Effects Of Spacing And Fertilization On Growth And Grain Yields Of Mung Beans (Vignaradiata (L) Wilckzeck) In Dry Areas Of Subukia, Kenya

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Abstract: Mung bean (Vigna radiata (L) Wilckzeck)is an important source of easily digestible high-quality protein for vegetarians and sick persons. The seeds are said to be a traditional source of cures for paralysis, rheumatism, coughs, fevers and liver ailments. It contains 24% protein, 0.326% phosphorus, 0.0073% iron, 0.00039% carotene, 0.0021% of niacin and energy 334 Cal/100g of Mung beans. Lack of use of the right spacing and either organic manure or inorganic fertilizers have greatly contributed to low yields of Mung beans in ASALS of SubukiaSub County. The gap between realizable and actual yields needs to be bridged up with appropriate technologies. Knowing the right spacing and correct fertilizer rates would be of paramount importance to low income farmers who depend on the crop. This study was carried out todetermine the effects of spacing and fertilizer application rates on growth and grain yields of mung beansof variety “K22” locally referred to as Ndenguspecial. It was a randomized complete block design (RCBD) with threereplicates. Theindividual plots measured 2.1 x 2 m and were separated by 0.5 m path. Application of P was done at the rate of 46kg P_20_5 /hafrom DAP (18:46:0) fertilizer at a rate of 100kg/haDAP. Farm Yard Manure (FYM) was applied at the rate of 5 and 10 tons per ha and a control plot included. Sowing of Mungbean wasdone at 3 spacing i.e.40 x 15cm,45 x15cm and 50 x 15 cm. Data was recorded on Plant height, Number of leaves at flowering, number of pods per plant, number of seeds per pod, 100 seed weight, dry matter yield, grain yield and harvest index. The results showed that there was significant difference in growth and grain yields of mung beans due to use of different spacing and different fertilizer application rates. The spacing for economic yield of mung beans was established as 45 x 15 cm given that this is the spacing that provides optimum plant population. The fertilizer application rate that gives improved productivity of mung beans is DAP applied at the rate of 100kg/ha. Nonetheless, FYM applied at the rate of 10 tons/acre has potential for improving productivity despite its low rate of nutrient release as well as low percentages of major plant nutrients (NPK). The study therefore recommended spacing of 45 x 15cm and application of DAP at the rate of 100kg/ha for improved growth and grain yields of mung beans in Subukia Sub County of Nakuru County. It is also important to note that spacing of 45 x 15 cm and 10 tons/ha of FYM provides an alternative where the cost of inorganic phosphorus is a limiting factor.

Keywords: Mungbeans, Dry areas, Crop Spacing, Fertilization, Grain Yields

1. INTRODUCTION

Mungbean Vignaradiata (L.)WilcKzek is one of the traditional food crops that are mainly grown in ASAL areas of Kenya. It is among the traditional food crops that have suffered from recognition for a long time thus resulting in relegation to the undeserving category of “minor crops” with little support for their research and development (Karanja, Githunguri, Ragwa, & Mulwa, 2006). This attitude is changing rapidly with the realization that these crops have been key to the food security to millions of people especially in ASALS that are characterized by recurrent drought, poor soils and general lack of resources for meaningful agricultural production (Karanja et al., 2006). Mung bean is a small seeded legume and belongs to the Papilionaceae sub familyof the Leguminosae family. It plays an important role in human diet by meeting protein requirements of the population and in improving soil fertility through atmospheric Nitrogen fixation. It is difficult to obtain credible production statistics for mung beans, as production figures are of often combined with that of Phaseolus and other Vigna species (Swaminathan, Singh, & Nepalia, 2012). India is the largest producer of mung beans and accounts for 54 % of the world production and covers 65 % of the world acreage. It is grown on about 3.70 million hectares with annual production of 1.57million tons (Shirma, et al., 2011). In the year, 2000, China produced 891,000tons from 772,000 ha.110, 000 tons were exported by China exported in 1998, 290,000 tons in 1999 and 88,000 tons in 2000. In India, all the mung bean produced is consumed domestically. In most parts of Africa, mung bean food products are sold in the cities where there are significant numbers of residents of Asian origin (Mogotsi, 2006). Although the crop is cultivated in many tropical African countries, it is yet to become a mainstream crop outside Asian countries and there are no mung bean production statistical figures available for the continent of Africa. However, in the dry parts of eastern Kenya, the main cash crop happens to be mung beans. In semi-arid regions of Kenya that experience about 600 - 800 mm of rainfall, mung bean crops are grown two times per year. Besides meeting the daily subsistence food requirement, Mung bean can also be transformed into a broad-based commodity for sustained food security, better nutrition and income generation (Mogotsi, 2006). The National Dry Land Farming Research Centre in Kenya has been carrying out mung bean improvement works at Machakos since 1979. Germplasm was collected locally as well as being introduced from elsewhere, mainly from India and Asian Vegetable Research and Development Centre (AVRDC) in Taiwan. Dana and Karmakar (1990) conducted the selection of promising lines and two cultivars i.e. N22 or KVR22 (KAT/MB22 Katumanimung bean 22) and N26 or KVR26 (KAT/MB26 Katumanimung bean 26) were released**.**Thevariety 'KVR22'also locally known as Ndengu Special, has golden-yellow seed Colour and determinate growth habit. The crop flowers in 55–60 days after germination and attains physiological maturity within 80–90 days. It has tolerance to aphids, high tolerance to Mung Bean Yellow Mosaic Virus (MYMV)and moderate resistance to powdery mildew. Potential yields range from, 1000-1300kg/ha or 400-500 kg/acre. Thevariety'KVR26' has green seed colour and a determinate growth habit. Flowering occurs in 40–45 days, and attains maturity in 60–65 days. It isan early maturing variety and has large sized seed. Potential yields range from 300-1500kg/ha. Studies by Pookpakdi and Pataradi (1993) show that optimum row spacing plays an important role in contributing to the high yields of mung beans, because thick plant population will not get a proper light for photosynthesis and can easily be attacked by disease. On the other hand, very small population will also reduce the yields and due to this reason, the normal population is necessary for high yields. In Kenya, mung beans are usually boiled and the seed consumed whole, accompanied with cereals such as maize or sorghum. The seeds are also boiled and subsequently fried with meat or vegetables and consumed as anaccompanimentwith pancakes ('chapatti') and thick maize porridge ('ugali.'), whereas split seeds (dhal) are commonly eaten by individuals who are of Asian descent. The mung bean is sometimes cultivated for organic compost, fodder or as a cover crop. According to Mogotsi (2006), the seeds of mung beans are considered a traditional source of medication for ailments such as fevers, paralysis, coughs and liver disorders. Mung bean is superior to other legumes due to its digestibility, high nutritional value, and non-flatulent behaviour. Furthermore, it is cultivated mainly for its edible seeds which are rich in proteins(Hague, 1989).Mung bean seeds contain 24.7% protein, 0.6% fat, 0.9% fibre and 3.7% ash (Chouldry, 2005). According to studies, the application of manure significantly impacts on the chemical, physical and biological properties of the soil. Most of these effects are due to an increase in soil organic matter resulting from manure application (Shirani, Hajabbasi, &Afyuni (2002): Bakayoko, et al., (2009). Manure is an excellent source of major plant nutrients such as N, P and K and provides many of the secondary nutrients that plants require. The actual nutrient value of manure will differ considerably due to the type of animal, its food ration, manure collection, storage and application procedures, climate and water holding capacity(Rasoulzadeh & Yaghoubi, 2010), reduced compaction and erosion (Liang, Zhang, Xing, & Wang, 2011). According to Kihanda, Warren and Michemi (2007), one of the most effective ways of improving fertility in tropical soils is through the application of manure. There has not been any study on the performance of mung bean under different levels of spacing and fertilizers application in dry areas of Subukia. Farmers have been using spacing and fertilizer recommendations for areas where Mung bean varieties were developed. This study is therefore aimed at assessing the effects of various Spacing and fertilization methods on growth and grain yield of mung beans under ASALs of Subukia Sub County, Nakuru County.

2. MATERIALS AND METHOD

2.1 Experimental Site Description

The Study was conducted on farmer's field at Wasege's ward of Subukia Sub County, Nakuru County. The site falls within an elevation range of 1000 - 1500 m above sea level. The area lies within Agro-ecological zone, UM4 and UM5. It has an annual rainfall of between700 - 800 mm per annum and a temperature range of 20-30°C. Soils are sandy loam soil. Soil analysis report indicated that the topsoil is slightly acidic, and also deficient in copper and zinc micronutrients. The ideal Ph for growth of mung beans is 6 - 7. The soil is also deficient in phosphates. The plant material used in this study was Mungbean variety KVR "22" also commonly referred to as "**Ndengu Special"** an emerging crop'' in Subukia Sub County.

2.2 Experimental Procedure

The land was prepared to a fine tilth before sowing (plate 3.1). Soil Sampling was done from the trial site and subjected to physical and chemical analysis before planting to determine various soil characteristics. An application of N and P was done at the rates of 18 and 46 kg/ha, respectively from DAP (18:46:0) fertilizer at a rate of 100Kg/ha. Manure was applied at the rate of 5 and 10 tons/ha, and a control plot with no fertilizer or manure applied was included. Sowing of Mung bean seeds was done at 3 spacing i.e. 40 x15cm, 45 x15cm and 50 x 15 cm. During planting, fertilizer and manure were applied as per the treatments stated above. Mechanical weed control was regularly done, first at 2 weeks after emergence and subsequently once during the vegetative stage and close to crop maturity. The Mung bean plants were fully protected against aphid infestation and other flower-sucking insects through the regular spray of insecticide. The plots size was2.1 x 2m and plots within the block were separated by 0.5 m path. The sizes of Individual block measured 2.1 x 29.5 m to give 61.95m^2 and were separated from the adjacent block by a 1m path. The entire experimental plot was 8.3 x 29.5 m = 244.85m^2 as shown in Figure 3.1. The plant population in individual plots depended on the spacing used. 40 x 15cm (70 plants), 45 x 15cm (62 plants) and 50 x 15 cm (56 plants). The experimental design used was the Randomized Complete Block Design (RCBD) with three replicates (Figure 3.1). Two factors were studied i.e. Spacing and Fertilization methods.

i) **Treatment Combinations**

Table 3.1: Treatment Combinations

	Fertilization Method			
Spacing	**F_0**	**F_1**	**F_2**	**F_3**
S_1	F_0S_1	F_1S_1	F_2S_1	F_3S_1
S_2	F_0S_2	F_1S_2	F_2S_2	F_3S_2
S_3	F_0S_3	F_1S_3	F_2S_3	F_3S_3

2.3 Data Collection

The following data was collected;

i. Plant height
Plant height data was taken from 10 plants in the inner rows once a week starting from (14 days) after emergence for 5 weeks (Plate 3.2 & 3.3)

ii. Number of leaves at flowering
Data was collected 45 days after sowing from 5 randomly sampled plants in each plot. (Plate 3.4)

iii. Number of pods per plant
This was done by randomly selecting 10 plants from each plot and counting the number of pods at the end of the experiment.

iv. Number of seeds per pond
This was carried out after pod count was done. All seeds in the pods were counted manually and data recorded.

v. 100 Seed weight
Hundred grains were randomly picked from amongst grains harvested from each net plot and their weight recorded in grams using an electronic weighing balance (Plate 3.5)

vi. Dry matter yield
For each treatment, measurements of fresh and dry matter weights were evaluated by destructive harvests of 10 randomly selected plants from the centre rows of each plot when over 75% of the pods were dry. Plants were harvested at the soil surface by cutting using secateurs and immediately weighed to give fresh biomass. To determine the dry weight, plants were sundried for 3 days to constant weight and weighed (Dry matter weight). The total biomasses of each plant were calculated by adding the dry weight of the leaves and the plant at harvest with the seeds removed.

vii. Grain yield harvest
Grain yield was determined at the end of the experiment where all pods were picked from 10 randomly selected plants from each plot when 75 % of the pods were dry to avoid shattering. The harvested pods were then sun-dried to a constant weight and measured. The grains were then removed from the pods and weighed. Finally, the moisture content (MC) of the grains was measured using a moisture meter and the weight of the grain determined at 13% moisture content. The yield was then converted to tonnes per hectare for each plot.

viii. Harvest index (HI)
The grain yield/ha was expressed as a percentage of the total harvested biomass yield in grams and reported as harvest index as illustrated below.

Harvest Index (HI) % = 100 x Grain dry weight (g)/Plant dry Weight (g)

While: **Average Harvest Index %** = Sum of harvest indices/Number of plant

Plant dry weight was gotten from dry matter yield above the ground while dry grain weight was gotten from Grain Yield.

3. RESULTS AND DISCUSSION

The study investigated the effects of Spacing and Fertilizer application on growth and grain yield of Mung beans in Semi-arid parts of Subukia, Nakuru County.

4.1 Effect on Mung Beans Plant Height

Measurements for plant height in centimetres were taken from 10 plants in the inner rows once a week starting 14 days after emergence and continued for 5 weeks. Although the results indicated that there were general increases in mean heights between closer and wider spacing under different fertilization methods, these mean differences were not significantly different as shown in Figure 4.1

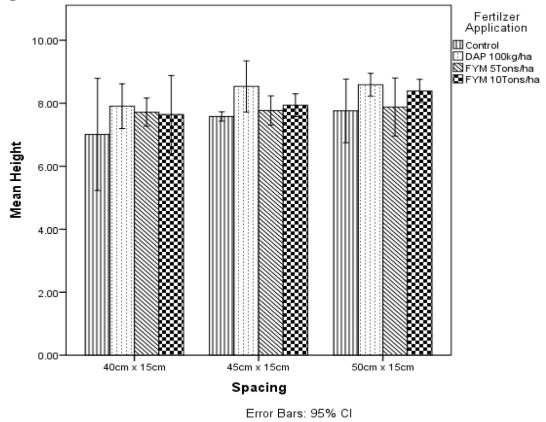

Figure 4.1*: Effect on Plant Height*

From the results, it shows that Mean height of Mung beans at a spacing of 50 x 15 cm (8.15cm) was marginally higher than mean height of the plant at 45 x 15cm spacing (7.96cm), while mean plant height at a spacing of 40 x 15cm was lowest (7.57cm). On the other hand, mung beans planted using 100kg of DAP per hectare had the highest average height of 8.34cm, followed by mung beans under FYM at 10tons/ha with a mean height of 7.99cm and beans under 5tons/ha of FYM (7.79cm). Mung beans had the lowest mean plant height of 7.45cm in the control set up that had no fertilizer. Analysis of Variance (ANOVA) on mean plant height showed that there was statistically significant difference in mung beans plant height under different spacing and by the method of fertilization at $p<0.05$ (Appendix 1).The Least Significance Difference test showed that the mean differences in height differed significantly between the treatments shown in Table 4.1.

Table 4.1: *LSD Summary for Spacing and Mung Beans Plant Height*

Spacing	40 x 15	45 x 15	50 x 15
40 x 15		-0.386*	-0.584*
45 x 15			-0.1983
50 x 15			

**The mean difference is significant at the .05 level.*

Spacing positively and significantly affected Mung beans plant height where plants at a closer spacing of 40 x 15cm were significantly lower than mean plant height at a wider spacing of 45 x 15cm and 50 x 15cm. The means were significantly different between the closer spacing of 40 x 15cm and the 45 x 15cm spacing (-0.386cm) and 50 x 15cm spacing (-0.584cm). These findings were in agreement with Rasul et al., (2012) who reported that mung beans plant height was significantly affected by inter-row spacing, with maximum plant height being observed at an inter-row spacing of 45 cm compared to the inter-row spacing of 30 and 60 cm. Application of phosphorus (DAP) and FYM significantly affected the height of Mung beans. As shown in Table 4.2, the mean height values for Mung beans planted under 100Kg/ha DAP, 5ton/ha FYM and 10ton/ha FYM were significantly higher compared to the mean height of the beans in the control (no fertilization) set up. Optimum height was achieved under 100Kg/ha of DAP application. Blocking had no effect on plant height under different spacing.

Table 4.2: *LSD Summary for Fertilization Method and Height of Mung Beans*

Fertilization Method	Control	100Kg/ha DAP	5ton/ha FYM	10ton/ha FYM
Control		-0.8933*	-0.3400*	-0.5411*
100kg/ha DAP			0.5533*	0.3522*
5ton/ha FYM				-.2011
10ton/ha FYM				

**. The mean difference is significant at the .05 level.*

The foregoing results were largely consistent with the results of a similar study by Kumar and Puri (2002), who found that increasing the rate of DAP rate from 25 to 100Kg/ha resulted in significant increase in plant height of French bean (Phaseolus vulgaris) compared with the control (without P).

4.2 Effect on Number of Leaves at Flowering of Mung Beans

Data on the number of leaves at flowering was collected 45 days after sowing from 5 randomly sampled plants in each plot. Figure 4.2 shows the effects of spacing and fertilization method on a number of leaves at flowering in Mungbeans.

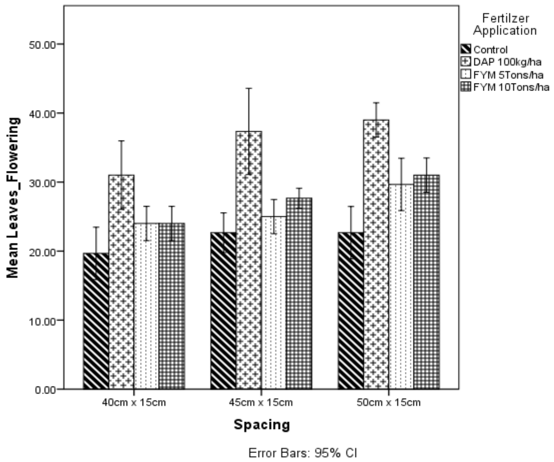

Figure 4.2: *Effect on Number of Leaves at Flowering.*

From the results, it shows that mean a number of leaves at flowering in plants at a spacing of 40 x 15cm was 25 compared to 28 among plants at 45 x 15cm spacing and 30 leaves in plants spaced at 50 x 15cm. Variations were also observed in the mean number of leaves at flowering obtained from mung beans planted under different fertilizer and FYM applications. The mean number of leaves at flowering was maximum in Mung beans planted under 100Kg/ha DAP (36 leaves) while the lowest mean in a number of leaves at flowering was realized in Mung beans planted in the control set up (22 leaves). At 10tons/ha and 5 tons/ha of FYM, the mean number of leaves at flowering in Mung beans were 28 and 26 respectively. The number of leaves at the flowering of Mung beans was significantly affected by the spacing and fertilization methods at $p<0.05$. The highest mean number of leaves at flowering was obtained at a spacing of 50 x 15cm and DAP 100Kg/ha (39 leaves), followed by a mean of 37 leaves obtained at a spacing of 45 x15 cm and DAP 100Kg/ha. The lowest mean number of leaves at flowering (20) was realized in the control set up at 40 x 15cm spacing. ANOVA results indicated that mean number of leaves differed significantly by spacing and also by fertilization method at $P>0.05$. A post-hoc analysis employing LSD test revealed that the mean differences in the number of leaves at flowering were significant at $P<0.05$ in treatments presented in Table 4.3and Table 4.4. Blocking had a significant effect on the number of leaves in mung beans under different spacing (Appendix 2).

Table 4.3: *LSD Summary for Spacing and Number of Leaves at Flowering*

Spacing (cm)	40 x 15	45 x 15	50 x 15
40 x 15		-3.500*	-5.917*
45 x 15			-2.417*
50 x 15			

**. The mean difference is significant at the .05 level.*

Mung beans planted at a spacing of 50 x 15cm and 45 x 15cm had a significantly higher number of leaves at the flowering stage than those planted at a spacing of 40 x 15cm. At a spacing of 50 x 15cm, the mean number of leaves at the flowering of Mung beans was significantly higher than at spacing of 45 x15cm. This indicates that spacing positively affected the growth of leaves, with wider spacing leading to significantly higher growth. The mean differences in a number of leaves at flowering also differed significantly by fertilization method and rates at p<0.05.

Table 4.4: *LSD Summary for Fertilization Method and Number of Leaves*

Fertilization Method	Control	100Kg/ha DAP	5ton/ha FYM	10ton/ha FYM
Control		-14.111*	-4.556*	-5.889*
100Kg/ha DAP			9.556*	8.222*
5ton/ha FYM				-1.3333*
10ton/ha FYM				

**. The mean difference is significant at the .05 level.*

Fertilization method significantly affected a number of leaves at flowering in Mung beans. DAP at 100Kg/ha produced an optimum number of leaves at flowering, significantly differing with control (14 leaves), 5ton/ha FYM (10 leaves) and 10ton/ha FYM (8 leaves). In addition, Mung beans planted at both 5ton/ha FYM and 10ton/ha FYM had a significantly higher number of leaves than the control (5 and 6 leave more respectively). These results were in agreement with Yeman and Skjelvag (2003) who reported P application increased leaf area of Pisum sativum, which closely related to the number of branches, which in turn increased the total number of leaves. Post-hoc pairwise comparisons using Bonferroni adjustment revealed that in Mung beans planted without fertilizer, significant mean differences in the number of leaves at flowering were equal between the spacing of 40 x 15cm and the other two types of spacing as shown in Table 4.5. However, these mean differences in the number of leaves at flowering were lowest compared to all other three treatments that are100Kg/ha of DAP fertilizer, 10 tons/ha FYM and 5 tons/ha FYM.

Table 4.5: *Summary of Pairwise Comparisons for Effect of Interaction.*

Fertilizer Application	Spacing (I)(cm)	Spacing (J)(cm)	Mean Difference (I-J)
Control	40 x 15	45 x 15	-3.000*
		50 x 15	-3.000*
DAP 100Kg/ha	40 x 15	45 x 15	-6.333*
		50 x 15	-8.000*
FYM 5ton/ha	40 x 15	45 x 15	-5.677*
		50 x 15	-4.677*
FYM 10ton/ha	40 x 15	45 x 15	-3.677*
		50 x 15	-7.000*
	45 x 15	50 x 15	-3.333*

**. The mean difference is significant at the .05 level.*

Mung beans planted under DAP 100Kg/ha produced the highest, significant mean difference in the number of leaves at flowering between spacing of 40 x 15cm and 50 x 15cm (-8) as well as between spacing 40 x 15cm spacing and 45 x 15cm (-6) compared to all the other treatments under control and fertilizer application. The next highest significant mean difference in a number of leaves at flowering was noted between Mung beans planted at a spacing of 40 x 15cm and 50 x 15cm under FYM 10ton/ha (-7). These results implied that an optimum number of leaves at flowering in Mung beans are obtained when there is a combination of DAP100Kg/ha and 45 x 15 cm spacing.

4.3 Effect of Number of Pods per Plant

At the end of the experiment, 10 plants were selected randomly from each plot and the number of pods on them counted. The effect of spacing and fertilization method on the number of pods per plant in Mung beans is presented graphically in Figure 4.3.

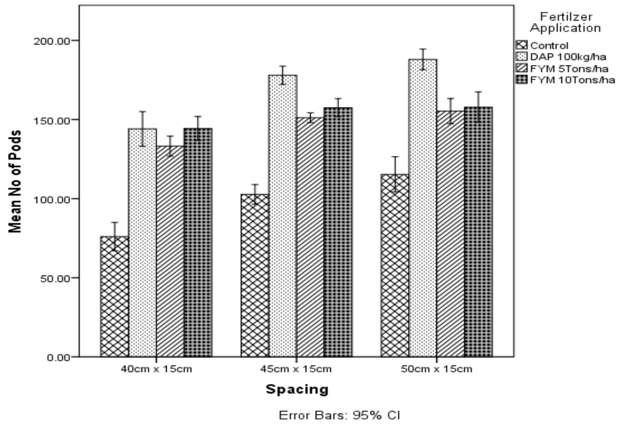

Figure 4.3: *Effect on Number of Pods per Plant*

From the results, the average number of pods per plant of Mung beans planted at a spacing of 50 x 15cm was 54 followed by an average of 52 pods per plant for the beans planted at 45 x 15cm spacing. Plants at 40 x 15cm spacing had the lowest average number of pods (24). A number of pods per plant differed by fertilization method, with the highest average number of pods being observed in mung beans planted under 100Kg/ha DAP (60 pods) followed by those at 10tons/ha FYM (52 pods) and 5tons/ha FYM (47 pods). The lowest mean numbers of pods per plant were observed in the control experiment (38 pods). Spacing and fertilization methods produced significant effects on the number of pods per plant in Mung beans at p<0.05 (Appendix 3). The highest mean number of pods per plant (188) was realized in Mung beans planted under DAP 100 Kg/ha at spacing of 50 x 15cm followed by 178 pods per plant obtained in beans planted using DAP 100 kg/ha at spacing of 45 x 15 cm. On the other hand, the lowest mean number of pods per plant was realized in beans planted at 40 x 15cm spacing in the control set up under no fertilizer. Analysis of variance showed that the mean number of pods per plant differed significantly by spacing and by fertilization method at p<0.5 (Appendix 3). Blocking also had a significant effect on the average number of pods per plant of mung beans at a different spacing (p<0.05). Least significant difference test results from post-hoc analysis showed that the mean differences in the number of pods per plant were significant at p<0.05

between the spacing presented in Table 4.6and fertilization as shown in Table 4.7

Table 4.6: *LSD Summary for Spacing and Number of Pods per Plant*

Spacing (cm)	40 x 15	45 x 15	50 x 15
40 x 15		-22.925*	-24.717*
45 x 15			-6.7917
50 x 15			

*The mean difference is significant at the .05 level.

The foregoing results imply that wider spacing had an incremental effect on the number of pods per plant, where the average number of pods per plant of Mung beans planted at spacing of 50 x 15cm and 45 x 15cm was significantly higher than the number of pods for the beans planted at spacing of 40 x 15cm. These results were a confirmation of Rasul et al., (2012) who reported that inter-row spacing significantly affected the number of pods per plant in mung beans.

Table 4.7: *LSD Summary for Fertilization Method and Number of Pods per Plant*

Fertilization Method	Control	100Kg/ha DAP	5ton/ha FYM	10ton/ha FYM
Control		-72.033*	-48.567*	-55.222*
100Kg/ha DAP			23.467*	16.811*
5ton/ha FYM				-6.656*
10ton/ha FYM				

*. The mean difference is significant at the .05 level.

A number of pods per plant in Mung beans were significantly affected by fertilization. Significantly higher means were obtained under all levels of fertilization compared to the control, with DAP 100Kg/ha producing optimum results. Ahmadi (2016) also recorded that application of P increased a number of pods/plant in mung beans. Pairwise comparisons showed that mean differences in the number of pods per plant of Mung beans were significantly different between closer and successive wider spacing under different fertilization methods. The significant mean difference in a number of pods per plant was highest in Mung beans under DAP 100kg/ha at a spacing of 40 x 15cm and 45 x 15cm (-44), followed by the mean difference between the spacingof 40 x 15cm and 50 x15cm (-44). On the other hand, the lowest significant mean difference in the number of pods per plant was noted between Mung beans planted at a spacing of 45 x 15cm and 50 x 15cm (-4) under FYM 5ton/ha as shown in Table 4.8.

Table 4.8: *Summary of Pairwise Comparisons for Effect of Interactions*

Fertilizer Application	Spacing (I)(cm)	Spacing (J)(cm)	Mean Difference (I-J)
DAP 100Kg/ha	40 x 15	45 x15	-33.900*
		50 x 15	-43.900*
	45 x 15	50 x 15	-10.000*
FYM 5ton/ha	40 x 15	45 x 15	-17.967*
		50 x 15	-22.133*
	45 x 15	50 x 15	-4.167*
FYM 10ton/ha	40 x 15	45 x 15	-13.167*
		50 x 15	-13.500*

*. The mean difference is significant at the .05 level.

4.4 Effect on Number of Seeds per Pod

The number of seeds in each pod from the 10 plants that had been randomly selected from each plot at the end of the experiment was counted. Figure 4.4 shows graphically the effects of spacing and fertilization method on the number of seeds per pod in Mung beans.

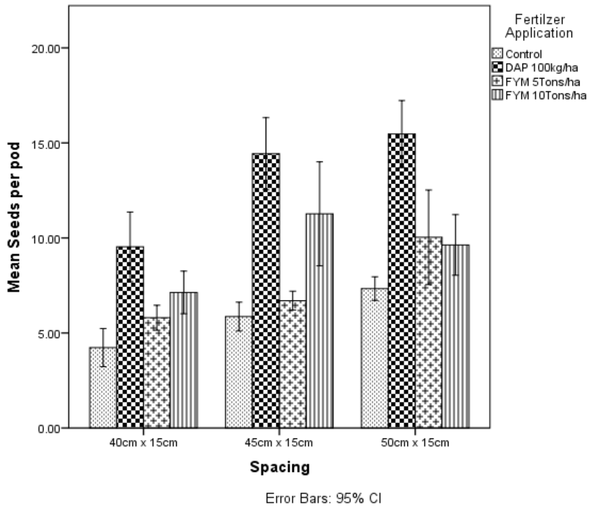

Figure 4.4: Effect on Number of Seeds per Pod

From the results, pods from mungbean planted at a spacingof 50 x 15cm and 45 x 15cm had an equal number of seeds (11) which were higher than the average number of seeds per pod for mung beans planted at 40 x 15cm spacing (7). Similarly, highest mean number of seeds per pod (11 seeds) was achieved in mung beans planted under 100Kg/ha of DAP while the lowest mean (6 seeds) was achieved in the beans planted under zero fertilization (control). Under FYM at rates of 10tons/ha and 5tons/ha respectively, the average number of seeds per pod were 9 and 8 seeds respectively. The highest mean number of seeds per pod (12) was obtained from a combination of

DAP 100 kg/ha and spacing of 50 x 15cm, followed by 10 seeds per pod in Mung beans at same fertilizer application level by the spacing of 45 x 15cm. The lowest mean number of seeds per pod was achieved in mung beans planted without fertilizer at a spacing of 40 x 15cm. ANOVA results showed that the average number of seeds per pod differed significantly by spacing and by fertilization at $p<0.05$. Least significant difference test results revealed that the mean differences in the number of seeds per pod occurred between spacing shown in Table 4.9. Blocking did not have any significant effect on the average number of seeds per pod of Mung beans (Appendix 4).

Table 4.9: *LSD Summary for Spacing and Number of Seeds per Pod*

Spacing (cm)	40 x 15	45 x 15	50 x 15
40 x 15		-3.892*	-3.942*
45 x 15			-1.0500*
50 x 15			

*. The mean difference is significant at the .05 level.

Spacing significantly affected the number of seeds per pod of Mung beans where the mean number of seeds per pod of Mung beans planted at spacing of 50 x 15cm and 45 x 15cm was significantly higher than the number of seeds per pod from mung beans planted at spacing of 40 x 15cm. Rasul et al., (2012) reported similar results where inter-row spacing significantly affected the number of seeds per pod with wider spacing giving a higher number pod. Table 4.10 shows where the significant differences occurred between the different fertilization methods.

Table 4.10: *LSD Summary for Fertilization Method and Number of Seeds per Pod*

Fertilization Method	Control	100Kg/ha DAP	5ton/ha FYM	10ton/ha FYM
Control		-7.333*	-1.700*	-3.533*
100Kg/ha DAP			5.633*	3.800*
5ton/ha FYM				-1.833*
10ton/ha FYM				

*. The mean difference is significant at the .05 level.

The number of seeds per pod was significantly affected by the method of fertilization. Significantly higher mean a number of seeds per pod were achieved under DAP at 100Kg/ha compared to the control (7 more seeds per pod), 10ton/ha FYM (4 more seeds per pod) and 5tons/ha FYM (6 more seeds per pod). Under 10ton/ha and 5ton/ha of FYM, the mean number of seeds per pod of Mung beans were significantly higher than in the crop under zero fertilization (control). These results were consistent with those of Ismail (2004) who found that application of phosphorus fertilizer significantly increased the number of seeds per pod in mung beans. Pairwise comparison of means showed that the mean differences were significant between different spacing under difference fertilization methods as shown in Table 4.11 below.

Table 4.11: *Summary of Pairwise Comparisons for Effect of Interaction.*

Fertilizer Application	Spacing (I)(cm)	Spacing (J)(cm)	Mean Difference (I-J)
DAP 100Kg/ha	40 x 15	45 x 15	-4.900*
		50 x 15	-5.933*
FYM 5ton/ha	40 x 15	45 x 15	-
		50 x 15	-4.233*
	45 x 15	50 x 15	-3.333*
FYM 10ton/ha	40 x 15	45 x 15	-4.133*
		50 x 15	-2.500*
	45 x 15	50 x 15	1.633*

*. The mean difference is significant at the .05 level.

As shown in Table 4.11, the highest significant mean difference in the number of seeds per pod was realized in mung beans planted under DAP 100kg/ha between the spacing of40 x 15cm and50 x 15cm (-6), with the later spacing producing the highest number of seeds per pod. Similarly, the second highest significant mean difference in the number of seeds per pod as a result of effects of spacing and fertilization method was obtained in mung beans under DAP 100kg/ha between the spacing of 40 x 15cm and 45 x 15cm.

4.5 Effect on Seed Weight of Mung Beans

Seed weight of Mung beans was obtained by randomly picking 100 seeds from amongst grains harvested from each plot taking their weight in grams using an electric weighing scale. Figure 4.5 shows graphically the mean seed weight of Mung beans as affected by spacing and fertilization.

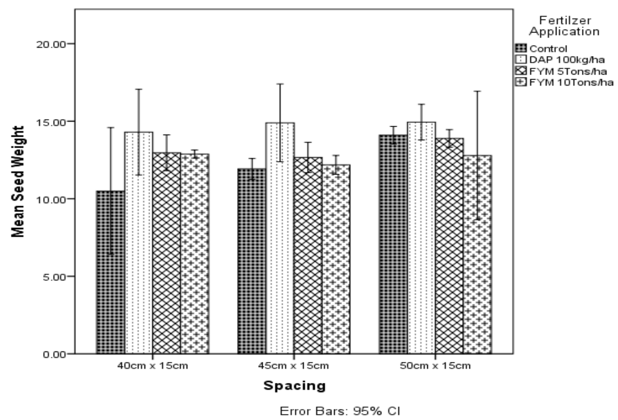

Figure 4.5: *Effect on Seeds Weights*

The statistical analysis of the collected seed weights showed that the highest mean seed weight (8.93g) was obtained on seeds of mung beans planted at a spacing of 50 x 15cm while the lowest mean (5.66g) was related to the seeds from plants at 40 x 15cm spacing. The seed weight of mung beans planted at 45 x 15cm spacing was 8.82g, the next highest. The average seed weight of mung beans was highest (9.17g) in the crop planted under 100Kg/ha of DAP. Under 10tons/ha and 5tons/ha FYM respectively, the average seed weight was 8.62g and 8.87g. The lowest average seed weight (7.18g) was realized in the crop planted in the control set up. Mean seed weight of mung beans ranged from 10.5 grams (lowest) at a spacing of 40 x 15cm in the control set up (no fertilizer application) to 14.94 grams (highest) at a spacing of 50 x 15cm under DAP 100 kg/ha. ANOVA results showed that the mean seed weights differed significantly by spacing and by fertilization methods (Appendix 5). Post-hoc analysis results employing the LSD test showed that the mean differences in the seed weight of Mung beans differed significantly by spacing at p<0.05 as summarized in Table 4.12 and by fertilization method as shown in Table 4.13

***Table 4.12**: LSD Summary for Spacing and Seed Weight of Mung Beans*

Spacing (cm)	40 x 15	45 x 15	50 x 15
40 x 15		-1.011*	-1.269*
45 x 15			-1.0112*
50 x 15			

*. The mean difference is significant at the .05 level.

The results in Table 4.12 show that different spacing produces different growth results in Mung beans. Mung beans plants spaced at 50 x 15cm and 45 x 15cm produced seeds that had significantly higher mean weight than those planted at 40 x 15cm spacing. These findings were in concurrence with Rasul et al., (2012) who found that wider inter-row spacing significantly affected seed weight of mung beans.

***Table 4.13:** LSD Summary for Fertilization Method and Seed Weight*

Fertilization Method	Control	100Kg/ha DAP	5ton/ha FYM	10ton/ha FYM
Control		-2.536*	-0.997*	-
100Kg/ha DAP			1.539*	2.094*
5ton/ha FYM				-1.0112*
10ton/ha FYM				

*. The mean difference is significant at the .05 level.

Fertilization method significantly affected seed weight of Mung beans. Under DAP 100Kg/ha the mean seed weight was significantly higher compared to the beans in the control experiment (mean difference = 2.54g), beans under 10tons/ha of FYM (mean difference = 2.094g) and beans under 5tons/ha of FYM (mean difference = 1.54g). The mean difference between FYM at 5tons/ha and the control set up was also 0.997 grams, which was significant at p<0.05. These results were in agreement with Kumar and Puri (2002) and Ismail (2004) who reported that application of P at the rate of 100Kg/ha resulted in significant increase in seed weight of mung beans.

4.6 Effect on Dry Matter Yield of Mung Beans

To obtain the weight of dry matter yield, destructive harvesting of 10 randomly selected plants from the centre rows of each plot was done when over 75% of the pods had dried. After uprooting, the soil on the roots was washed down and the plants sundried for 3 days to constant weight (13.0% moisture content) and their dry weight taken using electric measuring scale. The total biomass was then calculated by adding the dry weight of the plant (leaves + shoot + roots) at harvest to the weight of the pods and seeds removed. Graphical representation of the results is shown in Figure 4.6 below

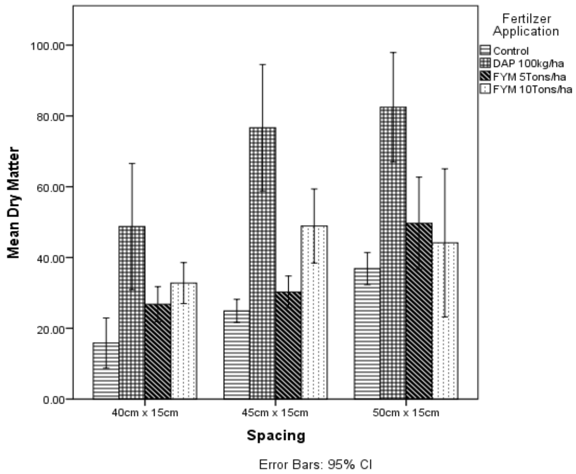

***Figure 4.6:** Effect on Dry Matter Yield*

The results indicated that mean dry matter yield of Mung beans at a spacing of 50 x 15cm was the highest (49.78g) followed by the mean of beans spaced at 45 x 15cm (41.68g), while beans at a spacing of 40 x 15cm had the lowest mean dry matter weight of 27.54g. Analysis of variance showed that the mean dry matter weight differed significantly by spacing at p<0.05 (Appendix 6). However, blocking had no significant effect on dry matter weight. Effects of spacing and fertilizer application significantly affected dry matter yield of mung beans. The lowest mean dry matter yield following the effects of spacing and fertilizer application was obtained under FYM 5 ton/ha at 40 x 15cm (26.82gm) while the highest mean dry matter yield (68.45gm) was realized from a combination of DAP 100 kg/ha and spacing of 50 x 15cm. Analysis of variance results (Appendix 6) showed that dry matter yield was significantly affected by spacing and fertilization methods at p<0.05. The highest significant mean difference in dry matter yield of Mung beans (-33.70gm) from a combination of spacing and fertilization method occurred under DAP 100 kg/ha, between 40 x15cm and 50 x 15cm spacing. This was followed by a significant mean difference in dry matter yield of the bean of -28gm under same fertilization method but between the spacing of 40 x 15cm and 45 x 15cm.Post-hoc analysis results deploying LSD test revealed that significant mean differences were between the treatments as summarized in Table 4.14

Table 4.14: *LSD Summary for Spacing and Dry Matter Weight of Mung Beans*

Spacing (cm)	40 x 15	45 x 15	50 x 15
40 x 15		-14.149*	-22.248*
45 x 15			-8.0989*
50 x 15			

*. The mean difference is significant at the .05 level.

The results show that spacing significantly affected dry matter weight of Mung beans, where dry matter weight at closer spacing was significantly lower than dry matter weight of the beans at wider spacing. At a spacing of 50 x 15cm and 45cm by 15cm, dry matter weights were significantly higher than dry matter weight of beans planted at a spacing of 40 x 15cm.Rasuland others (2012) had earlier reported that biomass of mung beans was significantly affected by spacing, results that were also consistent with those reported by Singh and others (2009). In terms of the effect of fertilization method on dry matter yield of mung beans, the mean dry matter weight was highest in DAP 100Kg/ha (55.28g) while the lowest was attained in the bean crop planted under the control set up (25.87g). Under FYM 10tons/ha and 5tons/ha respectively, the mean dry matter weights of bean were 41.93g and 35.58g. These mean dry matter weights under different fertilizer treatments were significantly different from each other at p<0.05 as depicted by the ANOVA results in Appendix 6. The LSD test results indicating where the significant differences lay are summarized in Table 4.15.

Table 4.15: *LSD Summary for Fertilization Method and Dry Matter Yield*

Fertilization Method	Control	100Kg/ha DAP	5ton/ha FYM	10ton/ha FYM
Control		-29.411*	-9.709*	-16.059*
100Kg/ha DAP			19.701*	13.352*
5ton/ha FYM				-6.349*
10ton/ha FYM				

*. The mean difference is significant at the .05 level.

The LSD test results show that fertilization significantly affected dry matter yield of Mung beans. Across all levels of fertilization, the mean dry matter weights were significantly higher than the dry matter weight of beans planted in the control set-up at p<0.05. On the other hand, the mean dry matter weight of Mung beans planted under DAP 100Kg/ha was significantly higher than the mean dry matter weight of beans under 10tons/ha FYM and 5tons/ha FYM. Mung beans planted under 10tons/ha FYM had a significantly higher mean dry matter weight than the beans planted under 5tons/ha FYM. Overall, DAP 100Kg/ha produced optimum dry matter weight for Mung bean. Ismail (2004) and Kumar and Chandra (2003) similarly showed that application of DAP significantly increased the plant dry matter and grain yield of mung bean.

Table 4.16: *Summary of Pairwise Comparisons for Effect of Interaction.*

Fertilizer Application	Spacing (I)(cm)	Spacing (J)(cm)	Mean Difference (I-J)
DAP 100Kg/ha	40 x 15	45 x 15	-27.917*
		50 x 15	-33.699*
FYM 5ton/ha	40 x 15	45 x 15	-
		50 x 15	-22.863*
	45 x 15	50 x 15	-19.420*
FYM 10ton/ha	40 x 15	45 x 15	-16.128*
		50 x 15	-11.388*

*. The mean difference is significant at the .05 level.

The foregoing results imply that application of DAP100kg/ha and spacing of 50 x 15 cm produced optimum dry matter yield of Mung beans. Competing results were however obtained under same fertilization but at a closer spacing of 45 x 15cm.

4.7 Effect on Grain Yield Harvest of Mung Beans

Grain yield was determined at the end of the experiment by picking all pods from 10 randomly selected plants from each plot when 75 % of the pods had dried to avoid shattering. The harvested pods were sun-dried to constant weight at13 % moisture content and their weight taken using an electric weighing scale. The grains were then removed from the pods, weighed and the yield converted to tonnes per hectare for each plot. Figure 4.7 shows the graphical representation of the results of spacing and fertilization methods on grain yield harvest of Mung beans.

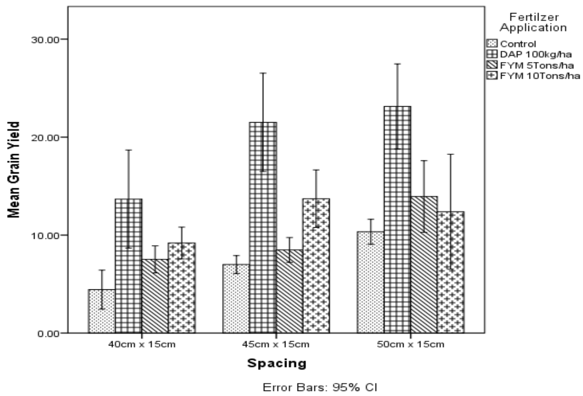

Figure 4.7: *Effect on Grain Yield Harvest*

The results showed that the mean grain yield was highest in Mung beans planted at a spacing of 45 x 15cm (1.27 tonnes/ha). Beans planted at 50 x 15cm spacing had a mean grain yield of 1.05 tonnes/ha while beans planted at a spacing of 40 x 15cm had the lowest grain yield of 0.87 tonnes/ha. Mung beans planted using DAP 100 kg/ha at a spacing of 50 x 15cm had the highest mean grain yield harvest of 23 grams while the lowest mean grain yield was obtained under FYM 5 ton/ha at 40 x 15 cm spacing. ANOVA results showed that the mean grain yield harvest differed by spacing significantly at p<0.05 as presented in Appendix 7. Blocking had no significant effect on grain yield harvest. LSD test results indicated that the significant mean differences occurred between the treatments as summarized in Table 4.17.

Table 4.17: *LSD Summary for Spacing and Grain Yield Harvest of Mung Beans*

Spacing (cm)	40 x 15	45 x 15	50 x 15
40 x 15		-0.397*	-0.174*
45 x 15			-0.223
50 x 15			

*. The mean difference is significant at the .05 level.

Grain yield harvest of Mung beans was significantly affected by spacing, with a spacing of 45 x 15cm and 50 x 15cm producing significantly higher mean grain yield harvest than 40 x 15cm. The mean difference in grain yield harvest between the spacing of 45 x 15 cm and 40 x 15cm spacing was 0.397 tons/ha while beans planted at a spacing of 45 x 15cm had a significant mean difference of 0.223 tons/ha with beans planted at a spacing of 50 x 15cm. On the other hand, mean grain yield harvest at a spacing of 50 x15cm and 40 x 15cm had a significant mean difference of 0.174 tons/ha. These results were consistent with Rasul and others (2012) and Ali and others (2012) who established that grain yield of mung beans was significantly affected by spacing, with higher grain yield being realized at inter-mediate inter-row spacing. DAP 100Kg/ha yielded the highest mean grain harvest of Mung beans (1.79tons/ha) while the lowest mean grain yield harvest of 0.58 tons/ha was obtained in the control set up. FYM 10tons/ha and FYM 5tons/ha produced mean grain yield harvests of 1.03tons/ha and 0.85 tons/ha respectively. These grain yield harvest means differed significantly by fertilization method at $p<0.05$ as shown by ANOVA results (Appendix 7).The results of post-hoc LSD test analysis indicating where the significant mean differences in grain yield harvest of Mung beans occurred are summarized in Table 4.18

Table 4.18: *LSD Summary for Fertilization Method and Grain Yield Harvest.*

Fertilization Method	Control	100Kg/ha DAP	5ton/ha FYM	10ton/ha FYM
Control		-1.218*	-0.272*	-0.450*
100Kg/ha DAP			0.946*	0.767*
5ton/ha FYM				-0.178*
10ton/ha FYM				

*. The mean difference is significant at the .05 level.

As the LSD test results presented in Table 4.19 confirm, grain yield harvest of mung beans was significantly affected by fertilization method where all levels of fertilization (DAP 100Kg/ha, FYM 10tons/ha and 5tons/ha) yielded significantly higher grain harvests compared to the control under zero fertilization. Significantly higher grain yield harvests were also realized under DAP 100Kg/ha than FYM 10tons/ha (mean difference = 0.77tons/ha) and FYM 5tons/ha (mean difference =0.95 tons/ha), indicating that the crop performed relatively better under DAP 100Kg/ha fertilization than under the two different rates of FYM and control. Results of post-hocpairwise comparisons of significant mean differences are presented in Table 4.19.

Table 4.19: *Summary of Pairwise Comparisons on Grain Yield Harvest*

Fertilizer Application	Spacing (I)(cm)	Spacing (J)(cm)	Mean Difference (I-J)
DAP 100Kg/ha	40 x 15	45 x 15	-0.783*
		50 x 15	-0.496*
	45 x 15	50 x 15	0.288*
FYM 10ton/ha	40 x 15	45 x 15	-0.453*
	45 x 15	50 x 15	-0.583*

*. The mean difference is significant at the .05 level.

The post-hocPairwise comparison showed that higher significant mean difference in grain yield harvest was between mung beans planted at a spacing of 45 x 15cm and 40 x 15cm under DAP 100kg/ha (0.78 tons/ha) and 50 x15cm and 40 x 15cm (0.496 tons/ha) under same fertilizer treatment. Other significant mean difference in grain yield harvest occurred in mung beans planted using FYM 10ton/ha between the spacing of 45 x 15cm and 40 x 15cm (0.45ton/ha) and also between the spacing of 50 x 15cm and 45 x 15cm (0.58ton/ha).

4.8 Effect on Harvest Index of Mung Beans

Harvest index was obtained by expressing the grain yield/ha as a percentage of the total harvested biomass yield in grams. Figure 4.8 shows the results of the effect of spacing and fertilization method on harvest index of Mung beans.

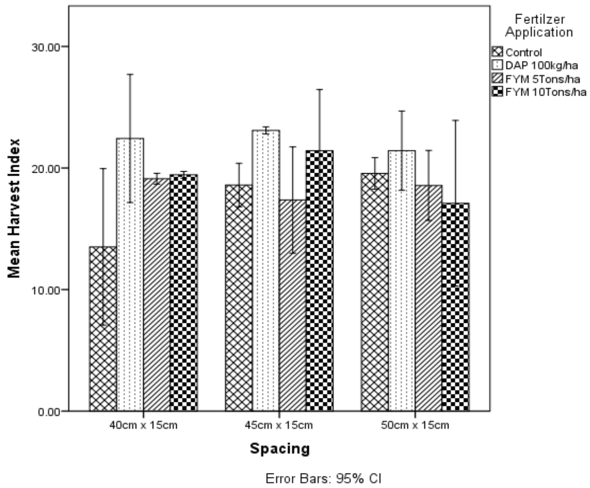

Figure 4.8: *Effect on Harvest Index*

The highest mean HI (20.12) was obtained in Mung beans planted at a spacing of 45 x 15cm followed by an HI of 19.16 obtained from the Mung beans planted at a spacing of 50 x 15cm. Mung beans planted at 40 x 15cm spacing produced the lowest HI of 18.62. Results from ANOVA showed that the mean differences in HI based on spacing were marginally significant at $p = 0.076$ as shown in Appendix 8. Mung beans planted under DAP 100 kg/ha produced higher mean harvest indices across all levels of spacing compared to the other fertilizer treatments (FYM 10 ton/ha and 5 ton/ha). ANOVA results indicated that combination of spacing and fertilization method significantly affected harvest index of Mung beans at p<0.05.The LSD test results showed that significant mean HI differences were between the spacing of 45 x 15 cm and 40 x 15cm as shown in Table 4.20.

Table 4.20: *LSD Summary for Spacing and Harvest Index of Mung Beans*

Spacing (cm)	40 x 15	45 x 15	50 x 15
40 x 15		-1.498*	-.5375
45 x 15			.9603
50 x 15			

*. The mean difference is significant at the .05 level.

Although the results show that the mean differences in HI between the 50 x 15cm and 45 x15cm spacing were not significant, it was generally found that spacing affected HI of Mung beans given that significant mean HI differences were obtained in Mung beans planted at 45 x 15cm and those planted at 40 x 15cm spacing (mean difference in HI = 1.498). These results concurred with the results of Ahmadi (2016) who found that harvest index of mung beans was significantly affected by plant density, which is a function of spacing. The mean harvest index was highest under DAP 100Kg/ha (22.32) while the lowest mean HI was obtained from the crop under no fertilizer application (17.22). FYM 10tons/ha and FYM 5tons/ha produces comparatively lower harvest indices (19.32 and 18.35 respectively) compared to DAP 100kg/ha. Analysis of variance results in Appendix 8 showed that the mean harvest indices differed significantly by fertilization method at p<0.05. LSD results showing the treatments that had significant differences in mean HI are summarized in Table 4.21.

Table 4.21: *LSD Summary for Fertilization Method and Harvest Index.*

Fertilization Method	Control	100Kg/ha DAP	5ton/ha FYM	10ton/ha FYM
Control		-5.097*	-1.1293	-2.102*
100Kg/ha DAP			3.967*	2.995*
5ton/ha FYM				-.9731
10ton/ha FYM				

*. The mean difference is significant at the .05 level.

The harvest index in Mung beans was significantly affected by fertilization, with beans planted using DAP 100Kg/ha giving significantly higher HI than the beans planted using FYM at 10tons/ha (mean difference = 3.0) and FYM 5tons/ha (mean difference = 3.97) as well as the control (mean difference = 5.1). The crop under 10tons/ha FYM had also a significantly higher mean HI than the crop planted in a control set up (mean difference = 2.102).Pair wise comparison of the mean differences showed that the mean differences in harvest index were only significant between Mung beans planted at a spacing of 40 x 15cm and 50 x 15cm under FYM 10ton/ha as shown in Table 4.22. The mean differences in harvest index among the other spacing-fertilizer combination were not significant.

Table 4.22: *Summary of Pairwise Comparisons for Effect of spacing and fertilization*

Fertilizer Application	**Spacing (I)(cm)**	**Spacing (J)(cm)**	**Mean Difference (I-J)**
DAP 100Kg/ha	40 x 15	45 x 15	
		50 x 15	
FYM 5ton/ha	40 x 15	45 x 15	
		50 x 15	
FYM 10ton/ha	40 x 15	45 x 15	
		50 x 15	4.327*

*The mean difference is significant at the .05 level.

4. CONCLUSION

This study aimed at determining the effect of spacing and fertilization on growth and grain yields of mung beans in the dry areas of Subukia, Nakuru County of Kenya. Consequently, the study has established and concludes that first, spacing significantly affects height, number of leaves at flowering, number of pods per plant, number of seeds per pod, seed weight, dry matter yield, grain yield and harvest index of mung beans. The optimum spacing for an economic yield of mung beans (grain yield and harvest index) is established as 45 x 15cm given that this is the spacing that provides optimum plant population or density. Second, the study concludes that growth and yield of mung beans are significantly affected by fertilizer application. The fertilizer that gives optimum productivity of mung beans in terms of growth parameters viz height, number of leaves at flowering, number of pods per plant, number of seeds per pod, seed weight and yield (dry matter yield, grain yield and harvest index) is DAP applied at the rate of $100kgha^{-1}$. Nonetheless, FYM applied at the rate of up to $10tonsha^{-1}$ has the potential for improving productivity despite its slow rate of nutrient release as well as low percentages of major plant nutrients (NPK). Third and finally, this study showed combining spacing of 45 x 15cm and DAP at the rate of $100kgha^{-1}$ had a significant effect on the growth and yield of mung beans in Subukia in Nakuru County of Kenya. While it suffices to conclude that economic production of mung beans can be attained with this combination, it is also important to note that interaction between the spacing of 45 x 15cm and up to $10tonsha^{-1}$ of FYM could provide an alternative combination where the cost of inorganic phosphorus becomes a limiting factor.

5. RECOMMENDATIONS

Based on the foregoing conclusions, the study recommends that holding other factors constant, mung beans farmers in Subukia Sub-county of Nakuru County should adopt a spacing of 45 x 15cm. Application of phosphorus plays an important role in growth, development and yield productivity of mung beans as established by this study. Phosphorus helps to increase grain yield, seed quality, regulate the photosynthesis, govern physiological and biochemical processes as well as the development of roots and modulation which facilitates Nitrogen fixation. Therefore, application of phosphorus by mung beans farmers in form of DAP(100kg^{-1}) is highly recommended by this study. Nonetheless, 10tons of FYM ha-^{1}can be considered as an alternative to DAP.

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