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Influence of Beans and Spacing on Management of Weed and Soil Fertility to Improve Rice Productivity through Bean-Rice Sequential Cropping, Mbarali –Tanzania

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3.1 Abstract

Weed management on rice fields is necessary to reduce yield loss. A field experiment was conducted during the season 2020-21 at Mbuyuni Irrigation Scheme of Mbarali District to assess the effect of bean varieties and spacing on management of weed and soil nutrients in a bean-rice sequential cropping. The study was laid out as a 3×3 factorial experiment arranged in Complete Randomized Block Design (CRBD) with three replications. Treatments in bean phase were bean varieties (Wanja, Njano Uyole and Mshindi) and row spacing (50 cm × 20 cm (S1), 50 cm × 15 cm (S2) and 50 cm × 10 cm (S3)) while treatments in the rice phase were bean residues at the weight of 5 t/ha, 10 t/ha and 15 t/ha for each bean varieties, weight of 5 t/ha used as control since it is farmer practice. The data were collected weed biomass, weed height, bean yield and rice yield and analysed using Genstat software (16th edition) and the means were separated using Tukey's significant test at a 5% level of significance. The results indicate significant effects (P=0.05) for treatments interaction of bean varieties and row spacing on weed count per m^2 and weed biomass. The interaction of Wanja 50 cm × 10 cm had weed count of 17 per m^2 and biomass of 7.3 gm^{-2}. The interaction of bean variety and row spacing were significant (P= 0.05) on the number of pods per plant, bean biomass and grain yield. The incorporated bean residues, significantly (P=0.001) improved spikelet count and weight of 1000 rice seeds whereby 15 t/ha had a high spikelet (20) and panicle weight of (24.7 g/panicle). From the results it is recommended that farmers should adopt bean- rice sequential cropping using bush bean varieties at the spacing of 50 cm x 20 cm on weed management and farmer should applying 15 t/ha of crop residues to improve soil nutrients.

Key words: *Bean, Rice, Weed, sequential cropping, crop residues*

3.2 Introduction

Weed is among the obstacles against rice productivity through their ability to compete for resources causing a negative impact on rice quality (Ghosh *et al*., 2000). Several studies report yield losses on rice production of up to 100% due to weeds (Mghase *et al*., 2010; Rao *et al*., 2007; Jat *et al*., 2011; Chauhan *et al*., 2013). Irrigated production systems where rice is transplanted and direct-seeded, reported yield reduction of up to 48% and 80% due to weed infestation (Becker *et al*., 2003; Ramzan, 2003; Sunil *et al*., 2010).

The management of weeds is a discipline in which the decision should be based on all technologies of weed biology, weed ecology, and economic and environmental information (Rao & Nagamani, 2010). From a survey conducted in Mbarali, the majority of farmers preferred using herbicides and hand pulling to control weeds. However, they encountered challenges resulting from weed infestation and poor soil fertility which increased the costs of production to farmers (Kayeke *et al.*, 2010). However, smallholder farmers used the hand-pulling method as a weed management option due to lacking basic knowledge on the use of modern agricultural technologies and capital. At a large scale production, however, the method requires huge amount of labour (Bosco *et al.*, 2015; Mkanthama. (2012) as cited by Kolleh *et al.*, 2017). On other hand, the use of herbicides to control weeds is limited by improper usage of herbicides such as the application of incorrect herbicide dosage, unsuitable weather conditions and weed development stage, contributing to the accumulation of active compounds in the soil, and in weed species leading to the evolution of resistant weeds (Rola *et al.*, 2007).

The studies by Dayan *et al.* (2009), Gniazdowska and Bogatek (2005) showed eco-friendly weed management practices such as the use of bio-herbicides, techniques of allelochemicals from plant extracts and natural compounds of plant species as the solution and tool of controlling weeds while maintaining the ecosystem.

Other studies identified various technologies including cover crops, crop rotation, mechanical weeding and herbicides as weed control measures (Zhang *et al*., 2000; Rao and Nagaman, 2010; Jat *et al*., 2011; Qasem, 2011; Gaba *et al*., 2014; Liebman *et al*., 2016). Among these technologies, Chauhan *et al.* (2013) documented the use of crop rotation viewed as one of the simplest and most effective methods of managing weeds. Crop rotation is important tool in reducing the incidences of pests, improving soil health, fertility and increasing crop yields (Daniel *et al*., 2008; Brust & Stinner, 1991). Moreover, crop rotation is the simplest and most effective method of managing weeds (Leibman & Dyck, 1993; Liebman *et al*., 2001).

It is important to develop sustainable weed management strategies to control the damage of weeds on rice. The best weed control method should prevent yield losses, reduce production costs and preserve good grain quality (Zhang, 2000). The development of effective weed control and management strategies to control the damage of weeds on rice fields will enable farmers to maximize and enhance sustainable rice production. Due to challenge of weeds in rice sustainable and economic weed control methods is need to be applied singly or in combination to reduce weed infestation and improve soil fertility in Mbarali so as to improve livelihood. This study intended to evaluate the effectiveness of the selected bean varieties as management options against weed infestation. This is meant to improve soil fertility in the bean – rice rotation systems as a long term weed management practice based on limiting competition of weeds in the field, preventing the introduction of new weeds in the field and preventing multiplication of weeds that are already in the field to increase crop productivity in Mbarali.

3.3 Materials and Methods
3.3.1 Location and Climate of the study area
The study was conducted at Mbuyuni village of Mapogoro Ward in Mbarali District between December 2020 and June 2021. The village is located at 8°40´S, 34°15´E and 1047 meters above sea level (TMA, 2021). The selection of Mbuyuni village was based on the information which indicated Mbuyuni village had potential for rice production and large producer of rice in the ward (DAICO, 2021). Based on weather meteorological data for the 2020-21 seasons, the area has an altitude of 1047 m above sea level with a dominant clay loam soil type and temperature ranges from 11.7 °C to 29.9 °C with an average annual rainfall of 873.4 mm. The area receives a unimodal type of rainfall. The rains fall between November and April and the daily maximum and minimum temperature ranges from 24.6 °C to 29.9 °C and 11.7 °C to 16.9 °C respectively, while a dry season is between May to mid-October (TMA, 2021).

3.3.2 Experimental materials
The experimental materials used were three bean varieties (Wanja, Njano uyole and Mshindi). Wanja and Njano Uyole varieties were collected from TARI Uyole–Mbeya while Mshindi was collected from SUA - Morogoro, and one rice variety SARO 5 (TXD 306) was bought from Agriculture seed agency of Tanzania

(ASA Tanzania). Mshindi and Wanja varieties are bush growth habit, while njano Uyole is tall growth habit. The bean variety used as treatment due to the growth habit of being as cover crop and ability of nitrogen fixation, also the bean crop selected due to the preference of farmers.

3.3.3 Soil sampling and analysis

Soil samples were collected using an auger in four phases, Phase I (before cultivation), Phase II (after harvesting beans), Phase III (21 days after incorporating bean residues in the field) and Phase IV (after harvesting rice). The procedure and method used by Fulford *et al*. (2013) were used, whereby a composite soil sample was collected from the experimental area. The composite sample was made up of four sub samples collected on a zigzag sampling method at the depth of 0 – 20 cm in each plot. The samples were reduced by the quartering procedure to obtain a representative sample weighing 0.5 kg and then passed through a 2 mm aperture sieve for laboratory analysis of physical and chemical properties. This procedure was carried out in the soil laboratory at TARI Uyole in Mbeya, Southern Highland Tanzania, following the methods indicated (Table 3.1).

Table 3.1: Analytical methods for soil samples

Characteristics	Method of analysis	Source
Total Nitrogen	Determined by the Micro-Kjeldahl Method	Bremner, (1996)
Organic Carbon	Determined by Walkley and Black Method	Nelson and Sommers, (1982)
Soil pH	Determined in 1: 2.5 (soil: water) suspensions using a pH meter	McLean, (1982)
Available P	Extracted by the Bray-1 Procedure	Bray and Kurtz, (1945)
Soil Particle distribution	Determined by the hydrometer method	Gee and Bauder, (1986)
Exchangeable bases, Ca^{2+} and Mg^{2+}	Determined by 1M NH4-acetate at pH 7 using UV-VIS spectrophotometer	Thomas, (1982)
Exchangeable base K^{+}	Determined by the Flame Photometer Method	

3.3.4 Experimental Design and Treatment Allocation

The experiment was laid out as a 3×3 factorial arranged in a randomized complete block design (RCBD) with three replications. In Bean phase; Factor (A) was bean variety at three levels: Wanja (V1), Njano Uyole (V2) and Mshindi (V3); factor (B) was bean spacing at three levels: 50 cm × 20 cm (S1), 50 cm × 15 cm (S2) and 50 cm × 10 cm (S3). The Njano uyole (V2) variety at spacing of 50 cm × 20 cm which is the current farmers practice was used as control. While in rice phase, factor A was bean residues at three levels: 5 t/ha, 10 t/ha and 15 t/ha, residues weight of 5 t/ha used as control since it is farmers practices. The plot dimensions were 2.5 m × 2.0 m separated by an alley of 1m, and distances between replications were 1.5 m (Appendix 3)

3.4 Crop Establishment and Management

3.4.1 Bean crop

Bean varieties (Wanja, Njano Uyole and Mshindi) were established in December 2020.The crop was planted at a spacing of 50 cm × 20 cm, 50 cm × 15 cm and 50 cm × 10 cm, whereby two seeds per hole were planted. Thinning was done 14 DAP to keep a single plant per hole. Each plot had 4 rows with 11, 15 and 19 plants per row on spacing 50 cm × 20 cm, 50 cm × 15 cm and 50 cm × 10 cm, respectively, equivalent to 100,000, 133,333 and 200,000 plants per hectare. Weeds were managed by hand weeding once at 4 weeks after planting (WAP) while insect pests (ants) were managed by spraying Chlorpyrifos 180 EC at 1 ml/litre of water equivalent to 20 ml/20 lt.

3.4.2 Data collection in the bean phase

3.4.2.1 Weed count

Weed counts were done at 6 WAP and 9 WAP using a 1 m^2 quadrant placed randomly in the net harvestable area of 2.2 m^2 in each plot. The number of weeds from each quadrant was used to calculate weed density per square metres. Weed density indices were summarized using quantitative measurements as originally described by Thomas (1985) for assessing weeds in fields.

Density measures the number of target species per given area (e.g. square meter or hectare). Eq.1

$$\text{Dki} = \sum \left(\frac{\text{number of individuals of target species occured}}{\text{surface area of sampling unit}} \right) x100 \qquad \text{eq(1)}$$

Frequency is concerned with the presence or absence of a species in a quadrat, a field, or a region (*Eq. 2*): Frequency reflects both a species' presence or absence and how much it is distributed within a community. (Thomas, 1985)

$$\text{Fk} = \sum \left(\frac{\text{number of sampling units in which target species occured}}{\text{surface area of sampling unit}} \right) x100 \qquad \text{eq (2)}$$

3.4.2.2 Weed height

Weed height (cm) was obtained by measuring plant height from the ground to the tip of the plant using a meter rule. In each experimental plot, five plants were selected from each weed species within 1 m^2 quadrant and their average heights recorded (Thomas, 1985)

3.4.2.3 Weed biomass (g/m^2)

Dry weed biomass was measured at 9 WAP obtained by uprooting all weeds in 1 m^2 quadrant and grouped into specific species in each experimental unit, and cleaned using water and kept under a shade for 24 hours to remove excess moisture content ;the fresh weight (in gram) was measured using a digital weighing balance. Later, the weeds were dried in an oven drier for 72 hours at 70 ^oC; the dry weight (g) of the weed was recorded by species (Thomas, 1985)

3.4.2.4 Bean crop data

Ten plants from the net harvestable area (2.2 m^2) of each plot were randomly selected and tagged to be used for recording bean growth and yield variables. On crop growth and development, the number of leaves per plant was counted and recorded at 14 days intervals. The plant height was measured using a tape measure from the ground to the tip of the plant at the same interval as that of a leaf count. Leaf length was measured from nodes that attached stem to the tip of the leaf using a meter ruler at the same interval as that of a leaf count. However, at 45 DAP, the number of flowers per plant were counted and recorded. At maturity, beans were harvested from net plots (2.2 m^2) (excluding border row), the ten selected and tagged plants were used to count the number of pods per plot; the length of the pod was measured using a meter ruler from 10 pods samples per plot, and the number of seeds per pod was counted from a sample of 10 pods per plant in each net harvestable plot. The sample of 10 pods per plot was dried on an oven drier at 70 ^oC for 72 hours weight to determine the shelling percent from each net plot.

The harvested bean pods were shelled to measure and record bean grains' weight. However, the bean grain of 0.5 kg was taken as a sub-sample from each treatment lot and submitted to TARI-Uyole laboratory for drying in the oven drier at 70 ^oC for 72 hours to determine dry grain weight in gram. Dry biomass in the net plot of 2.2 m^2 for each plot was harvested and kept under the shade for 24 hours and fresh weight was measured. However, the bean residues of 1 kg were taken as a subsample from the treatment lot, tied and dried in an oven at 70 ^oC for 72 hours at TARI–Uyole laboratory and dry biomass was recorded. In line with other data from experiments, weather data (Temperature and amount of rainfall) were also recorded.

3.5 Rice Phase

3.5.1 Land preparation, crop establishment, treatment allocation and crop management

After harvesting the bean, each experimental plot were cultivated with bean residues at levels 2.5 kg, 5 kg and 7.5 kg which were equivalent to 5 t/ha, 10 t/ha and 15 t/ha as a treatment to different plots, whereby plots planted beans at spacing 50 cm × 20 cm, a 15 t/ha of bean residues were incorporated, while plots planted beans at spacing 50 cm × 15 cm, a 10 t/ha bean residues were incorporated and plots planted beans at spacing 50 cm × 10 cm, a 5 t/ha bean residues were incorporated. Two seedlings per hill were transplanted in the recommended spacing of 20 cm × 20 cm equivalent to 250,000 plants per hectare. Weeds were managed by hand weeding (once) on 4 WAP and insect pests (cutworms) were controlled by the application of insecticides (Karate 2.5 EC, 100ml/Acre) twice on 2 WAP and 8 WAP. The fields were irrigated at intervals of 2 days with 2-5 cm water level and birds were controlled by scaring method.

3.5.2 Data collection in rice phase

3.5.2.1 Weed data

Weed counts, height and biomass were collected using the same procedures as described in Sections 3.4.2.1 – 3.4.2.3 on the beans phase.

3.5.2.2 Rice crop data

Twelve plants from the net harvestable area of (2.2 m^2) for each plot were randomly selected and tagged to be used for recording rice growth and yield variables. On crop growth and development, leaves count per plant was done and recorded at 14 days intervals. Plant height was measured on the 28, 40, 60, 90 and 120 days after planting (DAP) using a tape measure placed at the soil surface to the tip of the flag leaf. Moreover, tillers counts per plant as done counted at 40 DAP and 90 DAP. The length of the flag leaf and panicle was measured on 120 DAP using a meter ruler, from the panicle base to the tip of the spikelet and the mean length was recorded. At maturity, rice was harvested from net plots (2.2 m^2) and panicles weights were determined by cutting 12 panicle samples from each plot and drying them in an oven at 70 ^{0}C for 72 hours, its weight in grams was measured using a digital weight balance. Also, on 120 DAP the number of spikelets per panicle were counted and the mean recorded. The root to shoot ratio was determined from 12 plant samples. The roots and shoots were separated by cutting in the base of shoot and drying using an oven drier at 72 ^{o}C for 72 hours; and weight recorded using a digital balance; the roots and shoots were measured, the average weight recorded, and the root shoot ratio calculated. However, rice straws in the net plot of 2.2 m^2 for each plot were weight and recorded using digital balance. The subsample of 2 kg of rice straw from each net plot were tied and dried using an oven drier at 70 ^{o}C for 72 hours at TARI – Uyole laboratory to obtain biomass.

3.5.3 Weather records during experiments

3.5.3.1 Rainfall (mm)

The monthly rainfall amount during the cropping season 2020 to 2021 was indicated in Fig. 3.1. The amount of rainfall distribution varies according to months, whereby the highest average monthly rainfall amount during the experiment was 190.7 mm on January followed by 187.1 mm in February 2021 while the lowest average monthly rainfall amount was 13.6 mm in May 2021 followed by 63.7 mm in November 2020.

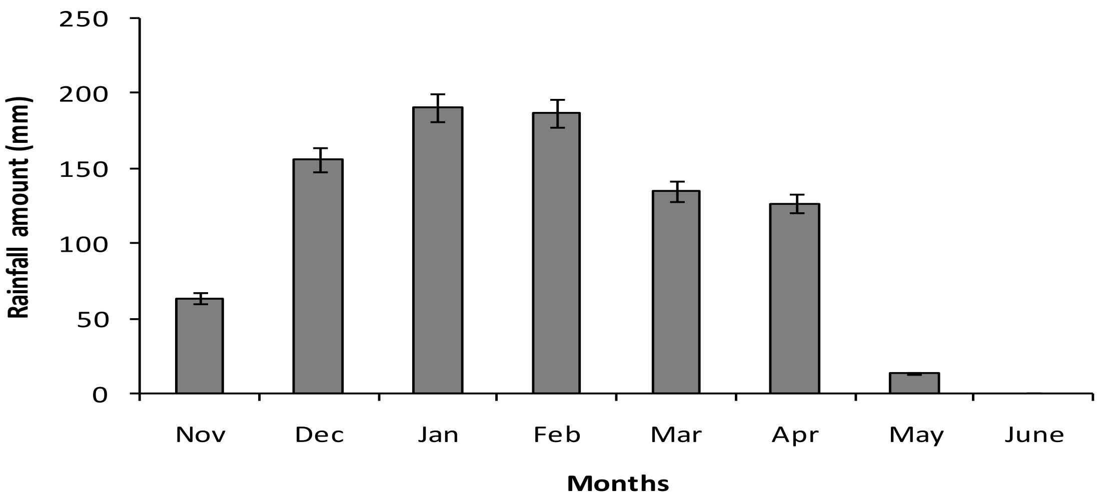


Figure 3.1: Monthly amount of Rainfall in Mbarali District

3.5.3.2 Temperature monthly maximum and minimum

The recorded mean monthly maximum temperature during the cropping season the highest was 25.9 ^{0}C in November 2020; while the mean monthly minimum temperature during the same period lowest was 15.3 ^{0}C in June 2021 (Fig.3.2).

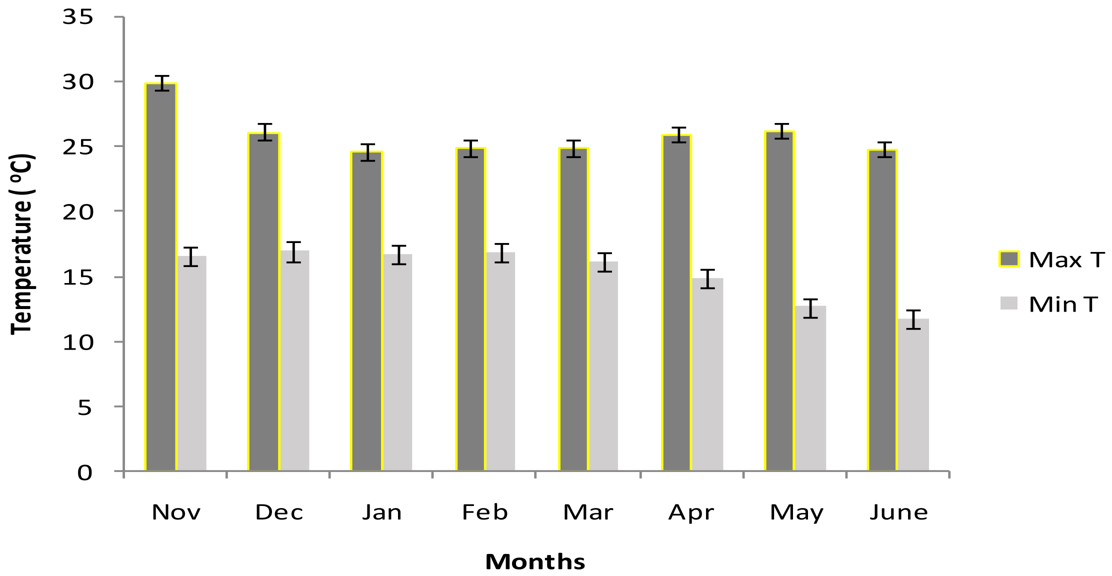


Figure 3.2: Maximum and Minimum Temperature in Mbarali District

3.6 Data Analysis

The collected data were subjected to the analysis of variance (ANOVA) using Genstat 16th version statistical software. Treatment means were separated using Turkey's, significant test at 5% level of significance.

3.7 Statistical mode

3.7.1. Bean phase

The statistical model is

$$Y_{ij} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ij}$$

Where: Y= response (weed biomass), u= grand mean, α = effect of bean variety (v), β = effect of spacing αβ = interaction between v and S, ε = error/residual

3.7.2 Rice phase

The statistical model is

$$Y_{ij} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ij}$$

Where: Y= response (spikeletes), u= grand mean, α = effect of bean variety (v), β = effect of quantity of residual (w), αβ = interaction between v and w, ε = error/residual

3.8 Results

3.8.1 Effect of cropping practices on soil fertility

The results of the soil properties determine before and after bean cultivation indicated general increase in K, P, Fe, Zn, OC, and total N, after bean cultivation (Table 3.2). However, nutrient levels required by rice, as diagnosis of recommendation integrated system (DRIS) are shown in Appendix 4.

Table 3.2: Chemical and Physical Properties of the Soil

Soil property	Optimum value	Soil property before cultivation	Soil property after beans harvesting	Soil property after bean crop residues incorporated	Soil property after rice harvesting
pH	5.5 – 6.5	6.53	5.96	6.4	6.2

OC	2.0 – 7.5%	2.13%	2.11%	2.49%	2.17%
Tot. N	0.2 – 0.5%	0.14%	0.07%	0.21%	0.11%
P	0.3– 0.6 mg/kg	0.5 mg/kg	0.3 mg/kg	0.57 mg/kg	0.43 mg/kg
K	2.0–3.9 cmol/kg	2.6 cmol/kg	2.1 cmol/kg	3.2 cmol/kg	2.9 cmol/kg
Ca	0.4–1.1 mg/kg	1.19 mg/kg	0.82 mg/kg	1.01mg/kg	0.93 mg/kg
Mg	0.2–0.4 mg/kg	0.3 mg/kg	0.03 mg/kg	0.19 mg/kg	0.02 mg/kg
Fe	0.34 – 0.79 mg/kg	0.21 mg/kg	0.13 mg/kg	0.82 mg/kg	0.56 mg/kg
Zn	0.27 – 0.83 mg/kg	0.72 mg/kg	0.6 mg/kg	0.8 mg/kg	0.7 mg/kg
Soil Particle Size	% Clay	88.8	86.8	77.2	73.2
	% Silt	10	12	10.8	8.5
	% Sand	1.2	1.2	1.6	1.4
	Colour	Brown	Brown with Dakish	Black	Black
	Bulk density (g/cm^3)	1.23	1.37	1	1.2
	Porosity (%)	53.59	51.7	45.66	47.74

Source: Edrees *et al* (2001) – Optimum Soil pH
Anago *et al* (2020) – Optimum Nutrients
TCT (Textural Class Triangle) – Soil particles size

3.8.2 Bean phase

3.8.2.1 Main effect of bean varieties and spacing on bean performance

The performance of bean varieties were significant (P= 0.04), on pod count, whereby Mshindi had 11 pods per plant, Wanja 9 pods per plant and Njano Uyole 9 pods per plant. However, there was no significant difference at (P = 0.5) on flower counts per plant between varieties (Fig. 3.3). Plant height had a significant difference (P=0.03) across varieties whereby Njano Uyole was tallest (40.37 cm) followed by Mshindi and Wanja with the height of 30.75 cm and 29.16 cm respectively. However the leaf length was significantly (P=0.001) across varieties whereby Wanja had 19.49 cm and Mshindi had 19.11 cm (Fig. 3.4). Row spacing showed significant (P=0.03) recorded on leaf length, whereby row spacing 20 cm × 20 cm had the highest leaf length of 18.42 cm and row spacing 15 cm × 15 cm had lowest leaf length of 17.97 cm (Figure 3.5). Row spacing results recorded significant (P= 0.04) on pod count among, row spacing (50 cm × 20 cm) had more pods per plant (11) while spacing 50 cm ×15 cm had 10 per plant and spacing 50 cm ×10 cm had 8 pods per plant (Fig.3.6). A highly significant difference was recorded at P=0.001 on pod length among varieties, whereby Wanja had the highest pod length (12.53 cm) followed by Mshindi (10.34 cm) and Njano Uyole (9.43 cm) as shown in Figure 3.7. Row spacing had significant difference at P = 0.03 on pod length, the highest pod lengths was observed on row spacing of 50 × 20 cm (11.03 cm); while row spacing of 50×15 and 50 × 10 cm had 10.87 cm and 10.39 cm respectively as indicated in Figure 3.8.

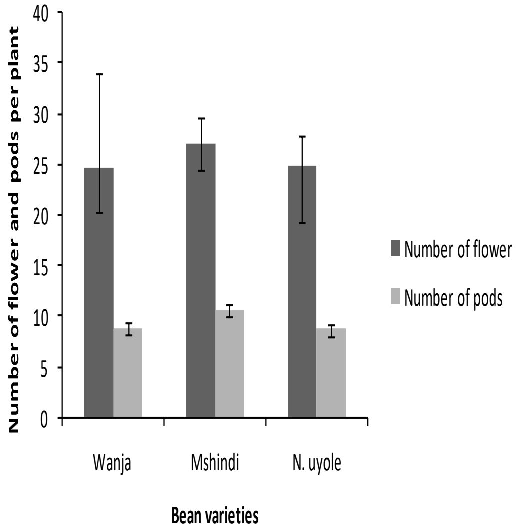


Figure 3.3: Bean variety on pod count

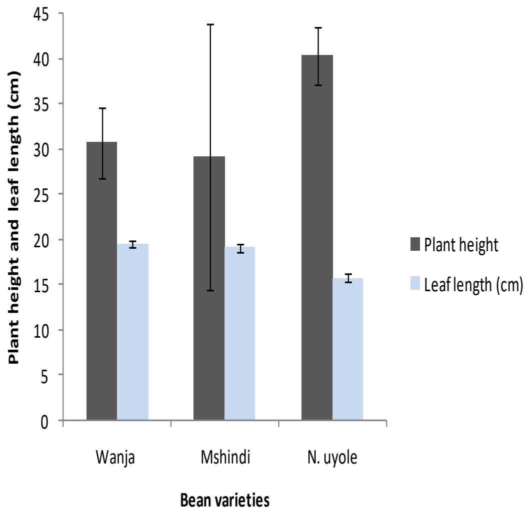


Figure 3.4: Plant height across varieties

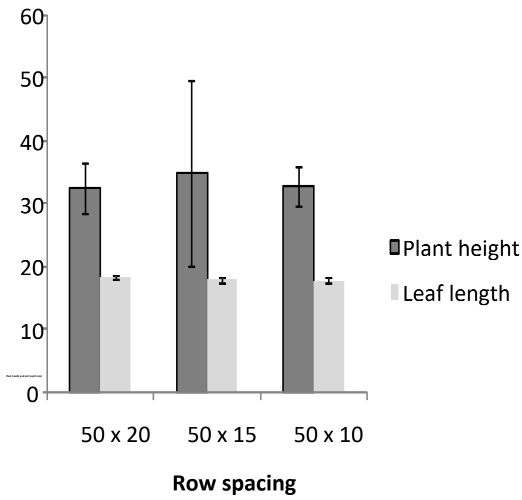


Figure 3.5: row spacing on plant height

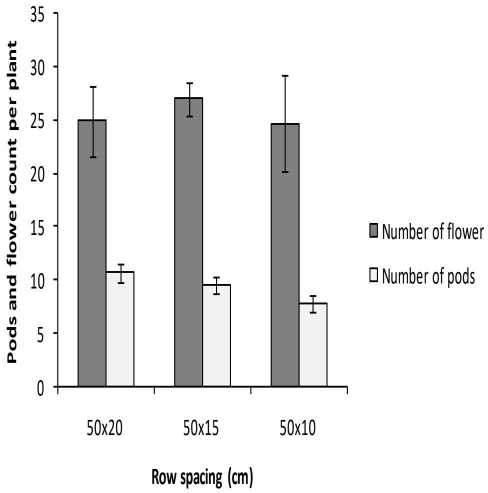
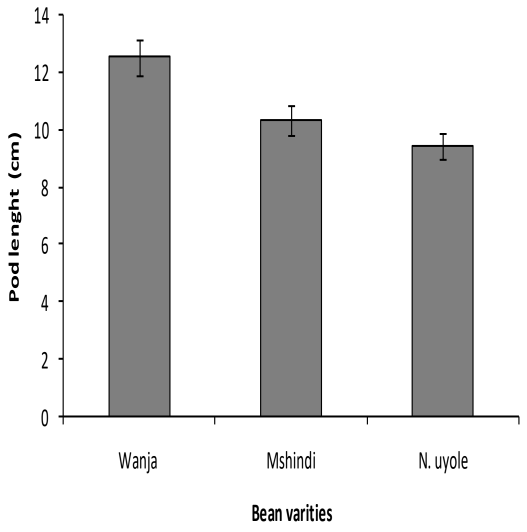


Figure 3.6: row spacing on pod count



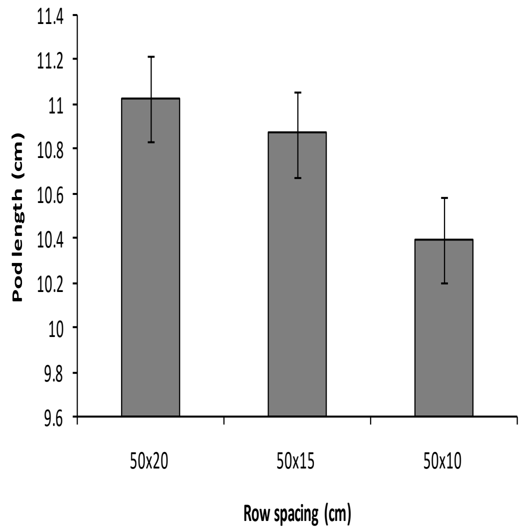


Figure 3.7: Bean pod length on varieties   *Figure 3.8: Bean pod length on row spacing*

3.8.2.2 Interaction effects of bean varieties and spacing on bean performance

The results on the interaction between bean variety and row spacing on bean performance are shown in Table 3.3. The interaction of bean variety and row spacing had significant effects on the number of pods, length of pods, the number of seeds per pods, shelling percentage, bean biomass and grain yield at P= 0.05.

Table 3.3: Interaction effects of bean varieties and spacing on bean performance

Factor (a) x Factor b): (Bean variety × row spacing)	Plant height (cm)	Number of leaves per plant	Leaf length (cm)	Number of flowers per plant	Number of pods per plant	Pod length (cm)	Number of seeds per pod	Shelling percentage (%)	Biomass (t/ha)	Grain yield (t/ha)
Wanja 50×20	29.4 a	9a	19.7 b	26 a	10 ab	12.6 c	4 b	77.3 a	18.6d	0.92 ab
Wanja 50×15	31.1 a	9 a	19.2 b	25a	9 ab	12.6 c	3.7 ab	78.3 a	13.0 abc	0.72 ab
Wanja 50×10	31.7 a	9 a	19.5 b	23 a	7 ab	12.4 c	4 .0b	79.0 a	8.8a	0.61 a
Mshindi 50×20	27.6 a	8 a	19.4 b	25 a	12 b	10.7 b	4 .0b	79.2 a	16.9cd	1.25 b
Mshindi 50×15	28.3 a	8 a	18.9 b	29 a	10 ab	9.9 ab	4 .0b	79.9 ab	14.4 bcd	0.90 ab
Mshindi 50x10	31.6 a	8 a	19.0 b	28 a	10 ab	9.7 ab	3.7 ab	80.1 ab	11.4ab	0.65 ab
NjanoUyole 50×20	40.4 a	10 a	16.2 a	25 a	10 ab	9.9 ab	4.0 b	82.6 bc	15.2bcd	0.85 ab
NjanoUyole 50×15	45.5 a	10 a	15.9 a	29 a	10 ab	9.6 ab	3.7 ab	83.7 c	14.4 bcd	0.72 ab
NjanoUyole 50×10	35.2 a	8 a	15.3 a	20 a	6 a	8.9 a	3.0 a	84.6 c	12.0abc	0.53 a
Mean	**33.4**	**8.9**	**18.1**	**25.5**	**9.3**	**10.8**	**3.8**	**80.5**	**13.9**	**0.80**
CV	**3.8**	**8.6**	**0.4**	**20.0**	**25.0**	**7.0**	**2.9**	**1.1**	**18.8**	**29.2**
SE	**1.3**	**0.8**	**0.1**	**5.11**	**2.3**	**0.75**	**0.11**	**0.89**	**2.60**	**312.3**
P-value	**0.76**	**0.58**	**0.05**	**0.21**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**

Means in the same column followed by the same letter(s) do not differ significantly at P≤0.05 according to Tukey's honestly significance test.
CV (%) = coefficient of variation and SE = Standard error

3.8.2.3 Main effect of bean varieties and spacing on weed diversity

The study identified eight weed species belonging to the families Cyperaceae, Poaceae, Asteraceae, Acanthaceae and Commelinaceae, in which six were annual species and two were perennial species (Table 3.4). Moreover, one species was sedge type, three were grass type and four were broadleaf type. For each weed species identified, frequency and density indices were determined, in which *Eleusine indica* had high weed density (96 weed/m^2) followed by *Ageratum conyzoides* (39 weed/m^2)

Table 3.4: Weed type, family and indices

S/N	Scientific Name	Type	Family name	Life cycle	Density (weed/m^2)	Frequency (%)
1	*Cyperus rotundus*	Sedge	Cyperaceae	Perennial	13.6	70.4
2	*Eleusine indica*	Grass	Poaceae	Annual	95.7	100.0
3	*Ageratum conyzoides*	Bload leaf	Asteraceae	Annual	38.5	75.9
4	*Seteria pumila*	Grass	Poaceae	Annual	0.3	21.3
5	*Hygrophila auriculata*	Bload leaf	Acanthaceae	Annual	0.6	9.3
6	*Commelina benghalensis*	Bload leaf	Commelinaceae	Perennial	0.2	4.6

3.8.2.4 Interaction effect of bean varieties and spacing on weed diversity

Interaction of bean varieties and row spacing had significant effect on weed count per m^2 and weed biomass at P = 0.05. The interaction of Wanja 50 cm × 10 cm and Mshindi 50 cm × 10 cm had lower weed count of 17 per m^2 and 18 per m^2 respectively and weed biomass of 7.3 gm^{-2} and 6.7 gm^{-2} respectively while interaction of Njano uyole 20 cm × 20 cm had highest weed count of 32 per m^2 and weed biomass of 15.2 gm^{-2} (Table 3.5).

Table 3.5: Interaction effect of bean varieties and spacing on weed diversity

Treatments Factor A: Varieties	Weed count (n/m^2)	Weed height (cm)	Weed biomass (gm^{-2})
Wanja	20 a	9.8 a	9.7 a
Mshindi	17 a	9.9 a	6.1 a
Njano Uyole	28 b	11.1 a	13.2 b
Mean	**25.1**	**10.3**	**11.7**
CV	**26.6**	**9.3**	**28.3**
SE	**6.7**	**0.9**	**5.6**
P- value	**0.05**	**0.7**	**0.05**
Factor B: Spacing			
50 × 20 cm	27 b	9.7 a	13.9 b
50 × 15 cm	23 b	10.9 a	12.5 ab
50 × 10 cm	19 a	10.2 a	8.5 a
Mean	**25.1**	**10.3**	**11.7**
CV	**26.6**	**9.3**	**28.3**
SE	**6.7**	**0.9**	**5.6**
P value	**0.05**	**0.78**	**0.03**
Factor C (A × B)			
Wanja 50 × 20	32 b	9.2 a	14.8 b
Wanja 50 × 15	24 b	10.7 a	13.9 b
Wanja 50 × 10	17 a	9.5 a	7.34a
Mshindi 50 × 20	25 b	9.9 a	11.9 b
Mshindi 50 × 15	19 ab	10.7 a	8.6 ab
Mshindi 50 × 10	18a	9.3 a	6.7 a
Njano uyole 50×20	32 b	10.0 a	15.2 b
Njano uyole 50×15	28 b	11.5 a	15.0 b

Njano uyole 50×10	25 b	11.8 a	9.5 a
Mean	**25.1**	**10.3**	**11.7**
CV	**26.6**	**9.3**	**28.3**
SE	**6.7**	**0.96**	**5.6**
P-value	**0.05**	**0.98**	**0.05**

3.8.3 Rice phase

3.8.3.1 Main effect of bean varieties and residues on rice performance

Figure 3.9 shows the influence of treatments on plant height, leaf length and length of panicle. The results on plant height were significant (P=0.001) between bean residue varieties. However, a significant difference (P = 0.03) was recorded among bean residue varieties in terms of leaf length. The results indicate further that there is no statistically significant difference (P = 0.25) recorded among bean residue varieties in terms of the length of panicle. More over the results in table 3.6, shows number of spikelet per panicle had significant difference at P = 0.001 between bean residues varieties, whereby Mshindi variety had higher spikelet (19) than control (Njano Uyole). Further results recorded significant (P=0.005) in biomass between bean residues varieties; the residues of Wanja variety had high straw biomass at (20.11 t/ha), while Njano Uyole had 15.61 t/ha. Moreover significant difference at P = 0.001 was recorded between bean residues varieties, in weight of 1000 seeds. The highest weight was recorded on residues of Mshindi variety (24.2 g).However results indicate no significant difference (P=0.06) between bean residues weight on tillers count per hills. However effect of bean residues weight on spikelet count results recorded highly significant difference at P=0.001 whereby weight of 15 t/ha had a high spikelet (20) compared to 5 t/ha (17), furthermore a highly significant difference at P=0.001 was recorded on weight of 1000 seeds, between different weights of residues applied, the weight of 15 t/ha had a high weight (24.7 g), compared to control, more over the results shown no significant difference P=0.29 between bean residues weight of panicle per plant.

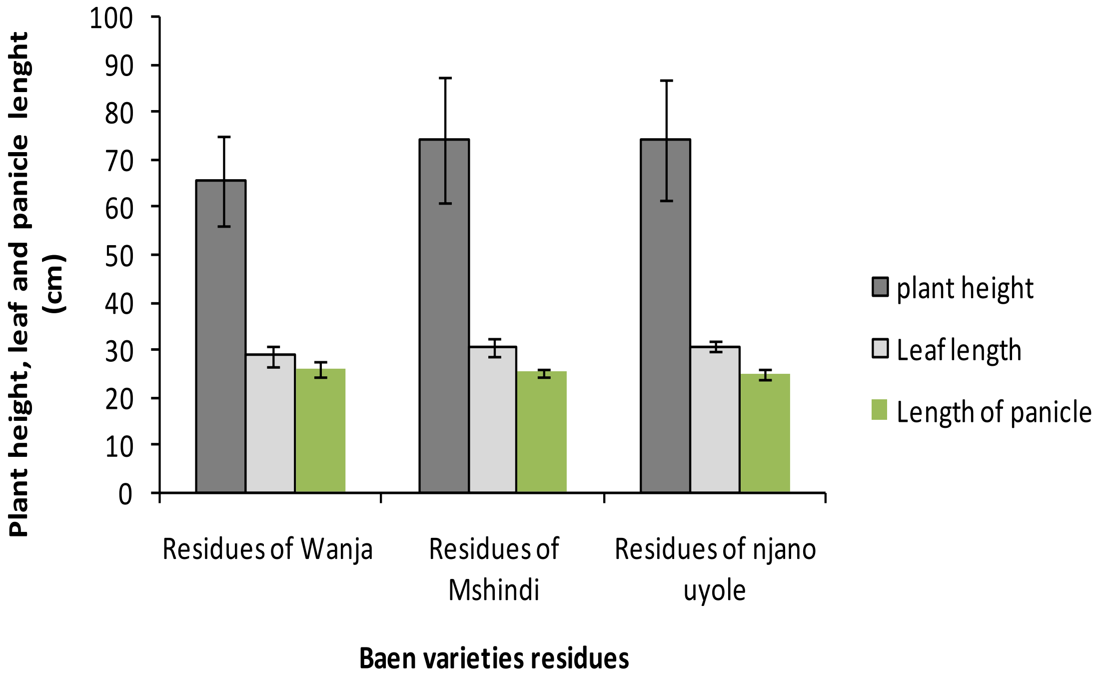


Figure 3.9: Plant height, Flag leaf length and Panicle length

Table 3.6: Main effect of bean varieties and residues on rice performance
Means in the same column followed by the same letter(s) do not differ significantly at P≤0.05 according to Tukey's honestly significance test. CV (%) = coefficient of variation and SE = Standard error.

Treatments	Number tillers per hill	Root/ shoot (Ratio)	Number of Spikelet per panicle	Weight of single panicle (g)	Biomass (t/ha)	1000 seed weight (g)
Factor A: Bean residues Varieties						
Wanja	30.31a	0.2 a	18.0 a	8.4 a	20.1 b	24.1 b
Mshindi	29.0 a	0.1 a	18.9 b	12.2 a	15.6 a	24.2 b
Njano Uyole	31.6 a	0.1 a	17.9 a	8.4 a	19.8 b	23.4 a
Mean	30.3	0.1	18.3	9.7	18.5	23.9
CV	6.3	6.2	0.9	21.8	6.6	1.2
SE	1.9	0.0	0.2	2.1	1.2	0.3
P value	0.51	0.19	0.01	0.44	0.01	<0.001
Factor B: Bean residues weight						
5 t/ha	28.5 a	0.2 a	17.1 a	7.9 a	17.3 a	23.0 a
10 t/ha	28.9 a	0.2 a	18.6 b	8.4 a	18.0 a	23.9 b
15 t/ha	33.4 a	0.1 a	19.1 b	12.6 a	20.2 a	24.7 c
Mean	30.3	0.1	18.3	9.7	18.5	23.9
CV	6.3	6.2	0.9	21.8	6.6	1.2
SE	1.9	0.0	0.2	2.1	1.2	0.3
P value	0.06	0.69	<0.001	0.29	0.09	<0.001

3.8.3.2 Interaction effect of bean varieties and residues on rice performance

The interaction effect between bean variety and weight of residues on plant growth and development are shown in Table 3.7. The combination of bean variety and crop residues weight had significant effects on the number of spikelets, straw biomass and weight of 1000 grains at P = 0.05 respectively. However, the results on a combination between bean variety and weight of bean crop residues recorded no significant difference on plant height, number of tillers, leaf length, and root to shoot ratio, length of panicle and weight of panicle.

Table 3.7: Interaction of bean variety residues and weight applied on rice growth and yield

Factor (a) x Factor (b): (Bean variety × row spacing)	**Plant height (cm)**	**Number of tillers per hill**	**Length of the leaf (cm)**	**Root/shoot (ratio)**	**Panicle length (cm)**	**Number of spikelets per panicle**	**Weight of single panicle (g)**	**Straw biomass (t/ha)**	**1000 seed weight (g)**
Wanja 5	65.1 a	29.8 a	29.6 a	0.2 a	25.7 a	17.0 a	7.9 a	18.1 ab	22.9 ab
Wanja 10	65.5 a	28.3 a	29.0 a	0.2a	26.3 a	18.3 abcd	8.4 a	19.6 ab	24.4 ef
Wanja 15	65.8 a	32.9 a	27.8 a	0.2 a	25.9 a	18.7 bcd	8.8 a	22.6 b	24.9 ef
Mshindi 5	73.9 a	25.4 a	31.6 a	0.1 a	24.6 a	17.7 abc	7.9 a	14.9 ab	23.5 bcd
Mshindi 10	73.7 a	27.8 a	29.8 a	0.1 a	25.5 a	19.0 cd	8.3 a	14.6 a	24.2 def
Mshindi 15	75.4 a	33.8 a	30.2 a	0.1 a	25.7 a	20.0 d	20.3 a	17.3 ab	25.0 f
N. Uyole 5	71.3 a	30.3 a	30.2 a	0.2 a	24.2 a	16.7 a	7.9 a	18.9 ab	22.6 a
N. Uyole 10	73.7 a	30.8 a	31.4 a	0.1 a	25.5 a	18.3 abcd	8.4 a	19.9 ab	23.4 abc
N. Uyole 15	77.2a	33.5 a	30.8 a	0.1 a	25.1 a	18.7 bcd	8.8 a	20.7 ab	24.2 def
Mean	**71.3**	**30.3**	**30.0**	**0.1**	**25.4**	**18.3**	**9.7**	**18.5**	**23.9**
CV	**3.7**	**6.3**	**4.8**	**6.2**	**2.7**	**0.9**	**21.8**	**6.6**	**1.2**
SE	**2.7**	**1.9**	**1.5**	**0.0**	**0.7**	**0.2**	**2.1**	**1.2**	**0.3**
P value	**0.88**	**0.83**	**0.44**	**0.52**	**0.94**	**0.05**	**0.44**	**0.05**	**0.05**

Means in the same column followed by the same letter(s) do not differ significantly at P≤0.05 according to Tukey's honestly significance test. CV (%) = coefficient of variation and SE = Standard error

3.8.3.3 Main effect of bean varieties and residues on weed diversity

The study identified eight weed species belonging to the families Cyperaceae, Poaceae, Asteraceae, Acanthaceae and Commelinaceae, in which six were annual species and two were perennial species (Table 3.8). Moreover, one species was sedge type, three were grass type and four were broadleaf type. For each weed species identified, frequency and density indices were determined, in which
Ageratum conyzoides had high weed density (7 weed/m^2) followed by *Eleusine indica* (6 weed/m^2)

Table 3.8: Main effect of bean varieties and residues on weed diversity

S/N	Scientific Name	Type	Family name	Life cycle	Density (weed/m^2)	Frequency (%)
1	*Cyperus rotundus*	Sedge	Cyperaceae	Perennial	1.4	37.0
2	*Eleusine indica*	Grass	Poaceae	Annual	6.2	94.1
3	*Ageratum conyzoides*	Bload leaf	Asteraceae	Annual	7.0	50.4
4	*Hygrophila auriculata*	Bload leaf	Acanthaceae	Annual	0.1	5.9
5	*Galinsoga parviflora*	Herbaceous	Asteraceae	Annual	1.0	17.8
6	*Clamagrostis epigejos*	Grass	Poaceae	Annual	2.4	37.8

3.8.3.4 Interaction effects of bean varieties and residues on weed diversity

Crop residues had significant effect on weed biomass per m^2 at P = 0.05. Residues weight of 15 t/ha had lower weed biomass of 1.6 gm^{-2} while residual weight of 5 t/ha resulted in the highest values of 2.6 gm^{-2}.While combination of weight and residues source was not significance P=0.59 (Table 3.9).

Table 3.9: Mean Weed count, weed height and biomass in rice phase

Treatments	Weed count (n/m^2)	Weed height (cm)	Weed biomass (g/m^2)
Factor A:Residues Varieties			
Wanja	3 a	9.0 a	2.6 a
Mshindi	3 a	10.1 a	2.7 a
Njano Uyole	3 a	9.8 a	2.5 a
Mean	**3.0**	**9.6**	**2.6**
CV	**3.8**	**8.1**	**7.4**
SE	**0.1**	**0.8**	**0.2**
P- value	**0.98**	**0.74**	**0.93**
Factor B: Residues Weight			
5 t/h	3 a	8.6 a	2.6 b
10 t/h	3 a	9.9 a	2.4 b
15 t/h	3 a	10.4 a	1.6 a
Mean	**3.0**	**9.6**	**2.6**
CV	**3.8**	**8.1**	**7.4**
SE	**0.1**	**0.8**	**0.2**
P value	**0.87**	**0.44**	**0.05**
Factor C: A×B			
Wanja 5	4 a	10.0 a	2.9 a

Wanja 10	3 a	8.1 a	2.7 a
Wanja 15	2 a	8.9 a	2.1 a
Mshindi 5	3 a	7.1 a	2.9 a
Mshindi 10	3 a	12.4 a	2.7 a
Mshindi 15	3 a	10.8 a	2.4 a
N. Uyole 5	3 a	8.6 a	2.3 a
N. Uyole 10	3 a	9.5 a	2.3 a
N. Uyole 15	3 a	11.3 a	2.8 a
Mean	**3.0**	**9.6**	**2.6**
CV	**3.8**	**8.1**	**7.4**
SE	**0.1**	**0.8**	**0.2**
P value	**0.56**	**0.32**	**0.57**

Means in the same column followed by the same letter(s) do not differ significantly at $P \leq 0.05$ according to Tukey's honestly significance test.
CV (%) = coefficient of variation and SE = Standard error

3.8 Discussion

3.8.1 Bean growth and development

The study shows that Njano Uyole was the tallest variety (40.37 cm), these results correspond with the study of Shenkalwa *et al*. (2013) in study identified that Njano Uyole is a tall variety. The treatment Wanja variety had high leaf length that may result to better crop canopy which has influence on crop competitive ability against weeds (Saberali *et al*., 2016). However, recommended spacing of 50 cm × 20 cm had more pods per plants and pod length in each variety, these revealed that planting at recommended spacing result to high yield (Worku and Astatkie, 2011). Moreover, the study shows interaction of bean variety and row spacing had effect on number of pods, length of pods, and number of seed per pods, biomass of bean and grain yield. These correspond with the study by Fininsa (1997), which documents the use of improved varieties and spacing improves yield and yield components.

3.8.2 Rice growth and development

The result shows there were high plant height for the plot treated with crop residue of Mshindi cultivars and Njano Uyole. This shows Njano Uyole and Mshindi had high ability to fix nitrogen, hence their crop residues when decomposed by microorganism help to improve soil organic content and soil quality for the growing rice (Sharma and Mittra, 1991). However plots treated with crop residues of Mshindi cultivar produce high number of spikeletes (19) in rice due to more nutrients released to rice, so suitable to use as legume green manure in rice production. Furthermore residues at weight of 15 t/ha had high spikelet's per panicle. According to Saleque *et al*. (2004) uses of green manure should base on appropriate weight which brings high yield, possible crop residues weight of 15 t/ha is suitable for application to improve productivity.

3.8.3 Weed prevalence and biomass

The study showed that weed density during the bean phase was high (95.68 weeds/m^2) but decreased in the rice phase (6.97 weeds/m^2).These result as documented by Qasem *et al*. (2011) and Doucet *et al*. (1999) which revealed that effective practice of crop rotation reduces weed density and biomass. The reduction of weed density was probably caused by the effect of bean crop which suppressed weed growth and inhibit increase of new seeds in the field (Macías *et al*., 2019).

Characteristics of a bean variety had an impact on weed count and biomass, whereby the bush variety (Mshindi and Wanja) had a higher ability to suppress weeds than the tall variety (Njano Uyole). These findings were consistent with Wortmann (1993) who revealed that bean morphology and characteristics had different abilities in controlling weeds whereby bush varieties were more effective on weed control than was the case with tall varieties.

Studies revealed further that, cover crops such as beans, suppress weeds by reducing emerging seedlings' root growth, leaves and weed height as a result of allelochemical (Lemessa and Wakjira, 2015; Reeves, 2018; Brust *et al*., 2014). Allelochemical produced by bean (phenolic acids and pisatin) may be the cause for the reduction of weed count, weed height and biomass (Scavo and Mauromicale, 2021).

Moreover, the study showed that a decrease in row spacing improves weed management. This is in line with the finding by Mondal *et al.* (2013) who reported that closer row spacing manages weed infestation. Closer spacing affects weed growth due to an increase of plant competition on the resource between weeds and beans; since the bean has a high ability to compete for nutrients thereby suppressing weeds due to nutrients depletion (Sturm *et al*., 2018).

3.8.4 Yield and yield components

The study results indicate that planting of beans at a recommended spacing of 50 cm × 20 cm had a high yield; for Mshindi variety had grain yield of 1.25 t/ha at a spacing of 50 cm × 20 cm, Wanja variety had a yield of 0.92 t/ha at a spacing of 50 cm × 20 cm and Njano Uyole variety had 0.85 t/ha at a spacing of 50 cm × 20 cm. This spacing is in line with the description of the recommended spacing for higher yield (Malik *et al*., 1993). However, the study shows that row spacing of 50 cm × 10 cm had high residues dry biomass for Wanja variety at 18.62 t/ha, Mshindi variety at 16.96 t/ha and Njano Uyole variety at 15.19 t/ha. Similar results are reported in a study by Piggin *et al*. (2015) who revealed that closer spacing for bean crops helps to increase residues biomass. The results indicate further that the application of 15 t/ha of crop residues had high rice straw biomass and brings a high yield. Similarly, the results in a study by Singh *et al.* (2007) shows an increase in plant population, straw and grain yield, and high biomass obtained by the application of 15 t/ha of residues. This may also be caused by the addition of soil nutrients from residues as founding a study by Miyazawa *et al*. (2010) who documented that bean residues facilitate an increase of soil nutrients especially N obtained from nitrogen fixation when decomposed in the soil. However, the results in a study by Surekha *et al.* (2010) shows that straw is proportional to grain yield which means an increase in straw will increase grain yield. The records of high straw biomass from the study indicate that the application of 15 t/ha had a high grain yield, which is in line with the result by Salahin *et al*. (2013) who found that the application of green manure increased crop biomass leading to higher yields.

3.8.5 Soil characteristics

The study shows that the rotation of bean-rice and incorporation of crop residues facilitate the improvement of soil fertility in both chemical and physical properties. The study recorded an increase of the total N from 0.14 to 0.21, which is equivalent to a 20%increase of N in the soil. This is consistent with the findings by Rahman *et al.* (2012) and Zhao *et al.* (2015) who reported that the rotation of beans and rice increased N by (20 - 50%), however, the use of crop residues improved other soil nutrients such as P by 6.5%, K by 10.3 %, Fe by 59% and Zn by 5.3%. Moreover, the results showed an increase of organic carbon (OC) by 7% after practising bean – rice sequential cropping. Similar results are reported in other studies of Chauhan *et al*., 2012; Rahman *et al.*, 2012) revealing that rotation improves soil nutrients. Furthermore, the results recorded the improvement of soil physical characteristics; the soil which had 88% of clay decreased to 77.2% of clay; the reduction of the clay percentage facilitates aeration and penetration of roots (Ben-Noah *et al*., 2018).

3.9 Conclusion and Recommendation

3.9.1 Conclusion

This study played an important role in weed management and soil improvement. The result shows the benefits of cropping sequential in weed management. The selected bean varieties proven that bush varieties (Wanja and Mshindi) had a high ability to manage weed in rice when used in the bean-rice sequential cropping compared to tall cultivars (Njano Uyole). However, the incorporation of bean crop residues improves soil fertility and increases productivity. Therefore, it conclude that Incorporated crop residues (15 t/ha) and cropping sequential of bush varieties (Mshindi and Wanja) contribute to improve soil nutrients, and weed management.

3.9.2 Recommendation

This study recommends that, adoption of rice-bean rotation is the best agro ecological practice in weed management. The incorporation of crop residues is suitable to be applied to improve soil fertility. Therefore, sensitization is recommended to transfer this agro ecology technology of bean-rice sequential cropping to improve yields and soil fertility in study area.

3.10 References

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