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Vikram Singh
Department of Agronomy, CCS HAU, Hisar, Haryana, India

Ankush
Department of Soil Science, CCS HAU, Hisar, Haryana, India

Mehar Chand
Department of Agronomy, CCS HAU, Regional Research Station, Karnal, Haryana, India

SS Punia
Department of Agronomy, CCS HAU, Hisar, Haryana, India

Correspondence
Ankush
Department of Soil Science, CCS HAU, Hisar, Haryana, India

Study on yield and yield attributes of maize as affected by application of different herbicides

Vikram Singh, Ankush, Mehar Chand and SS Punia

Abstract
A field experiment was conducted at Regional Research station (RRS), Karnal, Haryana (India) during spring season. Field was randomized block design and comprises of eighteen treatments of different herbicides with or without combination. Highest yield attributes *i.e.* cob length, cob placement height, number of seed rows per cob, number of grain per cob, 100 grain weight, grain weight per cob, cob yield with or without husk, grain yield and stove yield were recorded with alachlor 2000 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (T_{11}), being at par with atrazine 750 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (T_{14}), tembotrione 140 g ha^{-1} + surfactant 1000 ml ha^{-1} (T_{10}), tembotrione 120 g ha^{-1} + surfactant 1000 ml ha^{-1} (T_9) over weedy check. Number of cobs per plant, shelling percentage and harvest index were found non-significant with the herbicidal application.

Keywords: Maize, yield, tembotrione, alachlor, hoeing

Introduction
Maize is on of the most important cereal crop after wheat and rice in India. It can grow in all the seasons but mainly it is grown in rainy seasons. It is used for human food, animal feed, starch industry, corn oil production etc. So, it plays an important role in improving economy and living standard of Indian farmers. In maize, first 30-60 days after sowing are considered as critical period for crop weed competition (Dass *et al*., 2012) [1]. Weeds compete for water and nutrient in soil and they do not allow to grow plants. At initial stage of development if plant do not get its basic requirements like nutrient and water then plant remains shorter and stunned thus become less enable to withdraw nutrients from soil. Weed infestation becomes unmanageable with the help of traditional method of inter-cultural weeding and manual hoeing and also due to the continuous rains during the entire vegetative and early reproductive stages of maize growth. During rainy seasons, it suffers from severe infestation of weeds and causes in reduction of yield ranges from 28 to 100 % (Patel *et al*., 2006 [2]). Weed management in maize become easy and cheaper due to the introduction of herbicides. Few herbicides like atrazine, pendimethaline, metribuzin, 2, 4-D are available for weed control in maize. At present farmers are applying only atrazine as PRE and 2, 4-D as post-emergence in maize, but these herbicides control only broad leaf weeds. Control of grasses and sedges remain a problem for the farmers, especially when too high or too low soil moisture hinders the inter-cultural operations. Scarcity of labour during critical stages of weeding is also a big problem for the farmers. Timely weeding is most important to minimize the yield losses and therefore, under such circumstances, the only effective tool is left to control the weeds through the use of chemicals. Thus, with undertaking all the above points mentioned in script an experiment was conducted with an objective to find out the effect of different weed control methods on yield and yield attributes of spring planted maize.

Material methods
An experiment was conducted at Regional Research Station of CCS Haryana Agricultural University, Karnal, Haryana during *spring season* 2016. The site is situated in semi-arid conditions at an elevation of 245 meter above mean sea level with latitude of 29^0 43' N in the North and longitude of 76^0 58' E in the East in sub-tropical zone. The soil of the region is derived from Indo-Gangetic alluvium and is clay loam in texture. The experiment was laid out in randomized block design and it involves application of different herbicides either alone or in combination with one another as given below Table 1.
HQPM-1 variety of maize was used in the experiment with row of 70X 20 cm. The crop was fertilized with 150-60-60 NPK kg/ha. The crop was raised as per package of practices of CCSHAU, Hisar. Major weed species appeared in the experimental plot at 40, 60 and 80 DAS

(Days after sowing) were recorded and identified which have been mentioned in Table 2 along with their taxonomic details. The major weeds appeared in the experimental field at all the stages of observation were *Cyperus rotundus* among sedges, *Anagallis arvensis, Eclipta alba, Ageratum conyzodies, Coronopus didymus* among broad leaf weeds, *Brachiaria reptans* and *Dactyloctenium aegyptium as* grassy weeds. Atrazine, alachlor and metribuzin were applied as pre-emergence spray to the soil surface as per treatment three days after sowing in good moisture. Tembotrione, atrazine and 2, 4-D Na salt were applied as post emergence spray to the foliage at 25-30 days after sowing as per treatments. Herbicides were applied through knap sack sprayer and sufficient moisture was maintained in the soil at the time of application. Hand weeding /hoeing was done manually with the help of Khurpi to remove the weeds in different treatments of manual weeding. Tractor drawn tiller was used for executing mechanical hoeing treatment at 20 and 40 days after sowing. Five plant and cobs were selected randomly, collected and stacked separately for sun drying and various observations for treatment evaluation were recorded as per plan of the experiment.

Table 1: Treatment Details

Tr. No.	Treatments	Dose (g ha^{-1})	Time of application
1	Atrazine	750	PRE
2	Atrazine *fb* 2, 4-D	750 &500	PRE & 30 DAS
3	Atrazine *fb* one hoeing	750	PRE & 30 DAS
4	One hoeing *fb* atrazine	500	20 & 30 DAS
5	Alachlor	2000	PRE
6	Alachlor *fb* hoeing	2000	PRE & 30 DAS
7	Alachlor *fb* 2, 4-D	1000 & 500	PRE & 30 DAS
8	Atrazine + alachlor	375 &1000	PRE
9	Tembotrione + surfactant	120	25 DAS
10	Tembotrione + surfactant	140	25 DAS
11	Alachlor *fb* tembotrione + S	2000 & 120	PRE & 25 DAS
12	Metribuzin	400	PRE
13	Metribuzin	500	PRE
14	Atrazine *fb* tembotrione + S	750 & 120	PRE & 25 DAS
15	Manual hoeing		20 & 40 DAS
16	Mechanical hoeing		20 & 40 DAS
17	Weedy check		
18	Weed free		

Table 2: Weed flora of the experimental field and their relative proportion

Scientific name	English name	Common name	Family	Relative weed density in Weedy check (%)		
				40 DAS	60 DAS	80 DAS
Cyperus rotundus	Purple nut sedge	Motha	Cyperaceae	29.6	23.9	30.9
Brachiaria reptans	Signal grass	Ghas	Gramineae	9.8	12.8	13.2
Dactyloctenium aegyptium	Crow foot grass	Makra	Gramineae	7.5	9.9	7.9
Anagallis arvensis	Scarlet pimpernel	Krishan neel	Primpulaceae	6.4	4.0	4.2
Eclipta alba	False daisy	Jalbhangra	Compositae	11.5	11.9	10.6
Ageratum conyzodies	Bill goat weed	Gandheli	Compositae	11.6	8.2	5.9
Coronopus didymus	*Swine cress*	Pitpapra	Cruciferae	10.9	14.5	9.7
Others;				12.7	14.8	17.6
Euphorbia hirta	Graden spurge	Badi dudhi	Euphorbiaceae			
Euphorbia microphylla	Spurge	Choti dudhi	Euphorbiaceae			
Chenopodium album	Lambsquarters	Bathu	Chenopodiaceae			
Rumex dentatus	Golden dock	Jangli palak	Polygonaceae			

Result

Yield and yield attributes: The data related to effect of herbicidal application on yield and yield attributes are presented in Table 3.

Cob length

Maximum cob length (16.7 cm) was recorded in weed free plot and minimum (11.8 cm) in weedy check. Among herbicide treatments, maximum cob length (15.3 cm) was recorded with alachlor 2000 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (T_{11}) being at par with weed free treatment (T_{18}) and cob length was minimum (12.0 cm) with the pre emrgence application of metribuzin at 500 g ha^{-1} which was significantly less than all other herbicide treatments.

Number of cobs per plant

Number of cobs per plant were found similar in each treatment (one cob per plant) (Table 3)

Cob placement height

Maximum cob placement height (93.6 cm) was recorded in weed free plot and minimum (64.3 cm) in weedy check. Among herbicide treatments, maximum height (90.7 cm) was recorded with alachlor 2000 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (T_{11}). Metribuzin 400 g ha^{-1} PRE (T_{12}) and metribuzin 500 g ha^{-1} PRE (T_{13}) being at par recorded lowest cob placement height *i.e.* 70.3 and 69.7 cm, respectively.

Number of seed rows per cob

Number of seed rows per cob was significantly influenced by various weed control treatments (Table 3). Highest number of seed rows per cob (14.9) was recorded in weed free and minimum (11.9) in weedy check. Among herbicidal application treatments, alachlor 2000 g ha^{-1} as PRE *fb*

tembotrione 120 g ha^{-1} + S (T_{11}) resulted in maximum (14.4) number of seed rows per cob whereas, metribuzin 400 g ha^{-1} PRE (T_{12}) and metribuzin 500 g ha^{-1} PRE (T_{13}) recorded lowest number of seed rows per cob.

Number of grains per cob

Perusal of data in Table 3 revealed that maximum number of grains per cob (549) were recorded under weed free treatment which being higher than all other treatments except alachlor 2000 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (541 grains/cob), atrazine 750 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (536 grains/cob), tembotrione 140 g ha^{-1} + surfactant 1000 ml ha^{-1} (533 grains/cob), tembotrione 120 g ha^{-1} + surfactant 1000 ml ha^{-1} (531 grains/cob). Minimum number of grains per cob were recorded under weedy check plot. All herbicidal treatments were significantly superior to weedy check. Metribuzin 400 g ha^{-1} PRE and metribuzin 500 g ha^{-1} PRE being at par recorded lowest number of grains per cob *i.e.* 461 and 458 respectively among herbicidal treatments.

100 grain weight

Data presented in Table 3 indicated that 100 grain weight under weed free treated plot was maximum (21.2 g) being significantly higher than all other treatments except alachlor 2000 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (20.7 g), atrazine 750 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (20.5 g), tembotrione 140 g ha^{-1} + surfactant 1000 ml ha^{-1} (20.3 g), tembotrione 120 g ha^{-1} + surfactant 1000 ml ha^{-1} (20.1 g), which was statistically at par with weed free treatment. Minimum grain weight (16.4 g) was recorded in weedy check. Among herbicide treatment, metribuzin 400 g ha^{-1} PRE and metribuzin 500 g ha^{-1} PRE being at par recorded lower 100 grain weight *i.e.* 16.7 and 16.5 g, respectively.

Grain weight per cob

Perusal of data pertaining to grain weight per cob (Table 3) revealed that maximum grain weight per cob was recorded under weed free plot (116.1 g) followed by alachlor 2000 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (112.3 g), atrazine 750 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (109.5 g), tembotrione 140 g ha^{-1} + surfactant 1000 ml ha^{-1} (108.5 g), tembotrione 120 g ha^{-1} + surfactant 1000 ml ha^{-1} (107.3 g) which were statistically at par with weed free treatment and lowest was recorded in weedy check. Among herbicide treatment, metribuzin 400 g ha^{-1} PRE and metribuzin 500 g ha^{-1} PRE being at par recorded lower grain weight per cob *i.e.* 74.6 and 72.9 g, respectively.

Cob yield with husk

All weed control treatments significantly increased the cob yield with husk over weed check (Table 3). Weed free treatment by virtue of providing a favorable environment registered maximum grain yield (8813 kg/ha), which was significantly higher to all other treatments. Cob yield with husk in alachlor 2000 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (8523 kg ha^{-1}), atrazine 750 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (8283 kg ha^{-1}), tembotrione 140 g ha^{-1} + surfactant 1000 ml ha^{-1} (8197 kg ha^{-1}), tembotrione 120 g ha^{-1} + surfactant 1000 ml ha^{-1} (8147 kg ha^{-1}) which were statistically at par with weed free treatment. Cob yield with husk was minimum (3435 kg ha^{-1}) in weedy check treatment. Among herbicide treatment, metribuzin 400 g ha^{-1} PRE and metribuzin 500 g ha^{-1} PRE being at par recorded minimum cob yield with husk *i.e.* 5770 and 5703 kg ha^{-1}, respectively.

Cob yield without husk

Maximum yield was recorded in weed free treatment (8503 kg ha^{-1}), which was significantly higher than all other treatments. Weedy check treatment recorded lowest yield (4763 kg ha^{-1}). All the weed control treatments produced significantly higher yield as compared to weedy check (Table 3). Cob yield without husk in alachlor 2000 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (8233 kg ha^{-1}), atrazine 750 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (7967 kg ha^{-1}), tembotrione 140 g ha^{-1} + surfactant 1000 ml ha^{-1} (7907 kg ha^{-1}), tembotrione 120 g ha^{-1} + surfactant 1000 ml ha^{-1} (7857 kg ha^{-1}) which were statistically at par with weed free treatment. Among herbicide treatment, metribuzin 400 g ha^{-1} PRE and metribuzin 500 g ha^{-1} PRE being at par recorded minimum cob yield without husk *i.e.* 5470 and 5387 kg ha^{-1}, respectively.

Shelling percentage

The data presented in Table 3 revealed that shelling percentage of crop did not differ significantly due to various weed control treatments.

Grain yield

Difference in grain yield due to different treatments was found to be significant. All herbicidal and intercultural treatments resulted into significantly higher grain yield as compared to weedy check. Weedy check resulted into nearly 47.7 per cent reduction in the grain yield of maize as compared to weed free treatment. The highest grain yield (7853 kg ha^{-1}) was recorded under weed free treatment and lowest (4101 kg ha^{-1}) under weedy check. Alachlor 2000 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (T_{11}), atrazine 750 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (T_{14}), tembotrione 140 g ha^{-1} + surfactant 1000 ml ha^{-1} (T_{10}), tembotrione 120 g ha^{-1} + surfactant 1000 ml ha^{-1} (T_9) produced grain yield at par with weed free check. Among herbicide treatment, metribuzin 400 g ha^{-1} PRE (T_{12}) and metribuzin 500 g ha^{-1} PRE (T_{13}) being at par recorded minimum grain yield *i.e.* 4878 and 4819 kg ha^{-1}, respectively.

Table 3: Effect of weed control treatments on yield attributing characters of the maize crop

Tr. No.	Cob length (cm)	No. of cobs per plant	Cob placement height (cm)	No. of seed rows per cob	No. of grains per cob	100 grain weight (g)	Grain weight cob^{-1} (g)	Cob yield with husk (kg ha^{-1})	Cob yield without husk (kg ha^{-1})	Shelling %	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index
T_1	12.7	1.0	73.6	13.9	472	17.1	78.2	6093	5799	79.7	5153	7083	39.0
T_2	13.0	1.0	75.9	14.0	478	17.2	82.3	6437	6144	80.4	5523	7462	39.9
T_3	13.9	1.0	80.8	14.1	500	19.1	90.2	6965	6665	81.8	6027	7960	40.3
T_4	13.7	1.0	79.7	14.0	494	19.1	87.5	6520	6220	81.4	5813	7627	41.1
T_5	14.2	1.0	84.3	13.4	518	19.4	97.3	7409	7119	81.5	6497	8420	41.1
T_6	14.6	1.0	87.6	14.6	527	19.8	104.2	7973	7683	82.5	6887	8780	41.0
T_7	14.1	1.0	82.3	14.2	512	19.1	94.6	7297	7007	81.7	6306	8240	40.5
T_8	14.5	1.0	86.0	13.5	523	19.5	101.5	7790	7500	81.8	6792	8623	40.2
T_9	14.9	1.0	89.1	14.3	531	20.3	107.3	8147	7857	83.2	7214	9002	42.1
T_{10}	15.0	1.0	89.3	14.4	533	20.5	108.5	8197	7907	83.6	7283	9047	42.3
T_{11}	15.3	1.0	90.7	14.4	541	20.7	112.3	8523	8233	83.1	7648	9527	42.4
T_{12}	12.2	1.0	70.3	12.1	461	16.7	74.6	5770	5470	79.7	4878	6657	39.3
T_{13}	12.0	1.0	69.7	12.0	458	16.5	72.9	5703	5387	80.0	4819	6637	38.9
T_{14}	15.1	1.0	89.7	14.0	536	20.5	109.5	8283	7967	83.2	7521	9245	44.1
T_{15}	13.8	1.0	78.3	14.3	488	18.9	86.6	6640	6330	81.3	5744	7523	40.5
T_{16}	13.6	1.0	78.0	14.2	486	18.0	86.1	6560	6250	80.8	5663	7490	40.4
T_{17}	11.8	1.0	64.3	11.9	416	16.4	62.3	5073	4763	78.2	4101	5933	38.0
T_{18}	16.6	1.0	93.6	14.9	549	21.2	116.1	8813	8503	83.1	7853	9763	42.2
S.Em	0.4	-	2.3	0.4	7.0	0.4	3.9	231.3	223.2	3.8	219.6	258.3	1.1
C.D.	1.3	-	6.5	1.2	21.0	1.2	11.4	670.0	650.8	NS	640	762	NS

Stover yield

Differences in stover yield due to different treatments were also significant. In general, all herbicidal and intercultural treatments exhibited significantly higher stover yield than weedy check. The highest stover yield (9763 kg ha^{-1}) was recorded under weed free treatment and lowest (5933 kg ha^{-1}) under weedy check. Alachlor 2000 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (T_{11}), atrazine 750 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (T_{14}), tembotrione 140 g ha^{-1} + surfactant 1000 ml ha^{-1} (T_{10}), tembotrione 120 g ha^{-1} + surfactant 1000 ml ha^{-1} (T_9) produced stover yield at par with weed free check. Among herbicide treatments, metribuzin 400 g ha^{-1} PRE (T_{12}) and metribuzin 500 g ha^{-1} PRE (T_{13}) being at par recorded minimum stover yield *i.e.* 6657 and 6637 kg ha^{-1}, respectively (Table 4.20).

Harvest index

The data presented in Table 3 revealed that harvest index of crop did not differ significantly due to various weed control treatments.

Discussion

Yield and yield attributes are governed by the growth and phonological parameters. Cob length, cob placement height, number of grain per cob, 100 grain weight, grain weight per cob, cob yield with husk and cob yield without husk were influenced significantly by all herbicidal treatments (Table 3). Significantly maximum cob length and cob weight were recorded in weed free treatment (T_{18}) and minimum in weedy check (T_{17}) as compared to other methods. The higher yield and yield attributes in weed free or herbicidal treatment is due to higher values of growth parameter in these treatments. Among herbicidal treatments, alachlor 2000 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (T_{11}), atrazine 750 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (T_{14}), tembotrione 140 g ha^{-1} + surfactant 1000 ml ha^{-1} (T_{10}) and tembotrione 120 g ha^{-1} + surfactant 1000 ml ha^{-1} (T_9) being at par exhibited higher values of cob length, cob placement height, number of grain per cob, 100 grain weight, grain weight per cob, cob yield with husk and cob yield without husk being at par with weed free treatment. Singh *et al*. (2010) [3] observed that maximum number of grains $cobs^{-1}$, taller plants, grain and biological yield were recorded in ridge planting. This might be due to the lower weed density, weed dry weight and higher weed control efficiency which ultimately resulted in better crop growth (Patil *et al.,* 2016 [4] and Walia *et al*., 2007 [5]). Another reason could be the effective control of weeds and minimum dry weight of weeds lead to direct increase in uptake of nutrients and thereby proper growth and development of crop which resulted in higher 100 grain weight and grain weight per cob and ultimately resulting into higher yield. Similar results have been reported by Patel *et al*. (2006) [2]. Metribuzin at 400 & 500 g ha^{-1} had lower yield due to effect on plant growth resulting in lesser plant height and dry matter accumulation by the crop. Similar results have been reported by Kumar, Punit (2015) [6].

Grain yield and stover yield were significantly affected by weed control methods are presented in Table 3. The highest maize grain yield (7853 kg ha^{-1}) and stover yield (9763 kg ha^{-1}) were obtained in weed free treatment whereas the lowest in weedy check. Similar results have been reported by Kolage *et al*. (2004) [7]. Among herbicidal treatments, alachlor 2000 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (T_{11}), atrazine 750 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} + S (T_{14}), tembotrione 140 g ha^{-1} + surfactant 1000 ml ha^{-1} (T_{10}) and tembotrione 120 g ha^{-1} + surfactant 1000 ml ha^{-1} (T_9) exhibited higher grain yield and stover yield being at par with weed free treatment. This might be due to the reduced crop weed competition and creating good environment for better growth of plant resulting in higher yield in herbicidal treatments. Similar results were reported by Sunitha *et al*. (2010) [8] and Singh *et al*. (2012) [9]. Metribuzin 400 g ha^{-1} PRE (T_{12}) and metribuzin 500 g ha^{-1} PRE (T_{13}) had lowest grain yield and stover yield due to phytotoxicity. Similar results have been reported by Kumar, Punit (2015) [6]. Harvest index was found non-significant. Similar findings have been reported by Owla *et al*. (2015) [10].

Conclusion

All weed control treatments proved effective in controlling weeds in maize and gave significantly higher grain yield over weedy check. Alachlor 2000 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} at 25 DAS +S, atrazine 750 g ha^{-1} as PRE *fb* tembotrione 120 g ha^{-1} at 25 DAS + S, tembotrione 140 g ha^{-1} + surfactant 1000 ml ha^{-1}, tembotrione 120 g ha^{-1} + surfactant 1000 ml ha^{-1} were found to be most effective and economical weed management treatments in terms of yield and yield attributes of spring maize in Haryana state.

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