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Effects of Intercropping Finger Millet (*Eleusine coracana*) with Common Beans (*Phaseolusvulgaris*) on Weed Management in Finger Millet in Trans Nzoia County, Kenya

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Abstract

Weed infestation is considered as one of the most important constraints affecting finger millet production causing significant yield losses. Weed management is a critical component of any farming system. Management of weeds is important for enhancing the production of finger millet. Recent research efforts suggested that intercropping legumes with cereals can have potential for weed suppression and may decrease the need to use herbicides. This study was aimed at evaluating theeffects of intercropping finger millet (Eleusine coracana) with common beans (Phaseolusvulgaris) on weed managementin finger millet in Trans - Nzoia County, Kenya. Field experiments were conducted on- farm at Kiminini Sub-County in Trans-Nzoia County. The treatments were laid out in a Randomized Complete Block Design (RCBD) over two seasons (2020 short rains and 2021 long rains season). The three improved finger millet varieties (Gulu- E, U-15 and P-224) and common bean variety (Rosecoco) were used. Each finger millet variety was grown in monoculture and intercropped with beans. The treatments were replicated three times giving a total of 27 plots. The plots measured 1.8m x 1.5m each and a path of 1m was used to separate one plot from the other. Parameters that were recorded during the growing season on weeds included; weed type, weed count and weed biomass. Data collected was subjected to analysis of variance (ANOVA) to determine the effects of seasons, treatments and their interaction using the mixed procedure of SAS (Institute 2012) software. The means of seasons, treatments and their interaction were compared by least significance difference at p< 0.05. The weedy treatments recorded the highest weed count and weed biomass. Finger millet-bean intercrop recorded the lowest valuesof weed count and weed biomass. The long rains season recorded significantly higher weed biomass than the short rains season. Intercropping was superior to monocropping in terms of smothering weeds. Small scale farmers in Trans-Nzoia County should be encouraged to grow finger millet varieties intercropped with common bean to assist in weed suppression and improve finger millet yield.

Keywords: Weed, Intercropping, Herbicides, *Eleusine coracana, Phaseolusvulgaris*

INTRODUCTION

Finger millet (*Eleusine coracana*) is one of the most important staple food crops in Kenya. Finger millet grain is the basic foodstuff for farm households in the worlds' poorest countries and among the poorest people. The crop is a highly nutritious, and versatile grain that would be worthy adding to ones' diet (Shadang et al., 2014).

Finger millet is an important crop in tropical regions of the world due to its resistance to pests and diseases, short growing season and productivity under hardy and drought conditions when major cereals cannot be relied upon to provide sustainable yields (Gebreyohannes et al., 2021; Sood et al., 2019; Devi et al., 2014). The crop was domesticated in Western Uganda and Ethiopia highlands at least 5000 years ago before introduction to India (Ouma, 2016). Finger millet is majorly grown in semi-arid tropics of Asia and Africa (Antony, 2018)

In Kenya, the adoption of improved finger millet varieties is reported to have reduced poverty and enhanced food security inmost parts includingTrans-Nzoia County, where the crop is considerably popularized. The result is increased production that meets farmer's household requirement and surplus that has helped to generate household income (Gitu et al., 2014).

It also has a higher and stable market price when compared to other cereals like maize (Mgonja et al., 2007). In spite of the preference for finger grain in Kenya, its production however is constrained by weeds, pests and diseases among others (Ouma, 2016). Weed competition is a major limiting factor for the productivity of finger millet in Trans- Nzoia County (Gitu et al., 2014). As finger millet is grown predominantly in warm rainy seasons, weeds of different kinds deprive the crop.

Weed management is an important factor for enhancing the productivity of millet, because weeds compete for nutrients, water, light and space; reduce crop yield and quality during the early growth period. Because the crop canopy forms slowly and provide little shading of weeds between the rows until mid-season; by then most weeds are well established (Chandhary et al., 2018).

Weeds cause nearly 37% of the total croploss, every attempt has to be made to contain the weed menace and uphold the production. Weed management takes away nearly one third of the total cost of production of field crops (Fakeerappa et al., 2017). Farmers in Trans- Nzoia County respond to the problem of weeds through various traditional control methods. These methods include use of manure, hand weeding and uprooting of the weeds. However, research findings indicate that these methods are insufficient to control weeds once they have well established on a field (Woomer et al., 2004).

One of the modern approaches in management of weeds in finger millet has been intercropping. Yield production through intercropping is higher than single cropping because in intercropping light, water, and nutrients uptake is more effective than sole cropping pattern (Ali et al., 2016). Intercropping has gained interest because of potential advantages it offers over yielding, that is improved utilization of growth resources by the crops and improved reliability from season to season. When a legume is grown in association with another crop, commonly a cereal, the nitrogen nutrition of associated crop may be improved by direct nitrogen transfer from the legume to the cereal (Bedoussac et al., 2015; Matusso et al., 2014; Dwivedi et al., 2015).

Growing of intercrops in a widely spaced row will not only reduce the intensity of weeds but also gives an additional yield. Chandhary et al. (2012) concluded that intercropping of pearl millet with green grams at 2:2 pair row ratio was clearly superior over sole pearl millet and found most profitable by making the highest net return and LER. While second weeding may be needed in sole crop, this is frequently not required in intercropping since the canopy coverage is nearly complete and weeds growth after the first weeding is minimal (Chaudhary et al., 2018).

In addition, legume intercrops are included in cropping systems because they reduce soil erosion and suppress weeds (Giller & Cadish, 1995). One of the most reliable and less costly approach in controlling weeds in finger millet has been intercropping with common beans (*Phaseolus vulgaris*) (Ali et al., 2016). The common bean (*Phaseolusvulgaris)* is one of the most important legumes in the world because of its commercial value, extensive production, consumer use and nutrient value (Xavery et al., 2006; CABI, 2007). In Kenya, over 75% of rural households depend on beans for home consumption as well as cash crop income. Common beans were used in intercropping since being legumes are able to increase soil nitrogen. Also, beans have an extensive canopy hence the ability to suppress weeds.

Despite the competitive benefits associated with intercrops, the ability of beans to suppress weeds has still not been extensively studied. Although several studies of intercropping have been conducted, there is limited literature published on the effect of intercropping finger millet with common bean on weed management in Trans- Nzoia County. Therefore, the aim of this study was to establish the potential of the common bean when intercropped with finger millet varieties in suppressing weeds to improve the productivity of millet.

METHODOLOGY

Study Site

The field experiments were conducted at Kiminini Sub-County in Trans Nzoia County. The altitude of the site is 1900 m above sea level and it receives an average annual rainfall of 1300 mm with a mean temperature of 24ºC. The site is located in the Upper Mid-land Agro –ecological Zone (UMZ) and is endowed with brown red and brown clay soils derived from volcanic ash. The soils are fertile and have high clay content. Kiminini lies on longitude 34^0 55' 27" E and latitude 0^0 53' 35" N.

Experimental Materials

The experimental materials comprised of three improved varieties of finger millet obtained from the local market. They included; Gulu-E, (It is high yielding, easy to thresh and tolerant to lodging), P-224 (It is early maturing, high yielding and easy to harvest as it grows to knee high in cold areas and up to waist height in warm areas).and U-15 (It is short, early maturing, high yielding and resistant to blast disease) and common bean variety (RosecocoGLP obtained from Kenya Seed Company) which is early maturing and has a higher ability to adapt to the study sites in terms of climate, soil type and soil fertility. This variety also has a restricted height and with fewer leaves. The other attributes considered when selecting this variety for intercropping include; market, nutritional and cooking qualities. This variety is also drought and pest resistant and has a high keeping quality.

Treatments

Each finger millet variety was grown in both monoculture and intercropping with the Rosecoco bean cultivar. The treatments within a replicate include;

i. Finger millet sole crop (Gulu-E) -Weed free

ii. Finger millet sole crop (P-224)- Weed free

iii. Finger millet sole crop (U-15)- Weed free

iv. Finger millet sole crop (Gulu-E) - Weedy

v. Finger millet sole crop (P-224) - Weedy

vi. Finger millet sole crop (U-15) – Weedy

vii. Finger millet (Gulu-E) intercropped with beans

viii. Finger millet (P-224) intercropped with beans

ix. Finger millet (U-15) intercropped with beans.

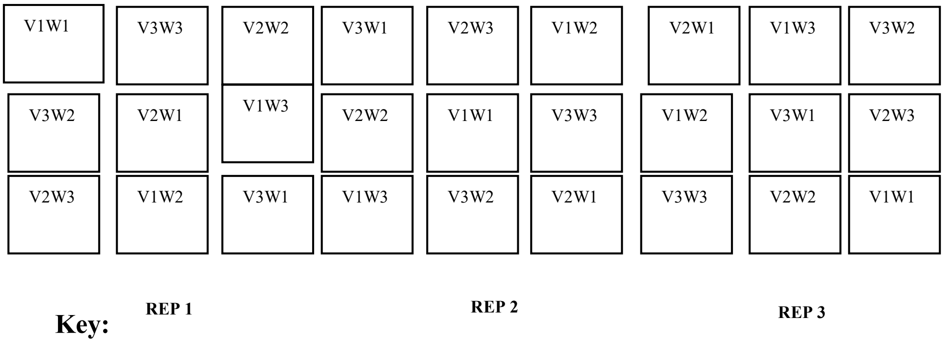
The intercropping pattern that was adopted is the additive series intercropping. The additive pattern holds the plant population of one species constant while varying the other species. In this case the plant population of finger millet was held constant while that of beans was varied.

Experimental Design

The treatments were laid out in a Randomized Complete Block Design (RCBD). The treatments were replicated three times giving a total of 27 plots.

Experimental Layout

The plots measured 1.8mx1.5m each and a path of 0.5 m was used to separate one plot from the other (Figure 1).



Key:

V 1= Gulu-E
V 2 = P -224
V 3 = U - 15
W 1= Weedy
W 2 = Weed free
W 3 = Intercropped

Figure 1: Experimental Layout.

Field Crop Management Practices

Before land preparation all the experimental plots were laid out. The major dominant weed species and their number were recorded from all plots before land preparation. The plots were cultivated by a hand hoe to break the soil and then harrowed before planting. The finger millet was planted in furrows at a spacing of 60 cm x 15 cm. While in the intercrop plots, a row of common beans was planted at the mid of every two rows of fingermillet and the seeds spaced at 15 cm from plant to plant. Two seeds of beans were placed in each hole and then covered with the soil. Fertilizer was applied at planting at the rate of 20 kg P_2O_5 per ha.

Hand weeding was done twice during the growing season, three weeks after emergence and three weeks later to reduce crop weed competition during finger millet's critical growing period. Weeding was done only in the weed free and intercropped treatments. The weedy check plots were left unweeded. After weeding 20 kgN as a top dress for finger millet was applied. Other recommended agronomic practices for production of finger millet and beans were undertaken.

Data Collection

Data was collected at the study site during the two cropping seasons; short rains (September 2020–December 2020) and long rains (March 2021–August 2021) seasons. All data for both finger millet and common bean was collected from plants in the middle rows of each experimental plot. Data collection commenced two weeks from germination and continued till plants matured and harvested.

Weed Assessment Parameters

Before land preparation, the major dominant weed species were determined by counting all the weeds and grouping them by their major groups; broad leaved and narrow leaved. After planting, weeds were identified and counted by species in a marked area of 50 x 50 cm in each plot. The following weed variables were determined;

Weed Type

Weed type was determined by counting the plants of each weed type in a marked area of 50 x 50 cm in each plot and then the number of each weed type recorded.

Weed Count

Weed count was determined by counting and summing the number of plants in a marked area of 50 x 50 cm in each plot and then the total number recorded.

Weed Biomass
The weed biomass was determined by collecting the above and below ground part of the weed species from a marked area of 50 x 50 cm in each plot at maturity stage. Then they were dried at 70^0C for 3 days and weighed in grammes and expressed as weed dry weight per m^2 and the weight was recorded.

Data Analysis
All the data collected on weed variables was subjected to analysis of variance (ANOVA) technique to determine the effects of seasons, treatments and their interaction using the mixed procedure of SAS Institute (2012) software. The means of seasons, treatments and their interaction were compared by least significance difference at $p \leq 0.05$. The results were presented using tables and figures.

RESULTS

Weed Type
The results of analysis of variance showed that treatments significantly ($p \geq 0.05$) influenced weed type (Figure 2). The highest recorded values were of broad-leaved weeds while the lowest values were of narrow-leaved weeds across all the treatments. The highest values of broad-leaved weeds were recorded in Gulu –E weedy, U15 sole weedy and P224 sole weedy in a descending order.

The broad-leaved weeds that were observed at the experimental site included: *Bidens pilosa, Commelina benglensis, Galinsoga parviflora, Oxalis latifolia*, among others. While narrow leaved included weeds such as *Digitaria scalarum, Cynodon dactylon* and *Cyperus rotundus.*The season significantly ($p \geq 0.05$) influenced the weed type in both seasons (Figure 3). The highest recorded value for broad-leaved weeds was during the long rains season. While the lowest value of the broad-leaved weeds wasduring the short rains season. Similarly, there were a higher number of broad–leaved weeds in both seasons as compared to narrow-leaved weeds.

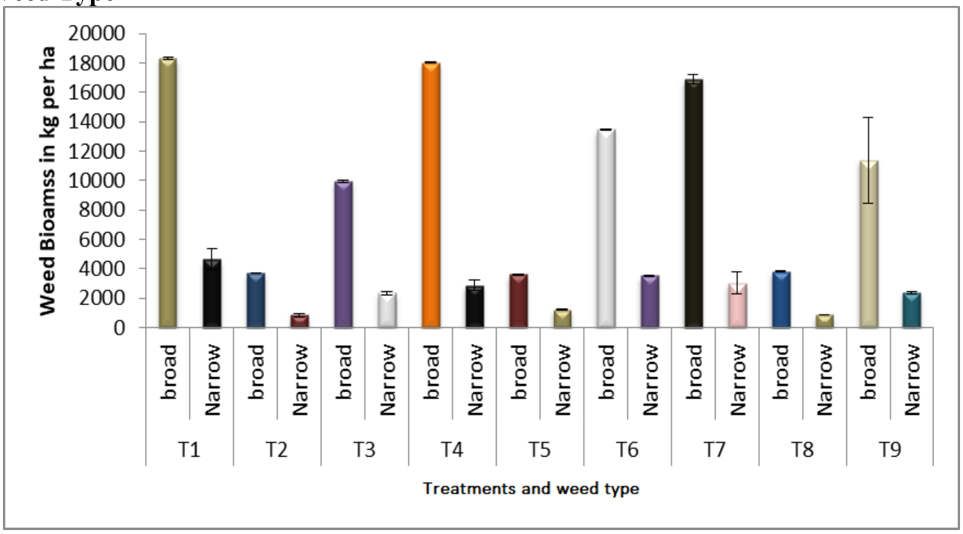


Figure 2: Effect of treatments on weed type.

T1: Gulu -E sole (weedy), T2: U-15 + beans, T3: P224 sole (weed free), T4: U-15 sole (weedy), T5: P224 + beans, T6: Gulu-E (weed free), T7: P224 sole (weedy), T7: P224 sole (weedy), T8: Gulu-E + beans, T9: U-15 sole (weed free).

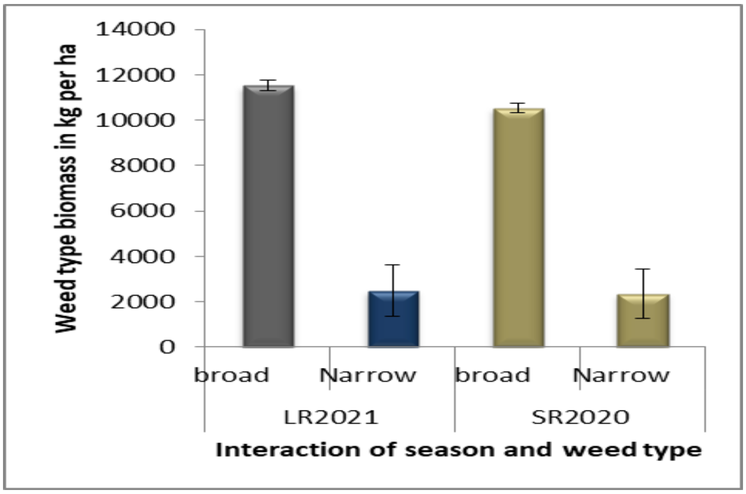


Figure 3: Effect of season on weed type.

Weed Count

Analysis of varianceshowed that intercropping finger millet with beans significantly (p ≥0.05) influenced weed count as shown in Figure 4. Gulu-sole weedy finger millet recorded the highest weed count followed by P224 sole weedy and U15 sole weedy and they were statistically different. U15 sole weed free, P224 sole weed free, P224 sole weed free and Gulu- sole weed free were also statistically different (p ≥0.05) but recorded moderate weedcount. In all treatments the Finger millet/bean intercrop recorded the lowestnumber of weedsthat is, U 15, P 224 and Gulu- E all intercropped with beans. Season significantly (p ≥0.05) influenced weed count with long rains recording more weeds than short rains as shown in figure 5.

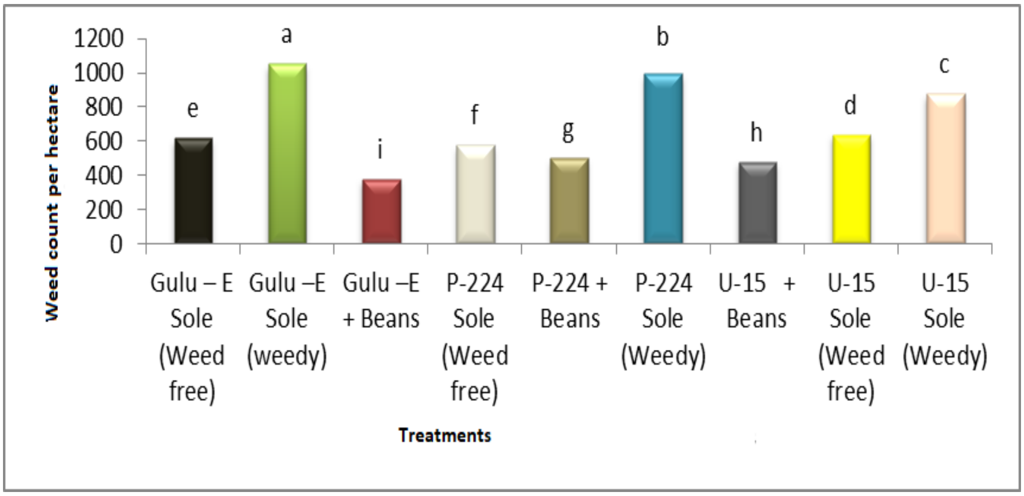


Figure 4: Effect of treatments on weed count.

The small letters at the top of the bars denote levels of significance

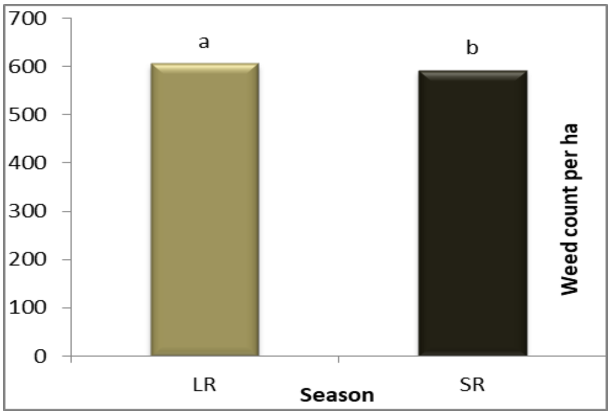


Figure 5: Effect of season on weed count.

Weed Biomass

Analysis of variance showed that treatments significantly (p ≥0.05) influenced weed biomass with weedy finger millet recording highest biomass on broad-leaved weeds compared to weed free finger millet and finger millet–bean intercrop which recorded the lowest weed biomass on broad and narrow- leaved weeds (Figure 2). The results of analysis of variance also showed that season positively influenced weed biomass in that long rains recorded significantly (p ≥0.05) higher weed biomass than short rains season as shown in Figure 6.

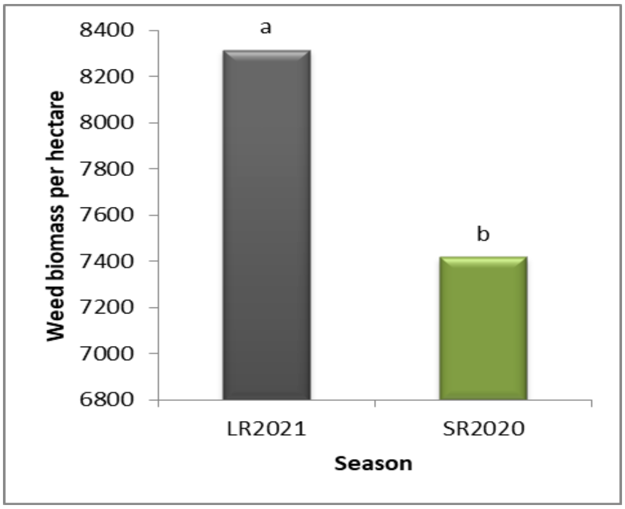


Figure 6: Effect of season on weed biomass.

DISCUSSION

Dominant weed species composition before and after treatment application

The major weed flora of the experimental field consisted of grass weeds: *Digitariascalarum, Cynodondactylon*, sedges: *Cyperusrotundus* and broad – leaved weeds: *Conyzabanariensis*, *Bidenspilosa*, *Commelinabenglensis, Galinsogaparvifiora, Daturastramonium, Oxygonumsinuatum, Oxalis latifolia* and *Leonitisnepetifolia.* The population of broad – leaved weeds was greater than narrow – leaved weeds. The results of weed species composition in this study showed that weed seed bank is dynamic because species changed from those observed before land preparation in both seasons. The most dominant weeds species were annual weeds. The presence of annual weeds could be due to soil disturbances during tillage operation such as seedbed preparation and weeding. The annual weeds are well adapted to succeed in environments which are highly unstable and unpredictable brought about by frequent tillage. This is in line with Begum et al. (2006) who reported that weed emergence is influenced by frequent soil disturbance.

Tillage operations influenced weed seed reserves by inverting the soil along with uprooting weed seedlings and deep burying of the mature seeds (Atkinson et al., 2007). Alongside this, the previously buried seeds were also returned to the soil surface (Streit et al., 2003). Seeds returned to the soil surface as a result of tillage operations germinated and infested the field. However, diversity of weed seeds returning to shallow depths owing to frequent soil disturbance hindered the domination of a few problematic weeds' species (Maqsood et al., 2020).

Deep tillage helped in achieving weed control goal by burying the weed seeds deeper or by destroying the roots of perennial weeds. Tillage is often necessary for removing established weeds especially perennial weeds emerging from storage roots, rhizomes or other underground vegetative propagules. Refsell & Hartzler (2009) reported that tillage operations might have positive or negative effects on weed seeds in the soil seed bank as some weed seeds are buried in the soil. In contrast, tillage was reported to work efficiently after the weed seeds had germinated as the weed seeds which had escaped deep burial were eliminated by subsequent tillage (Buhler, 2002).

Some weed species such as *Commelinabenglensis*, *Galinsogaparviflora*, *Oxygonumsinuatum* and *Cyprusrotundus* were not present before land preparation appeared during the cropping seasons. On the other hand, some weed species such as *Digitariascalarum*, *Conyzabanariensis* and *Daturastramonium* which were observed before land preparation disappeared during the cropping seasons.

These results could be explained from the fact that some seeds which were below the soil profile were moved up the profile by tillage and vice versa is true for the emerged weed species. Weed seeds stimulated by tillage to either emerge or die depends on depth to which germination occurs and whether current growing conditions are favourable. Generally, tillage hastens the decline in numbers of viable dormant weed seeds remaining in the soil.

Weed Type

The results from this study indicated that treatments positively influenced weed type. In this case, the highest recorded values were of broad- leaved weeds while the lowest values were of narrow – leaved weeds across all the treatments. The highest values of broad-leaved weeds were recorded in Gulu-E weedy, U15 sole weedy and P 224 sole weedy in a descending order. Gulu- E had the highest value of broad-leaved weeds which could be due to its lower performance in the competition with broad-leaved weeds compared to P224 sole weedy and U15 sole weedy.

The finger millet variety U15 and Gulu- E with beans recorded the lowest value of narrow- leaved weeds. These results indicate that the Gulu- E and U15 had a superior ability of suppressing narrow-leaved weeds when intercropped with beans. These results are similar to those of Nielson et al. (2003) who observed that less weed count under intercropping system may be due to higher inter-specific competition combined with complementarity between intercrop species that improved the crop stand competitive ability towards weeds.

According to the results, season positively influenced the weed type in both seasons. The higher recorded value for broad-leaved weeds was recorded during the long rains season. While the lowest value of the broad leaved weeds was recorded during the short rains season. Similarly, there was a higher number of broad-leaved weeds in both seasons as compared to narrow leaved weeds. The long rains resulted in good germination of broad-leaved weeds. Furthermore, the broad leaved weeds absorbed a lot of water from the soil than the narrow leaved weeds.

Weed Count

The results indicated that intercropping finger millet with beans significantly influenced weed count. Gulu-E sole weedy finger millet recorded the highest weed count followed by P224 sole weedy and U15 sole weedy and they were statistically different. The higher weed count in Gulu- E sole might be because of the lower performance of Gulu- E sole in the competition with weeds compared to P224 sole weedy and U15 sole weedy. On the other hand, high growth rate, faster canopy, and covering soil surface for a long time might be good reason for lower weed count in the P224 sole weedy and U15 sole weedy.

In fact, obstruction of light is the most important effect that could inhibit weed seed germination by a rapid occupation of the open space between the main crop rows and reducing weed seedling growth and development (Steinmaus et al., 2008). U15 sole weed free, P224 sole weed free and Gulu-E sole weed free were also statistically different but recorded moderate weed count. These results showed that these treatments had a moderate ability of suppressing the weeds at the site.

The finger millet bean intercrop recorded the lowest weed count, that is, U15, P224 and Gulu-E all intercropped with bean. The less weed count under intercropping system maybe was due to higher inter-specific competition combined with complementarity between the intercrop species that improved the crop stand competitive ability towards weeds (Nielson et al., 2003). These results were similar to those of Szumigalski and Van Acker (2005) who reported that intercrop treatment tended to provide greater weed suppression compared to sole finger millet.

The intercrops that are effective at suppressing weeds capture a greater share of available resources than sole crop and can be more effective in pre-emptying resources by weeds and suppressing weed growth. Other suppressive effect of finger millet intercrop has been reported Midega et al. (2010) reported that intercropping of finger millet with desmodium significantly reduced the striga population in the field. Generally, finger millet sole had significantly higher number of weed count compared with intercrop indicating that intercropping was more effective in suppressing the weeds thereby reducing their numbers.

The results revealed that season positively influenced weed count with long rains recording more weeds than short rains season. In this case, during the long rain season, the weed count was higher than that of the short rain season. This could be due to the fact that cumulative rainfall in the rain season, combined with other factors such as increased frequency and amplitude of wetting stimulated more weeds to germinate. Furthermore, additive weed emergence as the long rain season progresses is dependent on adequate soil moisture (Benech-Arnold et al., 2000).

Weed Biomass

The treatments from the study showed a positiveinfluence on weed biomass with weedy finger millet recording higher biomass on broad-leaved weeds compared to weed free finger millet and finger millet bean intercrop which recorded lower weed biomass on broad and narrow –leaved weeds. The higher weed biomass in sole weedy finger millet could be due to the intraspecific competition for growth resources. Intraspecific competition was more intense than interspecific competition.

These results are similar to those of Chandra et al. (2013) who reported that the weed biomass was higher in sole finger millet plots (250 kg/ha) compared to intercropping. The weed biomass was the lowest in intercropping because the finger millet had greater growth rate than beans when they were grown in mixture together. However, on the other hand finger millet occupied the upper part of the canopy and cast shadow on bean and on the other hand beans in the lower part of the canopy cast shadow on the soil and led to suppression of weeds in this system.

In addition, reduction of weed incidence was also observed in intercropping system with high coverage compared to monocropping (Daryanto et al., 2020). Hence, recent studies have addressed intercropping as an option for an integrated weed management particularly in farming system with low external inputs (Agegnehu et al., 2006). If the crops grown together differ in the way they utilize environmental resources they can complement each other and make better combined use of resources than when they are grown separately (Gomes et al., 2005).

Other similar results showed that intercropping of maize and soy bean, maize and cowpea significantly reduced weed growth than sole cropping (Kiwia et al., 2019). The morphological and physiological differences among intercrop components resulted in their ability to occupy different niches. Thus, environmental resources could be more efficiently utilized and converted to biomass by mixed stands of crops than by pure stands (Amar et al., 2015). Therefore, in the present study, more PAR interception and also greater water and nutrient extraction by intercrops could be the major reason for the lower weed biomass observed for intercropping over sole cropping.

According to the results of the study, season positively influenced weed biomass in that long rains recorded significantly higher weed biomass than short rains season. The highest biomass product of weeds was observed in long rains 2021 because of the high rainfall that favoured the increase of weed biomass. The conditions created by higher rainfall led to availability of soil water which favoured the increase of weed biomass and community. The low rainfall during the short rains season affected the weed germination hence lower weed biomass.

These results further emphasized that the very low rainfall coinciding with the germination period of the crop and associated weeds, reduced significantly the weed biomass (Maria & Juan, 2021). The results from this study further suggest that in short rains season soil moisture was not adequate at the beginning of the season to stimulate major flushes of weed germination. In the short rains season, the accumulation of adequate hydrothermal units for most weed species at the site to germinate and emerge was delayed by a high frequency of days when there was lack of moisture in the soil as a result of the low and erratic rainfall. Hence, this explains the increase in weed biomass that was recorded during the long rain season in this particular study.

CONCLUSION AND RECOMMENDATIONS

The broad-leaved weeds that were observed at the experimental site include: *Bidens pilosa, Commelina benglensis, Galinsoga parviflora, Oxalis latifolia*, among others. Gulu-sole weedy finger millet recorded the highest weed count. Results also showed that intercropping finger millet with beans significantly reduced weed count and biomass. Small scale farmers in Trans-Nzoia County should be encouraged to grow finger millet varieties intercropped with common bean to assist in weed suppression and improve finger millet yield. More research is needed on the sustainability of legume-finger millet intercropping for different agro-ecological zones for Kenya.

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