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Effects of selected herbicides on management of weeds in finger millet (*Eleusine coracana* L)

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A study was conducted to determine the suitable herbicide(s) for effective weed management in finger millet, in order to address the major biotic stress of weeds infestation and attain optimal productivity of finger millet. Field experiments were conducted in Baringo and Kericho counties in Kenya for two growing seasons, using a randomized complete block design (RCBD) and replicated three times. Three pre-emergence herbicides were used: Mesotrine + Metolachlor + Terbuthylazine, Atrazine + S-metolachlor, and S-Metolachlor. The abundance of weed species was affected by the environment, herbicides used, and types of weed species present. The herbicides used were 2, 4-D amine salts, Atrazine, Metribuzin, and Fluroxypyr + Chlorpyrlid + MCPA, while a control of no weeding was also included. A high weed species abundance was observed in Baringo (20.4%) as compared to Kericho (19.4%). The lowest weed species abundance (WSA) of 0.11% was observed with Mesotrine + Metolachlor + Terbuthylazine. Weeds from the Poaceae family had the highest WSA of 34%. At Kericho, a weed density of 6.47 weeds/m^2 was recorded, and a higher weed control efficiency of 90.56% and 88.88% was observed with Fluroxypyr + Chlorpyrlid +MCPA and 2, 4-D amine salts, respectively, with no phototoxicity observed. However, Metribuzin, Atrazine + S-Metolachlor, and Atrazine had higher weed control efficiency of 89.92, 90.13, and 88.34%, respectively, but caused high crop phytotoxicity, lower yields, and reduced crop biomass. Application of 2, 4-D amine salts and Fluroxypyr +Chlorpyrlid+ MCPA recorded higher yields of 5.04 t/ha and 5.4 t/ha respectively, with a higher crop biomass of 2.6 t/ha and 2.7 t/ha respectively, which was not significantly different. Positive correlation was observed between crop biomass and yield (r=0.98), suggesting that the use of 2, 4-D amine salts and Fluroxypyr + Chlorpyrlid + MCPA will ensure effective weed management and contribute to increased finger millet productivity.

Key words: Crop phytotoxicity, post-emergence, pre-emergence and weed management.

INTRODUCTION

Efforts to promote finger millet production have been constrained by weed infestation. Apart from expensive

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labor costs associated with manual weeding, timely availability of labor is crucial in undertaking manual weeding (Shanmugapriya et al., 2020). This calls for a technology that requires less labor and is more helpful in controlling weeds effectively.

Herbicide usage has been reported to be the most effective and economical method for weeds management (Westwood et al., 2018). Herbicides can either be applied as pre-emergence or post-emergence herbicides. Pre-emergence herbicides are herbicides that are applied prior to weed seedling emergence while post emergence herbicides are applied after they have emerged above the ground.

The uncontrolled weeds smothering finger millet can result in a significant reduction of yield of up to 70% (Rao, 2021). Furthermore, these weeds have the ability to adapt to different climatic conditions. The critical period for crop weed competition in finger millet occurs between 25-60 days after sowing (Chaudhary et al., 2018). Chauhan and Abugho (2012) reported that post - emergence herbicides provide an opportunity to control weeds and this may help increase gr`owers interest in conservation agriculture in the near future.

The most dominant method of controlling weeds is by mechanical weed control which is becoming uneconomical due to higher labor charges. Shubhashree and Sowmyalatha (2019) found out that hand weeding caused dying of weeds which resulted to higher grain yield as compared to unweeded plots. Small holder farmers prefer hand weeding as it is efficient where labor is cheaper and easily available. However during labor peak periods the crop may suffer losses labor unavailability during critical weed control period. Shekhawat et al. (2020) found out that labor requirements reduced by 21% upon application of post emergence herbicides as compared to cultural operations.

Herbicides provide crops with a competitive edge over emerging weeds, as demonstrated by Kumar et al. (2021), who showed that 2,4-D amine salts were effective in controlling weeds and increasing yields by up to 43% compared to the weedy check. Hayyat et al. (2016) reported that application of MCPA controlled broadleaf weeds in wheat. Greatest limitation of use of herbicide in finger millet is that no herbicide has been formulated or registered exclusively for the control of weeds in finger millet. In the present study the effectiveness of pre-emergence and post emergence herbicide were assessed for management of weeds of weeds in finger millet.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted at Koibatek and Soin in the counties Baringo and Kericho which are located in the Rift valley region of Kenya. Koibatek sub county lies 0^0 8`N $36^0$ 2` E in agro ecological zone iv and an altitude range of a between 1890 meters above sea level (m.a.s.l). It receives an annual precipitation of 700-900 mm per year with a mean daily temperature of 24.3^0 C. The soils are dark colored with high clay content and are classified as *vertisols.* Soin Sub County lies between in agro ecological zone III and altitude range of 1200 m above the sea level. It receives annual precipitation of between 1300-1580mm with a mean daily temperature of 22^0c.The soils are classified as *histosols* and are usually saturated with water creating anaerobic conditions causing faster accumulation of organic matter (Jaetzold, 2010).

Finger millet variety

Two varieties of finger millet namely; 'Egerton snapping' and 'U-15' were sourced from Egerton seed unit. Egerton snapping was selected because of its faster maturity characteristic and ease during harvesting manually.U-15 Variety was selected because of its color that is preferred by most farmers.

Experimental procedures

The experiment was laid out in a Randomized Complete Block Design split plot arrangement, with a main plot consisting of the herbicide, and a sub-plot of the variety. Each plot was 2m × 3.2m with 1 m separation between them. The two varieties of finger were planted with an equivalent seed rate of 8kg per ha and a spacing of 40cm drilled at a depth of 2-3 cm. At planting, N: P: K (23:23:0) fertilizer was applied at a rate of 60 Kg N ha-1 and 60 Kg P_2O_5 ha-1. Thinning was done to a 5-7.5 cm intra row spacing and topdressing of calcium ammonium nitrate (CAN) fertilizer at the rate of 60 kg N/ha was done at the seventh leaf stage. The fields were not sprayed with any pesticides during the whole experimental period.

The experimental treatments included seven commercially available herbicides in Kenya: Atrazine+S-Metolachlor, S-Metolachlor, Mesotrine+Metolachlor + Terbuthylazine, Metribuzin, Atrazine, 2,4-D amine salts, and Fluroxypr+chloropyrlid + MCPA (Table 1). These treatments were compared to an unweeded control, in which no herbicide was applied or any other weed management measures were not implemented. A guard row of sorghum was considered at the edge of each of the experimental plots, consisting of eight rows of crops with four rows of finger millet in between the first and last two rows of sorghum. Plastic barriers were installed between plots to avoid herbicide drift onto the adjacent plot. Herbicides were applied using a hand sprayer in each plot. Pre-emergence herbicides were applied at the early vegetative stage, while post-emergence herbicides were applied 14 days after planting (DAP). The application rates were followed as per the manufacturer's recommendation, and a polythene bag was used to cover each plot during spraying to avoid herbicide drift.

Data collection

Weed total count, weed density and weed biomass

Weed count was done by placing $1m^2$ quadrat randomly twice in each plot and counting all the weeds appearing within the quadrat. Counting was done at the early and late vegetative stages. Weed density was determined using the formula of Maszura et al. (2018).

Weed biomass was estimated by uprooting weed samples from each plot, oven-drying them, and determining their dry weight. Weed population is the number of weeds appearing within the quadrat, and weed density is the ratio between the number of weeds appearing within the quadrat and the area of the quadrat.

Table 1. Active ingredients and dose rates of herbicides used in the study.

Trade name	Rate of application (g/ha)	Active ingredient	Application timing herbicide
Lumax	3800	Metolachlor+Terbuthylazine+ Mesotrione –ready mix	Pre- emergence
Dual gold	1500	S-metolachlor-ready mix	Pre- emergence
Primagram	3200	S-metolachlor+Atrazine-ready mix	Pre- emergence
2,4-D	1380	Dmethylamine, Diethynolamine-ready mix	Post-emergence
Maguguma	1450	Atrazine-ready mix	Post-emergence
Sencor	1100	Metribuzin-ready mix	Post-emergence

Source: SAS Institute version 9.4, 2002

Weed control efficiency, Weed species abundance and phytotoxicity rating

Weed control efficiency was determined using the formula suggested by Kaushik and Mani (1978). Weed species abundance were determined by randomly placing a 1m^2 quadrat in each plot. The species were identified using pictorial aids (e-library). All the individual species that were inside the quadrat were counted in the ratio of one species to the total number of all the species inside a quadrat.

$$Wsa=\frac{Nsq}{Tns} \times 100 \quad (3)$$

Where, Wsa=Weed species abundance, Nsq =Number of specific species in a quadrat, Tns =Total number of species in a quadrat. Crop phytotoxicity was observed 7, 14 and 21 days after application of herbicides through visual observation using Jiddimani et al. (2017) Crop Phytotoxicity scale.

Crop yield and yield parameter

The number of plant stands was counted after thinning, and the days to 50% flowering was determined by taking the mean of ten randomly selected finger millet plants from the plot and counting the number of days from sowing to when 50% of the plants flowered. The number of days to finger millet maturity was determined by counting the number of days from sowing to when 90% of the fingers of ten randomly selected plants had matured, and the average number of fingers per plant was calculated by counting the number of fingers on ten randomly selected plants. Plant height was measured at maturity in centimeters, and crop biomass was determined by sampling the crop, oven-drying the aboveground biomass, and converting its weight to kilograms per hectare. Yield was determined by harvesting the four rows. The total yield from each plot was then weighed and converted into kilograms per hectare using the equation:

$$y = \frac{wgp\ (kg) \times 10000m^2}{ha\ (0.481m^2)} \quad (1)$$

Where, Y =yield, Wgp = weight grain per plot and Ha =Harvested area

Data analysis

All data on total weed count and yield was first subjected to Shapiro Wilk test to check if distribution of the values were statistically different from normal distribution. Weed density data were transformed using square root transformation before analysis. Weed species abundance, weed count, weed biomass, weed density and weed control efficiency were subjected to analysis of variance (ANOVA) using the general linear model procedure in SAS (SAS Institute version 9.4, 2002). Means were separated using Tukey's Honest Significant Difference (HSD) test at $P \leq 0.05$.

RESULTS

Weed species identified

Major weed species observed at both sites that affected finger millet production were *Biden pilosa*, *Amaranthus hybridus, Oxalis latifora, Datura stramonium***,** *Commelina benghalensis, Galinsoga parviflora, Taraxacum officinale, Cyperus rotundus, Eragrotis pilosa, Digitaria scalarum.* Among the broad leaved weeds were: *Biden pilosa*, *Amaranthus hybridus, Chenopodium album and Datura stramonium. Datura stramonium* and *Amaranthus hybridus* recorded the highest species population in weedy cheek (Table A1) *Amaranthus hybridus* is reported to have allelopathic properties which can lead to a decrease in agricultural production (Yu et al., 2022). *Biden pilosa* is one of the broad leaved that recorded higher species population. The maximum reduction of weed numbers was recorded with Mesotrine + Metolachlor +Terbuthylazine and Metribuzin usage (Table A1). Two troublesome narrow leaved weeds were recorded in the experimental plots these were *Cyperus rotundus* and *Eragrotis pilosa.* 2, 4-D amine salts and Fluroxypyr + Chlorpyrlid + MCPA had recorded the highest number of weeds of the Poaceae family. S-Metolachlor had the highest weed emergence by the time the crop was at it vegetative stage.

Effects of environment, seasons, species type and herbicides on weed species abundance

The analysis of variance (ANOVA) results revealed that environment had significant effect on weed species abundance $P\leq$ 0.05 (Table A2). Also significant differences in weed species abudance across the two sites with Baringo having a slightly higher number (20.39) than Kericho (19.83) that was significant (Table 2). Herbicides had a significant effect on weed species

Table 2. Effects of location and season on weed species abundance.

Location	%Weed species abudance
Baringo	20.39[a]
Kericho	19.83[b]
Tukey MSD $_{0.05}$	0.47
Season	
Season 1	20.20[a]
Season 2	20.01[a]
Tukey MSD $_{0.05}$	0.47

Means followed by the same letters along the rows for season and location are not significantly different according to Tukey MSD $_{0.05}$
Source: SAS Institute version 9.4, 2002

Table 3. Effects of herbicide on Weed Species Abundance.

Herbicides	% Weed species abundance
Atrazine + S-Metolachlor	1.99[a]
Mesotrine+Metolachlor+Terbuthylazine	0.11[d]
S-Metolachlor	23.75[c]
Metribuzin	2.08[a]
Atrazine	1.97[a]
2-4-D	16.12[d]
Fluroxypr+chloropyrlid+MCPA	14.87[d]
Control	100.0[e]
Tukey MSD $_{0.05}$	1.44

Means followed by the same letters along the column for weed species abudance are not significantly different according to Tukey MSD $_{0.05.}$
Source: SAS Institute version 9.4, 2002.

abundance. Similarly, the weed species categories had a significant effect on weed species abundance (P≤0.001). The environment by season interaction recorded significant effect on weed species abundance (P≤0.001) as did species type by herbicide interaction on weed species abudance at P≤0.001. The three way interarction of environment by season by herbicide interaction was significant at P≤0.001.

There was a significant difference in weed species categories that contributed to weed species abundance after herbicide application. Species belonging to the Poaceae family (*Digitaria scalarum*, *Eragrotis pilosa* and *Dactyloctenuim agyptium*) had the highest weed species abundance of 34%, while those belonging to the Fabaceae family had a weed species abundance of only 16%. This shows that some herbicides could only control Fabaceae species, leaving the Poaceae family dominant (Table A3). There was significant difference of weed species abudance after treatment.

Mesotrine + Metolachlor +Terbuthylazine showed lowest weed species abudance of 0.1% this shows that Mesotrine + Metolachlor + Terbuthylazine was able to control both broad leaves, narrow leaves and sedges weeds hence lowest weed species abudance (Table 3). No treatment application had the highest weed species abudance of 100%. There was no significant differences in the weed species abundance between 2, 4-D amine salts and Fluroxypyr + Chlorpyrlid + MCPA similary,there was no significance difference of species abundance between Atrazine+S-metolachlor, Atrazine and Metribuzin (Table 3). Fluroxypyr + Chlorpyrlid+MCPA had the highest weed species abundance of *Digitaria scalarum* (68.86%) (Table A4). There was no significant difference in the %weed species abundance of *Biden* pilosa, *Amaranthus hybridus* and *Oxalis latifora* across the two locations (Table A5).

Effects of environment, season, growth stage, varieties and herbicide on weed count weed density weed biomass and weed control efficiency

The ANOVA revealed that environment had a significant effect on weed count, weed control efficiency, weed

Table 4. Effects of season, location and varieties on weed count weed density weed biomass and weed control efficiency.

Location	Weed count (weed/m^2)	Weed density	Weed biomass	%WCE
Baringo	6.05±0.57^b	5.56±0.08^a	3.04±0.31^a	76.48±2.24^b
Kericho	6.49±0.58^a	5.76±0.09^b	3.34±0.34^b	75.16±2.25^a
Tukey MSD $_{0.05}$	0.34	0.16	0.11	1.26
Season				
Season 1	6.08±0.55^b	5.82±0.09^b	2.96±0.29^a	75.93±2.18^a
Season 2	6.47±0.61^a	5.52±0.08^a	3.44±0.37^b	75.66±2.24^a
Tukey MSD $_{0.05}$	0.34	0.16	0.11	1.26
Varieties				
U-15	6.11±0.58^a	5.56±0.40^a	3.08±0.22^a	75.15±5.42^a
Nakuru FM1	6.45±0.59^a	5.77±0.42^a	3.32±0.24^b	76.46±a
Tukey MSD $_{0.05}$	0.75	0.31	0.20	2.10

Means followed by the same letter along the column are not significantly different according to Tukey MSD $_{0.05}$. WCE =Weed Control efficiency.
Source: SAS Institute version 9.4, 2002

Table 5. Effects of growth stage on weed count weed density weed biomass and weed control efficiency**.**

Growth stage	Weed count (n/m^2)	Weed density	Weed biomass (g/m^2)	%WCE
Early vegetative	6.24±0.42^a	5.92±0.07^b	2.75±0.22^b	73.13±5.29^a
Late vegetative stage	6.31±0.70^a	5.41±0.09^a	3.64±0.41^a	78.44±5.65^b
Tukey MSD $_{0.05}$	0.34	0.16	0.11	1.26

Source: SAS Institute version 9.4, 2002

biomass, and weed density at p≤ 0.05, 0.001 and 0.01, respectively. Seasons also had a significant effect on weed biomass, weed density at p≤0.001 and weed count at p≤ 0.05, but no significant effect on weed control efficiency. The results of the study showed that variety had a significant effect on weed count (p≤0.05), weed biomass (p≤0.001), and weed density (p≤0.01), but there was no significant effect of variety on weed control efficiency. Herbicides had a significant effect on weed count, weed density, weed biomass, and weed control efficiency (p≤0.001) (Table A6). The growth stage had a significant effect on weed biomass, weed control efficiency, and weed density (p≤0.001), but no significant effect on weed count. Additionally, there was a significant environment by season interaction effect on weed biomass (p≤0.001) and weed density (p≤0.05). The interactions between environment, growth stage and herbicide had a significant effect on weed biomass (p≤ 0.01), weed count and weed density (p≤ 0.05), and weed control efficiency (p≤ 0.001). There was a significant difference in total weed count across the two environment. Kericho had a slightly higher weed count of 6.49/m^2 while Baringo had a weed count of 6.05/m^2 (Table 4). There was also significant difference in weed count across the seasons. Season one had a slightly higher weed count of 6.47 compared to season 2 which had a weed count of 6.08. There was significant difference in weed density across the two localities. Kericho had a higher weed density of 5.77 as compared to Baringo which had a weed density of 5.57 (Table 4). Similarly,there was a significant difference in weed density in between the two seasons. Season one had a slightly higher weed density as of 5.82 compared to season two which had a weed density of 5.52. There was no significant difference of weed density in Baringo in the two seasons. However, in Kericho the first season had a slightly higher number of weed density than in the second season (Table A7). There was no significance difference in weed count across the varieties. Similarily, there was no signifacane difference of weed density across the finger millet two varieties (Table 4). There was no significant difference in weed count across the two growth stages (Table 5). Late vegetative stage of the crop is associated with higher weed biomass of 3.64g/m^2 as compared to early vegetative stage of the crop which had a biomass of 2.75 g/m^2 due to longer periods of herbicides exposure as shown in (Table 5) similarily, the late vegetative stage of the crop recorded a higher weed control efficiency 78.44% compared to the early vegetative of the crop (Table 5).There was signifance difference in weed count across the herbicides. Mesotrine+Metolachlor+Terbuthylazine had the lowest weed count of 1.0/m^2 (Table 6). However, there was no significance differences in weed counts between

Table 6. Effects of herbcides on weed count weed density weed biomass and weed control efficiency.

Herbicides	Weed count (n/m^2)	Weed biomass (g/m^2)	Weed density	%WCE
Atrazine+S-Metolachlor	3.08±0.26[b]	1.40±0.06[b]	5.58±0.11[a]	88.34±0.89[a]
Mesotrine+Metolachlor+Terbuthylazine	1.00±0.13[a]	0.71±0.08[a]	4.75±0.15[b]	91.34±2.12[a]
S-Metolachlor	11.77±0.51[c]	4.64±0.28[c]	6.52±0.13[c]	67.23±1.17[b]
Metribuzin	2.44±0.25[b]	1.17±0.08[b]	5.30±0.13[a]	89.92±0.91[a]
atrazine	2.33±0.25[b]	1.18±0.07[b]	5.20±0.13[ab]	90.13±0.89[a]
2,4-D amine salts	2.81±0.25[b]	1.35±0.05[b]	5.47±0.11[a]	88.88±0.70[a]
Fluroxypr+chloropyrlid+MCPA	2.40±0.27[b]	1.09±0.09[b]	5.23±0.13[ab]	90.56±0.94[a]
control	24.46±0.82[d]	14.07±0.63[d]	7.30±0.17[d]	0.00±0.00[c]
Tukey MSD $_{0.05}$	1.05	0.36	0.49	3.91

Means followed by the same letter along the column are not significantly different according to Tukey MSD $_{0.05.}$
Source: SAS Institute version 9.4, 2002

Atrazine+S-metochlolar, 2-4-D, Metribuzin, Fluroxypr+chloropyrlid+MCPA and Atrazine, there was significant difference in weed counts between S-Metolachlor and the rest of herbicides. Control had the highest weed count of 24.46/m^2 (Table 6).

Similarily there was a significant difference in weed density across the herbicides. Mesotrine+Metolachlor+Terbuthylazine had the lowest weed density of 4.75 while control had the highest weed density of 7.30 (Table 6) there was no significant difference in weed density between Atrazine+S-Metolachlor, Metribuzin and 2,4-D amine salts similarily there was no significant difference in weed density between atrazine and Fluroxypr+chloropyrlid+MCPA, however there was significant difference between Mesotrine+Metolachlor+Terbuthylazine and S-Metolachlor also there was significant different between S-Metolachlor and Fluroxypr+chloropyrlid+MCPA. There was no significant difference in weed count, weed biomas, weed density and %WCE after treatment by both the herbicides in the two environment (Table A8).

There was significant difference in weed biomass across the two localities. Kericho had a higher weed biomass of 3.34g/m^2 as compare to Baringo which had a weed biomass of 3.04g/m^2 (Table 4). In addition, there was significant difference in weed control efficiency of the two localities Baringo had a weed control efficiency of 76.48% while Kericho had a weed control efficiency of 75.16%. In season one the weed biomass was 2.96g/m^2 which differed significantly when compared to season two which had a weed biomass of 3.44g/m^2 (Table 4). No significant difference in the weed control efficiency was experienced during the two growing seasons. Nakuru finger millet 1 varieties was associated with higher weed biomass of 3.32 g/cm^2 compared to 3.08 g/m^2 for U-15 (Table 4).

The highest weed biomass was recorded for the control where there was no herbicide application. Weed biomass in plots that received Mesotrine+Metolachlor+Terbuthylazine was low at 0.71g/cm^2 and differed significantly with other herbicides. Similarities in weed biomass were experienced in Atrazine+S-Metolachlor ,Metribuzin, Atrazine, Fluroxypr+chloropyrlid+MCPA and 2,4-D amine salts herbicides (Table 6). S-Metolachlor had higher weed biomass of 4.64g/cm^2. Weed control efficiency also was significantly different across the herbicides Mesotrine+Metolachlor+Terbuthylazine recored the highest weed control efficiency of 91.3% while the lowest was S-Metolachlor which had 67.22% there were no significant diferences in the weed control efficieny of Atrazine+S-Metolachlor, Metribuzin, atrazine Fluroxypr+chloropyrlid+MCPA and 2-4-D. In Kericho early vegetative was associated with higher weed density of 6.21 as compared to late vegetative stage which had a weed density of 5.13 as shown in (Table A9) similar trends were observed in Baringo.

Effects of environment, season, varieties and herbicide on phytotoxicity, finger millet yield and yield parameters

Analysis of variance revealed that environment had a significant effect on days to maturity (DAM) and days to grain filling (GFD) of the crop at $p \leq 0.001$ as shown in (Table A10). Seasons had a significant effect on crop stand, Days to 50% flowering (DTF), Days at maturity and days to grain filling at $p \leq 0.001$. Similarly season had a significant effect on yield of the crop at $p \leq 0.01$ and number of finger at p≤0.05 (Table A9). Environment by season interaction had a significant effect on days to maturity of the crop and Days to grain filling of the crop at $p \leq 0.001$. Variety had a significant effect on the number of tillers at $p \leq 0.05$ (Table A9). Environment by variety interaction had a significant effect on days to maturity and days to grain filling at $p \leq 0.001$ similar trends were observed for Season by Variety interactions. The three way interactions Environment by Variety by Season had a significant effect on number of fingers and tillers at $p \leq 0.05$.

Herbicides used had a significant effect on crop

Table 7. Effects of varieties and environment on crop phototoxicity, yield and yield parameters.

Variety	NFinger	Crop stand (n/ha)	Plant height (cm)	Grain yield (t/ha)	DTF	DAM	Phytotoxicity
U-15	21.32±1.06[a]	1406033[a]	45.86±1.82[a]	2.18±0.22[a]	80.69±3.13[a]	113.13±4.20[a]	4.34±0.41[a]
Snap	21.39±1.08[a]	1415799[a]	46.02±1.83[a]	2.15±0.22[a]	80.78±3.14[a]	112.97±4.40[a]	4.46±0.42[a]
Tukey MSD $_{0.05}$	1.20	113957	0.96	0.11	0.48	1.78	0.20
Environment							
Baringo	21.09±1.02[a]	1388888.89[a]	46.13±1.83[a]	2.17±0.23[a]	80.85±3.14[a]	111.63±4.35[a]	4.30±0.41[a]
Kericho	21.61±1.11[a]	1432942.71[a]	45.74±1.75[a]	2.16±0.22a	80.61±3.12[a]	114.46±4.45[b]	4.50±0.42[a]
Tukey MSD $_{0.05}$	1.00	52475	0.62	0.15	0.32	0.47	0.21

Variety	Biomass (t/ha)	GDF	Tillers
U-15	1.26±0.11[a]	32.44±1.33[a]	3.97±0.17
Snap	1.30±0.11[a]	32.19±1.32[a]	4.15±0.17
Tukey MSD $_{0.05}$	0.15	2.04	0.20
Environment			
Baringo	1.24±0.10[a]	30.78±1.28[a]	4.04±0.17[a]
Kericho	1.32±0.11[b]	33.84±1.35[b]	4.07±0.17[a]
Tukey MSD $_{0.05}$	0.05	0.51	0.14

Means followed by the same letter along the column are not significantly different according to Tukey MSD $_{0.05}$ where DTF=Days to Flowering, DAM=Days at Maturity, GDF=Days to Grain Filling and Nfingers=Number of fingers.
SAS Institute version 9.4, 2002

fingers and tillers at $p \leq 0.05$.

Herbicides used had a significant effect on crop phytotoxicity and all the yield and yield parameters at $p \leq 0.001$. The two way interaction Environment by herbicide had a significant effect on days to maturity at $p \leq 0.001$ and days to grain filling at $p \leq 0.01$ Season by herbicide interaction had a significant effect on number of tillers and plant biomass at $p \leq 0.001$and on Days to maturity and days to grain filling $p \leq 0.01$. The three way interaction Environment by Season by Herbicide had a significant effect on Days to flowering, Days at maturity and Days to grain filling at $p \leq 0.001$ and also on crop stand at $p \leq 0.05$.

There was significant difference in the plant biomass, Days to grain filling and Days to maturity of the crop between the two environments (Table 7). Kericho had a higher biomass of 1.32 t/ha when compared to that of Baringo at 1.24 t/ha. Regarding days to maturity for Baringo, it took 111days to attain maturity as compared to 114days for Kericho to attain maturity. Similar trends are observed with 30 days to grain filling for Baringo while in Kericho it took 33 days. Season two was associated with higher number of fingers (21.94) as compared to season one which had (20.77) fingers. In addition, greater crop stand was observed in season two (1447048/ha) as compared to season one (1374782/ha). In the second season the grain yield was 2.28t/ha which differed significantly when season one at 2.05t/ha (Table 8) similar trends were experienced in the crop biomass where season two had a crop biomass of 1.45t/ha as compared to season one where the crop biomass was 1.11t/ha. There was a significant difference in both 50% days to flowering, days to maturity of the crop and Days to grain filling of the crop in the two seasons. . In season one days to 50% flowering was 80 as compared to season two where the crop took 81 days to attain 50% flowering.

Maturity of the crop in season one was 112 days after sowing (DAS) which differed significantly with season two where the maturity of the crop was 114days (Table 8). Season one was associated with shorter days of grain filling (30 days) as compared to season two where the crop took (33 days) in grain filling.

There was significant difference in the yield obtain among the herbicides as shown in (Figure 1d). Highest yield was obtained where

Table 8. Effects of seasons on crop phototoxicity yield and yield parameters.

Season	NFingers	Crop stand (n/ha)	Plant height (cm)	Grain yield (t/ha)	DTF	DAM	Phytotoxicity	Biomass (t/ha)	GDF	Ntillers
Season 1	20.77±0.99[a]	1374782.99[a]	46.13±1.83[a]	2.05±0.22[a]	81.11±3.15[b]	112.02±4.37[a]	4.30±0.41[a]	1.11±0.09[a]	30.90±1.29[a]	4.01±0.17[a]
Season 2	21.94±1.14[b]	1447048.61[b]	45.75±1.82[a]	2.28±0.22[b]	80.35±3.12[a]	114.07±4.43[b]	4.50±0.42[a]	1.45±0.12[b]	33.72±1.34[b]	4.10±0.17[a]
Tukey MSD $_{0.05}$	1.00	52475	0.62	0.15	0.32	0.47	0.21	0.05	0.51	0.15

Means followed by the same letter along the column are not significantly different according to Tukey MSD $_{0.05}$ where,Nfinger=Number of Fingers,DTF=Days to Flowering,DAM=Days at Maturity,GDF=Days to Grain filling and Ntillers=Number of tillers.
Source: SAS Institute version 9.4, 2002.

Fluroxypr+chloropyrlid+MCPA was used (5.4 t/ha) however it was not statistically different from the yield obtained were 2, 4-D amine salts was used. Lowest yields were obtained where Mesotrine+Metolachlor+Terbuthylazine herbicides was used. There was no significant difference between the yields obtained where Atrazine, Atrazine+S-Metolachlor, Metribuzin and weedy check. Crop biomass was greatly influenced the herbicide used. Higher crop biomass was associated with Fluroxypr+chloropyrlid+MCPA and 2-D as shown in (Figure 2a). S-Metolachlor recorded crop biomass of 2.19t/ha that was significantly different from biomass recorded where Atrazine was used (0.8 t/ha) or where Metribuzin was used (0.7 t/ha).

Use of herbicides in controlling weeds of finger millets severely affected the crop stand. Severe stand loss was observed where Mesotrine+Metolachlor+Terbuthylazine were used; hence no crop stands as shown in (Figure 1b).

Fluroxypr+chloropyrlid+MCPA and 2-4 had no crop stand loss. Among the pre-emergent herbicides used S-Metolachlor had the least effect on crop stand In addition; there was no significant difference in the stand count between Atrazine+S-Metolachlor, Metribuzin and control. Mesotrine+Metolachlor+Terbuthylazine had the highest crop phytotoxicity that was characterized by severe stand loss and longer residual effect. S-metolachlor had the lowest crop Phytotoxicity amongst the pre-emergence herbicides. This was characterized by some stand loss. Use of Atrazine or Metribuzin had a significant effect on crop Phytotoxicity However, Fluroxypr+chloropyrlid+MCPA and 2, 4-D amine salts recorded no crop phytotoxicity (Figure 2b). Number of finger was influenced by crop stand which was affected by the herbicides applied more fingers were observed in Fluroxypr+chloropyrlid+MCPA and 2, 4-D amine salts where there was no stand loss (Figure 1a). An increased plant height was recorded where weeds were controlled the greatest plant height was recorded where Fluroxypr+chloropyrlid+MCPA and 2, 4-D amine salts was used while no herbicide application equates to low plant height (Figure 1c).

There was no significant difference in grain fillings days among the herbicides and weedy checks shown in (Figure 2d) However, there was significant difference in 50% days to flowering among the herbicides. The application of 2-D or Fluroxypr+chloropyrlid+MCPA resulted to crop attaining 50% flowering earlier as compared to use of either Atrazine+S-Metolachlor or Metribuzin. In no herbicides application crops attained 50% flowering late (Table 9). Due to significant stand loss after Metribuzin and Atrazine treatment fewer tillers were observed. There was no significant differences in the days at maturity of the crop among the herbicides used (Table 9). Crops matured late where no herbicides application was used. Grain yield showed a significant positive correlation with plant biomass *r*=0.98 (Table 10). In addition, stand count had a significant positive correlation with grain yield (*r*=1).Plant height had a positive correlation with grain yield (*r*=0.48) but that was not significant.

DISCUSSION

High weed densities were recorded in *Datura stramonium* and *Amaranthus hybridus*. This is attributed to the fact that *Datura stramonium* grows rapidly and leading to its ability to outcompete water, light and nutrient requirement (Karimmojeni et al., 2021). High numbers of *Amaranthus hybridus* could be as a result of them producing many seeds under favorable conditions. *Biden pilosa* is fast growing, very invasive and has allelopathic compounds and because of this, it has high potential to reduce drop yield (Mahmoud et al., 2015). 2, 4-D amine salts had the highest number of weeds from the Poaceae family his could be as a result of their active ingredients dmethylamine and diethynolamine that provides acceptable control of

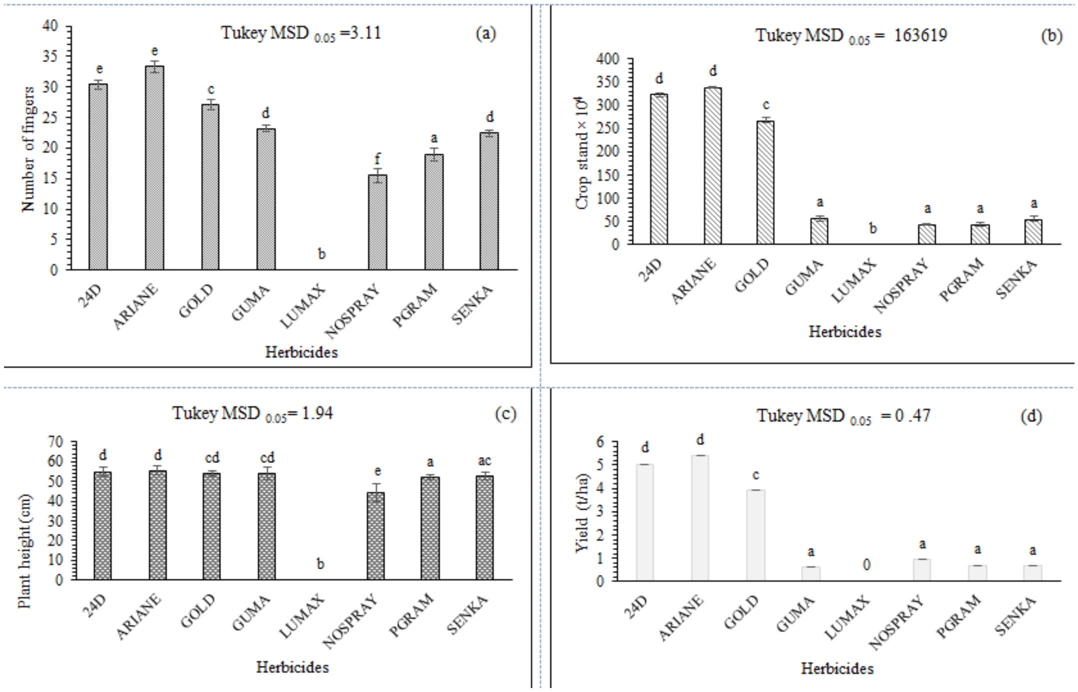

Figure 1. Effect of 2-4, Fluroxypr+chloropyrlid+MCPA, S-Metolachlor, Atrazine, Mesotrine+Metolachlor+Terbuthylazine, Atrazine+S-Metolachlor, Metribuzin herbicides and no spray on (a) number of finger (b) crop stand (c) plant height (d) yield of two finger millet varieties evaluated in Baringo and Kericho Kenya.
Source: SAS Institute version 9.4, 2002

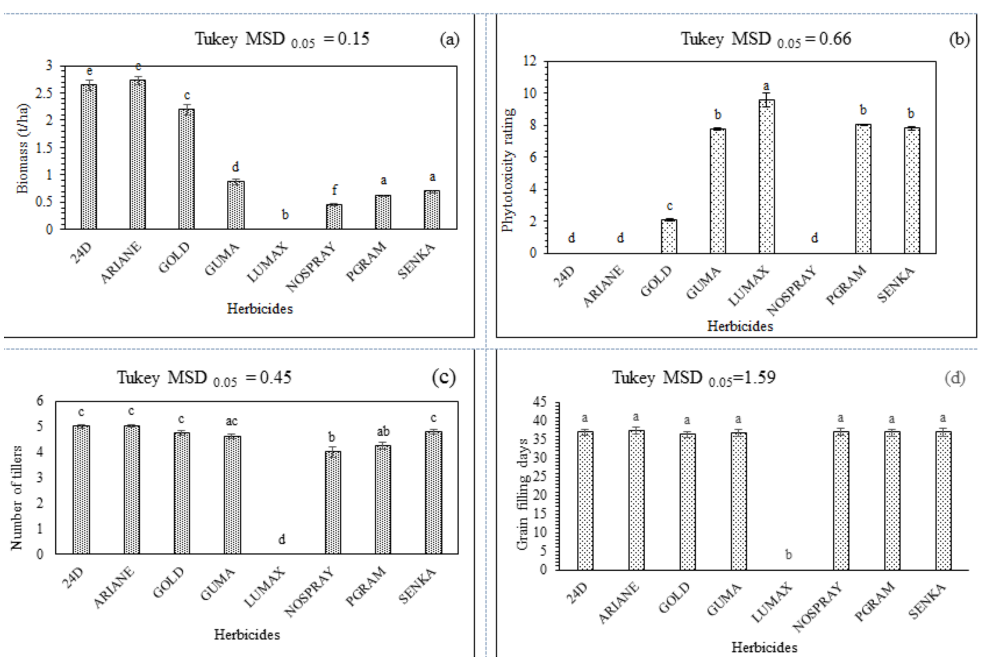

Figure 2. Effect of 2-4, Fluroxypr+chloropyrlid+MCPA, S-Metolachlor, Atrazine, Mesotrine+Metolachlor+Terbuthylazine, Atrazine+S-Metolachlor, Metribuzin herbicides and no spray on (a) biomass (b) crop Phytotoxicity (c) number of tillers (d) days to grain filling two finger millet varieties evaluated in Baringo and Kericho Kenya.
Source: SAS Institute version 9.4, 2002.

Table 9. Effects of herbicides on 50% days to flowering and days at maturity

Herbicides	Days to flowering	Days at maturity
Atrazine+S-Metolachlor	92.42 ± 0.26[a]	129.29±1.03[a]
Mesotrine+Metolachlor+Terbuthylazine	0.00 ± 0.00[b]	0.00±0.00 [b]
S-Metolachlor	92.71±0.24[ac]	129.17±0.68[a]
Metribuzin	92.29±0.39[ad]	129.21±0.75[a]
atrazine	92.33±0.26[a]	129.13±0.70[a]
2,4-D amine salts	91.33±0.24[d]	128.33±0.91[a]
Fluroxypr+chloropyrlid+MCPA	91.21±0.21[d]	128.55±0.90[a]
control	93.58±0.32[c]	130.71±0.73[c]
Tukey MSD $_{0.05}$	1.00	1.46

Means followed by the same letter along the column are not significantly different according to Tukey MSD $_{0.05.}$
Source: SAS Institute version 9.4, 2002

Table 10. Correlation among number of fingers, stand count, plant height, grain yield, biomass and grain filling days.

Traits	Stand count	Plant height	Grain yield	Biomass	Grain filling days
Number of fingers	0.80*	0.90**	0.78*	0.86**	0.83*
Stand count		0.49	1.00***	0.99***	0.40
Plant height			0.48	0.58	0.98***
Grain yield				0.98***	0.40
Biomass					0.48

*,**, *** Significant at (P≤0.05),(P≤0.01) and (P≤0.001), respectively.
Source: SAS Institute version 9.4, 2002

broad leaves but no control of the Poaceae weeds. This result confirms that of Hassan et al. (2008) that showed dmethylamine and diethynolamine controlled broad leaves but no control of the Poaceae weeds.

2, 4-D amine salts are synthetic plants hormones that mimic the natural plant hormones. A higher concentration of the synthetic plant hormones causes uncontrolled and unstainable growth causing stem curl-over, leaf withering, and eventual plant death (Davies, 2010). 23 DAT the weeds in the plots that were sprayed with S-Metolachlor had emerged hence call for another weed control strategy this could be as a result of its shortest residual effect. S-metolachlor, the active ingredient of the herbicide, has a residual effect of 23 days (O'Connell et al., 1998).

Mesotrine+Metolachlor+Terbuthylazine and Metribuzin were effective against reducing both broad and narrow leaf weeds. Mesotrine+Metolachlor+Terbuthylazine and Metribuzin act by inhibiting early seedling growth of the weeds (Fuerst, 1987) Fluroxypr+chloropyrlid+MCPA was effective against reducing the broad leafed weeds. These results confirmed to those of Magnoli et al. (2020) who found out that Application of Fluroxypr+chloropyrlid+MCPA at 1.25 l/ha can control broad leafed weed in wheat.

The results of this study showed a significant reduction in weed species abundance, weed count, weed biomass, and weed density after treatment by all the herbicides used, as compared to no herbicides application. All the herbicides used demonstrated significant weed control efficiency. Some herbicides caused crop injury that persisted for a longer period of time or greatly reduced the crop stand. Significant reduction in weed species abundance, weed count and weed biomass in Atrazine+S-Metolachlor can be attributed to their active ingredient S-metolachlor which negatively interferes with seedling development through inhibition of initial development (Silva et al., 2020). In the case of Atrazine its acts as a photosystem inhibitor II (Choe et al., 2014). This herbicide affects the electron transport in photosystem II that disrupts the photosynthetic process of weeds. However, the herbicide is associated with high crop toxicity levels. A combination of S-metolachlor, Atrazine and Mesotrione had the highest weed suppression and the ability to suppress weeds 60 DAT. However, it recorded the highest stand loss and crop phytotoxicity this could be attributed to the inability of finger millet seeds to metabolize the herbicide differently from other weed seeds hence the herbicide suppress just as it suppress other weeds. Metribuzin causes inhibition of enzyme activity and protein synthesis which results to inhibition of weed growth. However, few species were able to escape the herbicide action. S-Metolachlor had the lowest weed suppression among the pre-emergent herbicides used and did not have a longer residual effect. According to Chepkoech et al. (2020), S-Metolachlor are non-persistence However, it had the lowest crop phytotoxicity and was agronomically acceptable. This could be attributed to the fact finger millet seeds was able to detoxify S-Metachlor hence less crop losses and damages (Choudhary and Lagoke, 1981).

The differences in weed suppression amongst the herbicides could be attributed to properties of individual herbicides such as solubility, photo degradation and persistence. Pre-emergence herbicides kill weeds before they emerge. Once the seeds come in contact with the herbicide they cannot emerge (Mitchell et al., 2001). Application of Metribuzin l/ha recorded lower weed biomass as compared to no herbicides application. This result confirm to the findings of Kumar et al. (2014) who found out dry weight of sugarcane weeds significantly reduced with application of Metribuzin. In no herbicide application, weeds grow uninterrupted therefore they are able to maximize the available resources leading to higher biomass.

Application of 2, 4-D amine salts at 1.31l/ha or Fluroxypr+chloropyrlid+MCPA at 1.25l/ha recorded lower weed biomass, weed count and ensured significant weed control efficiency In addition, there was no injury or damage to the crop these could be attributed to their differential herbicide metabolism which resulted to selectivity between crops and weeds. The detoxicative activity of these active ingredients of the two herbicides is higher in finger millet than in weeds hence no injury to crop. Weed control efficiency implies the magnitude of weed reduction upon application of weed control treatment. Mesotrine+Metolachlor+Terbuthylazine being a non -selective herbicide had the highest weed control efficiency of both broad and narrow leave weeds. This can be attributed by its combination of its active ingredient (S-metolachlor atrazine and Mesotrione) and the duration of their residuals activities the results are similar to that of sarangi and Jhala (2018) that showed combination of metolachlor, atrazine and Mesotrione had the highest weed reduction at 42 DAT However, it had severe loss of the crop stand. In regard to stages, early growth stage of the crop had less weed count and weed biomass when treated with either, 2,4-D amine salts or Fluroxypr+chloropyrlid+MCPA. When finger millet is subjected to weed infestation during early growth stages it leads to a decline productivity of the crop (Mogaka et al., 2021). Regarding the locality of Kericho it was associated with higher weed count, weed density and weed biomass this is due cool and wet conditions at Kericho while Baringo has a relatively warm and dry environment. Hence, weeds tend to emerge faster in Kericho than Baringo. In addition, the resources are readily available to initiate seed germination and translocation of synthetates leading to higher weed biomass.

Tillering ability of the crop was affected by use of herbicide. Tillering of finger millet with of no herbicide application was poor, In addition application of 2,4-D amine salts at 1.3l/ha or Fluroxypr+chloropyrlid+MCPA at 1.25l/ha yielded more tillers similar results were reported by Pradhan et al. (2010) who reported that there were more tillers in finger millet where chemical control was applied. The increased finger millet height in treated plots could be as a result of reduction in crop-weed competition. Tippanagoudar et al. (2013) observed that millet acquired maximum growth due to good light interception, good root growth and nutrient acquisition as a result of reduced crop-weed competition.

Dry matter accumulation in crops differed significantly among the herbicides with no herbicides application recording the lowest dry matter accumulation as a result of severe competition for water, carbon dioxide and light leading to low biomass. 2, 4-D amine salts and Fluroxypr+chloropyrlid+MCPA recorded the highest dry matter accumulation

The presence of weeds can hinder the growth of plants, as they compete for resources such as moisture, nutrients and carbon dioxide (Singh et al., 2022). Therefore, the reduction in weed biomass provides an opportunity for the plants to utilize these resources more efficiently, resulting in higher biomass. Muoni et al. (2013) concluded that herbicide application is the best weed control method to obtain higher yields.

Conclusion

The findings of this study show that crops respond differently to herbicides. The present study showed that the application of 2,4-D amine salts or Fluroxypr + Chloropyrid + MCPA as a post-emergent in finger millet resulted in significant weed control efficiency, no phytotoxicity rate, and higher crop biomass, leading to higher yields. Therefore, it is not economical for farmers to apply S-Metachlor as a pre-emergent herbicide since another weed control strategy should be applied 23 days after treatment (Apendix A).

CONFLICTS OF INTERESTS

The authors have not declared any conflicts of interests.

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APPENDIX

Table A1. Effects of herbicides on weed species count n/m^{2}.

Weed species	Atrazine+S-Metolachlor	Mesotrine+Metolachlor+Terbuthylazine	S-Metolachlor	Metribuzin	atrazine	2,4-D amine salts	Fluroxypr+ chloropyrlid+ MCPA	Control
Biden pilosa	1	0	5	0	0	0	0	17
Amaranthus hybridus	1	0	4	1	0	0	0	16
Oxalis latifora	0	0	4	0	0	0	0	12
Datura stramonium	2	0	2	0	1	1	0	20
Abutilon hybridum	1	0	3	1	1	0	0	10
Commelina benghalensis	1	0	3	1	0	1	0	10
Chenopodium album	1	0	3	1	1	0	0	11
Oxygonum sinuatum	2	0	4	0	0	0	0	13
Galinsoga parviflora	1	0	2	0	0	0	0	12
Digitaria scalarum	1	0	3	0	1	9	7	14
Taraxacum officinale	0	0	1	1	0	0	0	5
Malva sativa	1	0	1	0	1	0	1	6
Lantana camara	0	0	2	0	0	0	0	7
Lantana camara	0	0	2	1	2	1	0	9
Eragrotis pilosa	1	0	3	0	0	10	7	10
Dactyloctenuim agyptium	1	0	3	0	1	11	7	13
Total	14	0	45	6	8	33	22	185
Broad leaf	11	0	36	6	6	3	20	148
Narrow leaf	3	0	9	0	2	30	21	37

Table A2. Results of Anova for weed species abundance for finger millet.

Source of variation	**df**	**Weed species abundance**
Environment(ENV)	1	120.098*
Season(S)	1	13.07
Replication (R)	2	128.57**
ENV×S	1	271.94***
Species(Sp)	15	4816.10***
ENV×SP	15	43.39*
S×SP	15	6.50
ENV×S×R×Sp	126	24.98
Herbicides (H)	7	214533.68***
ENV×H	7	80.621***
S×H	7	106.343***
E×S×H	7	202.951***
H×Sp	105	2183.008***
E×H×Sp	105	24.08
E×H×Sp	105	18.23
E×S×H×S	105	8.90
Error	896	21.68
CV (%)		23.15
R^2		0.99

Table A3. Effects of species categories on weed species abundance.

Species name	**% Weed species abundance**
Biden pilosa	16.71[a]
Amaranthus hybridus	16.85[a]
Oxalis latifora	17.12[a]
Datura stramonium	16.98[a]
Abutilon hybridum	16.62[a]
Commelina benghalensis	16.73[a]
Chenopodium album	16.91[a]
Oxygonum sinuatum	16.82[a]
Galinsoga parviflora	16.60[a]
Digitaria scalarum	34.06[b]
Taraxacum officinale	17.19[a]
Malva sativa	17.02[a]
Lantana camara	16.68[a]
Eragrotis pilosa	34.78[b]
Dactyloctenuim agyptium	34.27[b]
Cyperus rotundus	16.41[a]
Tukey MSD $_{0.05}$	2.31

Table A4. Effects of herbicides on species categories.

Species types	%Weed species abundance						
	Herbicides						
	Atrazine+ S-Metolachlor	Mesotrine+ Metolachlor+ Terbuthylazine	S-Metolachlor	Metribuzin	Atrazine	2,4-D amine salts	Fluroxypr+chloropyrlid+ MCPA
Biden pilosa	2.47	0.1	21.98	2.95	2.35	1.98	1.86
Amaranthus hybridus	1.81	0.1	24.98	2.25	1.81	2.00	1.84
Oxalis latifora	2.05	0.1	26.22	2.32	1.88	2.38	2.03
Datura stramonium	2.58	0.1	24.87	1.96	2.08	2.23	2.07
Abutilon hybridum	2.29	0.1	22.13	2.60	2.01	1.86	2.03
Commelina benghalensis	2.02	0.1	24.27	1.83	1.57	2.23	1.87
Chenopodium album	2.34	0.1	24.98	1.85	1.99	1.89	2.12
Oxygonum sinuatum	2.42	0.1	24.08	2.11	2.01	2.01	1.81
Galinsoga parviflora	2.12	0.1	23.11	1.57	2.00	1.93	2.00
Digitaria scalarum	1.56	0.1	21.11	1.92	2.23	78.71	66.86
Taraxacum officinale	1.89	0.1	27.10	2.01	2.10	2.04	2.28
Malva sativa	1.56	0.1	25.85	1.97	2.02	2.28	2.41
Lantana camara	1.76	0.1	23.47	2.11	1.76	2.13	2.04
Eragrotis pilosa	1.43	0.1	23.30	2.09	1.90	75.25	74.21
Dactyloctenuim agyptium	1.70	0.1	21.58	2.05	1.98	76.25	70.17
Cyperus rotundus	1.91	0.1	20.97	1.87	1.85	2.24	2.36

Table A5. Effects of interaction between species types and location.

Species type	% Weed species abundance	
	Baringo	Kericho
Biden pilosa	16.38	17.05
Amaranthus hybridus	16.50	17.93
Oxalis latifora	16.93	17.31
Datura stramonium	16.95	17.02
Abutilon hybridum	16.56	16.69
Commelina benghalensis	16.76	16.71
Chenopodium album	17.06	16.76
Oxygonum sinuatum	16.71	16.92
Galinsoga parviflora	16.64	16.55

Table A5. Contd.

Digitaria scalarum	35.76	32.64
Taraxacum officinale	17.54	16.84
Malva sativa	17.06	16.99
Lantana camara	16.81	16.54
Eragrotis pilosa	36.56	33.01
Dactyloctenuim agyptium	35.53	33.05
Cyperus rotundus	16.52	16.30

Table A6. Analysis of variance for weed count, weed biomass, weed density and weed control efficiency of finger millet evaluated in Baringo and Kericho.

Source of variation	df	Weed count	Weed biomass	WCE	Weed density
Environment (ENV)	1	14.56*	4.60***	194.97*	5.71**
Season(S)	1	14.03*	19.41***	17.23	7.95***
Replication (R)	2	14.710*	1.37**	7.76	1.37
ENV×S	1	9.91	0.59	283.72**	6.42***
Variety(V)	1	12.37*	5.52***	124.81	4.43**
ENV×V	1	9.73	4.34***	12.74	3.12*
S×V	1	0.21	0.02	21.24	2.48
ENV×S×V	1	0.28	0.69	188.77*	6.55**
ENV×S×R×V(Error a)	14	11.70***	0.84***	91.82**	2.04***
Herbicide (H)	7	3033.19***	964.26***	46816.91***	31.56***
ENV×H	7	4.20	0.97**	64.04	0.47
S×H	7	6.76*	10.34***	86.12*	0.74
ENV×S×H	7	2.12	4.31***	73.55	0.94
V×H	7	4.05	1.17***	37.38	0.76
ENV×V×H	7	1.92	3.32***	23.08	0.52
S×V×H	7	1.51	1.03**	31.79	0.19
E×S×V×H	7	1.64	0.11	37.06	0.34
Stage(st)	1	0.79	55.67***	3266.18***	24.14***
E×St	1	2.20	11.29***	26.07	0.17
S×St	1	2.83	3.85***	52.05	4.27**
V×St	1	0.34	0.98	212.48*	2.66**
St×H	7	229.10*	88.32***	265.37***	1.30*
V×St×H	7	1.37	0.44	19.29	0.93
ENV×S×St	1	8.28	4.08***	34.59	0.71
ENV×S×V×St	3	1.60	2.32***	35.56	1.48
ENV×S×V×St×H	42	2.90	2.92***	40.89	0.60
Error (B)	240	2.84	0.82	39.23	0.61
CV(%)		26.82	17.62	8.27	13.79
R^2		0.97	0.99	0.97	0.74

*,**, *** Significant at (p≤0.05),(p≤0.01) and (p≤0.001), respectively WCE=Weed Control Efficiency.

Table A7. Effects of interaction between environment by season on weed count,weed density,weed biomass and weed control efficiency.

Season	Weed count(n/m^2)		Weed density		Weed biomass(g/cm^2)		%WCE	
	Baringo	Kericho	Baringo	Kericho	Baringo	Kericho	Baringo	Kericho
Season one	5.72±0.77[a]	6.45±0.79[a]	5.38±0.18[a]	5.79±0.15[b]	2.93±0.44[a]	3.05±0.42[a]	77.54±3.11[a]	74.32±3.05[a]
Season two	6.42±0.83[b]	6.53±0.89[a]	5.43±0.18[a]	5.59±0.16[a]	3.31± 0.49[b]	3.60±0.60[b]	75.70±3.14[b]	75.63±3.22[a]

Means followed by the same letter along the column are not significantly difference according to Tukey MSD $_{0.05}$.

Table A8. Effects of interaction between environment and herbicide on weed count,weed density weed biomass and weed control efficiency.

Herbicides	Weed count(n/m^2)		Weed density		Weed biomass(g/cm^2)		%WCE	
	Baringo	Kericho	Baringo	Kericho	Baringo	Kericho	Baringo	Kericho
Primagram	2.96±0.38[a]	3.21±0.36[a]	5.40±0.21[a]	5.62±0.13[a]	1.38±0.11[a]	1.43±0.07[a]	88.50±1.26[a]	88.22±1.27[a]
Lumax	0.71±0.19[b]	1.17±0.19[b]	3.24±0.34[b]	4.15±0.31[b]	0.56±0.12[b]	0.85±0.10[b]	94.71±1.21[b]	87.99±3.99[a]
Dual gold	11.75±0.70[c]	11.79±0.76[c]	7.03±0.06[c]	7.03±0.06[c]	4.41±0.35[c]	4.70±0.44[c]	68.92±1.86[c]	65.52±1.38[b]
Sencor	2.13±0.37[ab]	2.75±0.34[a]	4.75±0.31[ab]	5.27±0.25[ab]	1.08±0.13[ab]	1.25±0.09[ab]	91.28±1.32[a]	89.17±1.26[a]
Maguguma	2.08±0.32[ab]	2.58±0.38[ab]	4.92±0.29[ab]	5.14±0.27[ab]	1.10±0.10[a]	1.25±0.10[ab]	90.86±1.09[a]	89.39±1.41[a]
2-4-D	2.96±0.39[a]	2.67±0.30[ab]	5.56±0.14[a]	5.44±0.12[ab]	1.42±0.08[a]	1.27±0.03[ab]	88.37±0.98[a]	89.40±1.01[a]
Ariane	2.29±0.39[ab]	2.50±0.36[ab]	4.59±0.37[ab]	4.91±0.33[ab]	1.04±0.13[ab]	1.13±0.11[ab]	91.00±1.38[a]	90.11±1.30[a]
Control	23.67±1.06[d]	25.25±1.25[d]	7.76±0.05[c]	7.90±0.10[d]	13.96±0.92[d]	14.65±1.38[d]	0.0±0.0[d]	0.0±0.0[c]

Table A9. Effects of interactions between environments by growth stage on weed count, weed density, weed biomass and weed control efficiency.

Millet growth stage	Weedcount(n/m^2)		Weed density		Weed biomass(g/m2)		%weedcontrolefficiency	
	Baringo	Kericho	Baringo	Kericho	Baringo	Kericho	Baringo	Kericho
Seedling	6.19±0.61[a]	6.45±0.60[a]	6.04±0.10[b]	6.21±0.08[b]	2.86±0.35[a]	2.74±0.31[a]	73.23±2.93[a]	72.26±2.90[a]
Vegetative	5.95±0.96[a]	6.53±1.03[a]	4.77±0.22[a]	5.13±0.19[a]	3.38±5.56[b]	3.89±0.66[b]	80.01±3.27[b]	77.70±3.34[b]

Table A10. Results of Anova for crop Phytotoxicity, yield and yield parameters for finger millet.

Source of variation	df	Number of fingers	Crop stand (N/ha)	Plant height (cm)	Yield (t/ha)	DTF	DTM	Prating	Number of tillers
Environment (ENV)	1	13.02	9316	7.44	0.07	2.76	382.5***	1.88	0.05
Season(S)	1	65.33*	2507***	6.83	2.47**	27.76***	202.13***	1.89	0.42
Replication (R)	2	111.35	1981	3.69	0.66	5.36	46.52	0.54	0.26
ENV×S	1	2.52	2216	0.65	0.03	1.17	693.89***	1.89	0.26
Variety (V)	1	0.19	4578	1.30	0.04	0.42	1.17	0.63	1.51*
ENV×V	1	0.33	8412	13.65	0.47	0.88	53.13***	0.63	0.05
S ×V	1	0.52	4494	11.02	0.04	2.76	94.92***	0.63	0.88
ENV×S×V	1	70.83*	3820	1.58	0.10	0.42	0.13	0.64	1.51*
ENV×S×R×V (Error a)	14	14.10	13555	9.57	0.13	2.37	33.00	0.43	0.45
Herbicides (H)	7	2595.19***	4.85***	8558.7***	119.26***	25553.60***	50087.06***	432.00***	67.55***
ENV×H	7	11.11	4902	3.47	0.17	1.31	11.60***	0.71	0.13
S×H	7	47.73***	6629	5.71	0.53	2.96	8.99**	0.71	0.24
ENV×S×H	7	4.32	8013*	9.43	0.53	4.78***	19.29***	0.71	0.10
V×H	7	11.56	1060	0.46	0.26	0.46	2.08	0.51	0.33
ENV×V×H	7	5.63	1479	6.24	0.22	1.42	2.11	0.52	0.46
S×V×H	7	15.99	2098	6.37	0.24	0.84	4.90	0.51	0.08
ENV×S×V×H	7	9.62	6507	1.81	0.26	0.24	1.61	0.51	0.21
Error	112	12.15	3367	4.75	0.27	125	2.68	0.55	0.26
CV (%)		16.33	13	4.74	24.19	1.39	1.45	16.84	12.52
R^2		0.93	0.98	0.99	0.96	0.99	0.99	0.98	0.94

Table A10 continued. Results of Anova for crop Phytotoxicity, yield and yield parameters for finger millet.

Source of variation	df	Biomass (t/ha)	GFD
Environment (ENV)	1	0.27	450.19***
Season(S)	1	5.44	379.68***
Replication (R)	2	0.01	83.31
ENV×S	1	0.01	752.08***
Variety (V)	1	0.07	3.00
ENV×V	1	0.05	67.69***
S ×V	1	0.04	130.02***
ENV×S×V	1	0.02	0.08
ENV×S×R×V(Error a)	14	0.03	43.58***
Herbicides (H)	7	27.61***	4092.40***
ENV×H	7	0.02	11.78**
S×H	7	0.43***	10.50**
ENV×S×H	7	0.01	16.92***
V×H	7	0.02	2.98
ENV×V×H	7	0.01	2.88
S×V×H	7	0.02	4.62
ENV×S×V×H	7	0.02	1.51
Error	112	0.03	3.18
CV (%)		12.78	5.52
R^2		0.99	0.99

*,**, *** Significant at ($P \leq 0.05$),($P \leq 0.01$) and ($P \leq 0.001$), respectively where GDF=Days to grain filling.