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Bio efficacy of pre and post-emergence herbicides on yield and economics of maize crop (*Zea mays*)

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Abstract
An AICRP- maize experiment was conducted at Crop Research Station, Bahraich, Uttar Pradesh, during kharif season of 2023 in randomized block design with three replications having twelve different treatments of weed management. Weed flora both broad- and grassy weeds were observed but dominance of broad-leaved weeds was more in entire field. Plant population was maximum in weedy free plots followed by pre emergence application of atrazine and hand weeding at 25-30 DAS than pyroxasulfone @ 127 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS, similar trend was recorded in weed density and weed dry weight. The weed dry weight was less with Pyroxasulfone @ 127 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS and pyroxasulfone @ 127 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS. At maturity of crop maximum weeds were found in weedy plots followed by Atrazine 500 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS treated plots. Among the treatments, maize grain yield was found significantly higher with the weed free plot (6967 kg/ha) followed by pre-emergence application of atrazine @ 500 g/ha + HW at 25-30 DAS (6798 kg/ha) while lower yield was obtained in weedy plot (4820 kg/ha). Pre emergence herbicides treated plots with pyroxasulfone fb post emergence yielded lesser due to poor plant population than Atrazine. Application of atrazine alone and with other post-emergence herbicide did not show any phytotoxic symptoms on crop except pyroxasulfone.

Keywords: Maize crop, herbicides, pre and post-emergence

Introduction

Maize (*Zea mays* L.) is a significant and adaptable crop raised in a wide range of environments and geographical regions for human food, feed, and animal fodder. It has also enormous potential to provide food security, feed security, nutritional security and enhanced income to maize growers. It is the third most important cereal crop in India after rice and wheat and is grown in a wide range of environments, extending from extreme semi-arid to sub-humid and humid regions, which predominantly occupies 82% of the area under cultivation in the kharif season, while rabi maize correspond to 18% maize area. Weeds are ranked as maize's number one enemy and can be attributed for the low production of the crop under Indian circumstances due to higher crop weed competition. Weeds lower the photosynthetic efficiency, dry matter production, and distribution to economically advantageous areas, which in turn diminishes the crop's sink capacity and leads to a low grain yield. Accordingly, depending on the kind of weed species in the standing crop, the decline in maize grain production has been observed to be in the range of 28 to 100%. Many weed management techniques, including mechanical, cultural, chemical, and biological are available to reduce weed losses. The most effective and extensively used method of weed management is manual weeding, although it is labour-intensive, time consuming, and expensive owing to high pay rates, which reduce the profitability of the cultivation. Timely weeding is most important to minimize yield losses and therefore under such circumstances the only effective tool is left to control weeds through the use of chemicals. Therefore, keeping the weeds below threshold level, herbicides provide the low-cost and effective tool through which excessive weed population can be controlled before crop-weed competition. The use of herbicides is the best approach for quickly and cheaply resolving the various weed issues in maize fields, and as a result, it has surpassed conventional methods in importance.

Pre-emergence herbicides have been recommended as the best choice since they can suppress weeds during the early phases of crop growth and also provide an environment free from weed competition to guarantee improved crop establishment. This is especially true for maize. However, weeds may develop a resistance problem if a single herbicide or herbicides with the same mechanism of action are used continuously. As a result, new herbicides are required to manage the mixed weed flora in maize. Mesotrione a p-hydroxyphenylpyruvate dioxygenase (HPPD) enzyme inhibitor mainly used to effectively control broad-leaved weeds and some grassy weeds by inhibiting the catalytic factors of plant photosynthetic process. Mesotrione is widely used in weed control of maize and winter wheat due to its high activity, low residue, strong compatibility and safety to the environment and subsequent crops. In order to assess the possibility of mesotrione application and understand the related mechanism, we investigated the weed control in this current study.

Some of the grassy and broad-leaf weeds found in maize field are *Cyperus rotundus, Cynodon dactylon, Commelina benghalensis, Cyanotis oxillaris, Denebra arabica, Tridax procumbens, Lagasca mollis, Euphorbia hirta, Euphorbia geniculata, Parthenium hysterophorus, Digera arvensis, Phyllanthus niruri, Celosia argentina and Acalyfa indica*. These are among the deadly weeds of the world which infest the maize field and thus, increase the cost of production as hand weeding is not effective against these weeds. Management of weeds is considered to be an important factor for achieving higher productivity. Rout *et al*. (1996) [7] revealed that weeds cause enormous damage up to 30 to 50% in maize crop. Uncontrolled weed growth may reduce maize yield as much as 90% (Ratta *et al*. 1991) [6]. Weeds also pose severe problems for crop husbandry and infest fallow land, reduce soil fertility and moisture conditions and develop a potential threat to the succeeding crops (Khan *et al*. 2003) [2]. Chemical weed management by using pre- and post-emergence herbicides can lead to the efficient and cost-effective control of weeds during critical period of crop weed competition, which may not be possible in manual or mechanical weeding due to its high cost of cultivation (Triveni *et al*. 2017) [12]. The present investigation was therefore, done with an objective to study the efficacy of pre and post-emergence herbicides and its effect on weed flora, growth and yield of maize.

Materials and Methods

A maize experiment was conducted at Crop Research Station, Bahraich, Uttar Pradesh during kharif season of 2023 in randomized block design with three replications having twelve different treatments of weed management. Crop Research Station, Bahraich is situated at 27^0 N latitude and 81^0E longitude and at a height of 130 m from sea level. Soil of the crop research station is sandy loam with pH 7.5 and available nutrient N ranged from 192-280 kg/ha, P_2O_5 ranged from 10-40 kg/ha and K_2O ranged from 222-285 kg/ha. Annual rainfall ranged from 820-1010 mm. The maximum temperature ranged from 10-40 °C, where the minimum temperature ranged from 6-24 °C. The experiment consisted of 12 treatments *viz*., T_1: weedy check, T_2: Weed free check, T_3: atrazine 500 g/ha + hand weeding (HW) at 25-30 DAS, T_4: pyroxasulfone @ 127 g/ha + HW at 25-30 DAS, T_5: Atrazine 500 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS, T_6: atrazine 500 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS, T_7: atrazine 500 g/ha fb topramezone @ 25 g/ha at 25-30 DAS,T_8: atrazine 500 g/ha fb mesotrione + atrazine @ 300 g/ha at 25-30 DAS, T_9: pyroxasulfone @ 127 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS, T_{10}: pyroxasulfone @ 127 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS, T_{11}: pyroxasulfone @ 127 g/ha fb topramezone @ 25 g/ha at 25-30 DAS and T_{12}: pyroxasulfone @ 127 g/ha fb mesotrione + atrazine @ 300 g/ha at 25-30 DAS. The maize hybrid 'Eagle 21' was sown at the spacing of 60 x 20 cm on July 04, 2023 with recommended dose of fertilizer 120:60:40 NPK kg/ha. Application of herbicide was done as per the treatments with manually operated knapsack sprayer attached with a flood jet nozzle. After calibrating the sprayer, water volume used was 700 l/ ha for PE and 500 liter per ha for PoE spray. The observations on weed density and weed biomass were taken at 30 days-intervals up to harvest from four randomly selected spots from net plot area by using quadrate of 50 x 50 cm. Then, weeds were grouped as monocot and dicot species. Visual assessment of herbicide toxicity on crop was monitored 10 days after application of herbicide in respective treatments.

Results and Discussion

Weed flora both broad- and grassy weeds were observed but dominance of broad-leaved weeds was more in entire field. The major weed flora in maize crop in the selected area composed of *Xanthium strumarium, Celosia argentea, Tridax procumbens, Phyllanthus niruri, Portulaca oleracae, Lagasca mollis, Euphorbia geniculata, Euphorbia hirta, Abutilon indicum, Abelmoschus moschatus, Boerhavia diffusa, Calotropis gigantea, Ageratum conyzoides, Bidens pilosa, Mimosa pudica, Alternanthera triandra, Parthenium hysterophorus, Digera arvensis, Cynodon dactylon, Cyperus rotundus, Amaranthis viridis, Dinebra arabica, Panicum spp., Commelina benghalensis, Ischaemum pilosum, Digitaria sanguinalis, Dinebra retroflexa, Poa annua, Cyanotis axillaris etc.* Weed control treatments significantly reduced the weed population and weed biomass when compared with weedy plot. Application of pyroxasulfone @ 127 g/ha fb halosulfuron methyl @ 67 g/ha at 25- 30 DAS produced less weed count than rest of the herbicides tested during the study and was at par with Pyroxasulfone @ 127 g/ha + HW at 25-30 DAS, Pyroxasulfone @ 127 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS, Pyroxasulfone @ 127 g/ha fb topramezone @ 25 g/ha at 25-30 DAS at 50 DAS and harvest. This might be due to the herbicidal application alone (higher dose) or in combination which were effective in timely reducing total weed population. Similar results were reported by Gantoli *et al*. (2013) [1], Madhavi *et al*. (2014) [3] and Singh *et al.* (2015) [11]. The sequential application of pre- emergence herbicides was found effective than post-emergence herbicide applications. Yield reduction varied from 12.49% to 54.17% in the herbicide applied plots as compared to weed free treatment. Plant population was significantly maximum in weed free plots followed by pre emergence application of atrazine at 25-30 DAS and hand weeding than pyroxasulfone @ 127 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS. The weed dry weight was low with Pyroxasulfone @ 127 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS Pyroxasulfone @ 127 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS and Pyroxasulfone @ 127 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS and Pyroxasulfone @ 127 g/ha + HW at 25-30 DAS. At maturity of crop maximum weeds were found in weedy plots followed by Atrazine 500 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS treated plots (Table 2).

Table 1: Plant population at 25 DAS and at 50 DAS of maize as affected by weed management

Treatment	Plant Population	
	25 DAS	At harvest
Weedy	67778	64667
Weed free	76667	73111
Atrazine 500 g/ha + HW at 25-30 DAS	75556	69556
Pyroxasulfone @ 127 g/ha + HW at 25-30 DAS	64889	60111
Atrazine 500 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS	75111	68444
Atrazine 500 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS	72667	64889
Atrazine 500 g/ha fb topramezone @ 25 g/ha at 25-30 DAS	71111	64000
Atrazine 500 g/ha fb mesotrione + atrazine @ 300 g/ha at 25-30 DAS	72222	68889
Pyroxasulfone @ 127 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS	69778	61556
Pyroxasulfone @ 127 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS	65333	62222
Pyroxasulfone @ 127 g/ha fb topramezone @ 25 g/ha at 25-30 DAS	68222	64000
Pyroxasulfone @ 127 g/ha fb mesotrione + atrazine @ 300 g/ha at 25-30 DAS	68667	63111
CD P (5%)	12564.4	11867.2

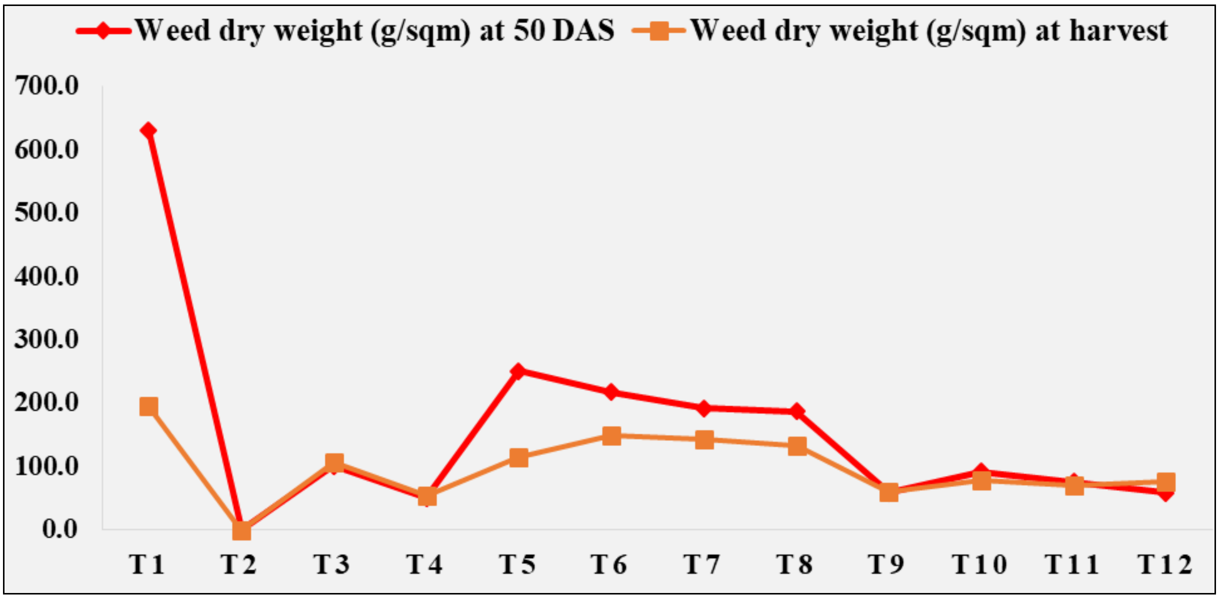

Fig 1: Weed dry weight at 50 DAS and at harvest as affected by weed management practices in maize

Table 2: Weed density at 50 DAS and harvest as affected by weed management practices in maize

Treatment	Weed Density/m^2 at 50 DAS	Weed density/m^2 at harvest
Weedy	486	230
Weed free	0	0
Atrazine 500 g/ha + HW at 25-30 DAS	300	124
Pyroxasulfone @ 127 g/ha + HW at 25-30 DAS	153	61
Atrazine 500 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS	323	94
Atrazine 500 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS	368	218
Atrazine 500 g/ha fb topramezone @ 25 g/ha at 25-30 DAS	348	193
Atrazine 500 g/ha fb mesotrione + atrazine @ 300 g/ha at 25-30 DAS	335	165
Pyroxasulfone @ 127 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS	97	80
Pyroxasulfone @ 127 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS	182	97
Pyroxasulfone @ 127 g/ha fb topramezone @ 25 g/ha at 25-30 DAS	171.7	76
Pyroxasulfone @ 127 g/ha fb mesotrione + atrazine @ 300 g/ha at 25-30 DAS	121.7	87
CD P (5%)	144.22	11.33

Among the treatments, maize grain yield was found significantly higher with the weed free plot (6967 kg/ha) followed by pre-emergence application of atrazine @ 500 g/ha + HW at 25-30 DAS (6798 kg/ha) while lower yield was obtained in weedy plot (4820 kg/ha). Pre emergence applied plots with Pyroxasulfone fb post emergence yielded lesser due to poor plant population (Fig 2). Application of atrazine alone and with other post emergence herbicide did not show any phytotoxic symptoms on crop Table 5.

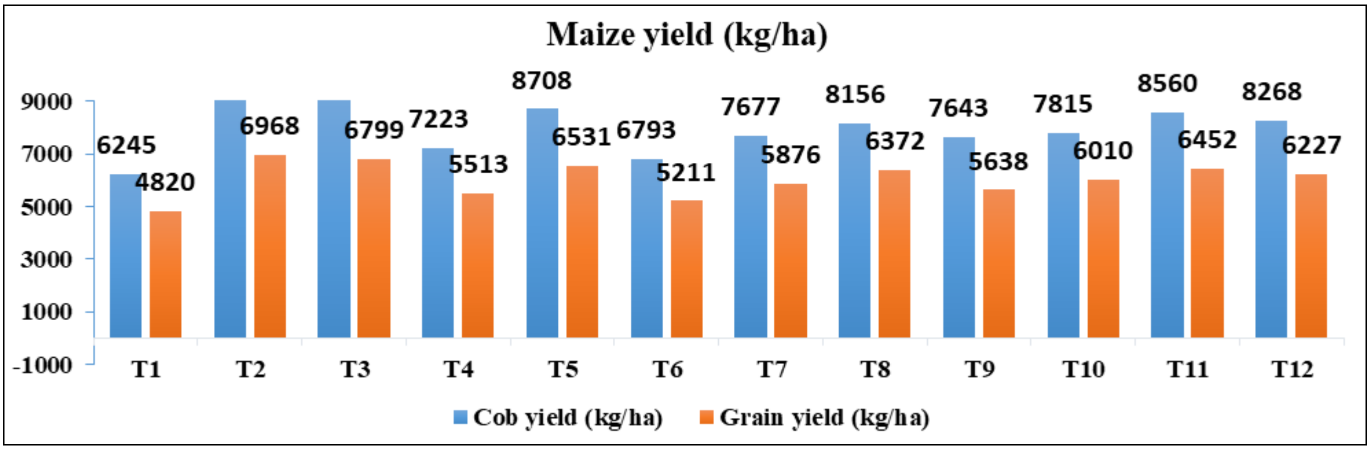

Fig 2: Cob and grain yield of maize as influenced by weed management practices

Table 3: Effect of weed management on cob and grain yield

Treatment	Cob yield (kg/ha)	Grain yield (kg/ha)
Weedy	6244.7	4820.41
Weed free	9215.9	6967.92
Atrazine 500 g/ha + HW at 25-30 DAS	9037.0	6798.96
Pyroxasulfone @ 127 g/ha + HW at 25-30 DAS	7222.8	5513.27
Atrazine 500 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS	8708.3	6530.56
Atrazine 500 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS	6793.2	5210.62
Atrazine 500 g/ha fb topramezone @ 25 g/ha at 25-30 DAS	7676.8	5876.20
Atrazine 500 g/ha fb mesotrione + atrazine @ 300 g/ha at 25-30 DAS	8155.9	6371.99
Pyroxasulfone @ 127 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS	7643.3	5637.56
Pyroxasulfone @ 127 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS	7814.8	6009.81
Pyroxasulfone @ 127 g/ha fb topramezone @ 25 g/ha at 25-30 DAS	8560.4	6451.54
Pyroxasulfone @ 127 g/ha fb mesotrione + atrazine @ 300 g/ha at 25-30 DAS	8267.9	6227.02
CD P (5%)	767.08	734.43

Maximum cost of crop cultivation and net return were recorded with weed free crops but the benefited marginal with Atrazine 500 g/ha + HW at 25-30 DAS.

Maximum cost of cultivation and net return were recorded with weed free crops being at par with Atrazine 500 g/ha + HW at 25-30 DAS followed by Atrazine 500 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS, and Pyroxasulfone @ 127 g/ha fb topramezone @ 25 g/ha at 25-30DAS. Maximum benefit cost ratio was obtained with Atrazine 500 g/ha fb mesotrione + atrazine @ 300 g/ha at 25-30 DAS followed by Atrazine 500 g/ha + HW at 25-30 DAS and Pyroxasulfone @ 127 g/ha fb topramezone @ 25 g/ha at 25-30 DAS (Table 4).

Table 4: Economics of maize as affected by weed management practices

Treatment	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B: C ratio
Weedy	34892	100747	65855	1.89
Weed free	44942	145629	100687	2.24
Atrazine 500 g/ha + HW at 25-30 DAS	41823	142098	100275	2.40
Pyroxasulfone @ 127 g/ha + HW at 25-30 DAS	44656	115227	70571	1.58
Atrazine 500 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS	40848	136489	95641	2.34
Atrazine 500 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS	37996	108902	70906	1.87
Atrazine 500 g/ha fb topramezone @ 25 g/ha at 25-30 DAS	38096	122813	84717	2.22
Atrazine 500 g/ha fb mesotrione + atrazine @ 300 g/ha at 25-30 DAS	36646	133174	96528	2.63
Pyroxasulfone @ 127 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS	42596	117825	75229	1.77
Pyroxasulfone @ 127 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS	42496	125605	83109	1.96
Pyroxasulfone @ 127 g/ha fb topramezone @ 25 g/ha at 25-30 DAS	42596	134837	92241	2.17
Pyroxasulfone @ 127 g/ha fb mesotrione + atrazine @ 300 g/ha at 25-30 DAS	41146	130145	88999	2.16

Application of Atrzine alone and with other Pos emergence herbicide did not show any phytotxic symptoms except Pyroxasulfone treated plots crop.

Table 5: Phytotoxicity effect of herbicides on crop

Treatment	Phytotoxicity effect		
	R1	**R2**	**R3**
Weedy	No	No	No
Weed free	No	No	No
Atrazine 500 g/ha + HW at 25-30 DAS	No	No	No
Pyroxasulfone @ 127 g/ha + HW at 25-30 DAS	Poor Germination	Poor Germination	Poor Germination
Atrazine 500 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS	No	No	No
Atrazine 500 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS	No	No	No
Atrazine 500 g/ha fb topramezone @ 25 g/ha at 25-30 DAS	No	No	No
Atrazine 500 g/ha fb mesotrione + atrazine @ 300 g/ha at 25-30 DAS	No	No	No
Pyroxasulfone @ 127 g/ha fb halosulfuron methyl @ 67 g/ha at 25-30 DAS	Poor Germination	Poor Germination	Poor Germination
Pyroxasulfone @ 127 g/ha fb tembotrione @ 120 g/ha at 25-30 DAS	Poor Germination	Poor Germination	Poor Germination
Pyroxasulfone @ 127 g/ha fb topramezone @ 25 g/ha at 25-30 DAS	Poor Germination	Poor Germination	Poor Germination
Pyroxasulfone @ 127 g/ha fb mesotrione + atrazine @ 300 g/ha at 25-30 DAS	Poor Germination	Poor Germination	Poor Germination

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