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Weed Control Practices and Inter-Row Spacing Influences on Weed Density and Grain Yield of Finger Millet (*Eleusine Coracana* L. Gaertn) in the Central Rift Valley of Ethiopia

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ABSTRACT

Weeds are one of the major constraints limiting finger millet productivity and production. Field experiment was conducted on weed control practices and inter-row spacing influences on weed density and grain yield of finger millet at Arsi Negelle during 2011 and 2012 cropping seasons. The objective of the study was to determine the influences of weed control practices, inter-row spacing and their interactions on weed density and grain yield of finger millet. The experiment was laid out in randomized complete block design in factorial arrangement using three replications. The treatment combination was four levels of inter-row spacing (30 cm, 40cm, 50 cm and 60 cm) and four levels of weed control practices (no weeding, one hand weeding (at 20 days after emergence), two hand weeding (at 20 and 40 days after emergence) and post-emergence herbicide (2, 4-D at 0.72 kg ha $^{-1}$) + hand weeding (at 40 days after emergence). *Galinsoga parviflora* was found to be the most dominant weed species affecting finger millet yield. Significant differences were observed at 5% probability among weed control practices and inter-row spacing on total weed density, weed biomass, grain yield, and plant height, finger per plant and crop biomass. The study indicated that 82% yield reduction was recorded from weedy plot. Twice hand weeding at 20 and 40 days after emergence resulted in the highest grain yield (3.42 t ha $^{-1}$) of finger millet. The highest yield was obtained from 40 cm inter row spacing; while the lowest grain yield was obtained from 60 cm inter-row spacing. There was no significant interaction effect of weed management practices by inter-row spacing. The narrower inter-row spacing resulted in reduced weed density and weed biomass as compared to wider inter row spacing. Therefore, the combination of twice hand weeding at 20 and 40 days after emergence and 40cm inter-row spacing was found to be good to manage weed problem and prevent significant yield loss. Moreover, the application of post-emergence herbicide (2, 4-D at 0.72 kg ha $^{-1}$) + hand weeding at 40 days after emergence with 40 cm inter-row spacing also reduce weed infestation and give good yield.

Keywords: Finger millet, interaction, inter-row spacing, weeds, weed control practice

INTRODUCTION

Finger millet *(Eleusine coracana)* is cultivated in drier parts of the world mainly in Asia and Africa. It is an important dry land crop due to its resilience and ability to withstand aberrant weather conditions and generally grown in soils having poor water supplying capacity and nutrients. Moreover, the crop has high impact on the poor in Africa for food security and source of energy and protein for millions of people in Sub-Saharan Africa [2,18]. In Ethiopia, finger millet is the 6th important crop after teff, wheat, maize, sorghum and barley. It comprises about 5 percent of the total land devoted to cereals. It is produced on 368,999.15 ha of land, from which 524, 191.1 tons are obtained at national level. It is mainly grown in North Gondar, West Gojam, some parts of Tigray and West Wollega [7]. The acreage under finger millet is increasing from year to year. Areas where the crop has not been known earlier such as the Central Rift Valley, South Central and parts of Eastern Ethiopia have seen increased production of the crop since 2001 [3,6]. Generally the production of finger millet is still at subsistence level by small scale holders and consumed as staple food and drink in most areas.

Finger millet is one of the most nutritious all of the world's major cereal crops [17]. The grain of finger millet is high in amino acid, lacking in the diets of the poor who live on starchy foods. It is also a rich source of Calcium, Iron, Protein, Fiber and other minerals which are all crucial for human health. The cereal has low fat content and contains mainly unsaturated fat. It is easy to digest and does not contain gluten; people who are sensitive to gluten can easily consume finger millet. In addition to its nutritive value to humans, the straw is used as feed for animals and for roof thatching. Finger millet has no major storage pest problems and can be stored cheaply for long periods, provided it is dried well to low moisture content. These finger millet attributes combine to make it a suitable crop for ensuring food security in drought prone areas.

Finger millet yield in Ethiopia is lower as compared to the potential yield of the crop. Weeds are considered as one of the major problems the farmer is faced with in the production of the crop. Finger millet has very poor competitive ability with weeds due to its initial slow growth. Since single method is not able to control all weeds up to desired level, integration of weed control practice and cropping system can be an effective weed control strategy. In an integrated approach, the development of cropping systems such as appropriate inter-row spacing will help crops themselves to compete with weed. Several reports indicated that crops planted in narrow row spacing suppress weed growth more than when planted in wide row spacing [13,14,16]. In spite of the crop importance, information on weed management practices in finger millet is limited. Hence, this study aimed at determining the separate and interaction influences of control practices, inter-row spacing and their interactions on yield and weed density of finger millet.

MATERIALS AND METHODS

Experimental Site Description

This experiment was conducted at Arsi Negele, West Arsi, Central Rift Valley of Ethiopia during 2011 and 2012 cropping seasons. It is situated at about 228 km South of Addis Ababa on the way to Shashemene. It is located at an elevation of 1960 m above sea level with latitude of 07°24' N and longitude of 38°09' E. The average annual rainfall in the area is 782 mm. which is erratic and uneven in distribution. The site has a mean maximum temperature of 25.2°C and mean minimum temperature of 12.4°C. The soil texture was clay loam with pH, bulk density, cation exchange capacity, total nitrogen and organic carbon of 6.5-7.5, 1.10, 20.48 – 22.23 Cmol kg^{-1}, 0.11 % - 0.14 % and 1.27 % - 1.35 % respectively.

Treatments and Experimental Design

The treatments consisted of the combination of four levels of inter-row spacing (30cm, 40cm, 50cm and 60cm) and four levels of weed management practices (no weeding, one hand weeding at 20 days after emergence, twice hand weeding at 20 and 40 days after emergence and post-emergence herbicide 2, 4-D at 0.72 kg ha^{-1}plus supplementary hand weeding at 40 days after emergence. The experiment was laid out in randomized complete block design in factorial arrangement with three replications. The gross plot size was 3 × 5 meters. Each plot and blocks were separated by 1.5m and 2m path, respectively. The land was prepared to fine tilt by tractor in early May. The plots was prepared as per the layout and leveled manually. The sowing was done by mid-May; crop variety Tadesse was drilled in furrows manually and the plants were thinned two weeks after emergence. Intra row spacing of 10cm was considered for all plots. 100 kg ha^{-1} of DAP and 50 kg ha^{-1} of Urea were applied at planting and prior to tillering respectively. The hand-pulling and hoeing as per the treatment was done in assigned plots at an appropriate time. The post-emergence herbicide (2, 4-D at 0.72 kg ha^{-1}) applied at 20 days after emergence with backpack sprayer with spray volume of 400 L of water. Hand-pulling and hoeing as per the treatment was done in the assigned plots at an appropriate time.

Data Collection

Weed: Weed density and biomass were collected four weeks prior to harvest of the crop. The weed species found in check plots were identified and recorded. The weed count was recorded species wise using 0.5m × 0.5m quadrant from four random places in each plot. The weeds falling within the frames of the quadrant were counted and each species sum value was expressed in number m^{-2}. In case of weed dry weight all weeds within the sample quadrants were cut from the ground level from each plot separately, dried under sun and their dry matter was measured. The dry weight was expressed in g m^{-2}. The Relative Weed Density (RWD) of each species was calculated with the help of the following formula:

$$RWD = \frac{NIW \times 100}{NTW} \quad [5]$$

Where: RWD = Relative weed density, NIW = Number of individual weed species in quadrant, NTW= Number of total weed species in quadrant

Weed Control Efficiency (WCE) was also calculated on the basis of dry matter production of weeds as per the procedure [4, 11]

$$WCE = \frac{WDC - WDT \times 100}{WDC}$$

Where: WCE= weed control efficiency (%), WDC= weed dry weight (g m^{-2}) in weedy check, WDT= weed dry weight (g m^{-2}) in treated plot,

Crop: Plant height, number of effective fingers per plant, 1000 grain weight, and grain yield and crop biomass were determined. A sample of ten plants was taken at random from the inner rows of each experimental unit and some yield components such as plant height and number of effective finger were taken at crop maturity stage. The inner rows were harvested, threshed and 1000 grains were counted from the bulk of threshed produce and their weight was recorded. Grain yield and crop biomass per plot was measured. Grain yield and crop biomass obtained from plots per hectare was calculated based on harvestable plot size.

Statistical Analysis

Collected data were subjected to the analysis of variance (ANOVA) using SAS Version 9.0 software [15]. Whenever treatment effects were significant, mean separation was made using the SNK test at five per cent probability level. Such of those treatments where the difference were not significant were denoted as NS.

RESULTS AND DISCUSSION

Weed Species Composition

The experimental field was found to be infested both with broadleaved and grassy weeds belonging to five families. *Ageratum conyzoides*, *Commelina benghalensis*, *Erucastrum arabicum*, *Galinsoga parviflora* and *Nicandra physalodes* were dominant among broadleaf weeds, while *Elusine indica*, *Digitaria ternata*, *Eragrostis aspera* and *Sorghum arundinaceum* were the dominant grass weeds. The relative density of broad leaved weeds (67 %) was more than that of grass weeds (33%). The maximum relative weed density was recorded from *Galinsoga parviflora* which was the most dominant weed species that contributed 41% of the total weed population (Table 1).

Table 1. *Weeds species and their relative density (%) recorded in the experimental field*

Family	Scientific Name	Common Name	Class	*RWD (%)
Asteraceae	*Ageratum conyzoides* L.	Goat weed	Dicotyledon	2.00
Commelinaceae	*Commelina benghalensis* (L.)	Wandering jew	Dicotyledon	3.00
Poaceae	*Digitaria spp*	-	Monocotyledon	10.00
Poaceae	*Elusine indica* (L.) Gaertner	Goose Grass	Monocotyledon	12.00
Poaceae	*Eragrostis aspera*	Rough Love grass	Monocotyledon	7.00
Brassicaceae	*Erucastrum arabicum*	-	Dicotyledon	9.00
Asteraceae	*Galinsoga parviflora* Cav.	Gallant solder	Dicotyledon	41.0
Solanaceae	*Nicandra phayaslodes* (L.) Gaertner	Apple of Peru	Dicotyledon	12.00
Poaceae	*Sorghum arundinaceum* (Desv.) Stapf	Johnson Grass	Monocotyledon	4.00

**RWD-Relative weeds density*

The significant features of this weed, such as the lack of seed dormancy, rapid growth and development, early flowering, many generations per growing season, production of a great number of seed in a wide range of environmental circumstances, and the ability for easy vegetative reproduction under favorable conditions predispose the plant to be a troublesome weed. These features allow the easy distribution and rapid establishment of the weed in large populations, a fact that often makes this weed difficult to control.

Effect of Weed Control Practices

All weed management practices had significantly lower total weed density, weed biomass and highest weed control efficiency as compared to weedy check treatment (Table 2). The lowest total weed density (51.00 plant m^{-2}) and weed dry weight (166.00 g m^{-2}) was recorded when twice hand-weeding at 20 and 40 days after emergence were done. The reduction of weed density and biomass was due to the removal of weeds twice from plots at early weed emergence and at tillering phase that decreases weed infestation and enhances crop competition. Highest weed control efficiency (87%) was also found in the same treatment. Higher total weed density (473.00 no. m^{-2}) and weed biomass (1261.00 g m^{-2}) was obtained from weedy check.

Table 2. *Influences of weed control practices and inter row spacing on weed density, weed biomass and weed control efficiency (WCE)*

Weed Management Practices (WMP)	Weed Density (no. m^{-2})	Weed Biomass (g m^{-2})	WCE (%)
No weeding	473.00^{a}	1261.00^{a}	-
One hand weeding	141.00^{b}	545.00^{b}	57.00
Twice hand weeding	51.00^{d}	166.00^{d}	87.00
2,4-D at 0.72 kg ha^{-1} plus hand weeding	67.00^{c}	218.00^{c}	83.00
Inter row spacing (IRS)			
30cm	64.00^{d}	229.00^{d}	82.00
40cm	72.00^{c}	265.00^{c}	79.00
50cm	98.00^{b}	349.00^{b}	72.00
60cm	111.00^{a}	396.00^{a}	69.00
WMP* IRS	ns	ns	
Mean	86.10	310.00	
CV (%)	8.98	9.52	

The grain yield differed significantly ($p \leq 0.05$) due to management practices (Table 3). Twice hand weeding (hand pulling and hoeing) at 20 and 40 days after emergence recorded significantly higher grain yield (3.42t ha^{-1}). The creation of weed suppressive environment for crops helped to check the growth of the weeds. It also suppressed the weed growth for a longer period, led to improvement in growth and yield parameters. It might be attributed to the reduction in weed competitiveness with the crop as compared to weedy check.

The result is in conformity with the work by [10] and [9] that states the critical period of weed competition between the periods 25-45 after sowing for finger millet. Weedy check gave the lowest grain yield (0.63 t ha^{-1}) and lowered the grain yield by 82 percent. Weeds are naturally strong competitors and compete with crops for space, nutrient, moisture, light and carbon dioxides, that they could reduce the straw and grain accumulation [8,12]. Similarly, higher crop biomass (18.23 t ha^{-1}) was obtained from twice hand weeding. This higher dry matter of plant was supported by higher dry matter accumulation in leaf and stem. The reduced competition and increased availability of resources paved way for longer plant height and higher leaf area and consequently increased the biomass of the crop. In addition the weedy check reduced height, number of tillers and finger per plant plus crop biomass significantly (Table 3). Similar results were also reported by [9] confirming the present findings.

Table 3. *Influences of weed control practices and inter row spacing on yield and yield components of finger millet*

Weed Management Practices (WMP)	Height (cm)	Finger per Plant	1000 Grain Wt. (gm)	Grain Yield (t ha^{-1})	Crop biomass (t ha^{-1})
No weeding	73.00^{d}	7.00^{d}	4.60^{c}	0.63^{d}	4.50^{d}
One hand weeding	86.21^{c}	12.00^{c}	5.07^{a}	1.86^{c}	10.68^{c}
Twice hand weeding	96.15^{a}	24.00^{a}	5.52^{a}	3.42^{a}	18.23^{a}
2,4-D at 0.72 kg ha^{-1} plus hand weeding	91.61^{b}	19.00^{b}	5.45^{b}	2.97^{b}	16.00^{b}
Inter row spacing (IRS)					
30cm	92.52^{a}	18.67^{a}	5.34^{a}	2.99^{b}	16.14^{a}
40cm	94.30^{a}	26.67^{b}	5.43^{a}	3.24^{a}	17.22^{a}
50cm	89.66^{a}	14.44^{c}	5.30^{a}	2.48^{c}	13.98^{b}
60cm	88.81^{a}	13.78^{c}	5.30^{a}	2.18^{d}	12.54^{b}
WMP* IRS	ns	ns	ns	ns	ns
Mean	91.00	18.00	5.34	2.75	15.00
CV (%)	12.83	8.00	3.20	8.05	9.30

Effect of Inter-Row Spacing

Significant differences in weed species distribution were observed due to inter- row spacing variation. The narrower (30cm) inter row spacing resulted in reduced weed density and biomass and increased weed control efficiency as compared to wider (60cm) inter row spacing (Table 2). The significant reduction in weeds densities with the decrease in row spacing showed that under narrower spacing, the non-availability of enough space to the weeds might have become a limiting factor resulting in lower densities compared to wider spacing. The ground is shaded sooner in narrow rows and weed development is suppressed and their densities decreasing from 60cm to 30cm inter-row spacing. Weed infestation was decreased from 82% in wide inter row to 69% in narrow inter row. This finding is in agreement with the work of [1] who stated that as availability of lesser space for weed development, better crop competition for development resources, crop growth, early space covering, light interception might have effectively controlled weeds and decreased weeds density and biomass.

Significant difference in yield was also observed due to inter row spacing variation. Higher grain yield (3.24 t ha^{-1}) and crop biomass (17.22 t ha^{-1}) was recorded in 40 cm inter-row spacing compared to wider row spacing (60cm) with grain yield and biomass yield of 2.18 t ha^{-1} and 12.54 t ha^{-1} respectively (Table 3). This variation was accounted for a number of productive tiller per plant and number of fingers per tiller. The grain yield obtained from the narrower (30cm) inter row spacing is lower than the yield and crop biomass obtained from 40cm inter-row spacing. This reduction might be due to finger millet plants competition between rows. In general, yield of narrower inter-row spacing (30cm and 40cm) had shown increment over wider row spacing (50cm and 60cm). This might be due to high density of crop in narrower inter row spacing resulting in lower weeds infestation which was suppressed by crops.

Interactive Effect of Weed Control Practices and Inter-Row Spacing

The interactive effect of different weed control practices and inter-row spacing showed non-significant difference at 5% probability for weed density, weed biomass, plant height, finger per plant, grain yield, crop biomass and 1000 seed weight (Table 3).

CONCLUSION

Weeds are one of the major constraints limiting finger millet productivity and production. According to the result of this study up to 82% yield loss could be occurred by leaving weeds unchecked. The lowest weed density and weed biomass was recorded from twice hand weeding at 20 and 40 days after emergence resulted in the highest yield as compared to other control practices. The narrower inter row spacing (40cm) also resulted in reduced weed density, weed biomass and highest yield as compared to wider inter row spacing. Thus twice hand weeding at 20 and 40 days after emergence and

40 cm inter row spacing could be the best combination to reduce infestation of weeds and increase the yield of finger millet. Furthermore, the application of post-emergence herbicide (2,4-D at 0.72 kg ha^{-1}) + hand weeding at 40 days after emergence with 40 cm inter-row spacing also reduce weed infestation and give good yield.

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