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Effect of Pre and Post-emergence Herbicides on Weed Flora of Maize

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Weeds have been a problem creator in crops since time immemorial competing with them for all the growth resources. Weeds cause around 28-100% loss in the maize crop which necessitates their control. The usage of herbicides for the control of weeds has been the most prominent method among farmers. However, the continuous usage of similar herbicides can develop herbicide resistance which needs the exploration to newer herbicides. Therefore, a field experiment was carried out to assess the effect of broad-spectrum herbicide, mesotrione on the weed flora and seed yield of maize at JNKVV, Jabalpur (M.P.) in the *kharif* season of 2019. The experiment was carried out in randomised block design consisting of eight treatments of weed control including six herbicidal treatments with hand weeding and weedy check and replicated thrice. Based on the results, it was concluded that the post emergence application of mesotrione 350 g ha^{-1} at 30 DAS had most effectively controlled the weeds resulting in highest weed control efficiency (69.25%) and lowest weed index (12.62%) than the rest of the treatments. It also resulted in highest grain and stover yield (2.44 and 21.80 t ha^{-1}) in maize. Thus, the application of mesotrione @ 350 g ha^{-1} can be a promising technology for the control of complex weed flora in maize.

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Keywords: Herbicide resistance; mesotrione; stover yield; weeds; weed control efficiency; weed index.

1. 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 [1]. Maize is one of the major cereal crops with wider adaptability to diverse agro-climatic conditions [2]. With a production of 945.8 million tonnes and a yield of 5.7 t ha^{-1}, maize is produced across an area of 168 million hectares worldwide [3]. In India, during 2018–19, it was cultivated over an area of 9.18 million ha, with an annual production of 27.23 million tonnes and average productivity of 2,965 kg/ha [4]. In Madhya Pradesh maize is cultivated in 1.35 million hectares with production of 3.54 million tonnes with a productivity of 2615 kg ha^{-1} [5].

Weeds rank 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 [6]. 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% [7, 8].

Many weed management techniques, including mechanical, cultural, chemical, and biological ones, are available to reduce weed losses [9, 10]. The most effective and extensively used method of weed management is manual weeding, although it is labor-intensive, time-consuming, and expensive owing to high pay rates, which reduce the profitability of the cultivation [11]. 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 [12].

Management of weeds through the use of chemicals has also been found as effective as realized under manual eradication in various crops with over and above benefits in saving extra costs involved in use of labour on manual eradication of weed [13]. 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 [14].

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 [15]. 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 [16,17]. 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 gramineous weeds by inhibiting the catalytic factors of plant photosynthetic process [18,19]. 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 [20,21]. In order to assess the possibility of mesotrione application and understand the related mechanism, we investigated the weed control in this current study.

2. MATERIALS AND METHODS

An experiment was conducted at Research Farm, AICRP on Forage Crops, Department of Agronomy, JNKVV, Jabalpur (Madhya Pradesh) during *kharif* season of the year 2019. The soil of the research field was neutral in reaction (pH 7.21), and medium in organic carbon (0.58%) as well as with medium available nitrogen (285.56 kg ha^{-1}), available phosphorus (16.59 kg ha^{-1}) and available potassium (262.66 kg ha^{-1}) contents with normal electrical conductivity (0.33 dS/cm). During experiment, mean weekly maximum and minimum temperature ranged between 27.1°C to 44.4°C and 18.0°C to 27.3°C, respectively. The total rainfall received during the crop season was 1642.3 mm, which was equally distributed in 56 rainy days from June second week to last week of October. The experiment consisted of eight treatments viz., pre-emergence application of atrazine 1000 g ha^{-1}, pre-emergence application of pendimethalin 750 g ha^{-1} and post emergence application of mesotrione 250 g ha^{-1}, post emergence application of mesotrione 300 g ha^{-1}, post emergence application of mesotrione 350 g ha^{-1} and post emergence application of tembotrione 286 g ha^{-1} and hand weeding twice at 20 and 40 DAS and weedy check laid out in randomized block design with three replications. Sowing of maize cultivar “African tall” at the rate of 20 kg/ha was carried out at 60 cm row to row spacing and 15-20 cm plant to plant spacing. Weed parameters such as relative density of weeds, weed density and dry weight, weed index, weed control efficiency and grain and stover yields of maize were recorded in the present investigation. The data from the various observations were tabulated for statistical analysis, and the analysis of variance (ANOVA) method was applied to analyze the data statistically. The F test was then used to evaluate the treatment. A critical difference (CD) was computed for each character at a 5% level of significance to assess the differences between treatment means. The data on weed population and dry weight were square roots transformed, i.e., √x+0.5, before analyzing variance, and only transformed values were compared.

Relative Density (%) = No. of individuals of the same species / No. of individuals of all species x 100

3. RESULTS AND DISCUSSION

3.1 Weed Flora

Different weeds severely infested maize in weedy check plot of experimental site. The relative density of predominant monocot weeds was *Echinochloa colona* (31.48%), *Commelina communis* (11.48%), *Digitaria sanguinalis* (11.37%), *Cyperus rotundus* (10.31%) and *Eleusine indica* (7.79%) and relative density of broad-leaved weeds was *Phyllanthus niruri* (9.78%) and *Eclipta alba* (9.36%) and relative density of other minor weeds was 8.42% (Fig. 1). Similar weed flora also observed by [22,23].

3.2 Weeds Density and Dry Weight

The weed density and dry weight was affected by different weed control treatments at 30 and 60 DAS in comparison to weedy check plot (Tables 1-4). It is evident from the data that the density and dry weight of all the weeds was maximum under weedy check plot due to uninterrupted growth of weeds as no weed control measures were adopted in weedy check plots. However, considerable reduction in density and dry weight of weeds were observed when weeds were controlled by chemical method of weed control [24,25]. Among herbicides, post emergence application of mesotrione 350 g/ha controlled weed species successfully and recorded a lower weed population which is at par with mesotrione 300 g/ha and tembotrione 286 g ha^{-1}. [26,27] also reported that mesotrione provided consistent control of four annual grass species including: *Echinochloa crusgalli, Digitaria ischaemum, Panicum miliaceum,* and *Digitaria sanguinalis* when applied at the 2- to 3-leaf or 5- to 6-leaf stage of seedling growth. Among the weed control treatments, hand weeding done at 20 and 40 DAS reduced the density including dry weight of weeds to maximum extent over herbicidal treatments due to elimination of most of weeds. Similar view was also endorsed by [28,29].

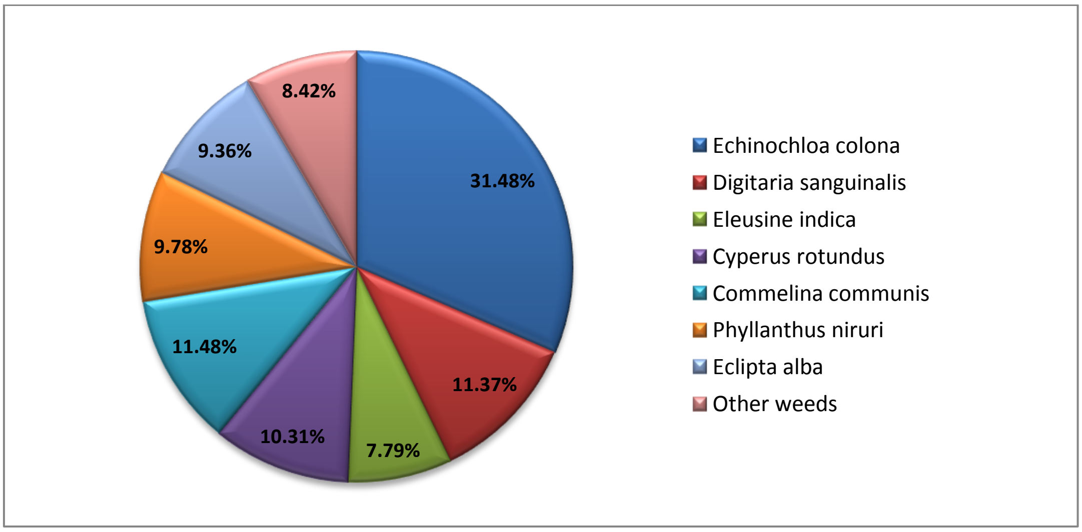

Fig. 1. Relative density of weeds in weedy check at 30 and 60 DAS

Table 1. Effect of different weed control treatments on weed density (no./m^2) at 30 and 60 DAS (grassy weeds and sedges)

Treatments	Type of weeds							
	Echinochloa colona		Digitaria sanguinalis		Eleusine indica		Cyperus rotundus	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60DAS	30 DAS	60 DAS
T_1: Mesotrione 250 g ha^{-1}	7.28 (52.50)	7.80 (60.42)	4.65 (21.17)	5.49 (29.67)	2.94 (8.17)	4.14 (16.67)	4.32 (18.17)	4.87 (23.25)
T_2: Mesotrione 300 g ha^{-1}	6.67 (44.00)	7.57 (56.75)	4.31 (18.08)	5.09 (25.42)	2.36 (5.08)	3.59 (12.42)	4.19 (17.08)	4.67 (21.33)
T_3: Mesotrione 350 g ha^{-1}	6.18 (37.67)	7.34 (53.42)	4.04 (15.83)	4.89 (23.42)	2.18 (4.25)	3.30 (10.42)	3.77 (13.75)	4.32 (18.42)
T_4: Tembotrione 286 g ha^{-1}	6.92 (47.33)	7.61 (57.42)	4.40 (18.83)	5.28 (27.33)	2.41 (5.33)	3.85 (14.33)	4.26 (17.67)	4.86 (23.17)
T_5: Atrazine 1000 g ha^{-1}	7.36 (53.67)	8.00 (63.58)	4.70 (21.58)	5.54 (30.17)	3.01 (8.58)	4.20 (17.17)	4.44 (19.25)	5.02 (24.67)
T_6: Pendimethalin 750 g ha^{-1}	7.51 (55.97)	8.03 (63.92)	4.87 (23.25)	5.69 (31.83)	3.17 (9.58)	4.40 (18.83)	4.52 (19.92	5.19 (26.42)
T_7: Hand weeding	3.50 (11.75)	4.35 (18.50)	3.28 (10.33)	4.01 (15.58)	1.50 (1.75)	2.25 (4.58)	2.80 (7.33)	3.29 (10.33)
T_8: Weedy Check	9.61 (91.92)	10.09 (101.42)	5.44 (29.17)	6.42 (40.67)	4.32 (18.17)	5.49 (29.67)	5.45 (29.17)	5.89 (34.17)
SEm±	0.27	0.33	0.21	0.26	0.17	0.21	0.19	0.25
CD at 5%	0.81	1.01	0.65	0.80	0.51	0.65	0.58	0.75

Table 2. Effect of different weed control treatments on weed density (no./m^2) at 30 and 60 DAS (broad-leaved & other weeds)

Treatments	Type of weeds							
	Commelina communis		Phyllanthus niruri		Eclipta alba		Other weeds	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
T_1: Mesotrione 250 g ha^{-1}	4.20 (17.17)	5.00 (24.33)	2.98 (8.42)	2.98 (8.42)	2.98 (8.42)	4.02 (15.75)	2.59 (6.22)	3.49 (11.75)
T_2: Mesotrione 300 g ha^{-1}	4.02 (15.75)	4.65 (20.42)	2.52 (5.92)	2.52 (5.92)	2.52 (5.92)	3.90 (14.75)	2.04 (3.72)	3.35 (10.75)
T_3: Mesotrione 350 g ha^{-1}	3.59 (12.42)	4.27 (17.75)	2.22 (4.42)	2.22 (4.42)	2.22 (4.42)	3.61 (12.58)	1.79 (2.70)	3.00 (8.58)
T_4: Tembotrione 286 g ha^{-1}	4.08 (16.17)	4.43 (20.58)	2.83 (7.50)	2.83 (7.50)	2.83 (7.50)	3.98 (15.33)	2.40 (5.30)	3.44 (11.33)
T_5: Atrazine 1000 g ha^{-1}	4.37 (18.58)	5.09 (24.83)	3.00 (8.50)	3.00 (8.50)	3.00 (8.50)	4.04 (15.83)	2.61 (6.30)	3.50 (11.83)
T_6: Pendimethalin 750 g ha-1	4.55 (20.25)	5.06 (25.83)	3.05 (8.83)	3.05 (8.83)	3.05 (8.83)	4.15 (16.75)	2.67 (6.63)	3.60 (12.75)
T_7: Hand weeding	3.04 (8.75)	3.57 (11.92)	1.67 (2.30)	1.67 (2.30)	1.67 (2.30)	2.08 (3.85)	1.65 (2.22)	2.04 (3.67)
T_8: Weedy Check	5.38 (28.50)	6.58 (42.03)	4.86 (23.17)	4.86 (23.17)	4.86 (23.17)	5.90 (34.33)	4.54 (20.13)	5.66 (31.55)
SEm±	0.16	0.20	0.14	0.14	0.14	0.17	0.12	0.14
CD at 5%	0.47	0.61	0.42	0.42	0.42	0.52	0.38	0.44

Table 3. Effect of different treatments on dry weight of weeds (g/m^2) at 30 and 60 DAS (grassy weeds and sedges)

	Type of weeds							
Treatments	***Echinochloa colona***		***Digitaria sanguinalis***		***Eleusine indica***		***Cyperus rotundus***	
	30 DAS	**60 DAS**	**30 DAS**	**60 DAS**	**30 DAS**	**60 DAS**	**30 DAS**	**60 DAS**
T_1: Mesotrione 250 g ha^{-1}	5.07 (25.20)	5.41 (28.80)	4.14 (16.60)	4.39 (18.75)	3.18 (9.60)	3.53 (11.95)	3.61 (12.53)	3.76 (13.67)
T_2: Mesotrione 300 g ha^{-1}	3.78 (13.82)	3.96 (15.21)	4.01 (15.59)	4.24 (17.44)	3.02 (8.59)	3.34 (10.64)	2.96 (8.25)	3.11 (9.17)
T_3: Mesotrione 350 g ha^{-1}	2.74 (7.00)	3.59 (12.42)	3.93 (14.92)	4.19 (17.08)	2.95 (8.20)	3.28 (10.28)	2.63 (6.43)	3.06 (8.83)
T_4: Tembotrione 286 g ha^{-1}	3.90 (14.73)	4.43 (19.08)	4.08 (16.15)	4.32 (18.16)	3.11 (9.15)	3.44 (11.36)	3.57 (12.24)	3.56 (12.17)
T_5: Atrazine 1000 g ha^{-1}	5.19 (26.43)	5.44 (29.05)	4.94 (23.93)	5.02 (24.70)	3.97 (15.30)	4.18 (16.93)	3.62 (12.63)	3.81 (14.00)
T_6: Pendimethalin 750 g ha^{-1}	5.38 (28.45)	5.86 (33.87)	4.95 (24.02)	5.11 (25.63)	4.16 (16.83)	4.42 (19.00)	3.91 (14.77)	4.45 (19.27)
T_7: Hand weeding	1.49 (1.73)	3.13 (9.28)	1.33 (1.27)	1.94 (3.26)	1.21 (0.97)	1.26 (1.10)	0.97 (0.45)	1.75 (2.57)
T_8: Weedy Check	8.12 (65.38)	9.22 (84.50)	5.17 (26.23)	5.40 (28.63)	4.43 (19.14)	4.78 (22.35)	4.98 (24.30)	5.54 (30.20)
SEm±	0.31	0.33	0.20	0.31	0.26	0.15	0.13	0.16
CD at 5%	0.93	1.00	0.60	0.94	0.78	0.45	0.40	0.48

Table 4. Effect of different treatments on dry weight of weeds (g/m^2) at 30 and 60 DAS (broad-leaved & other weeds)

	Type of weeds							
Treatments	***Commelina communis***		***Phyllanthus niruri***		***Eclipta alba***		**Other weeds**	
	30 DAS	**60 DAS**	**30 DAS**	**60 DAS**	**30 DAS**	**60 DAS**	**30 DAS**	**60 DAS**
T_1: Mesotrione 250 g ha^{-1}	4.43 (19.14)	5.06 (25.13)	4.15 (16.72)	4.73 (21.84)	3.54 (12.05)	4.16 (16.83)	3.25 (10.03)	3.74 13.47)
T_2: Mesotrione 300 g ha^{-1}	3.39 (11.00)	4.17 (16.93)	3.21 (9.83)	3.60 (12.47)	3.35 (10.74)	3.59 (12.41)	2.58 (6.17)	2.83 (7.50)
T_3: Mesotrione 350 g ha^{-1}	2.86 (7.66)	3.57 (12.25)	2.74 (7.02)	3.34 (10.66)	2.98 (8.40)	3.30 (10.38)	2.28 (4.70)	2.47 (5.58)
T_4: Tembotrione 286 g ha^{-1}	4.18 (16.93)	4.44 (19.25)	3.92 (14.85)	4.16 (16.83)	3.35 (10.74)	3.91 (14.77)	3.11 (9.18)	3.59 12.36)
T_5: Atrazine 1000 g ha^{-1}	5.06 (25.13)	5.24 (27.00)	4.22 (17.33)	5.09 (25.38)	3.73 (13.40)	4.20 (17.16)	3.36 (10.80)	3.78 13.77)
T_6: Pendimethalin 750 g ha^{-1}	5.24 (27.00)	5.87 (34.00)	4.42 (19.06)	5.21 (26.60)	3.83 (14.19)	4.22 (17.33)	3.44 (11.32)	3.82 14.10)
T_7: Hand weeding	0.99 (0.48)	3.37 (10.84)	0.97 (0.43)	3.34 (10.65)	1.17 (0.87)	1.59 (2.03)	1.49 (1.73)	1.94 (3.26)
T_8: Weedy Check	5.83 (33.50)	6.51 (41.91)	5.24 (27.00)	5.75 (32.53)	4.68 (21.40)	5.28 (27.33)	3.89 (14.64)	4.20 17.11)
SEm±	0.14	0.18	0.16	0.15	0.13	0.09	0.11	0.11
CD at 5%	0.41	0.55	0.49	0.45	0.40	0.26	0.34	0.34

3.3 Weed Control Efficiency

Weed control efficiency (WCE) of various treatments was determined based on relative weed biomass recorded under weedy check and other treatments at 30 and 60 DAS. The weed control efficiency varied due to different weed control treatments (Table 5). The weed control efficiency (WCE) had inverse relationship with dry matter production by weeds. The weed control efficiency was maximum with hand weeding twice (96.58% and 84.89%) at 30 and 60 DAS, respectively. It was due to the production of minimum dry matter of all the associated weeds. All herbicidal treatments reduced weed growth, but the post emergence application of mesotrione 350 g ha^{-1} had greatest amount of suppression of weeds, *fb* mesotrione 300 g ha^{-1} *fb* tembotrione 286 g ha^{-1} resulting in highest weed control efficiency. The results are in conformation with [30,31].

3.4 Grain and Stover Yields

Weed control treatments also influenced the maize grain yield and stover yield (Table 5). The uncontrolled weed competition during the crop duration in weedy check resulted in the lowest grain yield and stover yield of 1.39 and 16.25 t ha^{-1} respectively. It was due to due to severe weed and crop competition from germination to harvest, leading to poor growth parameters, yield attributing characteristics and finally the grain yield [32,33]. Except, application of pendimethalin 750 g ha^{-1}, the rest of herbicide treatments (atrazine 1000 g ha^{-1}, mesotrione 250 g ha^{-1}, mesotrione 300 g ha^{-1}, mesotrione 350 g ha^{-1} and tembotrione 286 g ha^{-1}) produced higher grain yield and stover yield compared with untreated weedy check. However, higher grain and stover yield were recorded with the application of mesotrione 350 g ha^{-1} (2.44 and 21.80 t ha^{-1}). Among all the weed control treatments, highest grain and stover yield were observed under hand weeding treatment. The crop under weed free plots attained lush growth due to elimination of weeds from inter and intra row spaces besides better aeration due to manipulation of surface soil and thus, more space, water, light and nutrients were available for the better growth and development, which resulted into superior yield attributes and development, and consequently the highest yield. The research findings are in conformity with [34,35].

3.5 Weed Index

Weed index measures the reduction in crop yield due to weed competition as against two hand weeding treatment and is expressed in percentage (Fig. 2). Weed index was significantly affected by different weed control treatments. The data revealed that maximum reduction in yield (50.22%) occurred in weedy check pots where weeds were not controlled throughout the crop season. This might be due to the competition of weeds with the crop for the useful resources which may have resulted in suppressed the growth and development of the crop. The post emergence application of mesotrione 350 g ha^{-1} resulted in the minimum weed index (12.62%) among the weed control treatments due to the effective and timely control of weeds in the crop [36,37] also reported a similar findings.

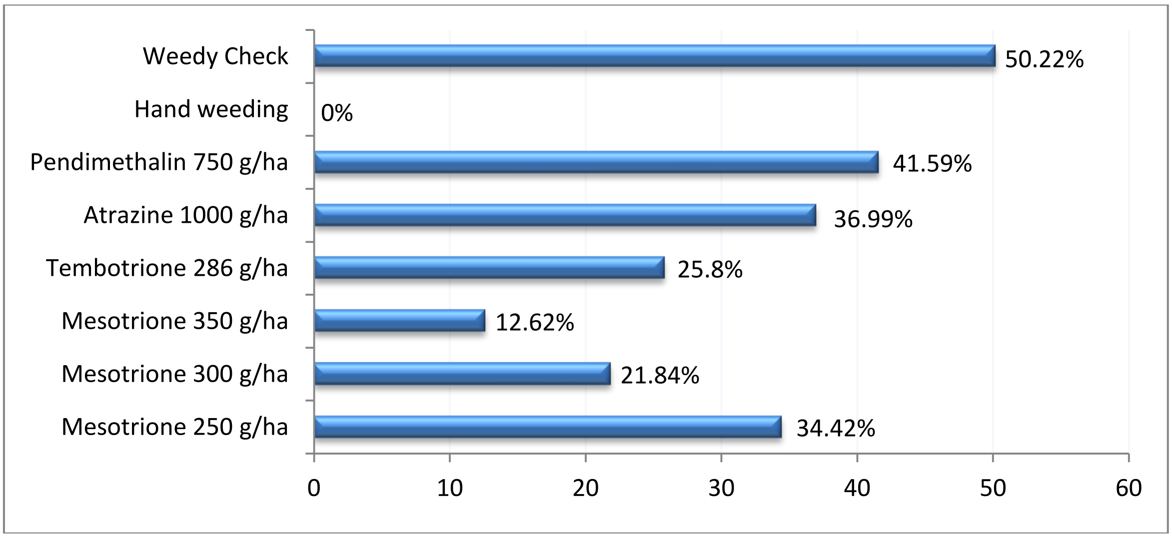

Fig. 2. Effect of weed control treatments on weed index in maize

Table 5. Effect of different weed control treatments on weed control efficiency, grain yield and stover yield

Treatments	Weed control efficiency (%)		Grain yield (t/ha)	Stover yield (t/ha)
	30 DAS	**60 DAS**		
T_1: Mesotrione 250 g ha^{-1}	47.37	47.13	1.83	19.70
T_2: Mesotrione 300 g ha^{-1}	63.73	64.24	2.18	20.95
T_3: Mesotrione 350 g ha^{-1}	72.23	69.25	2.44	21.80
T_4: Tembotrione 286 g ha^{-1}	55.10	56.43	2.07	20.61
T_5: Atrazine 1000 g ha^{-1}	37.40	40.96	1.76	18.40
T_6: Pendimethalin 750 g ha^{-1}	32.80	33.30	1.63	17.12
T_7: Hand weeding	96.58	84.89	2.80	22.52
T_8: Weedy Check	0.00	0.00	1.39	16.25
SEm±	-	-	0.04	0.90
CD at 5%	-	-	0.13	2.60

4. CONCLUSION

Weed infestation in maize is the key detrimental factor causing huge grain yield losses because of severe weed infestation. Hence, different pre and post emergence herbicides were applied in the current experiment. From these one-year experimental findings, it can be concluded that the application of mesotrione 350 g ha^{-1} as post emergence application effectively controlled the diverse weed flora of maize with highest weed control efficiency and found to be most promising weed control treatment for obtaining highest grain and stover yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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