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Leaf Yield of Cowpea (*Vigna unguiculata*) as Influenced by Harvesting Regimes Under Greenhouse Conditions

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Abstract: With the rising global human population, decreasing mass of arable land, increasing demand for food and the emergence of biotic and abiotic constrains to crop production in the advent of climate change, the future of food security stares at intensified production under controlled environments such as greenhouses. Cowpea [*Vigna unguiculata* (L.) Walp.], is an economically and nutritionally important vegetable crop widely cultivated by smallholder farmers both for subsistence and income generation. Uprooting the entire plant as a form of harvest is common in open-field subsistence farming systems. However, little is known about the effect of harvesting regimes on total productivity of cowpea under greenhouse conditions. This study was conducted in a greenhouse at Mundika Boys' High School farm, Busia County with an objective of evaluating growth and yield of cowpea (M66 variety) in response to different harvest regimes under controlled (greenhouse) conditions. Plots of cowpea stands/clusters each with four plants were subjected to three different treatments, i.e., harvest 1 (H1), harvest 2 (H2), harvest 3 (H3) and a control (no harvest or H0) in a randomized complete block design. Overall crop yield was measured by the number of trifoliate leaves (NTL) and plant height (PH) at 7-day intervals. Data collection was initiated at week 1 (for PH) and week 2 (for NTL) after emergence. The results revealed significant differences in both PH and NTL between H0 and H1, H2, or H3 ($p \leq 0.05$), implying that cowpea yields can be significantly improved by applying harvesting regimes to vegetable-only production systems. For PH, maximum values were obtained for H1 and H3. Thus, farmers can obtain higher vegetable productivity by harvesting cowpea for consumption or sale at intervals, as opposed to a one-time mass harvesting.

Keywords: Greenhouse, Harvesting Regimes, Cowpea, M66 Variety, Productivity

1. Introduction

Cowpea [*Vigna Unguiculata* (L.) Walp], is a food legume of the family Fabaceae/Papilionaceae [1]. Its main botanical variants are; *Vigna unguiculata* var. spontanea and *Vigna unguiculata* var. unguiculata. The cultivated variant (*Vigna unguiculata* var. unguiculata) comprises of five cultivar groups with unguiculata being the biggest since it consists of 11 sub species complexes [2]. All cultivated cowpeas are grouped under the species *Vigna unguiculata* with seed size and color, taste, yield, and maturity time being the primary physiologic varietal differentiators [3]. The plant is an herbaceous legume showing considerable adaptation to warm climates with adequate rainfall and is cultivated across Southeast Asia, Africa, Southern United States and Latin America. Cowpea is also traditionally cultivated in some Mediterranean countries [4]. It is a major grain legume grown in semi-arid regions of Sub-Saharan Africa. Because of its high proteins, vitamins and minerals contain, cowpea plays an important role in human consumption and animal feeding [5]. Cowpea leaves and green pods are consumed as vegetable and the dried grain is used in many different food preparations. The crop continues to attract global attention of consumers and research scientists due to existing information on its beneficial health properties as a nutritional remedy for diabetes, cancer, and hypertension [6]. Fresh leaves of Cowpea (*Vigna unguiculata*) are ranked among the most valued indigenous diets among Kenyan local communities. Unfortunately, seasonal production patterns greatly limit the utilization of this highly nutritious vegetable [7].

In dual-purpose production, the leaf harvests are made during the vegetative stage before pod formation [8]. Where the crop is cultivated purely for vegetable production, the whole plant with 3-5 true leaves is uprooted when the leaves are tender and less fibrous [8]. The consumption of cowpea leaves by farmers enables them to fully exploit the nutritional values of this crop as a vegetable and guarantees food security to resource-poor families as growing season advances [9]. The latter system is a predominant practice, which influences subsequent productivity of remnant cowpea crops. However, there is a paucity of information on the effect of harvesting regimes on subsequent vegetable yield of the remaining plants under greenhouse conditions. Harvesting by occasionally picking a leaf from each branch of a cowpea plant may not sustain the household vegetable requirement for food. Consequently, harvesting methods which sustain leafy vegetable supply to poor households with no adverse effects on the ultimate yield of grains are needed [9].

With the rising global human population, decreasing mass of arable land, increasing demand for food and the emergence of biotic and abiotic constrains to crop production in the advent of climate change, the future of food security stares at intensified production under controlled environments such as greenhouses. The low yields of cowpea in open fields have been attributed to a number of climate change-related constraints such as prolonged droughts and diminishing soil fertility among other factors [10]. Insect pests are the main biotic constraint faced by farmers throughout a cowpea cultivation season more so under unpredictable weather patterns occasioned by climate change [11]. Greenhouse production has the potential to double yields due to lower exposure to pests/diseases and bad weather as well as reduced production costs and possibility of off-season production [12]. Thus, characterizing the cowpea crop for greenhouse microclimate is required to produce nutritionally and commercially high-quality leaf yields. The purpose of this study was, therefore, to identify the vegetative growth and development (number of leaves and plant height) changes under greenhouse conditions in response to harvesting intervals. Specifically, the study sought to evaluate growth and yield of cowpea (M66 variety) in response to different harvest regimes under controlled (greenhouse) conditions.

2. Materials and Methods

2.1. Plant Material

A popularly cultivated cowpea variety in Western Kenya, M66, was used in this research. M66 is a determinate, dual-purpose cultivar characterized by extensive vegetative growth and drought resistance. The cowpea seeds for planting were procured from a registered agrovet.

2.2. Experimental Design and Treatments

The experimental design was randomized complete block design (RCBD) with three replicates and three treatments/harvesting regimes: (1) harvest 1 crop (H1); (2) harvest 2 crops (H2); and (3) harvest 3 crops (H3) and a control (no harvest or H0). Harvesting (uprooting the entire plant) was initiated at 2 weeks after emergence (formation of 4-5 true leaves) and was done at a frequency of 14-day intervals until all plants in a cluster were harvested. In the RCBD, individual plots in a block measured 6m by 0.5m with a 1m separation buffer. Data were collected from 12 plants from 3 tagged monocrop clusters, and not all the plants in non-control plots. The parameters measured were (1) plant height (PH) and later (2) number of trifoliate leaves (NTL) after the emergence of trifoliate leaves.

2.3. Crop Establishment and Agronomic Practices

The M66 cowpea cultivar seeds were planted in clusters of four seeds at each drip-nozzle at a cluster-to-cluster spacing of 30cm x 50cm in two rows within each plot. No fertilizer was applied in the plots before, during, or after planting. Drip irrigation was undertaken at a 2-day interval, ensuring adequate soil moisture availability. The indeterminate and/or semi-determinate growth nature of cowpea evenly covers the soil thereby helping to smoother weeds [13]. However, routine hand-weeding was uniformly applied to control weeds along the paths between plots. The crops were free from pests and diseases thus, no spraying was necessary.

2.4. Data Collection

Growth and development data of the cowpea were collected on two parameters; plant height (PH) and later number of trifoliate leaves (NTL). PH was measured on the entire above-ground shoot (i.e., from base of the stem to the tip of the youngest leaf) and was initiated at week one after germination. PH was obtained from each of the four plants in a cluster in each treatment and continued for the entire data collection period. NTL was obtained by counting the number of true leaves and was initiated at week two after the emergence of trifoliate leaves. All true leaves (an indicator of productivity per unit area) were counted except the apical bud.

2.5. Statistical Analysis

Data collected were subjected to analysis of variance ($P \leq 0.05$) or one-way ANOVA using the SPSS software to determine within- and between-group differences in means of PH and NTL. Harvesting initiation time and interval were consistent for all treatments. Therefore, the effect of harvesting regimes (H0, H1, H2, and H3) on cowpea growth and development was determined based on the significant differences in PH and NTL amongst the treatments.

3. Results

The average plant height (PH) was not significantly different between any of the four treatments (n=36) in two consecutive weeks (wk2 and wk3) after germination. PH averaged 16.2cm and 27.1cm at week 2 and 3. However, NTL was significantly different in treatments H0/H1 and H0/H2 at week 2 when counting of trifoliate leaves was initiated (mean = 2.6). Mean NTL and PH difference was significant ($p \leq 0.05$) at week 3 through 5, when the harvesting regimes were applied to the plots, as summarized in Table 1.

Table 1. *Significant Differences amongst Harvesting Regimes ($p \leq 0.05$).*

Parameter	Week	Treatment (I)	Treatment (J)	Significance
NTL	Week 3	H0	H1	0.02
			H2	0.02
			H3	0.05
	Week 4	H0	H3	0.015
	Week 5	H0	H1	0.021
PH	Week3	H0	H1	0.012
			H3	0.034
	Week 4	H0	H3	0.009
		H1	H3	0.021
	Week 5	H0	H1	0.010

NTL increased for all treatments from week 3 to week 5 when the final harvesting was completed, as shown in Figure 1.

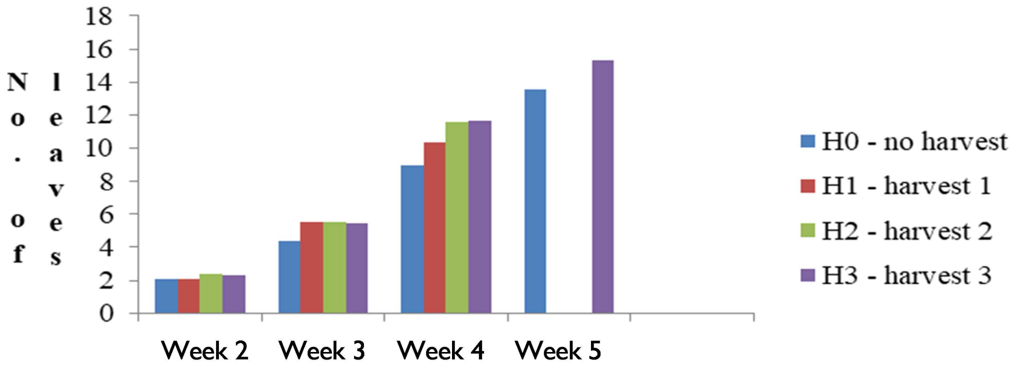

Figure 1. *Number of leaves from week 2 to 5.*

Plant Height

An exponential growth in height occurred during week 2 to week 5 of the experiment (Figure 2).

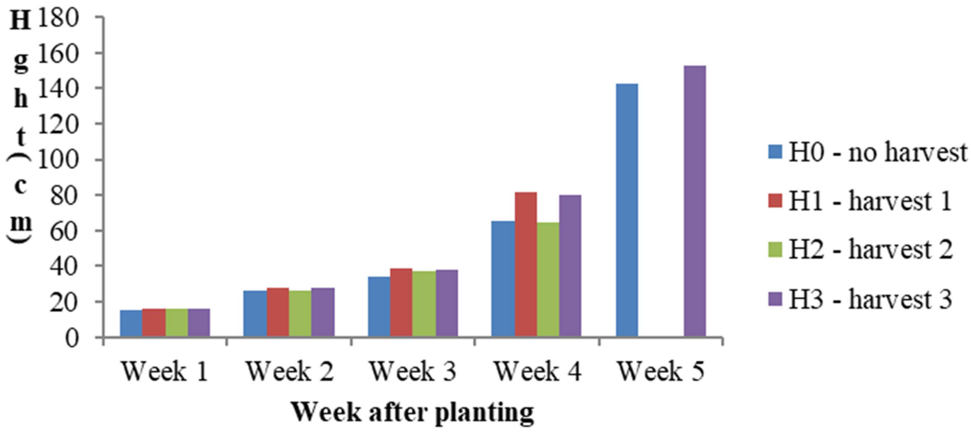

Figure 2. *Plant Height from week 1-5.*

4. Discussion

Increased cowpea production has the potential of meeting the nutritional requirements of the growing population and resource-poor households. Cowpea leaves are high in protein (27-43%), vitamins, and minerals [4].

The realization of the full potential associated with whole-plant harvesting for vegetables remains low due to limited information on the harvesting regime that would give optimal overall productivity per unit area of land.

4.1. Number of Trifoliate Leaves

Results from this research indicate that cowpea vegetable yields are influenced by harvesting regime. Four to five young, tender consumable true leaves are harvested by uprooting the plant [14], hence, a strong predictor of crop productivity or yield. In week 2, the mean differences in NTF were not significant prior to applying the harvest regimes. However, between-group mean difference in NTF was significant in week 3-5.

The average number of leaves was lowest in H0 (no harvest) treatment at 2, 4, 9, and 14 in week 2, 3, 4, and 5, compared to the other three treatments: H1 (2, 6, and 10 leaves), H2 (2, 6, and 12 leaves), and H3 (2, 5, 11, and 15 leaves) over the same intervals. Since water was not a limiting factor under greenhouse conditions, it implies that harvesting one, two, and three plants per stand increased vegetative growth rate in the remaining plants in a cluster. Since during sequential harvests, one, two, or three plants were uprooted from a cluster, unlike in controls (no harvest), competition for nutrients, space, and light was reduced, increasing vegetative growth [14]. This finding is consistent with the agronomic practices of thinning and defoliation to reduce overcrowding and maintain fewer strong plants that would guarantee better yields [15]. However, in this study, the average number of leaves did not vary significantly in H1H2, H1H3, or H2H3 comparison dyads. Adequate spacing may account for the low variation in leaf number between these treatments.

4.2. Plant Height

Cowpea plant height is another measure of productivity since the crop is cultivated by peasant farmers across sub-Saharan Africa for utilization of its entire shoot, including the leaf stalks, lateral leaves, and bud, as human food and livestock fodder [16]. Again, a lack of harvesting was found to reduce yield, in terms of average plant height. Mean PH was significantly higher in H1, H2, and H3 than in H0 in week 3-5 when the harvesting regimes were applied. The difference was highest between H0 (34.4cm) and H3 (37cm) and between H0 (34.4cm) and H1 (0.012cm) in week 3 ($p \leq 0.05$). At this time, the crop was at the exponential phase of growth and therefore, harvesting or thinning increased growth of the remaining plants due to diminished competition for nutrients, water, and light [17]. Additionally, the height difference between H1 (81.9cm) and H3 (64.9cm) was significant at week 4.

While H3 (three plants harvested) was expected to have higher growth than H1 (one plant harvested), differences in nutrient composition between beds could explain this outlier. The average height in H3 was 64.9cm, lower than H2 at 81.9cm in week 4. Nevertheless, overall, cowpea height increased when more plants were thinned from a cluster, as height in H1 (81.9cm) and H4 (79.9cm) were higher than in H0 (65.7cm) at week 4. In week 5, H3 also exceeded H0 in height (152.6cm vs. 142.6cm). This implies that harvesting regimes increases vegetative yield of the remaining plants when compared to controls and maximum yields can be obtained by harvesting 1 or three plants at each interval.

5. Conclusion

Cowpea is an economically and nutritionally important vegetable or dual-production crop. However, its commercial potential can be fully harnessed if optimal harvesting regimes are applied under greenhouse conditions. The findings of this study suggest that the number of plants harvested by uprooting from a pure stand affects the yield (plant height and number of leaves) of the remaining plants. Significant differences in NTL and PH were found between H0 (control) and H1, H2, or H3 but not between controls ($p \leq 0.05$). The harvesting regimes reduced competition for nutrient and light between plants, resulting in maximal photosynthetic output and growth. Therefore, based on the findings of this study, an economic analysis would suggest that farmers can obtain maximum returns by harvesting one or three crops at 7-day intervals for sale. However, the concentration and balance of various nutrient elements in cowpea leaves subjected to on-farm conservation under greenhouse conditions is a research gap that should be explored.

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