Determination of the Effect of Harvesting Interval on the Growth and Leaf Yield of Rattlebox (*Crotalaria Ochroleuca*)

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Abstract

Crotalaria addresses the problem of food security and forms part of a substantial proportion of diets. The production of Crotalaria ochroleuca ("rattlebox") has been on the decline in the Western and North Rift regions of Kenya due to poor agronomic practices, such as harvesting interval, amongst others which have not been fully exploited to maximize yield of this food crop. The objective of this study was therefore, to determine the effect of the harvesting interval on growth and leaf yield of Crotalaria ochroleuca during the long and short rainy seasons of 2016. The experiment was carried out in two sites; at the Kaimosi Agricultural Training Centre (KATC) in Nandi County and at the University of Eldoret (UoE)(Chepkoilel) farm in Uasin Gishu County. The treatments used consisted of three spacing regimes: (20x10, 30x10 and 40x10) cm and three harvesting intervals of 7, 14, and 21 days, respectively. The experiment was in a Randomized Complete Block Design (RCBD) laid out in a factorial arrangement. The treatments were replicated three times and the treatment effects measured on plant growth for a period of four (4) months. The data that were collected included; days at 50% flowering, number of branches, a thousand seed weight and fresh leaf weight. The data collected was then subjected to Analysis of Variance (ANOVA) on GenStat statistical software release 14.1 VSN International Ltd. Fisher's Least Significant Difference (LSD) at P = 0.05 was used for multiple comparison among treatments. The study revealed that the harvesting interval of 21 days produced the best plant performance and leaf yield at both sites. Variations in season and site were also found to be significant in the growth and leaf yield of rattlebox. Generally, rattlebox performance in Kaimosi produced a better leaf yield (7gm) than Chepkoilel (6gm) during the two seasons. Season one during the long rainy season in both sites drastically reduced the performance of rattlebox plant that led to low leaf yield.

Keywords: Rattlebox, Harvesting interval, Plant growth, Variations, Leaf yield,

INTRODUCTION

Rattlebox or rattle pod which is a common name of *crotalaria ochroleuca*, derived from the fact that the seeds become loose in the pod as they mature, and rattle when the pod is shaken (Bhatt *et al.*, 2015). Rattlebox plant, being a member of the pea/bean family, acts as a good soil builder because its roots support nitrogen-fixing bacteria, which improve yield and soil quality (Larum, 2018). It is relatively easy to establish a good plant stand of the crop that grows vigorously, competes well with weeds once established and can grow at elevations of up to 2000 meters above sea level. The crop does well mainly in damp grassland, especially in floodplains, depressions and along edges of swamps and rivers, as well as in deciduous bush land, roadsides and fields. The plants in this genus prefer generally a sunny position, succeeding in dry to moist, well-drained soils (Araujo *et al*, 2017). The local names of *Crotalaria* are miroo (Luhya), mitoo (Luo), Kamususu (Kamba), kipkururiet (Kipsigis), oleechei (Maa) lala (Acholi), aubi (Luganda) (Abukutsa, 2004). The plant has been adopted in the farming systems of the southern parts of Tanzania particularly for improving soil fertility and weed control in the farms. The crop may have a potential in alleviating poverty and ensuring household food nutrition security and economic value with several agronomic advantages (Abukutsa, 2007).

The crop is used by farmers either in crop rotations or as a companion crop with nematode-susceptible vegetables such as tomatoes and is known to suppress Meloidogyne root-knot nematode populations (Don, 2018). It is apparently good for use as a green manure and for adding organic matter to the soil and it suppresses weeds and slows soil erosion (Wang, *et* al., 2014). The crop has a potential use in reduction of striga seed population in the soil hence causes suicidal germination of striga weed as an obnoxious cereal crop weed. The sale of these vegetables in rural and urban areas is a source of income for the producers, who are mainly women (Abukutsa, 2007). *Crotalaria* is cultivated locally, mainly as a garden crop, for its edible leaves and good companion properties and in most cases the production of *Crotalaria ochroleuca* vegetables is mainly confined to the rural areas, where small-scale farmers grow them in kitchen gardens or harvest them from the bush for home consumption. These are chopped, boiled and eaten with the staple foods including: maize, beans or sorghum (Chauvet, 2018). The dietary importance of the crop is for its principal source of beta-carotene, which is a precursor of vitamin A (Sahou, 2015). They are inexpensive, easily accessible and excellent sources of micronutrients, for rural Kenyans (Sikuku, 2017).

The foliage contains high amounts of riboflavin, niacin, calcium, iron, thiamine, and ascorbic acid and most importantly, their nutritional contents have benefits that contribute health and medicinal properties to many human beings (Abukutsa, 2018). For instance, the rattlebox plant is used for the treatment of yellow fever in Nigeria (Hillary, 2016). Its fibre is used to make nets in Sudan, it can also be used as livestock fodder and seeds are fed to poultry and has the capacity to fix atmospheric nitrogen by bacteria in the root nodules. The industrial use of the crop is that the fiber found from the bark and stems is used to make nets and ropes and oil extracted from the seeds is insect repellent (Mabapa *et al*., 2017). Some species of the crop are grown as ornamentals (Larkin, 2013). However, it is one of the indigenous vegetables, whose potential in alleviating poverty in the rural areas has not been fully exploited this was confirmed by some researchers (Abukutsa, 2007). There is limited statistical data available on the production of rattlebox, due to environmental, economic and socio-cultural changes, *Crotalaria* species are neglected and threatened with extinction (Chauvet, 2018). The crop is cultivated in some parts of Kenya, but the yields obtained by these peasant farmers are often very low due to various production constraints (Abukutsa, 2018). Generally, there is lack of technical packages for optimum production, other constraints include poor quality seeds (Abukutsa, 2007) and harvesting interval that is related to the accurate management of defoliation when maximum production and quality of plant is expected (Prayitno, 2012).

Prayitno, (2012), reports further that the impact of harvesting interval gives the opportunity of photosynthesis in the plants to continue for a certain period, after which resulting in improved forage production whereby, harvesting may lead to decreased growth and productivity of some of the plants. Under humid conditions, leaf rust disease can damage the whole crop. Whiteflies maybe a menace during dry spell. Aphids which are green or yellow-like insects maybe found on the leaves where they sack sap and carry diseases. Cutworms are also capable of cutting the stems at the ground level causing the plant to fall (Abukutsa, 2007). Several studies have indicated that rattlebox consumption in Kenya is increasing due to increasing demand by urban consumers for indigenous vegetables though the supply is inadequate due to low production. Most farmers in the rural areas are showing interest in the cultivation of rattlebox as a source of income and there is an increased demand due to their nutritional importance (Abukutsa, 2018). The plant growth is mainly favored by warm conditions, after it is well established and has formed long taproots and long lateral roots, it can tolerate rather dry conditions (Chauvet, 2018). For instance, the Australian *Crotalaria* species also show many suitable traits of harvestibility, including an upright growth habit, a low tendency to bust open and shatter, the bearing of its fruits and flowers at the end of branches, and large to moderate seeds (Don, 2018). Most communities use farm yard manure as a source of micro and macro nutrients and use wood ash to control pest (Abukutsa, 2007). Overcrowding of crops may reduce yields and it may also lower quality of the fruits produced because of competition for light and soil nutrients (Ssali, 2016). Plant spacing also is one of the agronomic practices that influence crop growth and development (Araujo *et al*, 2017). For instance, when planting, there are two types of spacing to consider the distance between the plants and the distance between the rows of plants and if one is able to get the garden spacing right, you will have the yields increase significantly (Reilly, 2010).

Adequate spacing of crops is important for good yields, however for vegetables often it is not practical to start seeds off with the desired final spacing (Iannoti, 2014). Planting vegetables and other crops close enough for their leaves to touch, blocks the sunlight to those leaves underneath and in addition help in suppressing weeds and conserve water (Don, 2018). Based on the significant importance and constraints, search for optimal row spacing and harvesting interval for maximum yield of the crop is necessary in Kenya. In Africa, the most popular way of harvesting rattlebox as a vegetable is by uprooting the whole plant just before flowering when the stems are about 40 cm tall and 8 weeks old. Alternatively, thinning is used as a first harvest after about 6 weeks and use a ratoon system from there onwards. Nonetheless, this involves first plucking the main shoot at the 8-week stage and subsequent harvesting of the new side shoots. However, harvesting is the most labor-intensive activity of the growing season and if vegetables are not harvested at the proper stage of maturity, physiological processes occur that permanently change their taste, appearance and quality (Westerfield, 2013). Particularly, harvesting of the crop too soon may result in only a reduction in yield, while harvesting too late can result in poor quality due to development of objectionable fiber and the conversion of sugars into starches (Abukutsa, 2007). However, a late harvest can also cause plants to terminate, or stop producing as they complete their reproduction process. For instance, the best approach to planning for a continuous harvest is to keep good production records from previous growing seasons and to compare notes with other local growers. Again, the two ways to extend the harvesting period for some crops are: firstly; to plant varieties with a different number of days to maturity at the same time; and secondly; to plant the same variety multiple times in succession (Bachmann, 2008). In the USA for example, peas planted at the first possible planting date in the spring and then again two weeks later will usually mature only one week apart. It is therefore necessary to estimate; appropriate planting dates; length of the harvest from first to last pickings and the number of days to harvest that will be able to give a good yield of crop. Nevertheless, the impact of harvesting interval makes the process of photosynthesis in the plants to continue for a certain period of time thus, resulting in improved foliage production while defoliation may lead to decreased growth and productivity of the plants (Prayitno, 2012). In the present context, the cultivation of rattlebox is limited to marginal lands, subsequently the production has declined and that very few reports are available (Bhandari *et al*, 2016). Reports further indicate that there is insufficient information and technical packages concerning rattlebox production (Abukutsa, 2007). However, low economic value of rattlebox, despite its nutritional importance in solving food insecurity both in the tropics and sub-tropics, makes the production uneconomical and impractical (Abukutsa, 2004). In view of the fact that the crop does not require wet and rainy conditions, it makes farmers to plant rattlebox during the short rainy season as during the long rainy season the crop is completely wiped-out causing farmers economic loss thereby risk losing crop seeds resulting in low availability of quality seeds in the market (Araujo, 2017). Therefore, the harvest at the right time contributes to the achievement of better-quality seeds. Moreover, there are no improved technologies for farmers to grow *Crotalaria* under controlled conditions, though moist conditions are best for growth of the crop for farmers. Often the strategy is always threatened by adverse environmental changes that often result in low production (Rutherford, 2009).

Successful identification of packages like correct row spacing and harvesting interval will help in improving the yield of rattlebox against these environmental conditions and making them available under different environmental conditions (Melina, 2010). Even though, some studies have focused on the search for fiber content and digest-ability of rattlebox. A lot of work has also been done on the different species especially on genetic diversity, morphological diversity among other characteristics. The rattlebox plants in the field, under normal circumstances, are exposed to various stress factors including nutrient deficiencies, soil mineral toxicities, insect pests, parasitic weeds, diseases and drought among others (Abukutsa, 2007). However, majority of these studies are single problem solving only and specific problems facing the crop especially in Kenya. The technical packages in the production of the crop using the correct harvesting interval might be able to help farmers improve on the yields if managed effectively thereby, increasing their income and raise their standard of living (Jovicich *et al*., 2003). Indeed, there is not much information on the agronomy and production of the crop to increase yield. Consequently, this study is set to investigate the right harvesting interval that will increase the yield of rattlebox plant.

METHODODOLOGY

Study Site Characteristics

This study was conducted in Kaimosi Agricultural Training Centre (KATC) in Nandi County and at the University of Eldoret (UoE) also referred as Chepkoilel demonstration farm, between January 2016 and January 2017.

Site 1: Kaimosi Agricultural Training Centre (KATC) is located at an altitude range of 1699m -1708m above sea level and lies between latitude 0° 12' N and longitude 34^0 57'E of the equator. The area receives an average annual precipitation of 800 mm - 2000 mm whose distribution is marked by two (2) wet and two (2) dry seasons. There are two main cropping seasons: long rains (LRs) - mid February to July and short rains (SRs) - August to November. The remaining months are dry. The average daily temperature in this region ranges from 21^0C to 28^0C (Ministry of Agriculture (MOA) 2007). Predominant soil type in this region is sandy loam, which is well drained and easy to cultivate. The dry season begins at the end of November and ends in the month of March with some little rain in the month of February.

Site 2: The University of Eldoret or Chepkoilel demonstration farm is located on the Eldoret - Ziwa road at an altitude of between 2147m-2152m above sea level and lies between latitude 0° 34'N and longitude 35^0 18' E. The average annual rainfall ranges from 900 > 1400 mm.the rainfall distribution during the year is nearly unimodal, with a first peak in April/May and a second one in June/July and have at least a 100 mm higher rainfall expectation than first rains. Uasin Gishu is the coldest region in Kenya with average high temperatures of 24^0C. The area is surrounded by prime agricultural land and large-scale grain farming, dairy and horticultural farming. Eldoret town acts as a trading Centre for Uasin Gishu's and North Rift Kenya's economies with manufacturing factories, learning institutions, banks and other professional firms. The predominant soil types in this region are mainly the rhodic ferralsols (Okalebo, 2009).

Land Preparation, Planting Materials and Planting

During the long rainy (LR) season, the experimental plots at both sites were ploughed and leveled in the month of January 2016 and left to settle until the month of March 2016. The second ploughing was done and harrowing by hand followed; each operation was repeated after two weeks. A well-decomposed farmyard manure was then applied before the last harrow at the rate of 20 tons/ha, as a blanket application. The same operations were carried out in both sites during the short rainy season. Pegging was done to divide the 30meters by 10meters experimental plot into 3 meters by 3 meters experimental units. Planting was done one week after the onset of the long rains (March) and three days after the onset of the short rains (September) at the two sites. The seeds were purchased from a local market and planted by drilling along dug furrows at the rate of 15kg/ha. The three plant spacing adopted were; 20 cm x 10 cm, 30 cm x 10 cm, and 40 cm x 10 cm that realized 11 rows, 9 rows and 7 rows of plants in the experimental units respectively.

Treatments

The variety was *crotalaria ochroleuca.* whose common name is rattlebox. This variety is popular and highly utilized by the people of Western part of Kenya because of its mild taste. The crop has large leaves as compared to the other variety with bitter and small leaves. Its market value is also very high and is easy to sell.

Spacing

Three rows spacing were tested namely 20 cm, 30cm and 40 cm by 10 cm within the row in each case.

Harvesting intervals

The harvesting intervals were 7 days, 14 days and 21 days.

Experimental Design

The experiment was a Randomized Complete Block Design laid out in a factorial arrangement with three replicates. In total there were 27 experimental units, each unit measured 3 m x 3 m, these were made and raised thereafter separated by 0.50m space between the experimental units and one (1 m) between the blocks. After 4 weeks, thinning was done at 10 cm between the plants, and in every case at 5 weeks, pinching was done on all the remaining crops. This was to allow the side shoots to develop. Thereafter, ten plants from each experimental unit, with proper germination, were picked, pegged and numbered 1-10 for analysis based on the two treatments, these same plants were harvested and weighed. The harvesting of the leaves started at about eight (8) weeks after planting. For the seven (7) days harvesting interval crops, the leaves were first harvested at sixty (60) days after planting, this was done three (3) times after which, the crop started to produce buds. The fourteen (14) days harvesting interval crop the first leaves were harvested at 64 days after planting, the harvesting was done two times and then the crop started flowering. While the 21 days harvesting interval crop, the harvesting started at 68 days after planting, the crop was harvested only once and by the next harvest, the buds had formed. The harvesting stopped at the flowering stage for all the plots after about four (4) months, this was same for the two seasons.

The Layout of the Experimental Plots

The experimental plot measuring 30 meters by 10 meters ($300m^2$) were divided into three (3) blocks and replicated three times, each containing nine (9) experimental units of 3meters by 3meters ($9m^2$) with paths of 0.5 meter separating the units while one-meter paths separated the blocks. There was a total of 27 experimental units.

Field Experiment

The experimental design was a Randomized Complete Block Design (RCBD) laid out in a factorial arrangement with three replicates. The treatment factors comprised of three spacing and three harvesting intervals that gave rise to nine (9) treatment combinations; that were randomly allocated to 27 experimental units, (each unit measured 3 m x 3 m). The plots were made and raised thereafter separated by 0.5m space between the experimental units and one ;(1 m) between the blocks. The experimental factors were; Spacing of; 20 cm x 10 cm (S1) giving 11 rows of the plants 30 cm x 10 cm (S2) giving 9 rows of the plants and 40 cm x 10 cm (S3) produced 7 rows. Harvesting intervals of; (a) 7 days (HI1), (b) 14 days (HI2) and (c)21 days (HI3) (Table 1). The treatment combinations were as follows:

Table 1: Treatment Combinations

		Harvesting Interval		
		H1 (After 7 days)	**H2 (After 14 days)**	**H3 (After 21 days)**
	S1(20cmX10cm)	S1H1	S1H2	S1H3
	S2(30cmX10cm)	S2H1	S2H2	S2H3
Plant Spacing	S3(40cmX10cm)	S3H1	S3H2	S3H3

Data Collection

Data was collected, on growth and yield parameters from ten plants, that were randomly selected and tagged, during the growing period of the rattlebox plants at different row spacing and harvesting interval. The parameters measured included; days to 50% flowering, Number of branches, Stem diameter, 1000 Seed weight and Fresh leaf weight. The plants were physically counted when the plants in each block had attained 50% flowering. The number of branches was physically counted at every harvesting of; 7 days, 14 days and 21 days. The stem diameter was measured by use of hand calipers to establish the growth and the performance of the plant. The leaves were weighed in kilograms after each harvest by use of an electric weighing balance to ascertain the leaf yield of each plot.

Monitoring and Measurement of Plant Parameters

The following plant parameters were measured in both Sites:

Growth Parameters

Days to 50% Flowering

This was the number of days that the ten pegged plants within the experimental units attained 50% flowering from Kaimosi experimental site (Nandi County) and the Eldoret site (Uasin Gishu County), during the field experiment. The ten (10) plants were harvested and after 3 months, they started forming flowers. After 2 weeks, the 50% of these plants that had flowered were counted and recorded.

The Number of Branches

From the ten pegged plants of the experimental units, the number of branches formed were counted at each harvesting interval from the two sites and the number were there after recorded.

Yield Parameters

The Pod Number:

The dry pods of the selected plants at maturity were harvested from each plant and these were counted. The results were therefore, recorded in numbers.

A Thousand (1000) Seed Weight:

After harvesting the pods of the ten pegged plants for each experimental unit, they were put together, sundried for about one week, the dry seeds were then threshed from the pods, out of these, a thousand (1000) seeds were counted and weighed using a digital electronic kitchen scale (EKS) weighing machine, the weight was therefore recorded in grams.

Leaf length

The leaf at the base of the selected plants were plucked at every harvesting and measured by use of a graduated ruler and leaf length recorded in centimeters.

Fresh Leaf Weight

At every harvesting interval, two leaves and a bud were plucked from the ten pegged plants of each experimental unit. These were weighed by use of a digital weighing machine (EKS). Measurements were recorded in grams. These leaves were sold locally for an income.

Harvesting Intervals

The thinning of the crop was done on the sixth week at 10centimeters for inter-row spacing, this was followed by pinching a week later to allow for the growth of side shoots. Thereafter, harvesting started on the 8th week after planting and continued for 90 days. The harvesting interval of 7 days, 14 days and 21 days were applied. The suckers were carefully picked comprising of three leaves and a bud to ensure uniformity. After taking the necessary measurements, the harvested leaves were then sold to market vendors.

At maturity stage (3 months), the selected plants were uprooted from the plots, dried and the pods taken out from the plant for counting. The seeds were then extracted from the pods and measurements taken.

Data Analysis

The data collected was subjected to analysis of variance (ANOVA) to determine whether there were significant differences in row spacing and harvesting interval in the growth and yield of rattlebox. This analysis was conducted using GENSTAT statistical software, version 14.1 International Ltd at 5% level of significance and means reactions separated by CONTRAST COMPARISON. The mean separation approach was chosen mainly to avoid the demerits of other multiple comparison procedures (MCPs) and also to answer specific questions of the study related to leaf weight. Multiple comparison among treatments were done using Fisher's Least Significant

Difference (LSD) at P = 0.05. Correlation analysis was done to determine whether there were significant relationships between spacing, harvesting interval and leaf yield.

RESULTS AND DISCUSSION

The Effect of Harvesting Interval on Days to 50% Flowering

During the long rainy season, more plants had flowered at 7 days harvesting interval in site two (Chepkoilel) while in site one (Kaimosi)produced the highest number of plants at 14 days harvesting interval. However, Chepkoilel exhibited more plants at 14 days harvesting interval as opposed to the ones in Kaimosi during the short rainy period. The spacing that produced more flowers was 30 c x10 cm in Kaimosi during the long rainy season. Harvesting interval, season, site and their interactions were significant (Table 2). The mean score of 14 days harvesting interval exhibited a higher percentage (99.1%) with the 21 days' interval recording the least percentage of 95.5% (Table 2). The flower production shows the stages of development. They involve pollination, fertilization, flowering, fruit and seed formation, seed dispersal and seed germination. This cycle makes it easy for a farmer to monitor the plant growth. The timing of flowering for plants requirement and responsiveness to vernalization are major factors in regional climatic adaptation of elite germplasm. Genes that control flowering time affect hybrid vigor and thus are likely to impact on yield (Malik *et al*., 2017). Once flowering begins, vegetative growth declines this eventually leads to decreased leaf yield. There are differences in attainment of 50% flowering which is attributed to the wider the spacing, the more the amount of light that penetrates influences the plants reproductive development and is similar with the amount of flower formation (Thakur *et al.*, 2018). The flower formation is also attributed to the time the plant is fully grown and forms part of the plant cycle. This concurred with the findings that for a good flowering period, during the hours that there is light and that CO_2 circulates better, plants need enough carbon-dioxide to grow powerfully at an optimum spacing and at a shorter harvesting interval (Melina, 2010). Mostly, the plant spacing does not affect 50% flowering, the flower yield and the total time to the beginning of flowering are independent of plant density (Kapozynska, 2013). Hussein *et al*, (2010) reported through a research that crops planted at 30cm had the highest flowers per plant and at 20cm intra row had the minimum number of flowers this also concurred with the findings of this study.

Table 2: Harvesting Interval on days to 50% flowering

		DAYS TO 50% FLOWERING					
HI	**Spacing**	**Long Rains (2016)**		**Short Rains (2016)**		**Mean (Spacing)**	**Mean (HI)**
		Chepkoilel	**Kaimosi**	**Chepkoilel**	**Kaimosi**		
7 days	20 × 10	100.4	95.0	91.1	97.3	96.0	97.91b
	40 × 10	111.8	96.3	90.6	94.0	98.2	
	30 × 10	112.8	93.3	96.6	95.7	99.6	
MEAN		**108.3**	**94.9**	**92.7**	**95.7**	**97.9**	
14days	20 × 10	108.7	93.3	93.3	93.6	97.2	99.1c
	30 × 10	107.2	99.1	96.3	97.1	99.9	
	40 × 10	108.9	96.2	98.1	97.3	100.1	
MEAN		**108.3**	**96.2**	**95.9**	**96.0**	**99.1**	
21 days	20 × 10	99.3	96.6	94.4	93.2	95.9	95.5a
	30 × 10	95.1	93.3	97.2	95.1	95.2	
	40 × 10	96.8	94.8	94.1	96.0	95.4	
MEAN		97.1	94.9	95.3	94.8	95.5	
		104.6	**95.3**	**94.6**	**95.5**	**97.5**	

	HI	**Spacing (SP)**	**Season (SE)**	**Site (SI)**	**HI × SP**	**HI × SE**	**SP × SE**
Probability	0.001	0.237	<.001	<001	0.531	<.001	0.406
S. E	0.251	0.786	0.426	0.426	1.14	0.579	0.944

S.E. D	0.355	1.112	0.603	0.612	1.612	0.819	1.335
	HI × SI	**SP × SI**	**SE × SI**	**HI × SP×SE**	**HI × SP×SI**	**HI × SE×SI**	**SP × SE×SI**
Probability	0.004	0.329	<.001	0.004	0.001	<.001	0.67
S. E	0.579	0.944	0.603	1.455	1.455	0.938	1.198
S.E. D	0.819	1.335	0.852	2.058	2.058	1.327	1.694
	HI × SP × SE × SI						
Probability	0.391						
S. E	1.937						
S.E. D	2.739						
% C. V	5.6						

Table 3: ANOVA Summary on the Number of Branches

		NUMBER OF BRANCHES					
HI	**Spacing**	**Long Rains (2016)**		**Short Rains (2016)**		**Mean (Spacing)**	**Mean (HI)**
		Chepkoilel	**Kaimosi**	**Chepkoilel**	**Kaimosi**		
	20 × 10	5.0	6.1	5.3	9.1	6.4	5.6a
7 days	40 × 10	4.6	4.8	6.3	6.2	5.5	
	30 × 10	3.3	4.9	6.1	5.7	5.0	
MEAN		**4.3**	**5.3**	**5.9**	**7.0**	**5.6**	
	20 × 10	8.6	3.8	7.4	7.1	6.7	6.2a
14days	30 × 10	6.6	3.7	8.4	5.3	6.0	
	40 × 10	6.3	4.6	7.3	5.6	5.9	
MEAN		**7.1**	**4.0**	**7.7**	**6.0**	**6.2**	
	20 × 10	8.4	3.1	10.4	5.4	6.9	7.0b
21 days	30 × 10	9.2	3.0	11.6	4.7	7.1	
	40 × 10	7.9	3.1	11.4	5.2	6.9	
MEAN		8.5	3.1	11.1	5.1	7.0	
		6.6	**4.1**	**8.2**	**6.0**	**6.3**	
	HI	**Spacing (SP)**	**Season (SE)**	**Site (SI)**	**HI × SP**	**HI × SE**	**SP × SE**
Probability	0.013	0.019	0.114	<.001	<.001	0.01	0.805
S. E	0.1717	0.1509	0.09992	0.09992	0.2739	0.2104	0.1938

S.E. D	0.2429	0.2134	0.1403	0.01403	0.3874	0.2975	0.274
	HI × SI	**SP × SI**	**SE × SI**	**HI × SP×SE**	**HI × SP×SI**	**HI × SE×SI**	**SP × SE×SI**
Probability	<.001	<.001	0.272	0.43	0.03	0.014	<.001
S. E	0.2104	0.1938	0.1403	0.3455	0.3455	0.2176	0.259
S.E. D	0.2975	0.274	0.1984	0.4886	0.4886	0.3842	0.3663
	HI × SP × SE × SI						
Probability	0.172						
S. E	0.456						
S.E. D	0.6449						
% C.V	20.1						

Harvesting interval on the Number of Branches

The plants exhibited more branches at harvesting interval of 21 days at spacing (30cm x 10 cm) while the lowest numbers of branches were at harvesting interval of 7 days at same spacing of 30 cm x 10 cm. The highest numbers of branches were exhibited by treatment 20 cm x10 cm spacing at harvesting interval of 7 days and that of 14 days as opposed to the plants harvested at 21 days' interval (Table 3). The average number of branches were more in site two during the long and short rainy seasons, than in site one. This agrees with the findings of Tripathi *et al*., (2013) who observed that wider spacing of *Crotalaria juncea* L. produced the highest number of branches of primary and secondary branches. The increased spacing reduces the process of photosynthesis and fewer branches are found at a larger spacing even though they have lighter through for maximum vegetative growth (Thakur *et al*, 2016). Furthermore, the interactions between the harvesting interval and the site were clear evidence that the observed number of branches were greatly influenced by the effect of each factor. The association of site and harvesting interval affected branch formation. The interaction between harvesting interval x site, site, and the interaction between harvesting interval and spacing were significant ($p < 0.001$) (Table 3).

Effect of Harvesting Interval on a Thousand (1000) Seed Weight

There was a uniform declining sequence of spacing and harvesting interval on 1000 seed weight in both sites. The harvesting interval at the two sites had a reverse sequence in that the longest HI of 21 days, produced more seeds followed by HI of 14 days, lastly was H1 of 7 days. The highest 1000 grain weight was at harvesting interval of 21 days during the long rainy season in UoE site with the lowest weight exhibited at harvesting interval of 7 days during the short rainy season at the same site (Figure 1). In the Kaimosi site, the harvesting interval that produced the highest seed weight was that of 21 days during the long rainy season while the lowest seed weight was realized at harvesting interval of 7 days during the same season (Figure 1). This result concurred with the findings of Yonpaladyot and Surapong, (2014) who revealed that seed yield and quality are higher when sun hemp plant was harvested after a longer interval. Spacing is a factor that affects seed yield of different crops (Tripathi *et al*., 2013). This also concurred with the findings that lower grain yield of *crotalaria* was recorded in treatments having greater row spacing due to higher weed infestation, poor radiation, use of inefficient water would produce lower yield. Minimum grain yield at wider row spacing and maximum grain yield at low spacing can be due to weed infestation and lodging of plants (Gondal *et al*., 2017). The harvesting interval was not significant on the 1000 seed weight ($p > 0.05$).

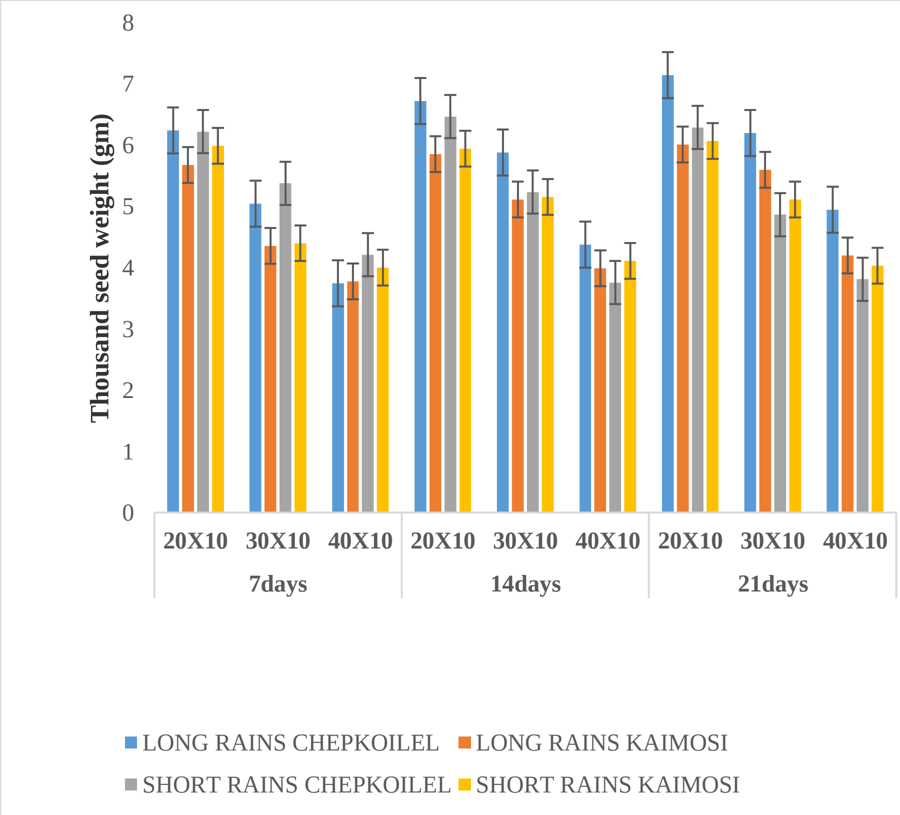

Figure 1: Effect of spacing, harvesting interval and season on a thousand seed weight

Effect of Spacing and Harvesting Interval on Leaf Length

During the field study, harvesting interval of 21 days produced the longest leaves in Kaimosi site while in Chepkoilel site it was 14 days HI. The spacing of 20 cm by 10 cm produced short leaves while 30cm by 10cm, the optimum spacing, exhibited the longest leaves both in Kaimosi and Chepkoilel sites. For both sites, the interaction that produced the longest leaf was spacing 30 cm x 10 cm at harvesting interval 21 days (S2H3) in Kaimosi and same spacing 30 cm x 10 cm at harvesting interval of 14 days (S2H2) at The UoE (Chepkoilel) site (Figure 2). The interactions between spacing 30cm by 10cm and harvesting interval of 21 days (S2H3) gave the longest leaf length in Kaimosi site while in Chepkoilel site, the longest leaf length was at spacing 30cm by 10cm with 14 days harvesting interval (S2H2) (Figure 2).

This was also supported by ANOVA table, showing that spacing, season and site were significant ($p < 0.001$) on leaf length of *crotalaria* as well as the interactions between HI x season, spacing x season, HI x site, spacing x site, and season x site was significant ($p < 0.001$). Moreover, the interactions between harvesting interval x spacing x site and HI x season x site were also significant on the leaf length of rattlebox ($p < 0.001$) (Table 4). There was however no correlation effect on leaf length during the long and short rainy seasons. The rattlebox leaf length varied with spacing, harvesting interval, site and season (Table 4). There is a result of a study that indicated that a morphological characteristic significantly affected by plant spacing was leaf length (Tilahun *et al*., 2017).

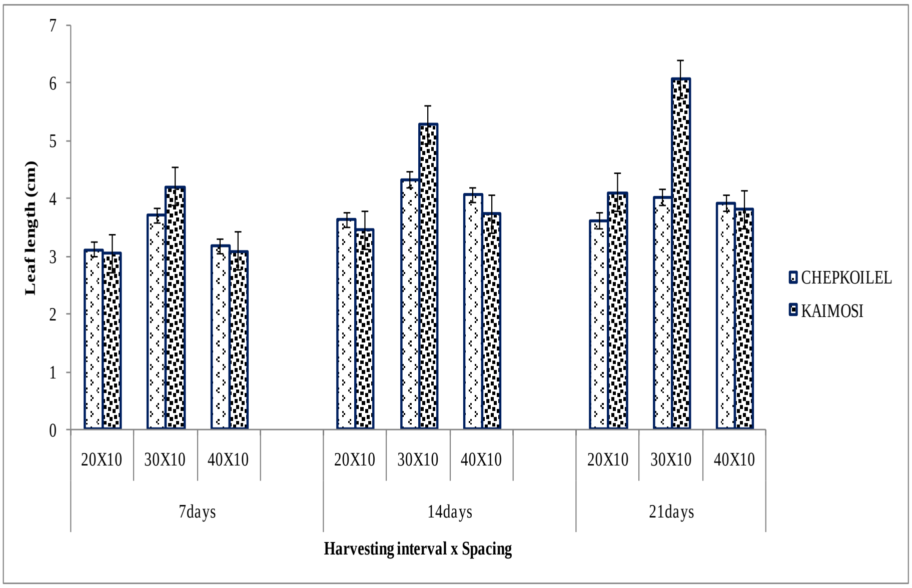

Figure 2: Effect of harvesting interval and spacing on the leaf length of rattlebox

Table 4: Anova summary of leaf length (cm)

Analysis of variance					
Variate: LEAF LENTH (CM)					
Source of variations	**df**	**s.s**	**m.s**	**v.r**	**Fpr.**
BLOCK_NO Stratum	2	0.3227	0.1613	0.3	
HI	2	45.2	22.6482	41.52	0.002
Residual	4	2.1822	0.5455	1.46	
SPACING	2	78.6675	39.3337	105.3	<.001
HI. SPACING	4	2.7896	0.6974	1.87	<.001
Residual	12	4.4824	0.3735	2.01	<.001
SEASON	1	131.6119	131.6119	708.01	<.001
SITE	1	10.4185	10.4185	56.05	<.001
HI. SEASON	2	8.6234	4.3117	23.19	<.001
SPACING.SITE	2	8.5249	4.2624	22.99	<.001
HI. SITE	2	8.1767	4.0884	21.99	<.001
SPACING.SITE	2	27.363	13.6815	73.6	<.001
SEASON. SITE	1	35.2704	35.2704	189.74	<.001
HI. SPACING.SEASON	4	3.0296	0.7574	4.07	0.003
HI. SPACING. SITE	4	5.7625	1.4406	7.75	<.001
HI. SEASON.SITE	2	5.3519	2.676	14.4	<.001
SPACING.SEASON. SITE	2	1.9241	0.9621	5.18	0.006
HI. SPACING. SEASON.SITE	4	1.7633	0.4408	2.37	0.053
Residual	270	50.1906	0.18591		
TOTAL	323	431.7515			

Effect of Harvesting Interval on Leaf Weight

The study found out that, the 21 days harvesting interval yielded more leaf weight at the two sites followed by the 14 days HI while the 7 days HI produced the lowest leaf weight. The Kaimosi site produced the highest leaf yield of 7 gm at spacing 20 cm x 10 cm and the lowest leaf yield was at 3.8 grams at spacing 40 cm x 10 cm and the Chepkoilel site had the highest leaf yield of 6gm also at spacing 20 cm x10 cm with the lowest yield producing 3 grams at spacing 40 cm x 10 cm (Table 4). The study revealed that, the 7 days harvesting interval produced very low yield of *crotalaria* plant indicating that there was not enough time given for photosynthesis to take place to produce vegetative parts. A study by Momanyi *et al.*, (2020) did not concur with this finding, that wider spacing and less frequent leaf harvesting resulted in low fresh and dry leaf weight yields. The finding of Saidi, *et al*, (2021) concurred with this result that weakly (7 days) harvesting gave higher leaf yield but reduced seed weight. Abukutsa, (2007) also agreed with the findings of this study, that harvesting of the crop too soon may result in only a reduction in yield. However, a late harvest can also cause plants to terminate, or stop producing as they complete their reproduction process. The anova table analysis showed that harvesting interval, spacing, season, site, the interactions between harvesting interval * season and harvesting interval * site were significant on leaf weight (Table 4). The harvesting interval and their interaction were significant ($p < 0.001$) this was similar to season, site the interaction between HI x season, HI x site, as well as harvesting interval x spacing x site ($p < 0.001$) (Table 4). Additionally, "success of vegetable production is dependent on-site selection which is one of the key factors to be considered carefully during the planning stage of farming operation" (Michael, 2018). Site selection minimizes potential production problems essential to all farming operations. It is expressed by vegetative development (node and leaf appearance rate) increases as temperatures rise to the species optimum level (Amaglo *et al*., 2006). For most plant species, vegetative development usually has a higher optimum temperature than for reproductive development. For example, more yield of fresh leaves is produced when plant population is low especially with wider spacing due to less competition for water uptake (Lanza, 2014).

Table 5: Effect Harvesting Interval on Leaf weight

Analysis of variance Variate: LEAF_WT_G					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
BLOCK_NO stratum	2	2.9902	1.4951	1.48	
HI	2	339.8906	169.9453	168.02	<.001
Residual	4	4.0459	1.0115	6.04	
SPACING	2	264.4569	132.2284	789.64	<.001
HI.SPACING	4	42.0709	10.5177	62.81	<.001
Residual	12	2.0094	0.1675	1.3	
SEASON	1	26.7519	26.7519	207.04	<.001
SITE	1	8.5069	8.5069	65.84	<.001
HI.SEASON	2	7.6745	3.8373	29.7	<.001
SPACING.SEASON	2	5.9856	2.9928	23.16	<.001
HI.SITE	2	2.568	1.284	9.94	<.001
SPACING.SITE	2	1.2702	0.6351	4.92	0.008
SEASON.SITE	1	0.2445	0.2445	1.89	0.17
HI.SPACING.SEASON	4	0.4722	0.118	0.91	0.456
HI.SPACING.SITE	4	2.5491	0.6373	4.93	<.001
HI.SEASON.SITE	2	0.1512	0.0756	0.58	0.558
SPACING.SEASON.SITE	2	0.219	0.1095	0.85	0.43
HI.SPACING.SEASON.SITE	4	1.2385	0.3096	2.4	0.051
Residual	270	34.8878	0.1292		
Total	323	747.9831			

Site Effect on Leaf Yield of Crotalaria

There were no significant differences in the production of rattlebox leaves at the two sites. The leaf weight measured both in Kaimosi and Chepkoilel, showed similar exponential production pattern even though, the Kaimosi site exhibited a higher leaf weight than the Chepkoilel site. This difference in leaf weight may be attributed to the difference in soil type, temperature and altitude. The Kaimosi temperatures are higher with lower altitude than those at Chepkoilel site. However, site had a significant difference ($p < 0.001$) on leaf weight of rattlebox plant. Furthermore, the success of vegetable production is dependent on site selection which is one of the key factors to be considered carefully during the planning stage of farming operation (Michael, 2018). Site selection minimizes potential production problems essential to all farming operations.

Effect of Season on Leaf Yield

The observed differences in response to seasons during this study, confirmed that environmental factors affected the fresh leaf yield. Observed environmental factors that affected the leaf yield were mainly rainfall and temperature. The crop did well under moderate rainfall during the short rains as opposed to the long rainy season because it is susceptible to diseases with too much rainfall. For instance, the study noted that during the long rainy season, the crop produced less leaf yield as compared to the yield during the short rainy season where all growth parameters were affected both in Kaimosi and in Chepkoilel sites. The crop growth and yield were however observed, as healthy and rejuvenated when the rains subsided but with too much rainfall the crop was diseased and almost dried off. Ndamani and Watanabe, (2015) support this observation that if plant soil has too much water, the roots can rot, and the plant cannot get enough oxygen from the soil and if there is not enough water for a plant, the nutrients it needs cannot travel through the plant. Furthermore, the nutrients need to be transported from the roots to help in the plant growth, so proper balance of water is key when growing plants.

According to Peprah, (2014), variability in seasonal rainfall, that is, accumulated amount of rainfall from the planting to the harvest of the crop is higher in the areas with smaller amount of rainfall. Further research results indicate that, a hot rainy season enhances biomass production of plants and that maximum fresh leaves were obtained in the short rainy season when the plants were harvested at 21 days' interval (Amaglo *et al*., 2006). This was in agreement with the findings of (Sikuku *et al*., (2013) that there is a reduction of fresh leaf weight of *crotalaria ochroleuca* plants at water deficit and at too much rainfall. Possibly, drought or low rainfall condition resulted in stunted regrowth and reduced total leaf yield in both sites. Therefore, there was need for supplemented watering during dry spell (Ndamani and Watanabe 2015). In addition, temperature is the major regulator of crop development processes. Higher temperatures have more adverse influence on net photosynthesis than lower temperatures leading to decreased production of photosynthates above a certain temperature (Jerry and Prueger, 2015). Generally, the high temperatures in Kaimosi were observed as favorable for rattlebox growth because the crop yield was higher (7g) than the UoE site (6g). In addition, during the day, adequate sunshine and high temperature increase the rate of photosynthesis and respiration whereas low temperature during night reduces the rate of the two processes (Jerry, 2015). Consequently, such environment of sunlight and temperature is conducive to plant growth. Development rate is highest at this temperature. It is expressed by vegetative development (node and leaf appearance rate) increases as temperatures rise to the species optimum level (Amaglo et al., 2006). However, for most plant species, vegetative development usually has a higher optimum temperature than for reproductive development.

CONCLUSION

Generally, the 21 days or three (3) weeks harvesting interval was the best, it gave the optimal leaf yield of rattlebox for both sites. The growth and leaf yield of *crotalaria ochroleuca* was favored by the prevailing environmental conditions of season and site; in that, planting the crop during the short rainy season was found to improve the growth and leaf yield of the crop. While during the long rainy season, the performance of the crop was drastically reduced, this led to poor growth and leaf yield. Additionally, the Kaimosi site proved to be a better site to grow the crop of rattlebox due to high temperatures and altitudes that might have favored the performance of the crop.

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