Effect of Selected Weed Management Practices on the Growth and Yield Components of Finger Millet (*Eleusine coracana*) in Western Region of Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Author MJM designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors KKN and JPO reviewed the study design and all drafts of the manuscript. Authors KKN and WWN managed the analyses of the study and performed the statistical analysis. Author JPO G managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Finger millet (*Eleusine coracana*) accounts for 8% of the total area and 11% of the millet production worldwide. It is grown on over 4 million ha globally, mainly for food purposes. Millions of people in the dry lands of Central and East Africa, and South of India depend on finger millet as an important source of food to them (CGIAR, 2001). Finger millet is one of the most neglected and underutilized crops. Additionally, the crop has received limited research attention compared to wheat, rice, and maize (FAO, 2011). Therefore, production challenges such as those caused by weeds like goose grass *Eleusine indica* remain at large. Manual weeding is the commonly employed weed control method in finger millet production, but is expensive and labour intensive. The current study was set to evaluate the influence of weed management practices on finger millet growth and yield components. The experiment was laid out in a Randomized Complete Block Design (RCBD) with...
Keywords: Herbicide; weed; finger millet; labor; phytotoxicity.

1. INTRODUCTION

Finger millet (Eleusine coracana L.) is an annual and tufted crop that grows to a height of 30–170 cm and maturing in 75–160 days. It is a robust C4 crop, that has narrow leaves (grass-like) and capable of producing many tillers and nodal branches. Finger millet can be considered to have a well-balanced protein for a cereal grain [1]. Of the four essential amino acids, the proportion of lysine is 2.86 %, tryptophane 1.39 %, methionine 2.86% and threonine 3.06 %. This is especially good for diabetic patients [2]. According to [3] demand for small millets like finger millet need to be enhanced to act as a catalyst for increasing productivity.

Finger millet require nutrients, water, light and carbon dioxide for growth. Since weeds are among plant species, when found in the cultivated land, they compete with crop plants for these growth factors. The critical period of weed competition starts with the beginning of interference from weeds and ends when the crop covers 80 per cent of the soil. The length of critical period of weed competition depends on the nature of crop, its competitive ability, variety, and growing conditions. Nature of the crop Certain crops like sorghum, maize, and sunflower grow faster and cover the field quickly hence the length of critical period of weed growth is short. In other crops like sugarcane, potato and cotton whose initial growth is slow and as they are widely spaced, they take longer time to cover the soil. Critical period of weed competition is therefore longer, this is a similar case for finger millet which normally displays a slower field establishment [4]. At early stages of crop and weeds development, leaf area index and root density are low, and each plant is able to get its requirements as though every one of them is growing in isolation. In majority of crops, the period of non-interference between crop and weed is short. Even at low population of weeds, competition is set in at three leaf stage of weeds. The close proximity of weeds and their numbers cause sub-optimal absorption of growth factors resulting in reduction in growth and yield of crops. Among the growth factors, light and nutrients are particularly important in reducing growth [5].

Apart from cultural and mechanical means, weeds can be effectively controlled by use of herbicides. Ashton and Monaco [6] reported that work done in the communal areas, showed that the use of herbicides, combined with fine tillage, is a better and cheaper option for controlling weeds by these farmers. The most common weeds which were under the experiment could easily be controlled by the cheap pre-emergence herbicides, such as alachlor and atrazine.

In Western Kenya weed control in finger millet is usually done manually by several rounds of hand weeding which is not only hindered by lack of labour due to competition with other crops like maize but also the bad weather conditions such as heavy rainfall which makes the exercise difficult. Weeds are a serious problem in finger millet and the first two weeks after germination are critical. Several rounds of manual weeding are common, requiring much labour during this time. Weeding is labor intensive, and is further
complicated by wild relatives of the crop. Due to these constraints, the critical period of weed free competition is not achieved for the crop which is between 25 to 45 days thus leading to heavy losses. The 25 to 45 days is a window in the crop growth cycle during which weeds must be controlled to prevent unacceptable yield losses. It is therefore imperative that pre emergence herbicides should be used as an alternative for improved yields. The advantage of these herbicides is that they control weeds early and well and minimize competition. Most of the herbicides are usually applied 2-3 days after sowing when there is enough moisture in the soil for effective activity on the weeds. Most studies have not shown decreases in yields with the use of reduced rates of herbicides but none has been in the Western Kenya region on Finger millet. The objective of the study was to determine the weed management practices on the growth and yield components of finger millet (Eleusine coracana) in Western Region of Kenya.

2. MATERIALS AND METHODS

2.1 Study Sites

The study was carried out at Bukura Agricultural College (BAC) at the teaching and demonstration farm, which is situated at Butsotsot South sub-location, Butsotsot location, Lulambi Sub County, Kakamega County. The average rainfall in BAC is 1800 mm per annum, annual temperature of about 23°C and lies at an altitude of about 1400 m above sea level (BAC Meteorological station, 2015).

2.2 Experimental Design and Layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replicates and each replicate had seventeen treatments. The plots measured 2 by 2m with a border width of 1m. The chemicals which were applied included Pendimethalin, Dimethyl amine, Metolachlor, Metribuzin and Atrazine. The treatment comprised: No weeding, Hand weeding and the five herbicides. The five herbicides; Pendimethalin, Dimethyl amine, Metolachlor, Metribuzin and Atrazine were applied at three rates each 1.0, 1.5 and 2.0 l/ha in each replication as described in the treatments.

2.3 Cultural Practices

Land was prepared by doing primary, secondary, and tertiary cultivation with the aim of getting a fine tilth since finger millet seeds are small. Finger millet variety (P224) which is commonly grown in Western Kenya was sourced from Kenya Seed. Sowing was done at the onset of rains end of March 2015 during the first season and end of August 2015 during the second season, by drilling 30cm apart and a depth of 3-4 cm. The seeds were mixed with Di Ammonium Phosphate (DAP) fertilizer at a rate of 125 Kg/ha and then planted along the drills which were then followed by covering of the drills. This was followed by application of the selected pre emergence herbicides after three days. The herbicides were sourced from Kakamega farmers agrovet and Kenya Farmers Association (KFA), and applied using a well calibrated knap sack sprayer with a flat fan nozzle. Ten days DAS, the thinning was done to maintain an intercrop distance of 10 cm. Ten days after sowing, crop emergence count was recorded.

2.4 Data Collection

Data was collected on the number of weeds, plant height, height of weeds, weight of wet weeds, weight of dry weeds, number of panicles weight of panicles, weight of threshed panicles and a thousand grain weight. The numbers of weeds per plot were determined using 1m by 1m quadrants. Plant height and weed height were measured using a tape measure from the stem base to the tip of top most leaf. Six plants were tagged from each plot and data was recorded after 20, 30 and 45 days after sowing. The number of tillers was determined using twenty randomly selected plants at 20, 30 and 45 days after sowing. The crop was harvested at physiological maturity at the end of July 2015 for first season, end of December during second season and the number and weight of panicles from the net plot were recorded. The panicles from each net plot after weighing were dried, threshed separately, winnowed and all the dirt removed. One thousand grains for each plot were counted physically and their weights recorded. The grain yield from the net plot of every experimental unit was weighed and recorded at 13.5% moisture content.

2.5 Statistical Analysis

Data collected were compiled, cleaned and tabulated for statistical analysis. The data was then subjected to one-way ANOVA using GenStat version 15.1 to determine treatment effect. Tukeys Test was used to separate means at 5% probability level.
3. RESULTS AND DISCUSSION

3.1 Plant Height

There was an exponential increase in height between 20 and 30 days after sowing in all the treatments. In season one, at 20 days after sowing (DAS), use of all the herbicides in weed control resulted significantly (p < 0.001) higher plant height compared to no weeding and hand weeding. Although the performance of Atrazine at 1.0L in season two was significantly better than no weeding it was similar to that of hand weeding (p ≤ 0.001), with majority of herbicides at different rates giving significantly taller plants than both hand weeding and no weeding (Table 1). At 45 DAS of season two, the height of finger millet plants grown in plots treated with Metribuzin2.0L, Metribuzin1.5L, Pendimethalin 1.0L, Atrazine2.0L, Atrazine1.5L, 2,4D2.0L, 2,4D1.5L and Pendimethalin1.5L was significant (p<0.001) than finger millet plants grown in plots where Atrazine1.0L, Metolachlor1.0L, Pendimethalin2.0L, 2,4D1.0L, Metolachlor1.5L, Metolachlor2.0L, hand weeding and no weeding (Table 3).

The increased finger millet heights in herbicide treated plots could be due reduction in crop weed competition [7]. Crops could have got enough space for air, light interception, root growth and nutrient acquisition which led to maximum growth as reported by [8]. Early growth stages of finger millet if subjected to a lot of weed infestation leads to decline in the growth and productivity of the crop, hence it is important to control the weeds during the critical period [9].

3.2 Tiller Development in Finger Millet

There was significant difference between the weedy check and other control methods (p<0.05). The tillering of finger millet plants under no weeding was very poor. In addition, both Pendimethalin and 2, 4-D at 1.0L, 1.5L, and 2.0L and Metribuzin at 1.5L resulted in the highest number of tillers per plant (Fig. 1). Similar results were reported by Pradhan et al. (2010) who reported that there as more tillering in finger millet where chemical control and hand weeding was applied than the weedy check. Also Shanmugapiyra, (2019) reported that there were enhanced growth attributes like plant height and tillers in finger millet where pre emergence herbicides like bensulfuron methyl 60 g/ha + pretilachlor 600 g/ha fb EPOE bispyribac sodium 25 g/ha were applied and were comparable to hand weeding during the critical weed free period (Fig. 1).

Table 1. Effects of different weed control practices on growth of finger millet in height (cm)

| Treatments       | 20 DAS | 30 DAS | 45 DAS |
|------------------|--------|--------|--------|
| No weed          | 15.33f | 31.57e | 35.57a |
| Hand weed        | 15.93ef| 31.63de| 36.27a |
| Atrazine1.0L     | 16.00de| 31.50e | 36.00a |
| Metolachlor1.0L  | 16.07cde| 30.57g| 35.50a |
| Pendimethalin2.0L| 16.13bcde| 31.93cd| 36.53a |
| 2,4D1.0L         | 16.50abcde| 32.97b| 36.00a |
| Metolachlor1.5L  | 16.53abcde| 31.00f| 36.07a |
| Metolachlor2.0L  | 16.57abcde| 31.00f| 36.43a |
| Pendimethalin1.5L| 16.63abcd| 31.67cde| 36.03a |
| Metribuzin1.0L   | 16.70abc| 31.97cd| 36.07a |
| Metribuzin2.0L   | 16.77ab| 31.97cd| 36.50a |
| Metribuzin1.5L   | 16.77ab| 31.53e| 36.53a |
| Pendimethalin1.0L| 16.80a| 31.47e| 36.03a |
| Atrazine2.0L     | 16.83a| 32.00c| 36.73a |
| Atrazine1.5L     | 17.00a| 31.50e| 36.53a |
| 2,4D2.0L         | 17.03a| 33.50a| 36.03a |
| 2,4D1.5L         | 17.03a| 33.00b| 35.70a |
| SED              | 0.1706| 0.0905| 0.3377 |
| LSD              | 0.34  | 0.18   | 0.68   |
| P values         | < 0.001| 0.008  | 0.573  |

Treatments with different letters in the same column are significantly different at 5%
Table 2. Effects of different weed control practices on growth of finger millet in height (cm) season two

| Treatment               | 20 DAS | 30 DAS    | 45 DAS   |
|-------------------------|--------|-----------|----------|
| No weed                 | 15.03g | 30.03ghi  | 33.73g   |
| Hand weed               | 15.87ef| 31.67cd   | 35.37de  |
| Atrazine 1.0L           | 15.93ef| 30.30ghi  | 35.03e   |
| Metolachlor 1.0L        | 16.03de| 29.93hi   | 34.50f   |
| Pendimethalin 2.0L      | 16.23cd| 31.00ef   | 35.57cd  |
| 2,4D 1.0L               | 16.03de| 32.43b    | 35.03e   |
| Metolachlor 1.5L        | 16.47bc| 30.03ghi  | 35.07e   |
| Metolachlor 2.0L        | 16.00de| 29.50i    | 35.00e   |
| Pendimethalin 1.5L      | 16.53b | 30.57fg   | 36.00bc  |
| Metribuzin 1.0L         | 16.23cd| 30.00hi   | 34.97e   |
| Metribuzin 2.0L         | 16.53b | 31.07ef   | 36.37ab  |
| Metribuzin 1.5L         | 16.50b | 31.07ef   | 36.00bc  |
| Pendimethalin 1.0L      | 16.47bc| 31.47de   | 36.00bc  |
| Atrazine 2.0L           | 16.83a | 31.00ef   | 36.53a   |
| Atrazine 1.5L           | 17.03a | 30.10gh   | 36.00bc  |
| 2,4D 2.0L               | 16.47bc| 31.00ghi  | 36.00bc  |
| 2,4D 1.5L               | 15.70f | 33.03a    | 35.70cd  |
| SED                     | 0.0642 | 0.1482    | 0.1185   |
| LSD                     | 0.13   | 0.3       | 0.24     |
| P values                | <0.001 | <0.001    | <0.001   |

Treatments with different letters in the same column are significantly different at 5%

Fig. 1. Number of tillers across weed control treatments

Usually finger millet crop is free tillering especially when there is less competition of nutrients and other growth factors with weed. The good tillering under herbicide use was due to lower weed density and weed biomass caused low crop-weed competition and thus the crop plant fully utilized nutrients, moisture, space and light hence leading to production of more tillers.
Also, the increase in the number of tillers could be attributed to increased photosynthetic efficiency of finger millet as reported by [11] in kodo millet. The least tillering was observed at weedy check and this could be attributed to weeds competed for nutrients with the crop thus reducing its potential and eventually low yields [12, 13 and 14].

3.3 Yield of Finger Millet

The number of panicles averaged 84 in number except in the control under which produced significantly lower number of 63 compared to the 84-85 in other weed management methods (p<0.05) during the first season. Finger millet under Pendimethalin1.5L gave the highest number of 86 panicles which was significant (p<0.05) than other weed control methods. In terms of unthreshed weight yield, Atrazine2.0L and Pendimethalin1.5L methods of weed control, had significantly higher weight compared to all the other treatments (p<0.05) (Table 3).

The high yields achieved using pendimethalin could be attributed to the high number of tillers. Prashanth Kumar [15] and Prithvi [16]. Also increase of the yields in weeded plots was due to increased production and translocation of photosynthates to grains, due to adequate availability of growth resources which resulted of less competition offered by weeds. Rawat [17]. Increase in yield parameters in weeded plots is associated with better nutrition and increased nutrient uptake which result in better and healthy plant growth and development, leading to greater dry matter production and its translocation to the sink.

The panicle yield in the plots which were not weeded was small and this could be attributed to weeds compete with the crop for nutrients, water and space leading to the significant reduction in the number of panicles. Weeds compete with crop plants for water, nutrients, space, and solar radiation [18].

3.4 Weight of Threshed Grains and a Thousand Grain Weight

There was significance between the weights of un threshed panicles among the treatments (p<0.05). The weight of threshed grains ranged from 3.2 t ha⁻¹ to 5.5 t ha⁻¹ where by the unweeded plot and pendimethalin treated plots gave the least and highest yields respectively. (Table 5). Pendimethalin at 2.0,1.5 and 1.0 l/ha gave the yields of 5.4, 5.5 and 5.5 t ha⁻¹ respectively, this was followed by Atrazine which

| Treatment             | Number of panicles | Unthreshed Weight (Kg) |
|-----------------------|--------------------|------------------------|
| No weed               | 63.00c             | 0.84d                  |
| 2,4D1.0L              | 84.00b             | 1.61c                  |
| Metribuzin1.0L        | 84.00b             | 1.66c                  |
| Metolachlor1.0L       | 84.00b             | 1.6c                   |
| Hand weed             | 84.00b             | 1.60c                  |
| Atrazine1.5L          | 84.00b             | 1.77ab                 |
| 2,4D2.0L              | 84.33ab            | 1.6c                   |
| 2,4D1.5L              | 84.33ab            | 1.59c                  |
| Pendimethalin1.0L     | 84.33ab            | 1.80a                  |
| Atrazine1.0L          | 84.33ab            | 1.78a                  |
| Pendimethalin2.0L     | 84.67ab            | 1.84a                  |
| Metribuzin2.0L        | 84.67ab            | 1.64c                  |
| Metribuzin1.5L        | 84.67ab            | 1.67bc                 |
| Metolachlor2.0L       | 84.67ab            | 1.78a                  |
| Metolachlor1.5L       | 84.67ab            | 1.68bc                 |
| Atrazine2.0L          | 84.67ab            | 1.78a                  |
| Pendimethalin1.5L     | 86.33a             | 1.82a                  |
| SED                   | 0.5557             | 0.0249                 |
| LSD                   | 1.13               | 0.05                   |
| P values              | 0.004              | 0.004                  |

Treatments with different letters in the same column are significantly different at 5%
Table 4. Effects of different weed control practices on number of panicles and unthreshed weight

| Treatment           | Number of panicles Season 2 | Unthreshed Weight (Kg) Season 2 |
|---------------------|------------------------------|---------------------------------|
| No weed             | 60.33c                       | 0.79i                           |
| 2,4D1.0L            | 81.33a                       | 1.68defg                        |
| Metribuzin1.0L      | 81.00a                       | 1.69cdef                         |
| Metolachlor1.0L     | 81.33a                       | 1.70cde                         |
| Hand weed           | 81.00a                       | 1.57h                           |
| Atrazine1.5L        | 81.67a                       | 1.77ab                          |
| 2,4D2.0L            | 80.67ab                      | 1.63gh                          |
| 2,4D1.5L            | 82.33a                       | 1.64fg                          |
| Pendimethalin1.0L   | 80.67ab                      | 1.72bcd                         |
| Atrazine1.0L        | 80.67ab                      | 1.79a                           |
| Pendimethalin2.0L   | 78.33b                       | 1.77a                           |
| Metribuzin2.0L      | 80.67ab                      | 1.65efg                         |
| Metribuzin1.5L      | 81.67a                       | 1.67defg                        |
| Metolachlor2.0L     | 82.00a                       | 1.73abc                         |
| Metolachlor1.5L     | 80.33ab                      | 1.68cdef                        |
| Atrazine2.0L        | 80.00ab                      | 1.77ab                          |
| Pendimethalin1.5L   | 80.67ab                      | 1.78a                           |
| SED                 | 0.695                        | 0.0144                          |
| LSD                 | 1.41                         | 0.02                            |
| P values            | <0.001                       | <0.001                          |

Treatments with different letters in the same column are significantly different at 5%

Table 5. Effects of different weed control practices on threshed and a thousand grain weight

| Treatment           | Threshed grain weight(Kg) Season 1 | Thousand grain weight(Kg) Season 1 |
|---------------------|------------------------------------|------------------------------------|
| No weed             | 0.51f                              | 1.54c                              |
| Metribuzin1.0L      | 0.76e                              | 2.26ab                             |
| 2,4D1.5L            | 0.77de                             | 2.24ab                             |
| Metribuzin1.5L      | 0.77de                             | 2.19ab                             |
| 2,4D2.0L            | 0.78de                             | 2.24ab                             |
| 2,4D1.0L            | 0.78de                             | 2.26ab                             |
| Metribuzin2.0L      | 0.78de                             | 2.22ab                             |
| Metolachlor1.0L     | 0.81cd                             | 2.27ab                             |
| Hand weed           | 0.81cd                             | 2.03b                              |
| Metolachlor1.5L     | 0.83bc                             | 2.24ab                             |
| Atrazine1.5L        | 0.84bc                             | 2.15ab                             |
| Atrazine1.0L        | 0.84bc                             | 2.12ab                             |
| Atrazine2.0L        | 0.85abc                            | 2.25ab                             |
| Metolachlor2.0L     | 0.86ab                             | 2.27ab                             |
| Pendimethalin2.0L   | 0.87ab                             | 2.30a                              |
| Pendimethalin1.5L   | 0.88ab                             | 2.24ab                             |
| Pendimethalin1.0L   | 0.89a                              | 2.11ab                             |
| SED                 | 0.0122                             | 0.0643                             |
| LSD                 | 0.02                               | 0.13                              |
| P values            | 0.031                              | 0.166                              |

Treatments with different letters in the same column are significantly different at 5%
Table 6. Effects of different weed control practices on threshed and a thousand grain weight

| Treatment        | Season 2 Threshed grain weight(Kg) | Season 2 Thousand grain weight(Kg) |
|------------------|------------------------------------|------------------------------------|
| No weed          | 0.50h                              | 1.40f                              |
| Metribuzin 1.0L  | 0.75fg                             | 2.13abc                            |
| 2,4D 1.5L        | 0.76fg                             | 2.12abcd                            |
| Metribuzin 1.5L  | 0.74g                              | 2.16ab                             |
| 2,4D 2.0L        | 0.77efg                            | 2.14abc                            |
| 2,4D 1.0L        | 0.76fg                             | 2.09abcde                           |
| Metribuzin 2.0L  | 0.78def                            | 2.17a                              |
| Metolachlor 1.0L | 0.79cdef                            | 2.15ab                             |
| Hand weed        | 0.80bcde                           | 2.00de                             |
| Metolachlor 1.5L | 0.82abc                            | 2.15ab                             |
| Atrazine 1.5L    | 0.81bcde                           | 2.04bcde                           |
| Atrazine 1.0L    | 0.80bcde                           | 1.98e                              |
| Atrazine 2.0L    | 0.82abcd                           | 2.16ab                             |
| Metolachlor 2.0L | 0.83ab                             | 2.18a                              |
| Pendimethalin 2.0L | 0.83ab                         | 2.12abcd                            |
| Pendimethalin 1.5L | 0.83ab                            | 2.02cde                            |
| Pendimethalin 1.0L | 0.84a                             | 2.11ab                             |
| SED              | 0.0100                             | 0.0346                             |
| LSD              | 0.02                               | 0.07                               |
| P values         | <0.001                             | <0.001                             |

Treatments with different letters in the same column are significantly different at 5%

ranged between 5.2 to 5.2 t ha\(^{-1}\), Metolachlor between 5.0 to 5.3 t ha\(^{-1}\), Hand weeding 5.0 t ha\(^{-1}\), Metribuzin 4.8 to 4.9 t ha\(^{-1}\) and 2,4 D 4.8 to 4.9 t ha\(^{-1}\) (Table 5). A similar trend was observed in both seasons even though in the second season, the yields were slightly lower than the first season. The results are in conformity whit the findings of [19] who reported that application of pre emergence application of herbicides over weedy check even though a thousand grain weight was not affected by weed management practices.

The unweeded plots gave the least weight of the threshed grains due to weed infestation critically reduced grain yield of finger millet due to competition for growth factors like light, nutrients, and moisture. According to [20] obtained negative correlation of weed dry weight and grain yield in finger millet.

The weights of a thousand grains across the treatments ranged from 1.54 grams being that of unweeded crop to 2.307 grams being that of the crop where pendimethalin 2.0L/ha was applied (Table 5). This indicates that weeds indeed decrease both the quality and quantity of the produce because of competition for nutrients with the crop. In the other treatments the weights averaged at about 2 grams indicating that the control of weeds was good across all the herbicides which were applied including hand weeding. Pendimethalin was most effective in control of weeds thus giving higher yields and heavier a thousand grain yields confirming [4] that use of herbicides like Pendimethalin controls a wide spectrum of weeds which in turn gave higher grain weight because since the weeds had been controlled effectively. It was observed that the lowest grain weight was recorded from the unweeed plot and these results are in conformity with the findings of [21 and 22].

4. CONCLUSION

Pendimethalin and Atrazine pre-emergence herbicides at the rates of 1.5 and 2.0 L/ha respectively were the most effective in terms of weed control since they lead to enhanced crop growth and high yields among the treatments.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.
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