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Improving Maize Production and Decreasing Weed Pressure by Application of Weed Control Methods

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Abstract: *Weeds hampermaize productivity worldwide. However, weed control strategies strongly influence weed infestation in modern agriculture. Herbicides are the main means of weed control in modern agriculture. The study evaluated the effects of weed control methods on weed control and its effects on corn weeds and yield components. The study included treatments Coyote 440 SE 3 L ha-1, Primagramgold 660 SC 3 L ha-1, twice hand weeding, weed free and weedy check carried out with RCBD in triplicate. The fields were infested with several species of weeds;Polygonum nepalense, Raphanus raphanistrum, Guizotia scabra, Galinsoga pulviflora, Corrigiola capensis, Caylusea abyssinica, Plantago lanceoleta, Spergula arvensis, Medicago polymorpha, and Phalaris paradoxa. The highest relative density (18.28%) was observed inGalinsoga pulviflora. Weed control methods significantly changed the density of individual weeds. Weed free and weed check treatments recorded the lowest and highest densities of individual weeds. Application of COYOTE 440 SE effectively increased cob length by 6.3%, grain yield by 12 times, and reduced yield loss by 89.6%. On the other hand, weed control not only reduced the density of weeds, but also limited the number of weeds. It was concluded that applications of COYOTE 440 SE 3 L ha-1 followed by weed free successfully control corn weeds.*

Keywords: *application, control, exceeded, recorded, significant*

1. Introduction

Maize is one of the widely cultivated cereal crops in the irrigated and rain fed regions of Ethiopia (Shiferaw *et al*., 2011). In Ethiopia, maize is cultivated on an area of 1026 thousand hectares, with a production of 3.313 million tons and an average grain yield of 3264 kg ha^{-1} (CSA, 2020/21). However, the average national yield per hectare is much lower compared to other corn producing countries in the world such as Italy (9000 kg ha^{-1}), USA (9103 kg ha^{-1}), Canada (8200 kg ha^{-1}) (Edgerton, 2009; Klopfenstein *et al*., 2013; Leograndeet *al*., 2016).

Despite a desirable production environment and high-yielding maize varieties, yields per hectare are still very low in Ethiopia. Weed invasion is a major concern as a cause of low yields. Extreme weed growth in maize fields leads to yield reductions of 66-80 percent (Ghardee*t al*., 2018). Weeds compete with crops for space, light, moisture, nutrients and carbon dioxide, which not only reduces yield, grain value and complicates harvesting processes, but also increases production costs (Rutta *et al*. 1991; Kaur *et al*., 2018).

Several approaches are available to minimize weed losses, including mechanical, agricultural, biological, and chemical control methods. Due to the increase in production costs of cultural methods, farmers are switching to other alternative management methods. In this situation, chemical weed control is the best option. The chemical control method is faster, more functional and saves time and labor. Many researchers recommend a chemical method of weed control (Johnson *et al*., 1997, Khan and Haq, 2004, Imran *et al*., 2021). The success of weed control methods depends on several factors. However, weed germination, time of application and crop stage are important for chemical control (Hoverstad *et al*., 2004). Also, the timing of herbicide application is very important for proper weed control and the effectiveness of herbicides can be increased (Vandini *et al*., 2005; Tahir *et al*., 2009). The study was evaluated the effects of weed control methods on weed control and its effects on corn weeds and yield components.

2. MATERIALS AND METHODS

Treatment and experimental design

The field trials were conducted in Holeta and Medegudina during the main cropping season of 2021 under rainy conditions where the fields were infested with many weed species. The experiment was performed in RCBD with three replicates. Maize seeds with a weight of 25 kg ha^{-1} were sown in well-pretreated rows with a field size of 5 m x 3 m. Treatments included; Coyote 440 SE 3 L ha^{-1}, Primagramgold 660 SC 3 L ha^{-1}, twice hand weeding, weed free and weed check. Fertilizers rates 150 kg ha^{-1}nitrogen (urea) and 100 kg ha^{-1} phosphorus (NPS) were used as fertilizer. Phosphorus was applied in full doze during sowing, while nitrogen was applied in two doses, viz. half the dose at sowing and the rest at knee height. All recommended agronomic practices were applied during the growing phase of the crop. All herbicides were applied before emergence and immediately after planting.

Collection of data

Weed density was determined at 45 DACE by counting the total number of weed species per unit area (square) in each plot. Relative density (RD) was determined by dividing the total number of individuals of a weed species in all quadrants by the total number of individuals of all weed species in all quadrants multiplied by 100 (Raza *et al*., 2021). Plant height was determined by measuring the height of 4 randomly selected plants per plot using a metric ruler from the ground to the apical bud of the plant. Ear length was determined on four randomly selected plants from each plot. Grain yield was determined by weighing the harvested grain from each net plot, which was converted to kilograms per hectare after determining grain moisture content. The loss yield was calculated as follows; YL% = YL % = $\frac{MGYT-GYPT}{MGYT} X100$, YL = yield loss, MGPT = maximum grain yield of a given treatment, and GYPT = grain yield of a given treatment (Das *et al*., 2011).

Statistical analysis

Analysis of variance was performed on the collected data using SAS version 9.3 Statistical Package and where the F value was significant; means were separated using LSD at 5% probability (Gomez and Gomez, 1984).

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 L.	Polygonaceae	284.00	15.83	annual broadleaf
Raphanus raphanistrum L.	Brassicaceae	114.00	6.3	annual broadleaf
Guizotia scabra (Vis) Chiov.	Compositae	118.00	6.5	annual broadleaf
Galinsoga pulviflora Cav.	Compositae	328.00	18.28	annual broadleaf
Corrigiola capensis Wild.	Plantaginaceae	244.00	13.60	annual broadleaf
Caylusea abyssinica	Resedaceae	288.00	16.05	annual broadleaf
Plantago lanceoleta L.	Plantaginaceae	86.00	4.7	annual broad leaf
Spergula arvensis L.	Caryophyllaceae	117.00	6.6	annual broad leaf
Medicago polymorpha	Fabaceae	117.00	6.6	annual broad leaf
Phalaris paradoxa L.	Poaceae	98	5.4	annual grass

Effects of weed control treatments on weed densities after 45 days of treatment in Holeta and Medegudina

Polygonum nepalense L.

The effects of weed control treatments were significant (P≤0.05) on the density of *P. nepalense* in Holeta and Medegudina (Table-2). There is no density of*P.neplense* was recorded from the application of weed free. However, the maximum number 176 m^{-2} was obtained at weed check. The application of COYOTE 440 SE and twice hand weeding and weed free showed that statistically no significant difference in Holeta. Similarly, there was no weed density of *P. nepalense* was recorded from application of weed free in Holeta. However, the maximum number of 104 m^{-2} was obtained at the weed in Medegudina. The application of hand weeding twice showed that statistically no significant difference.

The application of weed free decreased the density of *P.nepalense* by 176% as compared to the density of weedy check plots in Holeta, while the mean weed density of *P.nepalense* was decreased by 104% due to application of weed free as compared to weedy check plots in Medegudina. The lowest weed density is probably continuous removal of weeds in the plots, resulting in minimal weed density.

Raphanus raphanistrum L

The effects of weed control treatments were significant (P≤0.05) on the density of *R. raphanistrum*in Holeta and Medegudina (Table-2). There is no density of *R.raphanistrum* recorded from application of weed free, whereas the maximum number of 100 m^{-2} was obtained at the weedy check in Holeta. The application of COYOTE 440 SE and twice hand weeding revealed that statistically no significant difference. The minimum weed density of *R. raphanistrum* was recorded from the application of COYOTE 440 SE and S-Maspor 960 EC, whereas the maximum number of 137 m^{-2} was obtained at weedy check. The application of COYOTE 440 SE and Primagramgold 660 SC showed that statistically no significant difference. Hence, the application of weed free decreased the density of *R. raphanistrum* by 100% as compared to the density of weedy check plots in Holeta, while the mean weed density of *R. raphanistrum* was decreased by 137% due to application of COYOTE 440 SE and S-Maspor 960 EC as compared weedy check plots in Medegudina. The lowest weed density showed that mortality of weeds in the plots resulted in minimal weed density. This is consistent with the findings of Carey and Kells (1991) who stated that herbicide application decreased weed density by eliminating most of the weeds in the field.

Guizotia scabra

The effects of weed control treatments were significant (P≤0.05) on the density of *G.scabra* in Holeta and Medegudina (Table-2). There is no density of *G.scabra* was recorded from application of weed free, while the maximum 62m^2 was obtained at the weed check. The applications of COYOTE 440 SE and weed free revealed that statistically no significant difference. The application of weed free decreased the density of *G.scabra* by 62% as compared to the density of weedy check plots in Holeta, while the mean weed density of *G.scabra* was decreased by 63% due to application of Surestart as compared to weedy check plots in Medegudina. The lowest weed density was due to continuous removal of weeds in the plots, which resulted in minimal weed density. This is consistent with the observation of Shehzad *et al*.(2012) who stated that herbicide application decreased weed density by eliminating most weeds in the field.

Table2. *Effect of Herbicides application on weed density at 45 days of application after sowing at Holeta and Medegudina*

Treatments	*Polygonum nepalense*		*Raphanus raphanistrum L.*		*Guizotia scabra*		*Galinsoga Pulviflora*		*Corrigiola capensis*	
	Holeta	Medegudina	Holeta	Medegudina	Holeta	Medegudina	Holeta	Medegudina	Holeta	Medegudina
COYOTE 440 SE	4.00b	14.6c	4.00c	3.3cd	1.6cd	3c	6.33c	5.6c	22c	20.6c

Primagramgold 660 SC	117a	89b	42b	3.3cd	26.6b	25.6b	66.00b	65b	89.6b	89b
Twice hand weeding	6.00b	10cd	5.66c	6b	4.33c	4c	6.33c	5.6c	10.3d	10d
Weed free	0.00b	0.0d	0.0 d	0.0d	0.00d	0.0d	0.00c	0.0c	0.0e	0.0e
Weedy check	176a	104a	100a	137a	62 a	63a	140a	141a	100a	104a
LSD (5%)	81.89	12.31	3.40	3.88	2.68	2.26	9.01	8.6	2.31	5.88
CV (%)	7.1	15.02	4.81	5.53	7.53	6.24	10.94	10.46	2.77	6.98

	Caylusea abyssinica		*Plantago lanceoleta*		*Spergula arvensis*		*Medicago polymorpha*		*Phalaris paradoxa*	
	Holeta	Medegudina	Holeta	Medegudina	Holeta	Medegudina	Holeta	Medegudina	Holeta	Medegudina
COYOTE 440 SE	2cd	2.6cd	2.6cd	3.3cd	2.6d	3.6cd	2.6cd	3.6cd	6.6b	6.6b
Primagramgold 660 SC	58b	57.3b	30.6b	30b	52b	51.3b	54.6b	54b	5.3b	5b
Twice hand weeding	6.3c	6c	6.0c	5.3c	7c	6.6c	6c	5.6c	5b	4.6b
Weed free	0.0d	0.0d	0.0d	0.0d	0.0d	0.0d	0.0d	0.0d	0.0d	0.0c
Weedy check	116a	117a	36a	36a	119a	120a	120a	122a	31.3a	32a
LSD (5%)	4.78	4.81	3.62	3.53	5.24	4.34	5.24	4.12	3.58	2.85
CV (%)	6.94	6.97	12.7	2.47	7.69	6.35	7.82	5.91	19.71	15.68

Galinsoga pulviflora

The effects of weed control treatments were significant (P≤0.05) on the density of *G. pulviflora* in Holeta and Medegudina (Table-2). There is no weed density of *G. pulviflora* was recorded from application of weed free while the maximum number 140 m^{-2} was obtained at weedy check. The application of all weed control treatments revealed that statistically no significant difference except for Primagramgold 660 SC in Holeta. There is no weed density of *G. pulviflora* was recorded from the application of Surestart, while the maximum number 141m^{-2} was obtained at weed check. The applications of all effects of weed control treatments revealed that statistically no significant difference excluding Primagramgold in Medegudina. The application of weed free decreased the density of *G. pulviflora* by 140% as compared to the density of weedy check plots in Holeta, while the mean weed density of *G. pulviflora* was decreased by 141% due to the application of Surestart as compared to weedy check plots in Medegudina. The lowest weed density was due to continuous removal of weeds in the plots, which resulted in minimal weed density. This is consistent with the findings of Fischer *et al*. (2002) who stated that herbicide application decreased weed density by eliminating most of the weeds in the field.

Corrigiola capensis

The effect of weed control treatments was significant (P≤0.05) on the density of *C.capensis* in Holeta and Medegudina (Table-2). There was no weed density of *C.capensis* that was recorded from the application of weed free, while the maximum number 100 m^{-2} was obtained at a weedy check in Holeta. There was no density of *C. capensis* that was recorded from the application of weed free, whereas the maximum number 104 m^{-2} was obtained at weedy check. The application of weed free decreased the density of *C. capensis* by 100% as compared to the density of weedy check plots in

Holeta, while the mean weed density of *C.capensis* was decreased by 104% due to application of weed free as compared to weedy check plots in Medegudina. The lowest weed density indicates continuous removal of weeds in the plots resulting in minimal weed density.

Caylusea abyssinica

The effects of weed control treatments were significant (P≤0.05) on the density of *C. abyssinica* in Holeta and Medegudina (Table-2). There was no weed density of *C. abyssinica* was recorded from application of weed free, while the maximum number 116 m^{-2} was obtained at weed check. The application of COYOTE 440 SE and weed free showed that statistically no significant difference. The minimum weed density of *C. abyssinica* was recorded from an application of Surestart, while the maximum number 117.3 m^{-2} was obtained at weed check. The applications of COYOTE 440 SE and weed free revealed that statistically no significant difference. The application of weed free decreased the density of *C. abyssinica* by 116% as compared to the density of weedy check plots in Holeta, while the mean weed density of *C. abyssinica* was decreased by 117.3% due to the application of Surestart as compared to weedy check plots in Medegudina. The lowest weed density was due to continuous removal of weeds in the plots, which resulted in minimal weed density. This is analogous with the discoveries of Khan *et al* (2016) who stated that herbicide application decreased weed density by eliminating most of the weeds in the field.

Plantago lanceoleta

The effects of weed control treatments were significant (P≤0.05)on the density of *P. lanceoleta* in Holeta and Medegudina (Table-2). There was no minimum weed density of *P. lanceoleta* was recorded from application of weed free, while the maximum number of 36 m^{-2} was obtained at weed check in Holeta. There are statistically no significant differences observed between applications of COYOTE 440 SE and weed free. Similarly, there was no weed density of *P. lanceoleta* recorded from an application of weed free, while the maximum number 53.6 m^{-2} was obtained at weedy check in Medegudina. Statistically no significant differences were observed between applications of COYOTE 440 SE and S-Maspor 960 EC. The application of weed free decreased the density of *P. lanceoleta* by 36% as compared to the density of weedy check plots in Holeta, while the mean weed density of *P. lanceoleta* was decreased by 53.6% due to application of weed free as compared weedy check plots in Medegudina. The lowest weed density could be continuous removal of weeds in the plots, resulting in minimal weed density.

Spergula arvensis

The effects of weed control treatments were significant (P≤0.05)on density of *S. arvensis* in Holeta and Medegudina (Table-2). There was no weed density of *S. arvensis* was recorded from application of weed free while the maximum number 119m^{-2} was obtained at weedy check in Holeta. Statistically no significant difference was observed between applications of COYOTE 440 SE and weed free. The minimum weed density of *S. arvensis* was recorded from, application of weed free, although the maximum number 36 m^{-2} was obtained at weed check. There are statistically no significant differences observed between applications of COYOTE 440 SE and weed free. The application of weed free decreased the density of *S. arvensis* by 119% as compared to the density of weedy check plots in Holeta, while the mean weed density of *S. arvensis* was decreased by 36% due to application of weed free as compared to weedy check plots in Medegudina. The lowest weed density could be continuous removal of weeds in the plots resulting in minimal weed density.

Medicago polymorpha

The effects of weed control treatments were significant (P≤0.05) on the density of *M. polymorpha* in Holeta and Medegudina (Table-2). There was no weed density of *M. polymorpha* that was recorded from the application of weed free, while the maximum number 120 m^{-2} was obtained at a weedy check in Holeta. Similarly, there were statistically no significant differences observed between applications of COYOTE 440 SE and weed free in Medegudina. There was no weed density of *M. polymorpha* recorded from the application of weed free, while the maximum number 122 m^{-2} was obtained at weedy check. There are statistically no significant differences observed between applications of COYOTE 440 SE and twice hand weeding. The application of weed free decreased the density of *M. polymorpha* by 120% as compared to the density of weedy check plots in Holeta, while the mean weed density of *M. polymorpha* was decreased by 122% due to application of weed free as compared to weedy check plots in Medegudina. The lowest weed density can be continuous removal of weeds in the plots, resulting in minimal weed density.

Phalaris paradoxa

The effects of weed control treatments were significant (P≤0.05)on density of *P. paradoxa* in Holeta and Medegudina (Table-2). There was no weed density of *P. paradoxa* that was recorded from application of weed free, while the maximum number 31.3 m^{-2} was obtained at a weed check in Holeta. Correspondingly, there was no weed density of *P. paradoxa* that was recorded from the application of weed free, while the maximum number 32 m^{-2} was obtained at weed check in Medegudina. There are statistically no significant differences observed between the applications of all weed control treatments, excluding weed free. The application of weed free decreased the density of *P. paradoxa* by 31.3% as compared to the density of weedy check plots in Holeta, while the mean weed density of *P. paradoxa* was decreased by 32% due to application of weed free as compared to weedy check plots in Medegudina. The lowest weed density is probably continuous removal of weeds in the plots, resulting in minimal weed density. This is consistent with the finding observation of Adingun (2001) who concluded that weed free plots produced no weed density because of subsequent removal of weeds.

Plant height

Plant height was significantly (P≤0.05)affected by application of different weed control treatments (Table 3). The maximum plant height (226 cm) was recorded due to application of COYOTE 440 SE at both locations whereas the minimum plant height (173.3 cm) was recorded from application of hand weeding twice at Holeta. The result also showed that statistically no significant difference was observed between COYOTE 440 SE and the weedy check application at both locations. This indicated that plant height was more influenced by genetic genetics than weed control treatments. Similarly, the result also showed that statistically no significant difference was observed between the remaining treatments application at both locations. A similar result was described by Tollenaar *et al*. (2018) who examined that the enlarged plant height with the weedy plot might be due to the effect of severe competition among plants which make them elongated in search of light and lack of availability of plentiful of growth encouraging factors in weedy plot that permitted the plants to upsurge in height, the opposition between weeds and crop for sun light and space in control plots caused in larger plants.

Ear length

Ear length was significantly (P≤0.05)affected by the application of weed control treatments (Table 3). The maximum ear length of 10.8 cm was recorded at Holeta by application of COYOTE 440 SE, however the minimum ear length (4.6 cm) was recorded from weedy check plots. The mean ear length produced at COYOTE 440 SE exceeded the mean ear length of weedy check by 6.3, 5.6 in Holeta and Medegudina respectively. There is no statistically significant variation between application of COYOTE 440 SE and weed free at both tested locations. The increase in ear length indicates that improved weed control allows the plants to exploit more growth resources, while the minimum spike length at weedy check is probably due to severe opposition of weeds. Analogous observations were reported by Ihsan *et al*. (2015), who concluded that this elongated cob length could be due to the inferior dry weight of weeds in treated plots, which likely led to better resources (water, light, nutrients) and enhanced spike length.

Table3. *Effect of herbicides on plant height and ear length in maize in Holeta and Medegudina*

Weed control treatments	Plant height (cm)		Ear length (cm)	
	Holeta	Medegudina	Holeta	Medegudina
COYOTE 440 SE	221.3a	221.3a	10.8a	10.6a
Primagramgold 660SC	183.4b	183.3bc	6.6b	6.6b
Twice hand weeding	173.3b	174c	5b	5.3c
Weed free	183.3b	186.6bc	10.6a	10.3a
Weedy check	226a	226a	4.6b	5c
LSD (5%)	13.8	11.56	2.07	1.61
CV (%)	3.71	3.09	14.56	11.26

Grain yield

Grain yield was significantly (P≤0.05)affected by the application of weed control treatments (Table 4). The maximum yield 4186 $kgha^{-1}$ and 4266 $kgha^{-1}$ were recorded from the application of COYOTE

440 SE at Holeta and Medegudina respectively, while the minimum values 416 kgha^{-1} and 316 kgha^{-1} were recorded from weedy check plots. The mean grain yield of COYOTE 440 SE exceeded the mean grain yield of weedy check plots by 9 and 12 folds in Holeta and Medegudina respectively. The increase in grain yield indicates that improved weed control aids the plants in using more growth resources. However, the decrease in grain yield at weedy check is perhaps due to higher competition from weeds. This is analogous with the observation by Shah and Wu (2019) who stated that the increased grain yield was found where the lowest weed crop opposition to nutrients and water happened.

Table4. *Effect of herbicides on thousand kernel weights and grain yield and yield loss in maize in Holeta and Medegudina*

Weed control treatments	Grain yield (kg ha^{-1})		Yield loss (%)	
	Holeta	Medegudina	Holeta	Medegudina
COYOTE 440 SE	4186a	4266a	1.49e	1.9e
Primagram gold 660 SC	2894c	2966c	31.8c	31.7c
Twice hand weeding	2585d	2600d	39.17b	40.2b
Weed free	3750b	3816b	11.7d	12.3d
Weedy check	416e	366e	90.19a	91.5a
LSD (5%)	177.7	267.38	4.17	6.14
CV (%)	3.41	5.06	6.35	9.18

Yield loss

Yield loss was significantly ($P \leq 0.05$)affected by application of weed control treatments (Table 4). The maximum yield losses of 90.19% and 91.5% were recorded at weedy check plots while the minimum values of 1.4 9% and 1.9 % were recorded at COYOTE 440 SE treated plots at Holeta and Medegudina respectively. The decreased yield losses show improved weed control that aids the plants to consume more growth resources, while the increase in yield loss in weedy check is perhaps due to extreme opposition of weeds. This is consistent with the observations of Abbas *et al*. (2018) who concluded that the smallest yield loss was gained where the lowest weed crop opposition to nutrients and water happened.

3. Conclusion

Weeds are universal and greatly reduce the yield and value of crops. Weed control measures should be taken in this period to minimize losses, and water and nutrient use efficiency of maize can be enhanced. Manual weeding needs a huge extent of labor and makes it inefficient, particularly where labor is luxurious. Chemical weed control is in advance wider suitability with the farmers in different circumstances. It would be wise to use different methods based on need. Most of the studies highlighted the importance of the use of herbicides (pre or post emergence) alone or in combination with other herbicides, plus manual methods for controlling weeds and obtaining higher returns. Weed-free and weedy-checking treatments recorded the lowest and the highest values of density of individual weeds. The application of COYOTE 440 SE effectively increased cob length, grain yield and decreased yield loss. Therefore, it can be summarized that applications of COYOTE 440 SE 3 L ha^{-1} followed by weed free can provide a complete solution. However, if various components of integrated weed management are implemented in a systematic manner, it can provide complete weed control with higher economic returns. Hence, it is recommended to implement an integrated weed management method that can help a bargain use of herbicides and focus on ecological crop production. Additionally, an increase in multi-herbicide tolerant maize cultivars for current regulator of all weeds is also essential.

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