**International Journal of Multidisciplinary Research and Development**
**Online ISSN: 2349-4182, Print ISSN: 2349-5979; Impact Factor: RJIF 5.72**
**Received: 23-05-2020; Accepted: 24-05-2020; Published: 11-06-2020**
**www.allsubjectjournal.com**
**Volume 7; Issue 6; 2020; Page No. 172-177**

# The effects of plant population and harvesting interval on the growth and yield of slender leaf (*Crotalaria Brevidens*)

**Granduel Jemutai Momanyi[1*], David Mushimiyimana[2], Peter A Kamau[3]**
[1-3] Department of Agriculture and Natural Resources, Kenya Methodist University, P.O. Box, Meru, Kenya

**Abstract**
Slenderleaf (*Crotalaria brevidens*), is a species of Crotalaria that is used as a vegetable in Kenya. It is a highly nutritive leafy vegetable, a sources of provitamin A, Vitamin C, carotenoids, iron protein and calcium. Production of slender leaf in Kenya is low at 3 tons per hectare compared to a research potential of 10 tons per hectare. Though extensive research has been done to evaluate the effect of nitrogen and phosphorus on the growth of slender leaf; no work has been carried out in Kenya on the effect of plant population and fresh leaf harvesting interval on the yields of slender leaf. An experimental study was carried out at Kisii Farmers Training Centre in Kisii County, Kenya, to determine plant population and harvesting interval effects on the fresh leaf yield and grain seed yield of the slenderleaf (*Crotalaria brevidens*). A Randomized complete block design with factorial arrangement of three levels of plant population 30 cm x 30 cm, 30 cm x 20 cm and 30 cm x 15 cm and four levels of leaf harvesting intervals 7days, 28days, 49 days and at maturity) treatments were used to evaluate the growth and yield potential of slenderleaf. Data collected was analyzed using SPSS 21.0. Analysis of variance was done to identify significant means between treatments and Least Significant Difference was used to separate the means at P=0.05. Results indicated that fresh leaf yield is depended upon the harvesting interval (intensity) and plant population ($p<0.05$). Wider spacing (low plant population) and less frequent leaf harvesting (defoliation) resulted in low fresh and dry leaf weight yields. Harvesting interval was significant and had a greater effect on fresh leaf yield ($p<0.05$) as opposed to plant population (p= 0.985). Plant population had a great significant on plant growth (stem height and number of branches). The effect of harvesting interval and plant population was significant in pod formation and seed weight as observed from all the treatment combinations with 30 cm x 30 cm and at maturity harvesting interval giving the highest number of pods. The dry grain weight was greatly influenced by both plant population and harvestings interval with 30 cm x 20 cm and at maturity, giving the highest seed yields of 3,500kg/Ha. The results of the study indicated that fresh leaf yield of slenderleaf can be greatly increased by using a harvesting interval of 28 days and 30 cm x 20 cm plant spacing.

**Keywords:** harvesting interval, plant population, slenderleaf, growth, yields

## 1. Introduction

Slender leaf (*Crotalaria brevidens*), alias the rattle pod, is a species of Crotalaria that is used as a vegetable in Kenya. It is a highly nutritive leafy vegetable, sources of provitamin A, Vitamin C, carotenoids, iron protein and calcium. Vegetables are an important component in human diet in almost every household in Kenya. Slender leaf is one of the African indigenous vegetables that have been grown and utilized traditionally by the Kenya communities. African indigenous vegetables (AIV) are well adapted to harsh climatic conditions and disease infestation and are easier to grow in comparison to other indigenous counterparts. African indigenous vegetables (AIV) have a short growth period, are often ready for 1st harvest within 3-4 weeks, and respond well to organic fertilizers. They have an inbuilt ability to withstand and tolerate some biotic and abiotic stress (Abakutsa - Onyango, 2004) [1]. The African indigenous vegetables in addition to being a highly nutritious (rich in several minerals, ascorbic acid and beta-carotene) component in food security, they have a high potential as a cash income earner, enabling the poorest people in the rural communities to earn a living (Muhanji *et al*. 2011) [12]. This aspect makes them a treasured supply of nutrients, considerably contribute to the intake of proteins, vitamins and also mineral in the rural areas. (Kaul & Das, 2011) [7]. They can also be afforded by most people both in rural and urban areas.

Slenderleaf (*Crotalaria brevidens*) commonly known as Marejea (Swahili) and internationally referred to a vegetable of small-scale production. The slenderleaf is among the African indigenous vegetables (AIV) that has for several years been planted while their young leaves and shoots are consumed as vegetables. The young leaves of slenderleaf are a good source of a number of vitamins and minerals as reported by Abakutsa- Onyango, (2004) [1]. Hundred grams fresh weight of slender leaf contributes 4.2-4.9 mg protein, 270 mg calcium, 4mg Iron, 2.9-8.7 mg beta carotene, 115-129 mg ascorbic acid (Sikuku *et al*. 2013). It is a whole purpose crop in agriculture, and it has a medicinal effect. It has high levels of antioxidant activities factors, expressed as bioactive components, just like any other AIV. The consumption of slender leaves can contribute to alleviating some of the malnutrition problem, which is a significant challenge in Kisii County. It is a good source of some of the critical micronutrients whose deficiency is of public health concern. Production of slenderleaf in Kenya is low at 3tons per hectare compared to a research potential of 10 tons per hectare. The low production in Kenya has been attributed to poor quality seed, low application of modern technologies and declining soil fertility (Gido *et al*. 2017) [4].

There is limited research on slender leaf agronomy and performance in different regions of Kenya, and the current study is part of the managed cultivation of slenderleaf under field conditions. The effect of nitrogen, phosphorus, and the impact of poor seed are the few agronomical studies on the slenderleaf that have been carried out in Kenya (John Harrison, 2010) [6]. In contrast, there is little or no information on plant population and harvesting interval effect on the growth and yield of the This research was done to determine the effect of plant population and harvesting interval agronomic practices on the fresh leaf yield and grain seed yields of slenderleaf. The specific objectives of the study were (i) to establish the effect of different plant spacing on fresh leaf yield of slender leaf; (ii) to determine the effect of different harvesting interval on fresh leaf yield of slender leaf and (iii) to determine the effect of different harvesting interval on the seed yield of slender leaf.

## 2. Materials and Methods

### 2.1 Site Description

The experimental site was located at Kisii Agricultural Training centre (KATC), within Nyaribari Chache Constituency of Kisii County in Western Kenya. The area lies within 10 South and longitude 340 East at a height of 1,722 meters above sea level. The Agro Ecological zone (AEZ) is upper midland (UM) with a diurnal temperature range of 21- 300C. The soils are red volcanic nitisols, deep and rich in organic matter; but with low soil fertility due to low mineral content and low cation exchange capacity (Jaetzold *et al.*, 2006) [5]. The annual precipitation 10-year cycle average range is 1,200 – 2,100 mm per annum.

### 2.2 Field Experiment

The experimental design was a Randomized Complete Block Design (RCBD) experiment with three replicates. The treatment factors comprised of three spacings and four harvesting intervals that gave rise to twelve (12) treatment combinations; that were randomly allocated to 36 experimental plots (each measuring 3mx2m). The plots were separated by 0.5m space and a path of 1m wide separated adjacent blocks. The experimental factors were; **i)** Spacings of (a) 30 cm x 30 cm (S1), giving a population of 110,000 plants/hectare population; (b) 30 cm x 20 cm (S2), giving 166,666 plants/hectare population; and (c) 30 cm x 15 cm (S3), giving 221,666 plants/hectare population. ii) Harvesting intervals of (a) 7 days (H1), (b) 28 days (H2), (c) 49, days (H3), (d) at Physiological Maturity (H4). The treatment combinations are as shown in Table 1.

**Table 1:** Treatment Combinations

| | | Harvesting Interval | | | |
|---|---|---|---|---|---|
| | | **H1 (after 7days)** | **H2 (after 28 days)** | **H3 (after 49 days)** | **H4 (at Maturity)** |
| Plant Spacing | S1(30cmX30cm) | S1H1 | S1H2 | S1H3 | S1H4 |
| | S2(30cmX20cm) | S2H1 | S2H2 | S2H3 | S2H4 |
| | S3(30cmX15cm) | S3H1 | S3H2 | S3H3 | S3H4 |

### 2.3 Data Collection

Six plants from each of the trial plots were randomly sampled and tagged avoiding the boarder rows. These plants were used to measure various parameters progressively throughout the experiment period. The parameters measured were; stem height, branch numbers, yields for both fresh and dry leaf, number of pods plus weight of seed.

The stem height of the plant above the soil level from the plant base to the tip of the terminal shoot was measured in centimeters using a tape measure to establish the growth of the plant. The measurements were taken initially at 7 days after emergence, then at 21 days after emergence, at 42 days after emergence and at physiological maturity.

The branch numbers for every plant per treatment plot were counted physically initially at 7 days after emergence, then at 21 days after emergence, at 42 days after emergence, and at maturity.

The plant’s fresh leaves were harvested after every 7 days, 28 days and 49 days for different plots according to the treatment after observation for readiness for harvesting and consumption. The leaves were weighed immediately in Kilograms using an electronic weighing balance. To obtain dry leaf yield the fresh leaves were placed on an oven pan and dried in an electric oven at 125˚F for six hours. This was done uniformly for all the fresh leaves harvested. After drying the leaves were weighed in Kilograms using an electronic weighing balance.

### 2.4 Data Analysis

The data collected was checked for consistency and completeness and then analyzed using SPSS

21.0 computer software. Both descriptive and inferential statistics were used to analyze the data.

Analysis of Variance (ANOVA) was done to identify mean differences between treatment combinations; and the differences among means were separated using the least significant difference (LSD) test at 0.05% significance level.

## 3. Results & Discussion

### 3.1 Plant Growth (Plant Height and Branch Numbers)

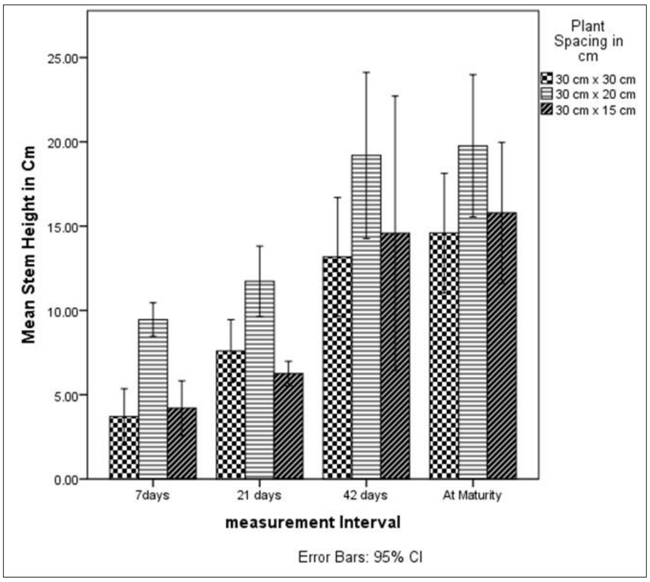


**Fig 1:** Effect of Measuring Interval and Plant Spacing on Stem Height

There were noted differences in slender leaf plant height at different stem height measurement intervals. Plant heights at a spacing of 30 cm x 20 cm were consistently fairly tall in all the measuring intervals followed by plant heights at spacing of 30 cm x 15 cm with the exception of 21 days measuring interval where a higher plant height was found at spacing 30 cm x 30 cm than at 30 cm x 15 cm. The plants at maturity recorded the highest mean stem height (19.76 cm) followed by the 42-day measurement interval which recorded a height of 19.19 cm (Figure 1).

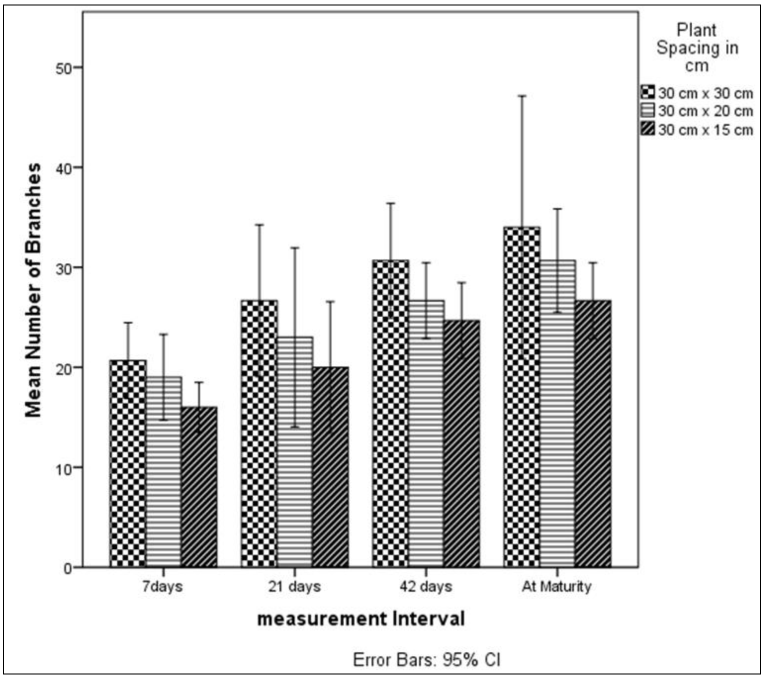


**Fig 2:** Effect of Measuring Interval and Plant Spacing on Number of Branches

The analysis showed that there were differences in mean number of branches per plant at different measurement intervals (of 7, 21, and 42 days after emergency and at maturity) and spacing (30cm x 30 cm, 30 cm x 20 cm and 30 cm x 15 cm) (Figure 2)

There were observed differences in the number of branches between different treatment combinations. The 30 cm x 30 cm plant spacing and at maturity exhibited the uppermost number of branches. The lowest number of branches were exhibited by treatment 30 cm x 15 cm spacing at 7 days measurement interval. Plant spacing 30 cm x 30 cm exhibited the highest number of branches in all the measurement intervals (Figure 2). This agrees with the observation made by Tripathi *et al*., 2013 [17] who observed that wider spacing in *Crotalaria juncea* L yielded the highest number of primary and secondary branches.

**Table 1:** Combined ANOVA Summary on Effect of Measurement Interval and Plant Spacing on Stem Height and Branch Numbers

| Tests of Between-Subjects Effects | | | | | | |
|---|---|---|---|---|---|---|
| **Source** | **Dependent Variable** | **Type III Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Measurement interval | Stem Height in Cm | 771.621 | 3 | 257.207 | 124.898 | .000 |
| | Number of Branches | 717.556 | 3 | 239.185 | 42.264 | .000 |
| Plant Spacing in cm | Stem Height in Cm | 205.132 | 2 | 102.566 | 49.805 | .000 |
| | Number of Branches | 228.222 | 2 | 114.111 | 20.164 | .000 |
| Error | Stem Height in Cm | 61.780 | 30 | 2.059 | | |
| | Number of Branches | 169.778 | 30 | 5.659 | | |
| Total | Stem Height in Cm | 1038.533 | 35 | | | |
| | Number of Branches | 1115.556 | 35 | | | |

Results indicated that both spacing and measuring interval were significant ($p \leq 0.05$) on stem height and branch numbers.

Post Hoc (LSD) test was conducted at $p \leq 0.05$ to separate the differences between the means as shown in Table 2 and 3 below. The results indicated that measurement intervals and the spacings means were statistically different from each other.

**Table 2:** Effect of Stem Measuring Interval on Stem Height and Number of Branches

| Report | | | |
|---|---|---|---|
| **Measurement Interval** | | **Plant Height in Cm** | **Branches Numbers** |
| 7days | Mean | 5.7889 b | 18.56 c |
| 21 days | Mean | 8.5233 b | 23.22 b |
| 42 days | Mean | 15.6478 a | 27.33 b |
| At Maturity | Mean | 16.7122 a | 30.44 a |

The results indicated that there was progressive increase in mean stem height and mean number of branches with time from the 7days DAE up to maturity (Table 2). The mean stem height increased with time, starting to show significant differences ($p \leq 0.05$) from the 42$^{nd}$ day. The mean plant height at 42 was not significantly different from the mean at maturity. While the mean plant height at 7 and 21 days is statistically different from the means at 42 days and maturity.

The mean branch numbers increased as the days after emergence increased. The mean branch number at maturity was significantly different from the mean at 42 days, 2 days and at 7 days. There was no significant difference between the branch number mean of 21 days and 42 days but there was significant difference from the mean at 7 days and that of 21 and 42 days (Table 2).

**Table 3:** Effect of Plant spacing on Stem Height and Number of Branches

| Report | | | |
|---|---|---|---|
| Plant Spacing in cm | | Stem Height in Cm | Number of Branches |
| 30 cm x 30 cm | Mean | 9.7633 b | 28.00 a |
| 30 cm x 20 cm | Mean | 15.0342 a | 24.83 a |
| 30 cm x 15 cm | Mean | 10.2067 b | 21.83 b |

Results indicated that there was a significant difference ($p \leq 0.05$) between the different plant spacing on stem height and branch number. There was a significant difference between the plant height mean at spacing 30 cm x 20 cm and 30 cm x 30 cm and also between 30 cm x 20 cm and 30 cm x 15 cm. There was no significant difference between the means of spacing 30 cm x 30 cm and 30 cm x 15 cm.
The results indicated that closer spacing (30 cm x 20 cm and 30 cm x 15 cm) showed the highest increase in stem height (Table 3). It agrees to what Amaglo, (2010) [2] found while working with Moringa (*Moringa oleifera*) that closer spacing showed the highest plant height increase whereas the wider spacing showing relatively lower plant height increase.
According to Lyons, (1968) [8], the rate of plant growth is enhanced by increasing plant density therefore increased heights in closer spacing. This could be due to the competition of the necessary plant growth requirements (light, nutrients, Space and moisture) by the higher plant population which in turn makes the stem to grow taller. According to Mabapa *et al*., (2017) [9] increase of plant population density (PPD) will lead to a decreased growth and yield per plant, but decrease of plant population density (PPD) will lead to an increased yields per plant. Different spacing is required by each plant according to its growth habits. Plants must be placed close enough so that there is no waste of precious garden space, but apart enough so that they have room to grow.
With branch numbers there was as significant difference between the branch number mean of 30 cm x 30 cm and that of 30 cm x 15 cm plant spacing while there was no significant difference between the 30 cm x 30 cm and 30 cm x 20 cm plant spacings. This shows that as the population density increases the branch numbers per plant reduces. The same outcomes were reported by Lyon *et al*. (2010) [8] presenting that more numbers of branches was recorded due to wider spacing and lesser plant density in Okra. This is contrary to what was found by Mabapa *et al* (2017) [10] who reported that closer plant spacing of sunflower produced more branches per plant than those of wider plant spacing.

### 3.2 Fresh Leaf Yield

Statistical analysis of mean weights using SPSS 21.0 showed differences in fresh leaf yield as presented in figure 3 below.

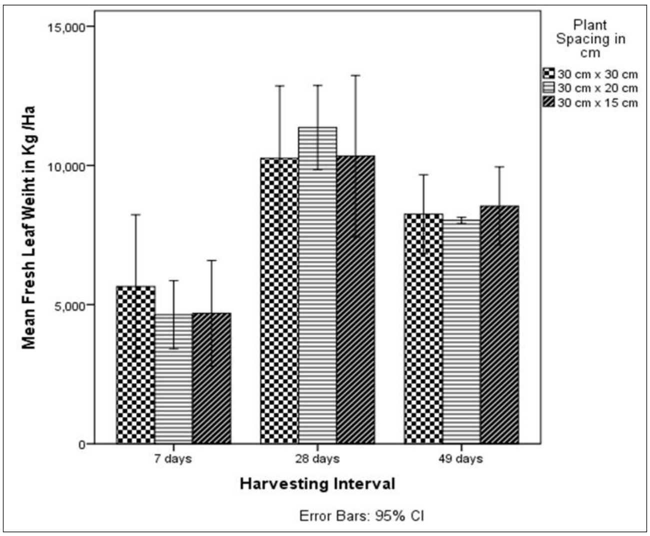


**Fig 3:** Effect of Harvesting Interval and Spacing on Fresh Leaf Yield in kgs/ha

The highest fresh leaf weight was observed at 28 days harvesting interval and of 30 cm x 20 cm spacing. This was followed by 30 cm x 15 cm at 28 days and 30 cm x 30 cm at 28 days respectively. Fresh leaf weight was lowest in 7 days harvesting interval (frequent harvesting) under 30 cm x 20 cm.
Univaraiate analysis of variance to identify harvesting interval factor treatments with significant statistical differences among them (Table 4) showed that, indeed there were significant differences in mean fresh leaf weight among all the treatments.

**Table 4:** Combined ANOVA Summary on Effect of Harvesting Interval and Plant Spacing on Fresh Leaf Yield, Dry Lef yield, Number of Pods and Seed yield

| Tests of Between-Subjects Effects | | | | | | |
|---|---|---|---|---|---|---|
| Source | Dependent Variable | Type III Sum of Squares | df | Mean Square | F | Sig. |
| Block | Fresh Leaf Weight in Kg /Ha | 4307920.963 | 2 | 2153960.481 | 3.957 | .036 |
| | Dry Leaf Weight in Kg/Ha | 46057.268 | 2 | 23028.634 | .239 | .789 |
| | Number of Pods | 7.630 | 2 | 3.815 | 1.147 | .338 |
| | Seed Yield in Kg/Ha | 300965.852 | 2 | 150482.926 | 1.067 | .363 |
| Harvesting interval | Fresh Leaf Weight in Kg /Ha | 145279484.519 | 2 | 72639742.259 | 133.458 | .000 |
| | Dry Leaf Weight in Kg/Ha | 12506625.988 | 2 | 6253312.994 | 64.957 | .000 |
| | Number of Pods | 420.963 | 2 | 210.481 | 63.285 | .000 |
| | Seed Yield in Kg/Ha | 5286956.963 | 2 | 2643478.481 | 18.742 | .000 |
| Plant Spacing in cm | Fresh Leaf Weight in Kg /Ha | 196659.852 | 2 | 98329.926 | .181 | .836 |
| | Dry Leaf Weight in Kg/Ha | 66412.602 | 2 | 33206.301 | .345 | .712 |
| | Number of Pods | 27.630 | 2 | 13.815 | 4.154 | .031 |
| | Seed Yield in Kg/Ha | 967481.407 | 2 | 483740.704 | 3.430 | .052 |
| Error | Fresh Leaf Weight in Kg /Ha | 10885808.519 | 20 | 544290.426 | | |
| | Dry Leaf Weight in Kg/Ha | 1925365.963 | 20 | 96268.298 | | |
| | Number of Pods | 66.519 | 20 | 3.326 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Seed Yield in Kg/Ha | 2820965.185 | 20 | 141048.259 | | |
| Total | Fresh Leaf Weight in Kg /Ha | 160669873.852 | 26 | | | |
| | Dry Leaf Weight in Kg/Ha | 14544461.821 | 26 | | | |
| | Number of Pods | 522.741 | 26 | | | |
| | Seed Yield in Kg/Ha | 9376369.407 | 26 | | | |

The mean difference is significant at (p≤0.05) level.

The tests indicated that there was significant differences (p≤0.05) between the harvesting intervals in all the agronomic parameters but plant spacing had no significant difference in all the agronomic parameters with the exception of number of pods. Blocking had a significant difference in fresh leaf weight (Table4).

A Post Hoc test to separate the means of harvesting intervals using the Least Significant Difference (LSD) (Table 5) indicated that all the harvesting intervals were statistically different from each other.

**Table 5:** Effect of Blocking on Fresh Leaf Yield, Dry Leaf Yield, Number of Pods and Seed Yield

| Block | | Fresh Leaf Weight in Kg/Ha | Dry Leaf Weight in Kg/Ha | Number of Pods | Seed Yield in Kg/Ha |
|---|---|---|---|---|---|
| 1 | Mean | 7590.89 a | 1927.3700 a | 28.67 a | 2288.33 a |
| 2 | Mean | 7799.33 a | 1917.5000 a | 27.92 a | 2112.33 a |
| 3 | Mean | 8523.00 a | 1946.2589 a | 28.00 a | 2198.50 a |

Table 5 indicates that the means of all the agronomic parameters at all the blocks was not significantly different from each other. This means that blocking had no significance on all the agronomic parameters (Table 5). This could be due to the fact that the site was not very sloppy, or had no major differences meaning that the blocks had some uniformity.

**Table 6:** Effect of Harvesting Interval on Fresh Leaf Yield, Dry Leaf Yield, Number of Pods and Seed Yield

| Harvesting Interval | | Fresh Leaf Weight in Kg /Ha | Dry Leaf Weight in Kg/Ha | Number of Pods | Seed Weight in Kg/Ha |
|---|---|---|---|---|---|
| 7 days | Mean | 4991.11 c | 945.9256 b | 21.56 b | 1460.78 d |
| 28 days | Mean | 10648.89 a | 2368.1478 a | 26.67 b | 1851.11 c |
| 49 days | Mean | 8273.22 b | 2410.2967 a | 31.22 a | 2531.67 b |
| At Maturity | Mean | | | 33.33 a | 2955.33 a |
| | | | | | |

The results for fresh leaf yield indicated that the mean fresh leaf weight at harvesting interval of 28 days was the highest and was statistically different from the mean at 49 days and at 7 days harvesting interval. The mean at 7 days harvesting interval had the least significant difference (Table 6). This indicates that when tender leaves are removed it increases the rate of reduction of photo assimilates. Therefore, when leaves are harvested at 7 days interval there is a great loss of the photosynthetic sites and thus the growth of the plant is reduced. Mabapa *et al.* (2017) [9] reported that frequent leaf harvesting reduced fresh leaf yield in amaranth plant. Related result finding where made by Amaglo (2010) [2] who showed significantly higher number of leaves, fresh and dry leaf yields from wholesome harvested plants than piecemeal harvested plants. Similar findings were made in amaranth plant whereby frequent leaf harvesting reduced fresh leaf yield (Amaglo, (2010) [2]. Same to observations made in sweet potato, pumpkin, cassava, cowpea and clover (Evers & Parsons, (2010) [3].

In white clover leaf removal has been observed to reduce the area for subsequent emerging of new leaves as they open fully. Some compensatory expansion occurs after but, the length of the petiole reduces substantially (Evers & Parsons, 2010) [3]. This is contrary to the finding made by Maurya *et al*. (2013) [11] who reported that frequent leaf harvesting initiated the formation of more vegetative growth in cowpeas.

Seed weight results indicated that the highest mean was at maturity harvesting interval followed by 49 days then at 28 days harvesting interval (Table 6). The grain yield tended to be high where harvesting was conducted once. The greatest reduction of grain yield was at harvesting interval of 7 days where the plants were subjected to frequent harvesting. The results showed that with increased harvesting interval there was gradual decrease of slender leaf seed yield. Similar results were reported by Maurya *et al*. (2013) [11] showing that Okra seed yield decreased gradually with increased harvesting interval.

**Table 7:** Effect of Plant Spacing on Fresh Leaf Yield, Dry Leaf Yield, Number of Pods and Seed Yield

| Plant Spacing in cm | | Fresh Leaf weight in Kg /Ha | Dry Leaf Weight in Kg/Ha | Number of Pods | Seed Weight in Kg/Ha |
|---|---|---|---|---|---|
| 30 cm x 30 cm | Mean | 8052.56 a | 1911.3340 a | 29.92 a | 2347.83 a |
| 30 cm x 20 cm | Mean | 8007.44 a | 1909.3330 a | 27.42 a | 2291.83 a |
| 30 cm x 15 cm | Mean | 7853.22 a | 1966.5990 a | 27.25 a | 1959.50 a |

Table 7 shows that there is no significant difference between the means of the different plant spacing on all the four agronomic parameters implying that plant spacing had no statistically significant differences between treatments.

## 4. Discussion

The present study has revealed that plant growth and fresh leaf yield is depended upon the spacing and harvesting interval. Plant heights at a spacing of 30 cm x 20 cm were consistently fairly tall followed by plant heights at spacing of 30 cm x 15 cm. The treatment 30 cm x 20 cm and 28 days interval (with moderate leaf harvesting frequency) gave the highest fresh leaf yield. Although a higher dry seed weight was realized with least harvesting interval, at maturity interval and high crop density at medium spacing (30 cm x 20 cm) as opposed to extensive harvesting (7 days interval) under wider spacing (30 cm x 30 cm). At medium spacing and average harvesting interval of 28 days both fresh leaf weight and dry leaf weight were moderately high as well as the number of pods and dry seed weight.

## 5. Conclusion

The 30 cm x 20 cm spacing and harvesting interval of 28 day be used for higher growth and yield of slender leaf. Further research to be done to establish the most efficient and profitable spacing and harvesting interval giving higher foliage and dry seed grains as the target products.

## 6. Acknowledgments
The author acknowledges financial support from John Billy Momanyi who financed the whole programme.

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