 g/ha as PoE at 25 DAS, pendimethalin 1.0 kg/ha as PE *fb* atrazine 0.75 kg/ha + 2,4-D amine 0.4 kg/ha at 25 DAS as PoE and atrazine 1.5 kg/ha as PE *fb* tembotrione 120 g/ha as PoE at 25 DAS and replicated thrice. Maize hybrid '*PMH-1'* was sown on 08.07.2016 and 14.07.2017, during 2016 and 2017, respectively at 60 x 20 cm spacing. Before sowing, the field was thoroughly ploughed and leveled. The crop was fertilized evenly irrespective of treatments with $N:P_2O_5:K_2O$ (125:60:30 kg/ha), where N was applied in three equal splits at the time of sowing, at knee high and tasseling stage.

Pre-emergence herbicides were applied within two days after sowing. Post-emergence herbicides were applied at 25 DAS. All the herbicides were sprayed as per the treatments. Weed density was recorded at 50 DAS using a quadrate of 100 x 100 cm (1 $m^2$) size from the center of the plot. The entire weeds inside the quadrate were uprooted and cut close to the transition of root and shoot in each plot and collected for dry matter accumulation (biomass). The samples were first dried in sun and then kept in an oven at 70 ± 2°C. The dried samples were weighed and expressed as biomass ($g/m^2$). Square root transformation was done for weed density and weed biomass by using the formula $x + 0.5$. Weed control efficiency (WCE) and weed index (WI) were calculated using formulae as given by Gill and Kumar (1969), Mani *et al.* (1973).

## RESULTS AND DISCUSSION

### Effect of herbicides on weed density and dry weight

Weed density and weed dry weight at 50 DAS was significantly influenced by weed management practices in maize (**Table 1**). Application of atrazine 1.5 kg/ha as PE followed by halosulfuron 90 g/ha at 25 DAS recorded significantly lesser grassy weed count (2.8 and 3.5 number/$m^2$) and weed dry weight (1.5 and 2.1 $g/m^2$) on 50 DAS and it was statistically at par with the application of halosulfuron 90 g/ha at 25 DAS, pendimethalin 1.0 kg/ha as PE *fb* atrazine 0.75 kg/ha + 2,4-D amine 0.4 kg/ha at 25 DAS and atrazine 1.5 kg/ha as PE *fb* tembotrione 120 g/ha at 25 DAS during the years 2016 and 2017, respectively.

The broad-leaved weeds (BLW) counts during 2016 and 2017 showed that the application of atrazine 1.5 kg/ha as PE *fb* tembotrione 120 g/ha as PoE recorded excellent control on BLW (2.4 and 2.5 number/$m^2$, respectively) and weed dry weight (2.1 $g/m^2$ each) on 50 DAS and it was significantly superior to the application of atrazine 1.5 kg/ha as PE (4.1 no./$m^2$ each) and (3.6 and 3.5 $g/m^2$, respectively), atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha as PE (3.5 no./$m^2$ each) and weed dry weight (3.4 and 3.3 $g/m^2$, respectively) and atrazine 1.5 kg/ha + 2,4-D amine 0.4 kg/ha as PoE (3.4 no./$m^2$ each) and weed dry weight (3.2 and 2.9 $g/m^2$, respectively). These results are in accordance with the findings of Swetha *et al*. (2015) and Sivamurugan *et al*. (2017).

**Table 1. Effect of different pre and post-emergence herbicides on weed density and weed dry weight of *kharif* maize**

| Treatment | Weed density (no./$m^2$) at 50 DAS | | | | | | Weed dry weight biomass ($g/m^2$) at 50 DAS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2016 | | | 2017 | | | 2016 | | | 2017 | | |
| | Grasses | Broad leaf | Sedges | Grasses | Broad leaf | Sedges | Grasses | Broad leaf | Sedges | Grasses | Broad leaf | Sedges |
| Atrazine 1.5 kg/ha as pre-emergence (PE) | 18.7 | 16.0 | 24.7 | 23.0 | 16.0 | 30.0 | 6.0 | 12.3 | 10.1 | 8.3 | 11.6 | 10.4 |
| | (4.4) | (4.1) | (5.1) | (4.9) | (4.1) | (5.6) | (2.6) | (3.6) | (3.3) | (3.0) | (3.5) | (3.4) |
| Atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha as PE | 16.0 | 11.7 | 20.7 | 21.0 | 11.7 | 26.0 | 4.3 | 10.4 | 9.5 | 6.6 | 10.1 | 9.8 |
| | (4.1) | (3.5) | (4.7) | (4.7) | (3.5) | (5.2) | (2.3) | (3.4) | (3.2) | (2.8) | (3.3) | (3.3) |
| Atrazine 1.5 kg/ha + 2,4-D amine 0.4 kg/ha at 25 DAS | 17.3 | 10.7 | 8.7 | 21.7 | 10.7 | 14.0 | 3.5 | 9.3 | 7.5 | 5.5 | 9.0 | 7.9 |
| | (4.3) | (3.4) | (3.1) | (4.8) | (3.4) | (3.9) | (2.1) | (3.2) | (2.9) | (2.5) | (3.1) | (3.0) |
| Halosulfuron 90 g/ha at 25 DAS | 9.3 | 8.0 | 10.3 | 13.7 | 7.3 | 16.0 | 1.5 | 5.0 | 6.9 | 3.5 | 4.7 | 7.2 |
| | (3.2) | (3.0) | (3.4) | (3.8) | (2.8) | (4.1) | (1.6) | (2.4) | (2.8) | (2.1) | (2.4) | (2.9) |
| Atrazine 1.5 kg/ha as pre-emergence *fb* halosulfuron 90 g/ha at 25 DAS | 7.0 | 7.0 | 8.3 | 11.3 | 6.7 | 12.3 | 1.3 | 4.5 | 6.4 | 3.3 | 4.1 | 6.7 |
| | (2.8) | (2.8) | (3.0) | (3.5) | (2.7) | (3.6) | (1.5) | (2.3) | (2.7) | (2.1) | (2.3) | (2.8) |
| Tembotrione 120 g/ha at 25 DAS | 18.0 | 6.3 | 8.7 | 22.3 | 7.3 | 14.3 | 2.3 | 5.1 | 8.6 | 4.4 | 4.4 | 8.9 |
| | (4.3) | (2.7) | (3.1) | (4.8) | (2.8) | (3.9) | (1.8) | (2.4) | (3.1) | (2.3) | (2.3) | (3.1) |
| Pendimethalin 1.0 kg/ha as PE *fb* atrazine | 8.3 | 6.0 | 12.3 | 13.0 | 6.7 | 18.3 | 2.6 | 4.7 | 10.4 | 4.7 | 4.1 | 10.7 |
| 0.75 kg/ha + 2,4-D amine 0.4 kg/ha at 25 DAS | (3.0) | (2.6) | (3.6) | (3.7) | (2.7) | (4.4) | (1.9) | (2.3) | (3.4) | (2.4) | (2.2) | (3.4) |
| Atrazine 1.5 kg/ha as PE *fb* tembotrione 120 g/ha at 25 DAS | 9.0 | 5.0 | 7.7 | 13.7 | 5.3 | 13.0 | 1.7 | 3.3 | 7.1 | 3.8 | 3.3 | 7.4 |
| | (3.2) | (2.4) | (2.9) | (3.8) | (2.5) | (3.7) | (1.6) | (2.1) | (2.8) | (2.2) | (2.1) | (2.9) |
| Control (weedy check) | 62.0 | 32.0 | 53.0 | 63.0 | 29.3 | 54.3 | 20.5 | 20.9 | 18.1 | 22.8 | 20.5 | 19.4 |
| | (7.9) | (5.7) | (7.3) | (8.0) | (5.5) | (7.4) | (4.6) | (4.7) | (4.4) | (4.9) | (4.6) | (4.5) |
| Weed free | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | (1.0) | (1.0) | (1.0) | (1.0) | (1.0) | (1.0) | (1.0) | (1.0) | (1.0) | (1.0) | (1.0) | (1.0) |
| LSD(p=0.05) | 0.74 | 0.71 | 0.49 | 0.74 | 0.91 | 0.59 | 0.38 | 0.64 | 0.31 | 0.35 | 0.49 | 2.52 |

Values in the parentheses are original values and are subject to square root transformation

With respect to sedges, application of atrazine 1.5 kg/ha as PE *fb* tembotrione 120 g/ha as PoE recorded significantly the lesser weed count (2.9 and 3.7 no/$m^2$) on 50 DAS and it was comparable with application of atrazine 1.5 kg/ha as PE *fb* halosulfuron 90 g/ha at 25 DAS (3.0 and 3.6 no./$m^2$), tembotrione 120 g/ha as PoE (3.1 and 3.9 no./$m^2$), atrazine 1.5 kg/ha + 2,4-D amine 0.4 kg/ha as PoE (3.1 and 3.9 no./$m^2$), halosulfuron 90 g/ha at 25 DAS (3.4 and 4.1 no./$m^2$). Significantly lesser weed dry weight (2.7 and 2.8 g/$m^2$) recorded with the application of atrazine 1.5 kg/ha as PE *fb* halosulfuron 90 g/ha at 25 DAS as compared to atrazine 1.5 kg/ha as PE (3.3 and 3.4 g/$m^2$), atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha as pre-emergence (3.2 and 3.3 g/$m^2$) and treatment pendimethalin 1.0 kg/ha as PE *fb* atrazine 0.75 kg/ha + 2,4-D amine 0.4 kg/ha at 25 DAS as PoE (3.4 g/$m^2$ each) during the years 2016 and 2017, respectively.

**Effect of herbicides on weed control efficiency and weed index**

Weed control efficiency (WCE) varied with different weed control methods at 50 DAS (**Table 2**). In WCE, total weed dry weight was taken into account which consisted of different weed species with varying proportions. WCE do not effect the individual weed species effect. Performance of crop is directly proportional to the WCE and inversely proportional to the weed index. At 50 DAS, the maximum WCE of grasses and sedges weeds were recorded with the application of atrazine 1.5 kg/ha as PE *fb* halosulfuron 90 g/ha at 25 DAS (93.7 and 85.5%) and (64.6 and 65.5%) followed by halosulfuron 90 g/ha at 25 DAS (92.7 and 84.6%) and (61.9 and 62.9%), and atrazine 1.5 kg/ha as PE *fb* tembotrione 120 g/ha as PoE (91.7 and 83.3%) and (60.8 and 61.9%) respectively, during 2016 and 2017. In broad-leaf weeds higher WCE was recorded with the application of atrazine 1.5 kg/ha as PE *fb* tembotrione 120 g/ha as PoE (84.2 and 83.9%) But lesser WCE was recorded with the application of atrazine 1.5 kg/ha as PE (41.1 and 43.4%) during 2016 and 2017. It was due to lower weed population and total dry weight of weeds in these treatments due to better control of weeds following exposure to PoE application of herbicides Hatti *et al*. (2014) and Sah *et al*. (2015)

Weed index data computed on the basis of maximum grain yield as (**Table 2**) it showed that un-weeded control recorded the maximum yield loss of 45.5 and 34.7% during 2016 and 2017, respectively. Minimum yield loss were observed in treatments pendimethalin 1.0 kg/ha as PE *fb* atrazine 0.75 kg/ha + 2,4-D amine 0.4 kg/ha at 25 DAS (4.9 and 3.9%) and atrazine 1.5 kg/ha as PE *fb* tembotrione 120 g/ha at 25 DAS (5.6 and 4.4%) as compared to the all other treatments. Slow growth of crop in the early stages offered much scope for the development of weeds beside the competitiveness of weeds in utilizing the resources which resulted in more loss of yield Patel *et al.* (2006). This clearly indicated that the sequential use of PE herbicides followed PoE spray at 25 DAS was the most effective approach in controlling weeds and thus resulted in recording significantly lower values for weed index. These findings were in conformity with the findings of Sreenivas *et al*. (1992) and Hawaldar and Agasimani (2012).

**Effect of herbicides on growth and yield of maize**

A comparatively lesser number of plants per hectare was recorded in the weed check (control) treatment but it did not bring a significant difference in plant population than all other treatments during both the years. Weed control treatments brought about significant variation in cobs per hectare. Significantly lesser number of cobs per hectare were recorded in treatment weedy check (70.8 and 73.1 x $10^3$ /ha) and all the treatments, however, it was statistically at par with treatment atrazine 1.5 kg/ha as PE (74.8 and 77.8 x $10^3$ /ha) and treatment halosulfuron 90 g/ha at 25 DAS (74.5 and 74.8 x $10^3$ /ha) during 2016 and 2017, respectively **Table 3**. Weed-free condition recorded higher plant height

**Table 2. Weed control efficiency and weed index as affected by pre and post-emergence herbicides of *kharif* maize**

| Treatment | Weed control efficiency (%) | | | | | | Weed index (%) | |
|---|---|---|---|---|---|---|---|---|
| | 2016 | | | 2017 | | | | |
| | Grasses | Broad-leaf | Sedges | Grasses | Broad-leaf | Sedges | 2016 | 2017 |
| Atrazine 1.5 kg/ha as pre-emergence (PE) | 70.7 | 41.1 | 44.2 | 63.6 | 43.4 | 46.4 | 30.1 | 27.2 |
| Atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha as PE | 79.0 | 50.2 | 47.5 | 71.1 | 50.7 | 49.5 | 9.3 | 10.9 |
| Atrazine 1.5 kg/ha + 2,4-D amine 0.4 kg/ha at 25 DAS | 82.9 | 55.5 | 58.6 | 75.9 | 56.1 | 59.3 | 22.6 | 22.8 |
| Halosulfuron 90 g/ha at 25 DAS | 92.7 | 76.1 | 61.9 | 84.6 | 77.1 | 62.9 | 27.8 | 26.7 |
| Atrazine 1.5 kg/ha as PE *fb* halosulfuron 90 g/ha at 25 DAS | 93.7 | 78.5 | 64.6 | 85.5 | 80.0 | 65.5 | 12.1 | 16.6 |
| Tembotrione 120 g/ha at 25 DAS | 88.8 | 75.6 | 52.5 | 80.7 | 78.5 | 54.1 | 14.5 | 19.9 |
| Pendimethalin 1.0 kg/ha as PE *fb* atrazine 0.75 kg/ha + 2,4-D amine 0.4 kg/ha at 25 DAS | 87.3 | 77.5 | 42.5 | 79.4 | 80.0 | 44.8 | 4.9 | 3.9 |
| Atrazine 1.5 kg/ha as PE *fb* tembotrione 120 g/ha at 25 DAS | 91.7 | 84.2 | 60.8 | 83.3 | 83.9 | 61.9 | 5.6 | 4.4 |
| Control (weedy check) | - | - | - | - | - | - | 45.5 | 34.7 |

**Table 3. Effect of pre- and post-emergence herbicides on growth and yield of *Kharif* maize**

| Treatment | Plants (x10$^3$ `/ha) | | Cobs (x10$^3$ `/ha) | | Plant height (cm) | | Days to 50% tasseling | | Days to 50% silking | | Grain yield (t/ha) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 |
| Atrazine 1.5 kg/ha as pre-emergence (PE) | 79.9 | 78.9 | 74.8 | 77.8 | 198.3 | 202.3 | 60.0 | 57.7 | 61.7 | 59.7 | 4.69 | 4.85 |
| Atrazine 0.75kg/ha + pendimethalin 0.75 kg/ha as PE | 81.7 | 80.6 | 79.2 | 79.4 | 205.3 | 209.3 | 60.7 | 58.3 | 62.7 | 60.3 | 6.09 | 5.94 |
| Atrazine 1.5 kg/ha + 2,4-D amine 0.4 kg/ha at 25 DAS | 81.3 | 79.2 | 77.1 | 78.5 | 194.0 | 198.0 | 60.7 | 58.3 | 62.3 | 60.7 | 5.19 | 5.15 |
| Halosulfuron 90 g/ha at 25 DAS | 80.3 | 75.7 | 74.5 | 74.8 | 180.3 | 184.3 | 61.0 | 58.7 | 63.3 | 61.0 | 4.84 | 4.89 |
| Atrazine 1.5 kg/ha as PE *fb* halosulfuron 90 g/ha at 25 DAS | 81.7 | 79.4 | 77.8 | 78.0 | 183.3 | 187.3 | 61.3 | 59.0 | 63.7 | 61.7 | 5.90 | 5.56 |
| Tembotrione 120g/ha at 25 DAS | 80.8 | 78.9 | 77.5 | 78.0 | 197.7 | 201.7 | 59.7 | 57.3 | 61.7 | 59.7 | 5.74 | 5.34 |
| Pendimethalin 1.0 kg/ha as PE *fb* atrazine 0.75 kg/ha + 2,4-D amine 0.4 kg/ha at 25 DAS | 81.9 | 81.7 | 80.8 | 80.8 | 201.7 | 205.7 | 60.0 | 57.7 | 61.3 | 59.3 | 6.38 | 6.41 |
| Atrazine 1.5 kg/ha as PE *fb* tembotrione 120 g/ha at 25 DAS | 82.2 | 81.5 | 80.6 | 81.5 | 202.3 | 206.7 | 59.7 | 57.3 | 61.0 | 59.7 | 6.34 | 6.37 |
| Control (weedy check) | 80.6 | 76.4 | 70.8 | 73.1 | 161.3 | 163.3 | 61.7 | 60.0 | 64.3 | 62.3 | 3.66 | 4.35 |
| Weed free | 82.6 | 82.4 | 81.5 | 81.7 | 215.3 | 219.3 | 59.7 | 57.3 | 61.0 | 59.3 | 6.71 | 6.67 |
| LSD (p=0.05) | NS | NS | 4.4 | 5.0 | 27.2 | 197.8 | NS | NS | 1.8 | 1.8 | 0.84 | 0.94 |

(215.3 and 219.3 cm) as compared to treatments halosulfuron 90 g/ha at 25 DAS (180.3 and 184.3 cm), atrazine 1.5 kg/ha PE *fb* halosulfuron 90 g/ha at 25 DAS (183.3 and 187.3 cm) and weedy check (161.3 and 163.3 cm) and it was statistically at par with all other treatments during 2016 and 2017. The different weed management practices failed to exert any significant effect on days taken to 50% tasseling. Significantly more number of days taken to 50% silking was recorded with the weedy check treatment (64.3 and 62.3) as compared to all other treatments. However, it was statically at par with atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha as PE (62.7), halosulfuron 90 g/ha at 25 DAS (63.3), atrazine 1.5 kg/ha as PE *fb* halosulfuron 90 g/ha at 25 DAS (63.7) during 2016 and atrazine 1.5 kg/ha + 2,4-D amine 0.4 kg/ha at 25 DAS as PoE (60.7), halosulfuron 90 g/ha at 25 DAS (61.0) and atrazine 1.5 kg/ha as PE *fb* halosulfuron 90 g/ha at 25 DAS (61.7) during 2017.

Weed-free condition recorded significantly higher grain yield 6.71 t/ha and 6.67 t/ha, during both the years, but it was statistically at with the application of pendimethalin 1.0 kg/ha as PE *fb* atrazine 0.75 kg/ha + 2,4-D amine 0.4 kg/ha at 25 DAS as PoE (6.38 and 6.41 t/ha), atrazine 1.5 kg/ha as PE *fb* tembotrione 120 g/ha as PoE (6.34 and 6.37 t/ha) and atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha as PE(6.09 and 5.94 t/ha). The highest grain yield obtained under weed-free condition was mainly due to minimum crop-weed competition throughout the crop growth period, thus enabling the crop for maximum utilization of nutrients, moisture, light, and space, which favoured growth and yield components. Similar results have also been observed by Hatti *et al.* (2014) and Triveni *et al.* (2017).

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