Responses of Pre-emergence Herbicides for the Management of Annual Weeds in Highland Maize in Central Ethiopia

Bogale Ayana
Ethiopian Institute of Agricultural Research, Holeta Agricultural Research Center,
P.O. BOX 31, Holeta, Ethiopia
E-mail: bogaleayana@gmail.com

Abstract
A field trial was conducted at Holeta Agricultural Research Station and Medegudina, Central Ethiopia, during the summer season of 2021 to study the effects of different weed control methods against annual grasses and broadleaf weeds in summer planted Maize. The experiment included five treatments: AGENT 0.6 L ha^{-1}, Primagramgold 660 SC 3L ha^{-1}, S-Maspor 960 EC 3L ha^{-1}, weed-free and weedy check. Major weeds were *Polygonum nepalense*, *Raphanus raphanistrum*, *Guizotia scabra*, *Galinsoga pulviflora*, *Corrigiola capensis*, *Caylusea abyssinica*, *Plantago lanceoleta*, *Spergula arvensis*, *Medicago polymorpha* and *Phalaris paradoxa*. The result signified that the most dominant weed species was *Spergula arvensis* with a relative density of 18.28 %. Statistically non-significant results due to application of treatments except were recorded on cob per plant in both locations. The results showed that the most effective treatment was the application of AGENT producing the results of increased stand count by 63.3 %, increased grain yield by 7.9 folds and decreased yield losses 85.3% as compared to weedy check plots which could be followed by the application of weed free with increased weed control efficacy by 100%, reducing the dry matter of weed by 313% and increased thousand kernel weight by 37% as compared to weedy check plots. Hence, the study concludes the application of AGENT 0.6 L/ha and weed-free were more effective as compared to all other treatments without compromising on maize grain yield loss due to weeds.
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Introduction

Maize is one of the most imperative cereal crops in the world agricultural economy both as food for man and feed for animals (Awika, 2011; Zain,2011; Kamble *et al*., 2015). The maize is cultivated for grain, fodder, green cobs, sweet corn, baby corn, and popcorn in semi-urban areas. Being a rainy season crop, maize is severely infested with weeds from the time it is sown till harvesting. This is because recurrent rains boost numerous flushes of weeds; hot and humid climate is hospitable for the development of weeds especially broadleaf, wider row spacing, and increased use of fertilizers. The maize crop is sensitive to weed challenges during the early growth period due to slow growth in the first 3-4 weeks.

The critical period of weed competition is up to 40-45 DAS. Hence, managing weeds during this period is most critical for higher yields. Maize, being a rainy season and widely spaced crop, gets infested with a variety of weeds and is subjected to heavy weed competition, which often imposes enormous losses ranging from 28 to 100 percent (Patel *et al*., 2006).

The low yield of maize in Ethiopia as related to world productivity can be credited to several restraining factors and all but the most important among these has been the deprived weed controlling which poses a major threat to crop yield. Digging is labor exhaustive, luxurious, and tireless. Also, labor availability to carry out hand weeding is uncertain, thus making the timeliness of weeding difficult to achieve. This has caused a loss of yield (Lagoke *et al*.,1998). Actually, about 40-60% of production cost is consumed on physical weeding (Remison, 1979) which is comparable to the report of Chikoye *et al*. (2009) that 25–55% of the total cost of production is spent on labor and weeding operations (Yihun *et al*., 2002; Kebede and Anbesa, 2017).

Chemical weed control is a practical and economic, alternative to hand weeding. If herbicide is applied appropriately it could prevent weed infestation from planting to harvesting and promote higher yields by allowing closer crop spacing and therefore higher plant population.

Though chemical weed control has many advantages over hoe weeding, there is the possibility of reducing the herbicide rates to cut costs and mitigate the problem of an environmental buildup of herbicide residues and herbicide-resistant weeds. The study aimed to test the efficacy of different herbicides against annual weeds in maize.

Materials and Methods

Description of the study areas

The trials were carried out Holeta Agricultural Research center and Medegudina farmers field during 2021/22 main cropping season under rain fed conditions that are naturally infested with a heavy population of the commonly problematic weeds. Holeta is located 33km west of Addis Ababa at an elevation of 2400 m.a.s.l and within the geographic coordinates of 9 º 00′N and 38º 30′E. The area receives annual rain fall of 1144 mm with mean minimum and maximum temperatures of 6 º C and 22ºC respectively (EIAR, 2021).The soil of the experimental field is clay loam with p^H of 6.65, organic carbon (2.26%), available Phosphorus (14.17 mg kg^{-1}), total nitrogen (0.12%) and cation exchange capacity of 17 Cmol kg^{-1} (EIAR, 2021).

Treatments and experimental design

Afield experiments were conducted at Holeta and Medegudina locations from May 2021 to December 2021 main cropping seasons under rain fed conditions where fields were infested with many weed species. Accordingly, Randomized Completely Block Design was laid in each plot size of 5 m x 4 m along with the test herbicides AGENT 0.6 L ha^{-1}, Primagramgold 660 SC 3 L ha^{-1}, S-Maspor 3 L ha^{-1} and weed-free along with weedy check used for comparison.

Experimental procedure and crop management

The fields were tilled three times in each location before sowing to make a fine seedbed. Maize seeds were sown at 75 cm x 25 cm spacing to give a plant population of 53,333/ha. All suggested agronomic practices were applied at the time of sowing and throughout crop growth stages. The maize variety Hora was used as a test crop. Herbicides were applied as pre-emergence a day after planting with a CP-15 knapsack sprayer and a nozzle which were calibrated to deliver a spray volume of 200 L ha^{-1}. Fertilizer was applied at the rate of 150 kg ha^{-1} N, and 100 kg ha^{-1} P_2O_5. Harvesting of maize was done on a net plot of 4 m^2 after the rows at the edges at both sides of the plots were discarded to reduce error.

Data collection

Weed density was determined by counting individual weed species manually by quadrant of sizes 25cm x 25 cm and converted to 1 m^2 area bases. Relative density (RD) was determined by dividing the total number of individuals of a weed species in all the quadrants by the total number of individuals of all the weed species in all the quadrants multiplied by 100. The aboveground dry weeds harvested from each quadrant were placed into paper bags separately and oven-dried at 65ºC for 48 hours and subsequently, the dry weights were measured. Weed control efficiency (WCE) was determined by the following formula: $WCE\ \% = \frac{WDC-WDP}{WDC}\ X\ 100$ where, WCE=Weed Control Efficiency, WDC=Weed Dry weight in Control Plot, and DWP = Weed Dry weight in Particular treatment (Davasenapathy *et al*., 2008).

Stand count was performed by counting the total number of plants in quadrat and calculated on an m^2 area basis. The number of ears per plant was determined from randomly 4 plants per plot. Thousand kernel weights were counted from the bulk of threshed produce from the net plot area and their weight was recorded. Grain yield was calculated after the separation of the sun-dried plants harvested from each net plot and the yield was adjusted at 12.5% grain moisture content. Yield loss was also calculated by the formula, YL% = $\frac{MGYT-GYPT}{MGYT}\ X100$, YL= yield loss, MGPT=maximum grain yield of particular treatment and GYPT=grain yield of particular treatment.

Statistical analysis

The means of each data was checked by the normality test depending on the Shapiro test (Pr < W) before analysis of variance using the GLM procedure of SAS (SAS 9.3 version). When the treatment effects were significant, means were compared using Fisher's LSD test at a 5% level of significance (Gomez and Gomez, 1984).

Results and Discussion

Weed flora identification and relative density

The experimental sites were infested with various weed floras that are challenging in annual crops as well as perennial. Ten weed species were identified from the experimental locations in which all species were categorized as annuals (Table 1). This result revealed that the field was highly infected with annual weeds. The maximum relative weed density (18.28%) was calculated from *Spergula arvensis* while a minimum (4.7%) number was observed from *Phalaris paradoxa* L. which indicated that annual weeds are more problematic in maize at tested locations.

Table1. Weed species, relative density and life form at experimental fields

Weed species	Families	Weed density count m^2	Relative weed density (%)	Life form
Polygonum nepalense	Polygonaceae	284.00	15.83	Annual broadleaf
Raphanus raphanistrum	Brassicaceae	114.00	6.3	Annual broadleaf
Guizotia scabra	Compositae	118.00	6.5	Annual broadleaf
Galinsoga pulviflora	Compositae	117.00	6.6	Annual broadleaf
Corrigiola capensis	Plantaginaceae	244.00	13.60	Annual broadleaf
Caylusea abyssinica	Resedaceae	288.00	16.05	Annual broadleaf
Spergula arvensis	Caryophyllaceae	328.00	18.28	Annual broadleaf
Plantago lanceoleta	Plantaginaceae	86.00	4.7	Annual broad leaf
Medicago polymorpha	Fabaceae	117.00	6.6	Annual broad leaf
Phalaris paradoxa	Poaceae	98	5.4	Annual grass

Weed dry weight

Weed dry weight was significantly affected by the application of different herbicides (Table 2). The mean weed dry weight of AGENT, Primagramgold 660 SC, S-Maspor 960 EC and weed free reduced the mean dry weight of weedy check by 201%, 209%, 186.6%, 189%, 166.6%, 175%, 311.6%, 313% in both locations consequently. However, the maximum reduction of weed dry weight revealed that complete removal of weeds from plots consequently resulted in reduced dry weed biomass. This result is consistent with the findings of Das *et al*. (2011) and Megersa *et al*. (2017) who reported in barley that the lowest dry weight recorded was due to the removal of most of the weed plants there which suppressed the density of weeds and resulted in a lower competition between the crop and weeds for resources.

Table 3. Effect of herbicides on weed dry weight and weed control efficiency in maize at Holeta and Medegudina

Weed control treatments	**Weed dry weight (kg/ha)**		**Weed control efficiency (%)**	
	Holeta	**Medegudina**	**Holeta**	**Medegudina**
Agent	110.6b	104b	64.48b	97.4b
Primagramgold 660 SC	125b	124b	59.8c	96.8c
S-Maspor 960 EC	145b	138b	53.4d	96.6c
Weed free	0.0c	0.0b	100a	100a
Weedy check	311.6a	313a	0.0e	0.0d
LSD (5%)	71.83	681	2.54	0.29
CV (%)	27.55	5.1	2.43	0.2

Weed control efficiency

Weed control efficiency was significantly affected by the application of different herbicides (Table 2). The mean weed control efficiency of AGENT, Primagramgold 660 SC, S-Maspor 960 EC and weed free exceeded the mean of weedy check by 64.48%, 97.4%, 59.8%, 96.8%, 53.4%, 96.6%, 100%, 100% in both tested locations correspondingly. The maximum weed control efficiency from the application of weed-free due to complete weed removal from the field at all crop growth stages consequently resulted in minimum weed dry weight. This observation is consistent with the findings of Tollenaar *et al*.(1994) and Megersa *et al*. (2017) who also reported in barley that the reduction in weed dry weight might be due to the inhibition effect of treatments on the growth and development of weeds.

Stand count

Crop stand count was significantly ($P<0.05$) affected by the application of different herbicides (Table 3). The mean stand count of AGENT, Primagramgold 660 SC, S-Maspor 960 EC and weed free exceeded the mean stand count of weedy check plots by 63.3 %, 61.3%, 54.7%, 50.3%, 48.7%, 47.3%, 62%, 61.3% in Holeta and Medegudina respectively. The maximum stand count showed that better weed control enables the plants to produce more tillers but the minimum number of stand counts at weedy check is probably due to severe competition of weeds. Similar observation was discovered by Johnson *et al*. (1988) who stated increased in stand count was due to decreased weed density in treated plots.

Table 4. Effect of herbicides on stand count and ear per plant in maize at Holeta and Medegudina

Weed control treatments	Stand count / m^2		cob/plant	
	Holeta	Medegudina	Holeta	Medegudina
Agent	92.6a	91.3a	2a	2a
Primagramgold 660 SC	84b	83.3bc	1.4b	1b
S-Maspor 960 EC	78b	77.3c	2a	2a
Weed free	91.3a	91ab	2a	2a
Weedy check	29.3c	30d	1c	1b
LSD (5%)	6.5	7.89	0.32	0.32
CV (%)	4.6	5.62	10.09	10.36

Cob per plant

The application of different herbicides caused statistically significant differences ($P < 0.05$) on cob per plant in maize at both locations.

The mean of cob per plant produced at the application of AGENT, Primagramgold 660 SC, S-Maspor 960 EC and weed free exceeded the mean of cobs per plant in weedy check plots by 1 %, 1%, 0.4%, 0.0%, 1%, 1%, 1%, 1% in Holeta and Medegudina respectively. This implied that ear per plant is more affected by the genetic potential of the crop than herbicide application. This observation is consistent with the findings of Abuzar *et al*. (2011) who proved that the number of cobs per plant is more affected by genetic potential of varieties.

Thousand kernel weight

Thousand kernel weights were significantly affected by the application of different herbicides (Table 4). The mean thousand kernel weights produced at the application of AGENT, Primagramgold 660 SC, S-Maspor 960 EC and weed free exceeded the mean of thousand kernel weight of weedy check by 34.6%, 34%, 21.3%, 20%, 32%, 30.4%, 37%, and 36% at Holeta and Medegudina respectively. The maximum thousand kernel weight at weed-free plots implied that better weed control enables the plants to utilize more growth resources but the minimum thousand kernel weight at weedy check is probably due to a severe competition of weeds. This findings is consistent with the findings of Azim khan *et al*. (2012) and Muhammad *et al*. (2006) who identified that the probable reason for higher grain weight in plots where weed control practice was carried out was due to lower weed density which reduced the competition between wheat plants and weeds for nutrients, light, moisture, and space relating in maximized utilization of resources by crop plants.

Grain yield

Grain yield was significantly ($P < 0.05$) affected by the application of different herbicides (Table 4). The mean yield of grain yield produced at the application of AGENT, Primagramgold 660 SC, S-Maspor 960 EC and weed free exceeded the mean grain yield of weedy check by 7.9, 7, 5.5, 6.95, 4.56, 7.16, 7, 5 folds in Holeta and Medegudina locations respectively. The maximum grain yield from the application of showed that better weed control enables the plants to utilize more growth resources but the minimum grain yield at weedy check is probably due to severe competition of weeds. Analogous observations were discovered by Gul *et al*. (2011) and Shah *et al*. (2018) who reported that the maximum grain yield was obtained where minimum weed crop competition for nutrients and water existed.

Table 4. Effect of herbicides on thousand kernel weight, grain yield, and yield loss in maize at Holeta and Medegudina

Weed control treatments	100 kernel Weight (g)		Grain yield (kg/ha)		Yield loss (%)	
Weed control treatments	Holeta	Medegudina	Holeta	Medegudina	Holeta	Medegudina
Agent	234.6b	234b	4066a	3233b	3.5d	10.36d
Primagramgold 660 SC	221.3d	220.6d	2964b	3183b	27.0c	34.3c
S-Maspor 960 EC	232c	231c	2533b	3266ab	37.7b	43.3b
Weed free	237a	236.6a	3700a	2400b	9.0d	18.5d
Weedy check	200e	200.6e	455c	400c	88.8a	90.6a
LSD (5%)	1.61	2.06	446.89	260	7.9	10.38
CV (%)	0.38	0.48	8.64	29.7	12.78	13.9

Yield loss

Yield loss was significantly affected by the application of different herbicides (Table 4). The mean yield losses of AGENT, Primagramgold 660 SC, S-Maspor 960 EC and weed free reduced by 85.3%, 80.4%, 61.8%, 56%, 51%, 47.3%, 79.2% and 72% were recorded in weedy check plots at Holeta and Medegudina respectively. The minimum yield losses indicates that better weed control that enables the plants to utilize more growth resources resulted in higher grain yield while the maximum yield loss at weedy check is probably due to severe competition of weeds. This finding is consistent with the findings of Tesfaye *et al*. (2014) and Shah *et al*. (2018) who reported that the minimum yield loss was obtained where minimum weed crop competition for nutrients and water existed.

Conclusion

Application of herbicides decreased weed dry weight and increased grain yield of maize which mainly attributed to improvement in yield related traits due to increased in weed control efficiency. Moreover, increase in weed control and also attributed to decreased weed dry weight as herbicide is toxic to most weeds, caused mortality and fatty acids involved in the synthesis of protein and fatty acids. AGENT proved best pre emergence herbicide in this experiment which was conducted in moisture sufficient region , therefore it can be recommended to the farmers of the region for maximum seed production of maize with high nutritional quality. Based on the results, it is concluded that maize variety 'Hora' should preferably be grown, and AGENT should be applied soon after planting in rain fed regions at the rate of (0.6L ha^{-1}) in with spray volume of 200 L ha^{-1} water is recommended pre-emergence herbicide for the control of various annual broad leaf weeds in Maize.

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