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Research Article

Reducing weed impacts and yield losses by application of herbicides in summer-grown maize

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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; COYOTE 440 SE 3L ha^{-1}, Primagramgold 660 SC 3L ha^{-1}, twice hand weeding, weed-free and weedy check. Major weeds in the fields 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 *Polygonum nepalense* with a relative density of 18.28 %. Statistically non-significant results due to all treatments being recorded on ear per plant and 1000 kernel weights at both locations. The results showed that the most effective treatment with higher weed control efficacy (100%) and reduced weed dry weight (0.00 kg/ha) was weed-free. The application of COYOTE 440 SE produced maximum stand count (90 m^2), Grain yield (4266 kg/ha), and minimum yield loss (1.49%) while statistically non-significant results were produced in cob per plant and thousand kernel weights. Hence, the study concludes that COYOTE 440 SE 3L ha^{-1} and weed-free could be more effective as compared to all other treatments without compromising on maize grain yield loss due to weeds.

Introduction

Maize is one of the most imperative cereal crops in the world agricultural economy both as food for man and feed for animals (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; a 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 weeks - 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 [1]. Yield losses due to weeds under low infestation 20% [2], in medium infestation 27-38% [3] and in high infestation 35-83 % [4] in maize.

The low yield of maize in Ethiopia as related to world productivity can be attributed to several restraining factors and all but the most crucial among these has been the deprived weed control 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 [5]. Predictably, about 40% - 60% of production cost is consumed on physical weeding [6] 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.

Chemical weed control is a practical and economical, alternative to hand weeding. Several research works have been done with the application of pre and post-emergence

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herbicides [7-11]. Even though many herbicides have been registered to control weeds in corn, there is a limitation on the efficacy of various weeds and the low persistence of most weed species. Therefore, it is necessary to test new herbicide products to mitigate the problems exerted by weeds on maize to increase yield. 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.

In spite of chemical weed control having 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 sites

The trial was carried out at Holeta Agricultural Research Center and Medegudina during the main cropping season 2021/22 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 °00′N and 38 °30′E. The area receives an annual rainfall of 1144 mm with mean minimum and maximum temperatures of 6 °C and 22 °C respectively (EIAR, 2022). The soil of the experimental field is clay loam with a 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, 2022).

Treatments and experimental design

The fields were treated with two pre-emergence herbicides and hand-weeding frequencies. Accordingly, Randomized Completely Block Design was laid in each plot size of 5 m x 4 m treated with the test herbicides COYOTE 440 SE 3L ha^{-1}, Primagramgold 660 SC 3 L ha^{-1}, Twice hand weeding and weed-free along with weedy check used for comparison.

Experimental procedure and crop management

The field was 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 the crop growth stages. Herbicides were applied as pre-emergence. 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 convey a spray volume of 200 L ha $^{-1}$. Fertilizers were 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 65°C 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% $= \frac{MGYT - GYPT}{MGYT} X 100$, 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 perennials. 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 *Polygonum nepalense* 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.

Weed dry weight

Weed dry weight was significantly ($p \leq 0.0001$)affected by the application of different herbicides (Table 2). Treating maize plots with different weed control decreased weed dry weight significantly and consistently. Hence, the mean weed dry weight in plots treated COYOTE 440 SE, Primagramgold 660

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Table 1: Weed species, relative density, and life form in experimental fields.

Weed species	Families	Weed density count m^2	Relative weed density (%)	Life form
Polygonum nepalense	Polygonaceae	284	18.28	Annual broadleaf
Raphanus raphanistrum	Brassicaceae	114	6.3	Annual broadleaf
Guizotia scabra	Compositae	118	6.5	Annual broadleaf
Galinsoga pulviflora	Compositae	328	15.83	Annual broadleaf
Corrigiola capensis	Plantaginaceae	244	13.6	Annual broadleaf
Caylusea abyssinica	Resedaceae	288	16.05	Annual broadleaf
Plantago lanceoleta	Plantaginaceae	98	5.4	Annual broad leaf
Spergula arvensis	Caryophyllaceae	117	6.6	Annual broad leaf
Medicago polymorpha	Fabaceae	117	6.6	Annual broad leaf
Phalaris paradoxa	Poaceae	86	4.7	Annual grass

Table 2: Effect of herbicides on weed dry weight and weed control efficiency in maize at Holeta and Medegudina.

Weed control treatments	Dry weed biomass (kg ha^{-1})		Weed control efficiency (%)	
	Holeta	Medegudina	Holeta	Medegudina
COYOTE 440 SE	110b	106.6b	90.6c	94.4c
Primagramgold 660 SC	120b	119.6b	95.6b	96b
Twice hand weeding	122.3b	121.6b	95.6b	95.9b
Weed free	0.0b	0.0b	100a	100a
Weedy check	2666a	2833a	0.0d	0.0d
LSD (5%)	131.1	127.42	0.32	0.22
CV (%)	11.53	10.63	0.22	0.15

SC, twice hand weeding, and weed free reduced the mean of weed dry weight in weedy check by 2556%, 2726.4%, 2546%, 2713.4%, 2543.7%, 2711.4%, 2666%, and 2833% in both tested locations respectively. Moreover, the maximum reduction of weed dry weight from the application of weed-free implies that the complete removal of weeds from plots consequently resulted in reduced dry weed biomass. This is consistent with the findings of Abouziena, et al. [12] and Sunitha, et al. [13] who reported 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.

Weed control efficiency

Weed control efficiency was significantly ($p \le 0.0001$) affected by the application of different herbicides (Table 2). Treating maize plots with different weed control increased weed control efficiency significantly and consistently. Hence, weed control efficiency in plots treated COYOTE 440 SE, Primagramgold 660 SC, twice hand weeding, and weed free exceeded weed control efficiency of weedy check by 90.6%, 94.4%, 95.6%, 96%, 95.6%, 95.9%, 100%, and 100% in both tested locations respectively. The maximum weed control efficiency is due to complete weed removal from the field at all crop growth stages consequently resulting in minimum weed dry weight. This observation is consistent with Megersa, et al. (2017) who reported in barley that the reduction in weed dry weight is due to the inhibition effect of treatments on the growth and development of weeds.

Stand count

Crop stand count was significantly ($p \le 0.01$) affected by the application of different herbicides (Table 3). Treating maize plots with different herbicides increased the stand count significantly and consistently. Therefore, the mean stand count in plots treated COYOTE 440 SE, Primagramgold 660 SC, twice hand weeding, and weed-free exceeded the mean stand count of weedy check by 61.4%, 62.3%, 52.7%, 53.6%, 46.7%, 57%, 60.7%, and 62% in Holeta and Medegudina respectively. The maximum stand count revealed that better weed control enables the plants to produce more tillers while the minimum number of stand counts at weedy check is probably due to severe competition of weeds. This is consistent with the findings of Johnson, et al. [14] who found that herbicides with better weed control efficacy resulted in more crop stand.

Cob per plant

Application of different herbicides caused statistically non-significant ($p \ge 0.05$) cob per plant in maize at both locations (Table 3). 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 Subedi and Ma [3] who concluded that the number of cobs per plant is highly influenced by the genetic potential of the crop.

Thousand kernel weight

Application of different weed control treatments caused statistically ($p \ge 0.05$) no significant differences in thousand kernel weight in maize in both locations (Table 4). This implied that thousand kernel weights are more affected by the cultivars than weed control treatments. This observation is consistent with the reports of Maqbool, et al. [15] and Muhammad, et al. (2006) who identified the probable reason for non-significant thousand kernel weight varieties' ability to utilize resources to produce vigor seeds.

Table 3: 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^{-1}	
	Holeta	Medegudina	Holeta	Medegudina
COYOTE 440 SE	90a	89.3a	2	2
Primagramgold 660 SC	81.3b	80.6a	2	2
Twice hand weeding	75.3b	84a	2	2
Weed free	89.3a	89a	2	2
Weedy check	28.6c	27b	2	2
LSD (5%)	7.49	10.85	NS	NS
CV (%)	5.46	7.78	0.00	0.00

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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^{-1})		Yield loss (%)	
	Holeta	Medegudina	Holeta	Medegudina	Holeta	Medegudina
COYOTE 440 SE	234.3	234	4186a	4266a	1.49e	1.9e
Primagramgold 660 SC	222	221	2894c	2966c	31.8c	31.7c
Twice hand weeding	212.6	213	2585d	2600d	39.17b	40.2b
Weed free	223.3	230	3750b	3816b	11.7d	12.3d
Weedy check	218	216	416e	366e	90.19a	91.5a
LSD (5%)	NS	NS	177.7	267.38	4.17	6.14
CV (%)	5.94	6.23	3.41	5.06	6.35	9.18

Grain yield

Grain yield was significantly ($p \leq 0.0001$) affected by the application of different herbicides (Table 4). Treating maize plots with different herbicides increased grain yield significantly and consistently. Therefore, the mean grain yield in plots treated COYOTE 440 SE, Primagramgold 660 SC, twice hand weeding, and weed-free exceeded the mean grain yield of weedy check by 9.06, 10.65, 6.17, 7.1, 5.21, 6.1, 8, and 9.42 folds in Holeta and Medegudina respectively. The maximum grain yield indicates 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. This result is consistent with the findings of Seran and Brintha [16], Fahad, et al. [17], Gul, et al. [18], and Shah, et al. (2018) who reported that the maximum grain yield was obtained where minimum weed crop competition for nutrients and water existed.

Yield loss

Yield loss was significantly ($p \leq 0.0001$) affected by the application of different herbicides (Table 4). Therefore, the mean yield losses in plots treated COYOTE 440 SE, Primagramgold 660 SC, twice hand weeding, and weed-free exceeded the mean yield loss of weedy check by 88.7%, 89%, 58.39%, 59.8%, 51%, 51.3%, 78.49 and 79% in Holeta and Medegudina respectively. The minimum yield losses revealed 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 observation is consistent with the findings of Lindquist, et al. [19], Fahad, et al. [20-27], 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

Maize is one important cereal crop cultivated over large areas in Ethiopia. Its production has been limited by various factors. Weed is one of the yield-reducing factors in maize. A field trial was aimed to study the effects of different weed control methods against annual grasses and broadleaf weeds in summer planted Maize. The experimental sites were infested with major weeds species of *Polygonum nepalense*, *Raphanus raphanistrum*, *Guizotia scabra*, *Galinsoga pulviflora*, *Corrigiola capensis*, *Caylusea abyssinica*, *Plantago lanceoleta*, *Spergula arvensis*, *Medicago polymorpha*, and *Phalaris paradoxa*. The most dominant weed species was *Polygonum nepalense*. Application of treatment revealed statistically non-significant results due to all treatments being recorded on ear per plant and 1000 kernel weights in all tested sites. Application weed-free produced superior results in some of the traits includes; weed control efficacy, and reducing the dry matter of weed which could be followed by COYOTE 440 SE. The maximum grain yield and minimum yield loss were gained at COYOTE 440 SE and weed-free. Hence, the study concludes that COYOTE 440 SE 3 L ha^{-1} followed by weed-free is more effective as compared to all other treatments in terms of maximum grain yield and minimum yield loss due to weeds.

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