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Original Research Article

Response Of *Striga* Resistant Maize Varieties To Natural Weed Conditions and Weed Control Measures Under Tropical Rainforest Condition

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Abstract: The effect of weed infestation and the impact of different weed control method on *Striga* resistant maize varieties were studied in a field experiment. Eighteen *Striga* resistant varieties including a local check were evaluated under four weed control treatments. The experiment was laid out using a split plot arrangement in a randomized complete block in two replicates. Weed control treatments {Herbicides, Manual (Hoe weeding twice 2 and 5 WAP), Weedy plot and Weed free (weeding weekly)} were considered as the main plots while varieties served as the subplots. No significant differences were detected among weed free, manual and chemical plots, but there were significant varietal differences for some agronomic traits. Yield performance of the maize varieties differ among the treatments. For instance, in the weed free plots, Variety 5 had lowest yield of 1.8 tons/ha while variety 10 had highest yield of 4.7 tons/ha. Also, in manual treatment where weeding was done twice, lowest yield was obtained in variety 6 (0.6 ton/ha) while highest yield was recorded in variety 13 with 2.8 tons/ha. Also, there was significant variety by treatment interaction effect for some agronomic traits. Herbicide and manual weed control methods were able to reduced weed density and biomass production when compared with what was obtained under weed free plots and maize varieties in weed free plots had the best performance in terms of grain yield and other agronomic traits followed by chemical control measures.

Keywords: Striga, Resistant, Weed Infestation, Control methods

Introduction

Maize (*Zea mays* L.*)* is one of the most important cereals in Nigeria because of its industrial and domestic uses and it is produced throughout the country's diverse agro-ecologies. Maize production in Nigeria is plagued by many constraints such as biotic and abiotic stresses, prohibitive cost of fertilizer, poor agronomic practices, lack of high quality seeds and poor extension services [1]. An important biotic constraint is weed infestation. Yield loss due to weeds in maize varies from 28-93%, depending on the type of weed flora, weed intensity and duration of crop-weed competition [2]. Weeds reduce crop yield by competing for space, light, water, soil nutrients and carbon dioxide, interfere with harvesting and increase the cost involved in crop production. Some weed species exhibit allelopathic properties while others live as facultative or obligate plant parasites on maize plant. *Striga hermonthica* (Del.) Benth, otherwise known as witchweed, is obligate parasitic plants indigenous to Africa. Its seeds germinate in response to stimulants in the root exudates of maize plants. Germinated *Striga* seedlings produce a haustorium that establishes contact with the host root and withdraws water, minerals, and organic compounds.

Striga is responsible for an annual yield loss estimate of US $7 billion in the savanna regions of West and Central Africa, which is detrimental to the lives of more than 100 million Africans [3]. Average yield reduction caused by *Striga* on susceptible maize plant was 67 % with a range of 41 – 91 % [4]. The International Institute of Tropical Agriculture (IITA) had developed several *Striga* resistant/tolerant maize varieties, populations and hybrids to combat this menace in the savanna region of the country. The response of these resistant maize varieties to other weed species under rainforest conditions, which is a non-*Striga* environments has not been studied. This information is important to know if the *Striga* resistant varieties would also demonstrate resistance or tolerance to other non-parasitic weed species in the non-*Striga* region or introducing the varieties will bring about evolution of new weed species with its associated problems.

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Many weed control measures have been proposed, which includes mostly the use of herbicides and hoe or manual weeding. Herbicide use is known to be effective and fast in action as a weed control measure [5], although it is quite expensive and not economically viable in low output farming systems where weeds are most problematic. Manual weeding is the oldest form of weed control as it has been used since time immemorial and it does not involve any expenses, though it is labour intensive, and not attractive. Hence, another important question this study is going to answer is how *Striga* resistant varieties react to other weed infestation apart from *Striga* in terms of the effect of weeds on yield and different control methods on growth characteristics of *Striga* resistant varieties.

From literatures, extensive works had been done on *Striga* resistant maize varieties such as its effectiveness in managing *Striga* [6], less work had been carried out on the evaluation of these varieties in non-*Striga* infested areas as their reaction other weed infestation outside *Striga* which these varieties were bred for. The objectives of this study therefore were to assess the response of *Striga* resistant maize cutivars to weed infestation under rain forest conditions and evaluate their performance under different weed control measures in the tropical rain forest.

Materials and Methods

The experiment was carried out between July and October 2012 at the Teaching and Research Farm, Obafemi Awolowo University, Ile –Ife, Osun State (Latitude 7^0 28' N and Longitude 4^0 33' E) which is located in the Tropical Rainforest of South Western Nigeria, characterized by bimodal rainfall pattern, relatively long day time duration, and high day and night temperatures. The soil on the experimental site was a sandy loam. The experimental location were ploughed two times and then harrowed to a depth of 25cm. The field was layout and marking was carried out in a randomized complete blocks with a spilt plot arrangement with two replicates.

The trial consisted of eighteen Striga resisitant maize varieties including on adapted local check (Table 1). Varieties were planted in a single 5m rowwith 0.75m spacing between rows and 0.25 m spacing between plants. The seeds were sown on each hill which were later thinned to two plants per stand to achieve a plant population of 53, 000 plants/ha.

Table 1: List of *Striga* resistant maize varieties used in the Study

VARIETIES	NAMES OF *STRIGA* RESISTANT MAIZE VARIETIES
1	TZL Comp 1 SynW-1
2	OBATNPA/Z.Diplo Syn W-1/Z.DiploSyn W-1
3	Z.diplo-BC4-C3-W/DOGONA-1/Z.diplo-BC4-C3-W
4	Z.diplo-BC4-C3-W/DOU-1/Z.diplo-BC4-C3-W
5	Obantanpa/TZLCOMP1SYNW-1/TZLCOMP1SYNW-1
6	TZCOM1/ZDPSYN
7	STR-SYN-W1
8	STR-SYN-Y1
9	IWD C3 SYN
10	DTSTR-W SYN2
11	STR-SYN-Y2
12	((TZL Comp 1-WC6*2/(White DT STR Syn))-DT C1
13	((IWD C3 SYN*2/(White DT STR Syn))-DT C1
14	Z. Diplo.BC4C3-W-DT C1
15	TZB-SR (Susceptible)(RE)
16	8331-1 (Susceptible Hybrid)
17	9022-13 (Resistant Hybrid)
18	TZE-YPOP STR C□ DTC□S₀ 2/2 (Local check)

Source: International Institute of Tropical Agriculture (IITA), Ibadan

Four weed control treatments were applied: chemical control (herbicides), manual weed control, and two weed checks comprising of a weed-free and weedy checks. The chemical weed control used was pre-emergence herbicides (Primextra; consisting of Atrazine and Metolachlor) applied at and post-emergence herbicides (Gramozone) applied at. The pre-emergence and post emergence herbicides were applied 1 day after planting (DAP) and 7 weeks after planting (WAP) respectively. The manual weed control was carried out with hoe and hand pulling at 2 and 5 WAP. The weed-free control plot was weeded every week and the weedy plot was left unweeded from sowing to harvest.

Table 2: Effect of treatments on weed density, fresh biomass and dry biomass in maize varieties under different weed regimes

Treatment	Weed density (metre²)			Fresh biomass (kg)			Dry biomass (kg)		
	3wks	6wks	9wks	3wks	6wks	9wks	3wks	6wks	9wks
Weed free	39.5a†	46.5a	38.5a	0.05a	0.02a	0.02a	0.03a	0.014a	0.01a
Chemical	68a	182.5a	25.5a	0.09a	0.41a	0.05a	0.02a	0.099a	0.01a
Manual	68.5a	62.5a	237b	0.05a	0.11a	0.23a	0.04a	0.032a	0.05a
Weedy	234b	411b	444.5c	1.03b	2.5b	2.7b	0.21b	0.45b	0.60a
LSD(0.05)	41.8	161.4	113.7	0.395	1.95	0.73	0.10	0.25	0.61
Percentage change due to treatment	24.7	29.1	32.3	80.5	47.6	88.9	57.1	67.8	87.8

†Means followed by a common letter within the same column do not differ significantly at 0.05 probability level.

Maize Emergence percentage was determined seven days after planting. Days to tasselling, silking, and anthesis were recorded as number of days from planting to when 50% of the plants in a plot developed tassel, extruded silk and shed pollens, respectively. Anthesis-silking interval was recorded as the days to silk minus days to anthesis. Plant height and ear height were recorded as the distance from the base of the plant to the first tassel branch and the cob bearing node, respectively. At harvest, ear per plant, number of ear harvested/plot, field ear weight, moisture content in grain and grain yield were determined.

Weed density and biodiversity, as well as fresh and dry biomass were determined by throwing the 1 m^2 quadrat three times within a treatment in each replicate and counting the numbers of weeds within the quadrat and by harvesting the weeds within the perimeter of the quadrat. The harvested weeds were identified, and later oven dried at 80°C for 48 hours. Weed biodiversity was also scored on the experimental plot before planting of the maize varieties. Data collected were subjected to analysis of variance using statistical analysis software (SAS v.9.0) [7] and Variety and Treatment means were compared using LSD.

Results and Discussion

Weed Biodiversity

The weed species observed on the site were mostly broad leaved weeds with little or no grasses. Weeds such as; *Commelina benghelensis, Commelina erecta, Chromolaena odorata, Aspilia africana, Agerantum conyzoides, Euphorbia heterophylla, Spigelia anthelmia Amaranthus spinosus, Mucuna pruriens, Calapogonium mucunoides, Ipomea involucrata,* and *Tridax procumbens* were included. All weeds were identified and named using Handbook of West African weeds [8].

Weed Control Treatment

Results of the analysis of variance showed that weed control treatments significantly affected weed density, fresh and dry biomass at 3, 6 and 9 weeks after planting (Table 2), except for dry biomass at 9 weeks. Weed population in Herbicide and manual weed control plots were significantly lower than weedy check but were comparable with weed-free plot though weed free plot had the lowest weed population of 40 plants/m^2 while weedy plots has 234 plants/m^2 at 3 WAP. The biomass production (both fresh and dry) followed the same trend. At 6 and 9 WAP, the number of plants/m^2 increased in all the plots but weedy plots still produced the highest number and this indicated that weed-crop competition for nutrients will be higher in weedy plots than other plots which invariably will affect maize yield output at the end of the study. It was noteworthy that there was no significant difference between herbicide and manual weed control plots in terms of weed population (P= 0.05). In considering the four treatment altogether, there was a 28.7% change in weed density as a result of the treatments applied when compared chemical, manual and weed free plots with weedy plots. This result was in accordance with those of Fathi *et al.,*(2003) [9], Hassan and Ahmed (2005) [10], Hassan *et al.,*(1995) [11] who reported that number of weeds was highest in weedy check plots and lowest in chemical weed control treatments and also in hand weeded treatments. The higher weed density in weedy check plots was as a result of no weed control treatments applied to the plots, thereby giving the weeds an opportunity to quickly established and multiplied. Weeds fresh biomass was significantly reduced by the two control treatments under the three weeding regimes investigated. Highest fresh weed biomass (2.7 kg) was recorded in weedy checks plots while the lowest fresh biomass (0.02 kg) was recorded in the weed

free plots but it was not significantly different from those obtained from the manual and chemical control plots and the same trend was observed for weed dry biomass production in all the treatments. These results were in line with the findings of Saimblin *et al.,* (2000) [12], Thakral *et al.,* (2008) [13], Manisha *et al.,*(2005) [14], Qasem (2006) [15] and Zubair *et al.,*(2009) [16], who noted that application of herbicides and hand weeding significantly reduced weed biomass. Dry biomass was significantly reduced by the weed control treatments applied for all the regimes. Highest dry biomass was recorded for weedy check plots (0.45 kg) at 6 weeks but was unexpectedly at par with those of the control methods at 9 weeks. The results were also in accordance with Saimblin *et al.,* (2000) [12], Thakral *et al.,* (2008) [13], Manisha *et al.,*(2005) [14], Qasem (2006) [15] and Zubair *et al.,* (2009) [16], that application of herbicides and hand weeding significantly reduced weed biomass. Figure 1 and 2 shows the trends of weed population and weed biomass production. In Figure 1 at 3 weeks after planting, the weedy plot had significantly higher weed density than all the treated plots and there was no significant difference among the plots with different weed control treatments. At six weeks after planting, chemical weeding had significantly higher weed density than other weed treatment, indicating that chemical weed control was not as effect as others in controlling weeds at this week. However, at 9 weeks after planting, the chemical control was no different from weed free plot in terms of weed density. Similar trends were observed for weed fresh and dry biomass (Figure. 2 and 3).

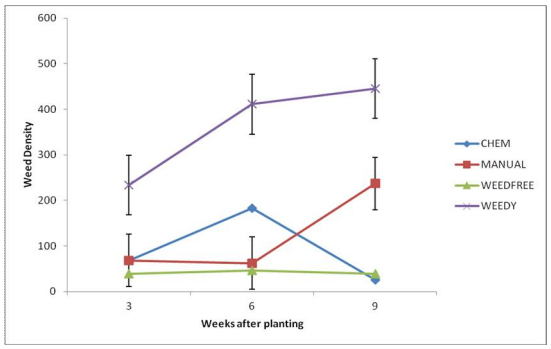

Figure 1: Effect of weed control measures on weed density on the maize plot

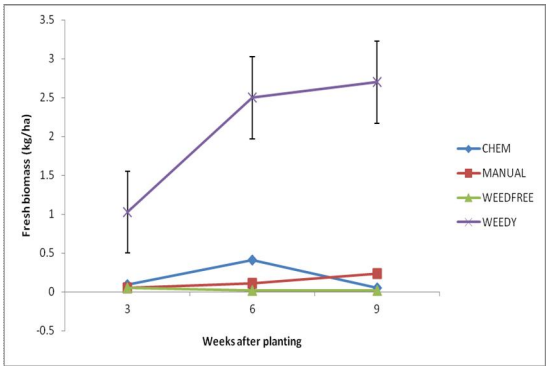

Figure 2: Effect of weed control measures on weed fresh biomass on maize plot.

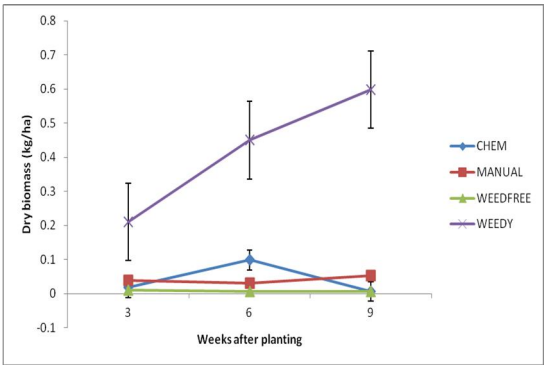

Figure 3: Effect of weed control measures on weed dry biomass on maize plot.

The resulting stand count of herbicide plots may be due to poor soil, uneven depth of planting and/or deleterious effect of the pre-emergence herbicide applied but generally, this may not be as a result of the treatments (Table 3). The highest length of maize plant was obtained from weed free plots (1.79) followed by herbicide control plots (1.74) though these were not statistically different from each other but were completely different from manual control plots (1.45). Analysis of the data revealed that plant height was significantly affected by control methods used in the experiment. Plant height is a key factor that contributes to yield because taller plants capture more light and therefore had more photosynthate available for grain filling [17]. This result is in line with findings of Oljaca *et al.,* (2007) [18] who reported a significant decline in plant height due to weed infestation especially at the peak of the vegetative stage of growth.

Table 3: Mean values of agronomic traits in each treatment applied.

Treatments	Stand count	Days to anthesis	Days to silking	Anthesis-silking interval	Plant height	Ear height
Weed free	25.94a†	64.72c	66.94b	2.22a	1.79a	0.82a
Herbicides	17.06b	67.39a	68.19a	0.81b	1.74a	0.77b
Manual	23.47a	66.17b	68.61a	2.44a	1.45b	0.59c
LSD (0.05)	2.94	0.81	1.10	1.03	0.06	0.05
% change due to treatments	24.7	2.17	1.7	57.78	16.2	21.9

†Means followed by a common letter within the same column do not differ significantly at the 0.05 probability level.

Results also showed that there was significant difference among the control treatments with the weed free plots having the lowest day to shedding of pollen (65 days) which is significantly different from that of manual control plots (66 days), which in turn is significantly higher than that of chemical control plots (67 days). Days to silking of the varieties was significantly reduced under a weed free conditions as compared to the other control methods, This implies that the maize varieties in the herbicides and manual weed control methods under investigation took more days to silk than weed free plots. Anthesis-silking interval (ASI) for both weed free and manual were significantly different from that of herbicide, with the manual having the highest (2.44) while the lowest ASI was recorded for herbicide (0.81).

Table 4: Mean values of agronomic traits of maize varieties following application of treatments for weed control.

Variety	Stand count	Days to anthesis	Days to silking	Anthesis-silking interval	Plant height (m)	Ear height (m)
1	20.17ab†	66.00ab	68.17a	2.17a	1.64a	0.75ab
2	20.50ab	65.83ab	67.67a	1.83a	1.70a	0.73ab
3	22.00ab	64.83b	67.83a	3.00a	1.62a	0.74ab
4	25.00ab	65.67ab	67.33a	1.67a	1.66a	0.76ab
5	25.33ab	66.17ab	67.33a	1.83a	1.67a	0.76ab
6	20.50ab	67.18a	68.00a	1.00a	1.71a	0.70ab
7	22.17ab	65.83ab	68.17a	2.17a	1.60a	0.65a
8	22.33ab	65.83ab	68.00a	2.83a	1.73a	0.77b
9	23.50ab	67.33ab	68.67a	1.00a	1.67 a	0.78b
10	23.00ab	67.50ab	67.33a	2.00a	1.65a	0.73ab
11	20.17ab	67.33ab	67.50a	1.17a	1.64a	0.75ab
12	18.53a	66.67ab	67.33a	1.00a	1.66a	0.71ab
13	19.00a	68.67ab	66.67a	2.00a	1.65a	0.71ab
14	23.50ab	67.83a	68.67a	1.00a	1.62a	0.67ab
15	20.50ab	68.83ab	68.83a	2.67a	1.66a	0.72ab
16	27.00b	68.17ab	68.17a	1.83a	1.66a	0.70ab
17	24.50ab	68.33ab	68.33a	2.00a	1.67a	0.70ab
18	20.83ab	68.00ab	68.00a	1.67a	1.68a	0.79b
LSD (0.05)	7.21	1.98	2.68	2.51	0.15	0.12

† Means followed by a common letter within the same column do not differ significantly at the 0.05 probability level.

For days to anthesis, most of the varieties were not significantly different from each other except varieties 14 and 6 with highest days to shedding of pollen being significantly different from variety 3 having the lowest days to shedding of pollen, the implication of these is that variety 3 will take shorter time to mature unlike varieties 6 and 14 taking a little bit of time for it to produce cobs. There was no significant difference among the varieties across the treatments applied for days to silking, ASI and plant height, but there was significant difference among the varieties for ear height, with varieties 8, 9 and 18 (local check) having the highest ear height while variety 7 had the lowest ear height among the varieties. The other varieties are not significantly different from the two varietal categories. For days to silking in weed free plots; variety 12 had the lowest value while variety 18 (local check) had the highest days to produce silk. Under herbicide treated plots, varieties 2, 3, 4 and 9 had the lowest days to silk while variety 13

had the highest days to silk (70). Observation in manual plots shows that varieties 11 and 12 had the least days to silk (66.5) while variety 7 had the highest days to produce silk (70).

Table 5: Mean values of grain yield and agronomic traits of 18 varieties of maize evaluated under weed free, herbicide and manual weeding regime at Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, during the growing season of 2012.

Variety	Stand count			Days to silking			Anthesis-silking interval			Plant height(cm)			Yield (kg)		
	Weed free	Herbicide	Manual	Weed free	Herbicide	manual	Weed free	herbicide	manual	Weed free	herbicide	manual	weed free	Herbicide	manual
1	22.5	16.5	21.5	67.5	69.5	69	0.5	3.5	2.5	1.74	1.66	1.51	2842	2445	1879
2	27	19	15.5	66	66.5	69	1.5	1	3	1.87	1.73	1.52	2613	1992	825
3	29	12.5	24.5	67.5	66.5	68.5	4.5	0	4.5	1.69	1.65	1.52	2063	2580	2384
4	29.5	23.5	22	68.5	66.5	69	2.5	0	2.5	1.68	1.79	1.49	4034	2264	1650
5	28.5	23	24.5	66.5	67.5	69	3.5	0.5	2.5	1.84	1.80	1.37	1834	2354	1375
6	22	20	19.5	67.5	67.5	70	2	1	2	1.69	1.85	1.59	3025	2988	642
7	19.5	25	22	68	67.5	69	2.5	2	2	1.95	1.45	1.41	2842	2219	688
8	22.5	19.5	25	66.5	69	69	4	1.5	3	1.98	1.86	1.34	1971	3532	1192
9	26.5	14	30	68	66.5	67.5	0.5	0.5	3	1.79	1.82	1.39	3851	2626	1513
10	24.5	17	27.5	66.5	68.5	66.5	2.5	2	1.5	1.79	1.85	1.31	4676	3169	1284
11	23.5	16	21	66.5	69	66.5	2.5	0.5	0.5	1.83	1.80	1.30	3117	2399	1467
12	29.5	9.5	17.5	66.5	69.5	69.5	0	1.5	1.5	1.75	1.81	1.43	3576	4100	779
13	27.5	12	17.5	64	70	68.5	2.5	2	1.5	1.95	1.65	1.35	2475	1539	2750
14	28	15.5	27	66.5	68.5	68.5	1.5	0.5	2	1.68	1.72	1.45	2521	2988	2017
15	22	15.5	24	66.5	69.5	69.5	3.5	1	3.5	1.66	1.69	1.63	3025	1449	2483
16	29	24	28	68.5	69	69.5	2	1.5	2	1.83	1.69	1.47	2934	1811	2658
17	28.5	16.5	28.5	66	69	67.5	1	1.5	3.5	1.71	1.70	1.59	4126	3079	1467
18	27.5	8	27	66.5	67.5	66	3	1	3	1.84	1.75	1.45	2567	2626	1650

Overall, variety 12 in weed free had the least days to silk while varieties 7 and 13 in manual and chemical control plots had the highest days to silk. The implications of this is that variety 12 in weed free will be able to receive pollen in shorter time and produces cobs there from unlike variety 7 and 13 in the two weed control methods under investigation that takes more time to maturity. For ASI, in weed free plots, variety 12 had the least ASI which is 0 day and variety 3 had the highest (4.5days). For herbicide treated plots, varieties 3 and 4 had the lowest ASI (0 day) while variety 1 had the highest ASI (3.5 days). In manual plots, variety 11 had the least interval of 0.5 days while variety 3 was the highest with 4.5 days interval. The implication of the ASI values is that, the variety with the highest ASI takes more time to produce cobs while those with lesser ASI produce cobs in a short time. Overall, varieties 3 and 4 in herbicide treated plots and variety 12 in weed free had the least anthesis silking interval while variety 3 in both manual and weed free plots, had the highest ASI. For plant height, variety 8 had the highest height (1.92 m) while variety 15 had the least height (1.66 m) in weed free plots. In herbicide treated plots; variety 7 had the least height (1.45 m) and variety 8 with the highest height (1.86 m). In manual plots, the highest plant height observed was 1.63 m for variety 15 while the least height was recorded for variety 11 (1.3 m).

Variety 8 had the highest plant height under weed free conditions while variety 11 in manual weeding treated plots, had the lowest plant height of 1.3 m. For yield of these varieties under the treatments applied, variety 5 of weed free plots had the lowest yield (1833.6 kg/ha) among the varieties under the treatment while variety 10 had the highest yield of 4675.68 kg/ha. In manual plots, the lowest yield was observed in variety 6 with 641.76 kg/ha while variety 13 had the highest yield of 2750.4 kg /ha. In herbicide treated plots, variety 12 had the highest yield (4100.4kg /ha) while variety 15 had the least yield (1448.96 kg /ha). Overall, variety 10 of weed free treatment had the highest yield, which is closely followed by variety 12 in herbicide treated plots. The lowest yield in all the varieties was recorded for variety 6 in manual weed control method.

Conclusion

The two weed control methods were able to minimise weed density and biomass within the critical period for wed removal to a safe level just as obtained under a no weed condition. Also, there were significant effects of treatments on agronomic traits observed especially for Ear height and days to silking with herbicide plots being the most affected negatively.

There was a low significant effect of cultivars on stand count, days to anthesis and ear height, this effect is expected as lines from different sources are expected to display differential growth vigour and yield potential [19]. The highest mean yield for the treatments was gotten under weed free plots, which was followed by herbicide treated plots, manual and weedy plots with no yield as the weed s on the plots interfered with the growth of the maize plants by denying them water, light and nutrients which are necessary for growth and reproduction. Even though the varieties were not able to manifest the resistant traits in them, they were able to tolerate weed infestation to some extent as influenced by the control methods applied.

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