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FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

DEPARTMENT OF CROP SCIENCE

Evaluation of the effects of different levels of artificial defoliation on the growth and yield of cowpeas (*Vigna unguiculata*)

By

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DECLARATION BINDURA UNIVERSITY OF SCIENCE EDUCATION

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The undersigned certify that they have read and recommended to the Department of Crop Science, this thesis entitled:

The effects of different levels of artificial defoliation on the growth and yield of cowpea (Vigna unguiculata).

Supervisor

Date: ***07/07/2025***

Chairperson ………………………………..

Date…………………………

Abstract

Cowpea (*Vigna unguiculata*), is a legume crop that is important for mainly food security in the semi-arid regions, especially in smallholder farmers in Zimbabwe. Its productivity is often affected by pests that feed on the leaves which causes defoliation. Many smallholder farmers cannot effectively control these pests due to the limited access to pesticides. Therefore, understanding how much photosynthetic cover loss on cowpea plants can tolerate without significant yield reduction is essential for informed pest management. This study evaluated the effects of different levels of artificial defoliation on the growth and yield of cowpea variety IT18. The experiment was laid out in a Randomized Complete Block Design (RCBD), with 4 treatments (0%, 25%, 50% and 75% defoliation) replicated four times. Defoliation was done at 4th leaf stage and it was done manually. The growth assessment was done using vine length and it was measured at 3-week intervals over 15 weeks and the yield was determined using the average number of pods per plant and average weight of the cowpea seeds per plant. Results showed that an increase in defoliation can significantly reduce vine length, pod number and yield. The control treatment (0% defoliation) produced the highest mean pod number of 16.9 whilst 75% defoliation produced the lowest pod number of 6.12. Defoliation beyond 25% affected cowpea yield and that defoliation at an early stage affected vegetative growth and reproductive output. The study concludes that cowpea variety IT18 has a moderate tolerance to leaf loss and that maintaining leaf area above 75% is critical for optimizing yield.

Keywords: cowpea, artificial defoliation, smallholder farmer, photosynthesis, vegetative growth, reproductive output, pest management.

Dedication

I would like to dedicate this project to my father, Mr. Matimba and my mother, Mrs. Matimba. These people have been supportive throughout my degree programme. After all, the praise goes to the Almighty God, whose name is Jehovah.

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CHARPTER 1: INTRODUCTION

1.1 Background of the study

In sub-Saharan Africa (SSA), cowpeas (*Vigna unguiculata (L.) Walp*.) are a major grain pulse that are farmed extensively for food and feed. Due to its capacity to endure alkaline soils and thrive in low-fertilized soils, this crop is successful in the majority of locations. Although they may grow in a variety of soil types, cowpeas prefer clay and loam soils that drain well. There are a number of cowpeas CBC2 cultivars that can thrive in Zimbabwe, according to local seed company National Tested Seeds (Chiduku, 2022). In most African countries, cowpeas are a staple crop (Mfeka, 2018).

According to Fatokun *et al*. (2002), cowpeas are a legume that is high in amino acids, mainly lysine and tryptophan, which are frequently deficient in the nutrition of resource-poor farmers who mostly eat cereals. Additionally, because of its capacity to fix nitrogen, cowpeas can increase soil fertility. They are also a great crop for interrupting disease cycles in crop rotations, mixed farming, and relay farming (Fatokun 2002).

More than 90% of smallholder farmers in semi-arid regions grow cowpeas for their own food or to sell in nearby markets (Fatokun et al., 2002).Although Zimbabwe has good soils and climate suitable for cowpeas farming, little is known about its production statistics. According to analysis, Zimbabwe has the potential to be a major player in the cowpea industry, but production of the legume has largely stayed low. (Chiduku, 2022). In some regions of SSA, young, succulent cowpea leaves are eaten as cooked vegetables. The production of cowpeas is essential to Zimbabwe's agricultural sector, contributing significantly to the national economy and providing small-scale farmers with their main source of income.

Despite their endurance, cowpeas are vulnerable to a variety of stresses, particularly pest infestations and abiotic challenges like heat and drought. Defoliation, or the loss of leaves of a plant, is commonly brought on by these factors. This reduces photosynthetic capability and, consequently, agricultural output (Jackai and Daoust, 1986). Effective control of these stressors requires a greater understanding of how defoliation impacts cowpea growth and yield, particularly in locations that are prone to stress.

Artificial defoliation is a widely used research method to mimic leaf loss caused by diseases, parasites, or environmental stresses. According to Sharma *et al*. (2010), this technique provides a controlled setting for studying how plants respond to defoliation in terms of growth, physiological changes, and yield outcomes. Finding the critical defoliation thresholds that cowpeas may tolerate without experiencing a significant yield loss is crucial for informing crop improvement and pest management strategies.

1.2 Problem statement

Few published studies have examined the effects of artificial defoliation on cowpea growth and yield. It is difficult to establish efficient management measures to reduce yield losses brought on by pests and environmental stress since it is unclear how tolerant cowpea plants are to defoliation. Furthermore, it's uncertain how crop protection resource allocation may be optimized and stress-resilient cultivars identified through artificial defoliation. By examining how well artificial defoliation mimics natural stressors and how it affects cowpea growth and yield, this study aims to close these gaps. Gaining insight into these dynamics will be essential for choosing resilient cowpea cultivars, enhancing pest management techniques, and guaranteeing sustainable cowpea production in stressful conditions (Sharma *et al*., 2010).

1.3 Justification

The recommendation to minimize high levels of defoliation in cowpeas is justified by the results of this study, which demonstrated that severe leaf removal, particularly at 50% and 75%, led to significant reductions in both vine length and grain yield. Leaves are the main sites of photosynthesis, and their removal limits assimilate production, thereby reducing biomass accumulation and reproductive output (Singh et al., 2017). This indicates that maintaining a higher proportion of leaf area is essential for sustaining growth and yield in cowpea variety IT18.

The justification for adopting integrated pest management (IPM) practices lies in the fact that, under field conditions, defoliation is commonly caused by insect pests such as *Maruca vitrata* and leaf beetles, which substantially reduce leaf area if left uncontrolled. Studies have shown that insect-induced defoliation in cowpeas can cause yield losses of up to 80% under severe infestation (Asiwe, 2009). Thus, effective pest management is critical in preventing natural defoliation that would otherwise mimic or exceed the effects observed under artificial defoliation in this experiment.

The recommendation for breeding cowpea varieties tolerant to partial defoliation is justified because different varieties vary in their ability to compensate for leaf loss. Research has shown that some genotypes exhibit higher recovery rates through increased branching or delayed senescence, thereby minimizing yield penalties from defoliation (Ikeogu et al., 2019). Therefore, incorporating tolerance traits into breeding programs will enhance resilience in environments where pest pressure and leaf loss are unavoidable.

Farmer training on canopy preservation is justified since most yield reductions observed in this study were linked to loss of photosynthetic tissue. Farmers often underestimate the impact of leaf damage, whether caused by pests, poor management, or livestock grazing. Raising awareness will help farmers adopt practices that protect canopy integrity, leading to higher yields (Adetumbi et al., 2011).

Finally, further research on the timing of defoliation is justified because the impact of leaf removal may vary with growth stage. Early defoliation during vegetative growth may allow partial recovery, whereas defoliation at flowering or pod-filling stages can directly reduce yield by limiting assimilate supply to developing pods (Hall and Patel, 1985). Investigating these aspects will provide a clearer understanding of the critical stages at which defoliation is most detrimental for cowpea production.

1.4 Main objective

To assess how artificial defoliation affects cowpea growth, physiological reactions, and yield.

1.5 Specific objectives

1. To evaluate the impact of different levels of artificial defoliation on cowpea growth in terms of vine length.
2. To determine the effect of different levels of artificial defoliation on cowpea yield components (pod number and grain weight).

1.6 Hypothesis

1. There is no significant effect of different levels of artificial defoliation on cowpea growth in terms of vine length.
2. There is no significant effect of different levels of artificial defoliation on cowpea yield components (pod number and seed weight).

CHAPTER 2: LITERATURE REVIEW

2.1 The origins of cowpeas

The cowpea was domesticated in Africa, most likely in Ethiopia's modern-day north-eastern region. The wild annual form, *V. unguiculata* var. spontanea, is most likely the ancestor of the contemporary cultivated *V. unguiculata*. West Africa is a potential genesis place due to the considerable variability of V. u. dekindtiana in this region (Faris *et al*., 1965).

2.2 Global and regional importance of cowpeas

Some studies in Ghana that use carbon dating suggest that cowpea cultivation may have started between 2500 and 1500 BC (D'Andrea *et al*., 2007; Herniter *et al*., 2020). The crop's yield is rising because it is more drought-resistant than other legumes like soybeans and groundnuts (Cui *et al*., 2020; Matsui and Singh, 2003; Ravelombola *et al*., 2020). These characteristics make cowpea a major economic crop for farmers and their families around the world (Langyintuo *et al*., 2003). On an estimated 14.5 million hectares of planted land worldwide, 6.2 million metric tons of cowpeas are produced annually. Over the last three decades, the world's cowpea production has grown at an average rate of 5%, with an annual increase in area of 3.5% and yield of 1.5%. Area expansion accounted for 70% of the growth throughout this period (Boukar *et al*., 2016).

2.3 Cowpea production in Zimbabwe

According to WordPress (2017), cowpeas are a low-input pulse that many smallholder farmers in Zimbabwe grow. In the meals of smallholder households, it is a staple grain and vegetable (leaves). The grain is an important source of protein. However, cowpea yields remain low, primarily due to poor husbandry practices, diseases, and pests. Cowpeas can be grown in the marginal areas of Zimbabwe (agro-ecological zones III, IV, and V). The annual rainfall is generally between 250 and 500 mm. The crop is highly valued because of its adaptability to drought conditions, short growth cycle, and multiple uses as food, fodder, and a soil fertility enhancer through nitrogen fixation. Improved varieties such as IT18, CBC1, CBC2, and CBC3 are commonly cultivated, with IT18 being popular for its early maturity and ability to perform well under limited rainfall. Despite the potential of improved varieties to yield up to 4 tonnes per hectare under favorable conditions, actual yields among smallholder farmers are much lower, often ranging between 100 and 500 kg per hectare. This yield gap is largely due to production challenges such as pest and disease pressure, poor soil fertility, limited access to quality seed, and frequent droughts. Nevertheless, cowpea remains an important food security crop, providing a reliable source of protein, income, and livestock feed in Zimbabwe's semi-arid areas.

2.4 Agro-ecological requirements and adaptations

D. Zaranyika et al. (2022) assert that because cowpeas are drought-tolerant, provide excellent human nutrition, and have significant rotational advantages, they make the ideal dryland crop (pulse) in areas with little rainfall. They are also an intercropping crop under maize. He added that in Zimbabwe, cowpeas can be planted at any point from the beginning of the rainy season until the end of December. Cowpeas should be planted late in areas with high rainfall to avoid infections when the crop reaches maturity (Zaranyika *et al*., 2022).
According to FAO et al. (2017), cowpeas can grow in a range of soil types. Sand loam to clay loam soils with a pH of 6.0 to 7.0 that drain well produce the highest yields. Cowpeas are sensitive to acidic soils, but they may be grown in a wide range of soil types. Cowpeas are legumes that can be farmed as a standalone crop or as a co-crop with maize. Cowpeas should be cultivated in rotation with other crops to help control infections (Zaranyika *et al*., 2022).

FAO *et al*. (2017) state that cowpeas respond well to the application of manure or basal fertilizer. The amount of basal fertilizer applied per hectare ranges from 100 to 200 kg. To determine the pH and fertilizer rates of the soil, analysis is essential. Cover a 30-cm section of each planting line or furrow with one or two handfuls of compost or well-rotted manure. On their own, cowpeas fix nitrogen, so they don't need a nitrogen top dressing.

According to Zaranyika *et al*. (2022), cowpeas can get a lot of different diseases. Virus-related illnesses can be fatal. Using virus-free seed grown under rigorous rogueing production systems which eliminate and destroy any plants exhibiting virus disease symptoms is the best control method. A fungus called anthracnose damages the stem, branches, leaves, and pods. Grow resistant cultivars for control; use of chemical control such as mancozeb, copper oxychloride or any other appropriate fungicide can help prevent such fungus.

Numerous microorganisms can cause leaf marks. A few bacteria result in spots that are yellowish or have a yellow halo. Other Brown to purplish patches are caused by bacteria. Spots typically appear on the lower leaves first. When plants are negatively impacted, there may be defoliation. The most dangerous leafspot infections occur on late plantings and throughout extended wet seasons. To reduce the disease's spread, stay out of the field when it is wet (FAO, 2017). Aphids, heliothis bollworm, CMR beetle, and tip-wilter are examples of pests that attacks cowpea plants. The seed is vulnerable to bruchids, a grain borer, after harvest. The right pesticides can be used to control these pests.

2.5 Physiological processes affecting yield

Light and water are two important environmental factors that impact plant growth and physiological functions (Barnabás *et al*., 2008; Kaushal *et al*., 2016). They are essential for several plant physiological and metabolic processes (Yang and Zhang, 2006; Du *et al*., 2010). Light and water are two things that plants need to grow and flourish. They control how much the stomata open and close as well as the water balance (Yu *et al*., 2004). Water is an essential reactant in processes like photosynthesis and a solvent in a variety of hydrolytic reactions. Lack of water and extreme heat caused by intense light lead to significant losses in agricultural output (Farooq *et al*., 2009; Singh and Reddy, 2011; Kaushal *et al*., 2016; Balla *et al*., 2019). Combining stressors, including extreme light and water scarcity stress, has been shown to cause photoinhibition, a reduction in photosynthesis, and a yield loss (Pinheiro and Chaves, 2011; Goufo *et al*., 2017; Qaseem *et al*., 2019).

Waterlogging drastically changes the soil environment by blocking the flow of gases required for root development and function (Arduini *et al*., 2019, Jayasundara *et al*., 1997). Waterlogged soils became anaerobic after being saturated for a few hours because the oxygen needs of the roots and soil bacteria exceed the amount of oxygen that is brought in from the surroundings (Ploschuk *et al*., 2018).

2.6 Biomass partitioning and photosynthesis

Biomass partitioning is the mechanism by which plants divide their energy among their reproductive organs, leaves, stems, and roots (Wikipedia, 2025).The vegetative parts like the leaves and stems in cowpeas are the early stages that are mainly focused whilst pod and seed formation are prioritized at a later stage. If defoliation takes place during the early stages, biomass is biomass is allocated to compensate the leaves and this may affect the yield by reducing pod filling and also the number of pods.

Photosynthesis is also stated to be affected by sink strength since a larger supply of photosynthate is required to meet the increasing demand for photoassimilates during early vegetative growth and seed development (Richards, 2000). Agronomic practices such as intercropping (or mixed culture) and planting density also affect photosynthesis and plant biomass growth (San-oh *et al*. 2006; Horton, 2000; Srinivasan *et al*., 1985; Andersen *et al*., 2005; Hooper, 1998; Akunda, 2001).

According to Oghiakhe *et al*. (1991), he found that defoliating early had more adverse effects on cowpea biomass accumulation than defoliating late. This suggest that removing leaves early affects vegetative growth thus reducing the photosynthetic capacity that is necessary for subsequent reproductive development.

2.7 Defoliation and its use

2.7.1 Purposes of artificial defoliation

Defoliation refers to the removal leaves from a plant intentionally. The purpose is to mainly assess how a plant responds when all the leaves are removed. The other reason is to study biomass partitioning. Defoliating heavily might then reduce the weight of seeds and number of pods due to limited allocation of biomass to the roots, pods and stems. Artificial defoliation is now used for educational purposes whereby children are taught about plant physiology, the importance of photosynthetic area and stress responses (Madan, *et al*, 2012).

2.7.2 Methods used in simulation

Artificial defoliation to simulate pest damage is when the leaves are cut to simulate the feeding of insects, or even hail damage. The leaves are cut using a scissors and this is done at different growth stages (Ahmed *et al*., 1992). Mechanical simulation is when uniform holes are punched to mimic damage by machinery (Nalaam *et al*., 2012).

According to (Rodenburg *et al*., 2016), he said water stress simulation is when irrigation is reduced at specific growth stages, this is mainly to simulate drought. Shade simulation is when leaves are covered to protect light from penetrating and this is to simulate the loss of the photosynthetic area and no physiological processes will occur (Taiz *et al*., 2015)

2.7.3 Historical and experimental contexts

Cowpea (*Vigna unguiculata*), is a leguminous crop that has originated from Africa and has been cultivated for centuries and it plays a critical role in the food systems especially in the sub-Saharan Africa (Sighn *et al*., 2002). Cowpea is mainly a major source of carbohydrates and proteins. Cowpea also enhances soil fertility through symbiotic nitrogen fixation (Timko *et al*., 2008).

In Zimbabwe, cowpea is mainly grown in natural regions 3, 4 and 5 where it thrives under conditions like low rainfall and also limited inputs (Mpereki *et al*., 2000). Cowpea is cultivated as both food crop as it provides leaves that can be eaten and also as livestock feed. There are biotic and abiotic constraints that causes a decrease in yield of cowpea. Insects that causes defoliation by eating on the leaves are among the biotic stresses and they cause defoliation especially during the vegetative stages and the reproductive stages. Common pests include aphids, pod and flower borer and beetles (Daoust and Jackai, 1986). These pests cause up to 100% damage if left uncontrolled as they feed on the leaves, pods and buds thus causing a reduction in photosynthetic capacity (Fatokun *et al*., 2012).

The method of artificial defoliation has been widely used in crop stress physiology. It is a controlled experimental method where a percentage of the leaf area is removed to either simulate pest damage therefor providing a way of assessing a plant's ability to tolerate defoliation under different growth conditions (Hammond *et al*., 1987). Higley *et al*. (1993) said that legumes like soybeans and groundnuts, defoliation at early vegetative stages has a little effect on the yield, whilst defoliating during flowering and pod formation is even more detrimental.

2.7.4 Concept of defoliation and its impact on crops

Defoliation causes plants to undergo severe physiological stress because it suddenly limits the amount of photosynthate available for growth. Young plants and plants without a storage reserve mechanism are the main targets of this sudden stress (Cyr and Bewley, 1990). According to Boote et al. (1980), artificial defoliation is used to treat insect damage and evaluate the effect of leaf loss on a plant's health and yield.

According to Mondel *et al*. (1978) and Selter *et al*. (1980), defoliation alters the hormone balance, starch, sugar, protein, and chlorophyll concentration of source leaves, as well as stomata resistance and senescence rate. However, the impact of defoliation depends on the growth rate at which it takes place. Kim *et al*. (2019) also reported that highly defoliated cowpea plants showed higher levels of oxygen radical accumulation leading to oxidative damage, redox imbalances and this highlights the importance of defoliation management.

2.7.5 Cowpea growth and artificial defoliation

According to Ibrahim *et al*. (2010), showed the effect of stage and intensity of defoliation on the vegetative, showed that the removal of young expanding leaves prior to podding suppressed the vegetative growth and altered partitioning. According to El-Juhany *et al*. 2009, artificial defoliation has shown varied effects on leaf area index (LAI), root-shoot ratio, and plant height at different stages of growth.

2.8 Knowledge gaps

Numerous studies under the effects of defoliation on the growth and yield of cowpeas especially in soybeans, groundnuts and some common legumes have agreed that low levels of defoliation especially below 25% may be tolerated by plants without a significant yield loss during vegetative stages and higher levels of defoliation during flowering and pod filling can reduce the cowpea yield significantly (Higley *et al*., 1993). Despite the crop's importance in Zimbabwe, there is limited research that has been published on the threshold level of defoliation that the Zimbabwean cowpea varieties can tolerate without yield reduction as most studies only focus on the soil fertility, intercropping systems and variety assessment but a few addresses defoliation as a simulate pest damage or physiological stresses under experimental conditions (Chikowo *et al*., 2004).

CHAPTER 3: MATERIALS AND METHODS

3.1 Study site

The study was carried out at Skora Farm plot 16 which is located in Wedza Mashonaland East province. The latitude is approximately 18.6433°South, latitude is approximately 31.6792°East and an altitude of approximately 1340 metres above sea level. The area falls in natural farming region 1b. The climatic conditions in Wedza include a mean annual temperature extending from 18 to degrees Celsius and an annual temperature of 800mm primarily received between November and March. The area is comprised of both small holder farmers and large scale commercial farmers who are mainly into tobacco, wheat and cattle production.

3.2 Experimental design

The research was a field experiment, laid in a Randomized Complete Block Design (RCBD), with 4 treatments replicated 4 times to give a total of 16 experimental units (plots). The defoliation process was done at 4-leaf stage and it was done manually using a scissors to minimize stem damage. Leaves were removed according to treatment. The treatments that were used were T0: control (no defoliation), T1: 25% defoliation, T2: 50% defoliation, T3 75% defoliation. 50% defoliation means that half of all the leaf area were removed or removing every second leaf. 75% defoliation means that only 25% of the photosynthetic area remained and the rest was removed. 0% defoliation means that no defoliation was done and it was the control treatment in this experiment. With the exception of not having any leaves intentionally removed, plants grown under 0% defoliation were treated exactly like the rest.

All the plots were managed equally with respect to sowing date, land preparation, weeding, irrigation, and also pest control.

3.3 Preparation of the land

For the experiment, 4 blocks with 4 plots each were selected. Each plot measured five meters by one meter, and there was a roadway that was two meters wide between blocks and one meter wide between plots. The land was set using conventional agronomic practices. Initially, the ground was cleansed of vegetation and refuse. An ox-drawn plough was then used to cultivate the ground in order to create a proper seedbed and loosen the soil. To get a finer tilth, the dirt clumps were further ground up with an ox-drawn harrow.

I excavated 2 furrows that were 45cm apart. Since cowpeas responds well to basal fertiliser application or manure, I applied compound D as basal fertiliser at 150kgs/ha. I then covered the furrows lightly to ensure proper irrigation of the fertilizer in the soil.

The cowpea seeds of variety IT 18 were sown in furrows about 3 cm deep, with plants spaced about 20 cm apart. Soil was poured into the furrows to ensure soil seed contact to promote germination.

To minimize any potential disparities, the planting method was applied consistently throughout each plot inside the blocks. To ensure accurate identification and data collection throughout the trial, the plots were labelled and marked.

Manual weeding was done for at least 2 times a week. Pest and disease control was applied uniformly using appropriate insecticides and fungicides like Malathion 50EC and metalaxl plus mancozeb.

3.4 Data collection and measurements

Five randomly chosen plants from each of the four plots, which were tagged at the beginning of the experiment, were used to collect the data. Vine length (cm) was measured using a string from the base of the tallest leaf tip, and the string was then measured using a ruler. The vine length was measured at 3 weekly interval.

Data was gathered from the net plot area during harvest. That is the weight of cowpea grain were weighed using a Nicolas scale. The number of pods per plant was also determined by counting every pod from 5 randomly selected plants from each plot and then the average was calculated. Every plant in each plot was harvested and the grain was left to dry up to 14% moisture content which is allowed for the calculation of grain yield. The average yield per plant is measured using the formula that is stated below.

$$average\ yield\ per\ plant\ (g) = \frac{number\ of\ plants\ harvested\ in\ plot}{total\ grain\ weight\ from\ plot\ (g)}$$

3.5 Data analysis

The collected data was analysed statistically to extract significant insights. GENSTAT 17th edition was used to carry out the statistical procedures of Analysis of Variance (ANOVA). The study employed the analysis of variance (ANOVA) to determine significant differences across multiple groups or treatments. The least significant difference (LSD) was used for separation of treatment means.

CHAPTER 4: RESULTS

4.1 Effect of artificial defoliation levels on cowpea vine length

There was a highly significant difference ($p < 0.001$) in vine length of cowpea variety IT18 among the treatments across all the weeks (weeks 3, 6, 9, 12 and 15 after planting). The results showed that as defoliation increased, vine length decreased (Figure 4.1). across all the weeks, the highest average vine length was recorded in 0% defoliation, followed by 25% and 50%. The lowest mean vine length was recorded under the 75% defoliation. As show in Figure 4.1, vine length increase from week 3 to week 15 after planting.

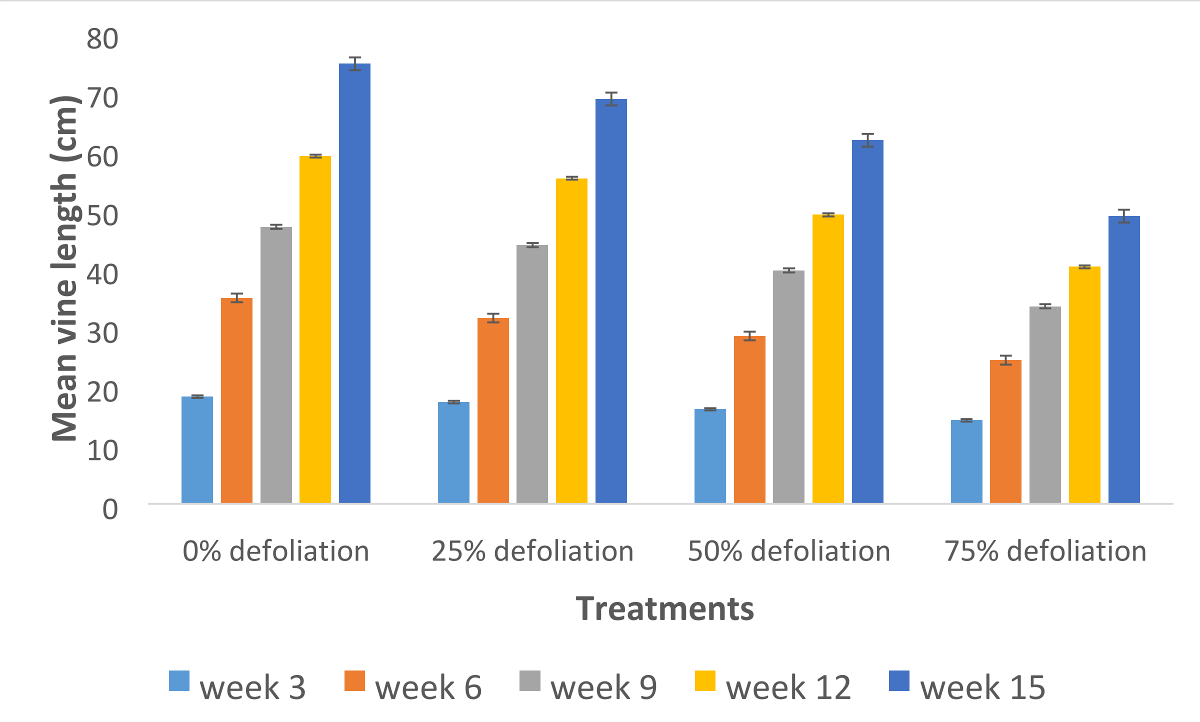

Figure 4.1: Effect of artificial defoliation levels on cowpea vine length

4.2 Effect of artificial defoliation levels on cowpea pod number

There was highly significant difference ($p < 0.001$) in cowpea pod number among the different levels of defoliation. The 0% defoliation treatment had the highest average pod number (16.90), followed by 25% (14.28) and 50% (8.43) defoliation. The 75% defoliation treatment had the lowest pod number of 6.12 (Table 4.1).

Table 4.1: Effect of artificial leaf defoliation levels on cowpea pod number

Treatment	Fruit number plant^{-1}
0% defoliation	16.90^{a}
25% defoliation	14.28^{b}
50% defoliation	8.43^{c}
75% defoliation	6.12^{d}
Grand mean Fprob	11.43
l.s.d	<0.001
CV%	1.436
	7.9

Means followed by a different superscript letter were significantly different at ($p < 0.001$)

4.3 Effect of artificial defoliation levels on cowpea yield

There was highly significant difference ($p < 0.001$) in cowpea grain yield among the different levels of defoliation. The mean yield decreased steadily as defoliation levels increased. The 0% defoliation treatment had the highest mean yield of 26.8g/plant, followed by 25% (21g/plant) and 50% (14.07g/plant) defoliation. The 75% defoliation treatment had the lowest grain yield of 7.77g/plant (Figure 4.2).

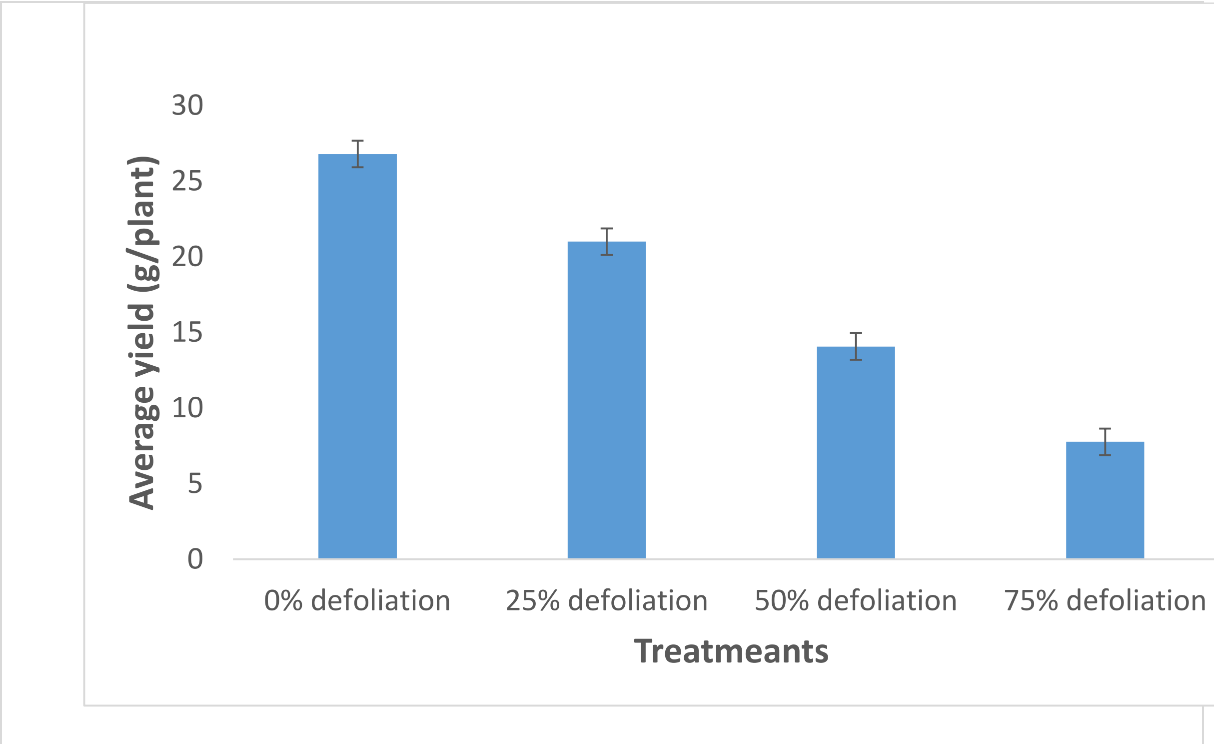

Figure 4.2: Effect of artificial defoliation levels on cowpea grain yield

Fig4.3

CHAPTER 5: DISCUSSION

5.1 Effect of artificial defoliation levels on vine length

There was a highly significant difference in vine length of cowpea variety IT18 among the different defoliation levels. This showed that as defoliation increased, vine length decreased. This can be attributed to the fact that increased defoliation reduces the vegetative growth of cowpeas.

The results on vine length showed that the vine length increased with time for all the treatments however there was variation in the extent of growth rate with defoliation level. Plants that were subjected to 0% defoliation showed the highest vine length throughout the growing period up to week 15 and it reached to an average length of 75cm and in contrast, 75% defoliation had a significantly reduced vine lengths and had an average of 49cm at week 15. This shows that defoliation affects photosynthesis by reducing leaf area which is suitable for photosynthesis. The effect was mostly pronounced over a period of time, a cumulative impact of defoliation on plant defoliation was seen after week 6. The results are consistent with Singh *et al*. (2016) who reported that heavy defoliation led to stunted growth and this is due to a reduction in carbohydrate availability for the elongation of stems.

Decreased vine elongation can be attributed to the fact that higher amounts of defoliation results in less photosynthetic surface area, which limits the production of assimilates needed for cell development and elongation (Boote et al., 2002). Furthermore, the plant's hormonal balance is changed when leaves are detached, mainly auxins and gibberellins, which are vital for stem growth. This is in agreement with Giri et al. (2006) who observed that severe defoliation frequently interferes with these hormone signals, resulting in shorter internodes and subpar vegetative development.

In support of these conclusions, Mahalakshmi and Bidinger (2002) revealed that stress-induced metabolic shifts in legumes such as sorghum caused in a considerable reduction in canopy size and shoot elongation following artificial defoliation. In a similar vein, Pandey et al. (2014) found that excessive defoliation in mungbean affected biomass buildup, stunted blooming because of decreased glucose translocation, and decreased vine length.

The slow variation in vine length over time between treatments further suggests that cowpea plants with higher degrees of defoliation were not able to make up for the lost leaf area. Cowpeas can regenerate some of their leaves following moderate stress, but the energy cost of doing so competes with vine elongation and reproductive development (Masarirambi et al., 2009). Because of this, the plants that were extensively defoliated (between 50% and 75%) probably redirected assimilates in order to survive, which hindered vegetative regrowth and resulted in shorter vine lengths by maturity.

5.2 Effect of artificial defoliation on pod number

There was highly significant difference in pod number among the different levels of defoliation. The coefficient of variation was 7.9% and this is indicating a low experimental error and a good precision in the measurements. The results on defoliation effect on pod number shows that the leaf area is very important in determining the yield due to their role in photosynthesis. The more the defoliation, the fewer the pods are produced.

Reduced leaf area directly affects photosynthetic efficiency, which explains why there are fewer pods as defoliation increases. The main source of the assimilates needed for seed filling, pod development, and flowering is leaves. The ability of the plant to produce and distribute carbohydrates is seriously hampered when a sizable amount of the leaf area is eliminated, as occurs in 50% and 75% defoliation treatments (Boote et al., 2002). As a result, fewer floral structures are started, and a lack of energy may cause many developing pods to abort.

The results of this investigation align with the findings of Singh et al. (2016), who noted that pigeonpea and other legumes exhibited a notable decrease in pod count when exposed to elevated levels of defoliation. Similarly, Pandey et al. (2014) discovered that mungbean pod formation significantly decreased with increasing defoliation levels, underscoring the vulnerability of reproductive development to early vegetative damage.

The source-sink relationship is crucial to the reproductive growth of legumes like cowpeas, as the energy needed to create reproductive structures (sink) comes from the leaves (source). When defoliation takes place during the early or mid-vegetative stages, it upsets this equilibrium and results in poor pod setting, increased pod abortion, and decreased flower initiation (Mahalakshmi & Bidinger, 2002). The gradual decline in pod quantity from 0% to 75% defoliation suggests that when cowpea plants experience a large loss of leaf area, they have few compensatory mechanisms to sustain reproductive output.

5.3 Effect of different defoliation levels on yield

Different defoliation levels had highly significant effect on cowpea grain yield. The mean yield decreased steadily as defoliation levels increased as lowest yield was shown in 75% defoliation treatment with a mean yield of 7.77g/plant and highest yield was shown in 0% defoliation treatment with a mean yield of 26.8g/plant. This indicates that defoliation has a strong negative impact on cowpea yield. This could be attributed to a reduction in leaf area thus causing minimal photosynthetic activity and assimilate production for pod filling

Higher defoliation levels caused a decline in reproductive output and this can be attributed to the reduced energy reserves that are available for pod development and flowering. Defoliating, particularly beyond 25% disrupts the source-sink relationship in plants as leaf area have vital role in the assimilate production. According to Kamara et al. (2014), there is a direct correlation between leaf retention and yield in cowpea. Although the 25% defoliation showed some reduction, it was still relatively reproductive and this means that cowpeas can tolerate low levels of defoliation without yield penalties.

This study's findings on cowpeas are consistent with Giri et al. (2006), who found that French beans with higher levels of artificial defoliation had considerably lower yield components such pod number, pod weight, and seed size. Similarly, Pandey et al. (2014) reported that defoliation of mungbean plants over 25% significantly decreased grain yield because the reproductive organs received less carbohydrate. The study highlighted the direct relationship between grain fullness and the residual foliage's capacity for photosynthetic activity.

According to Masarirambi et al. (2009), defoliation minimizes the translocation of stored reserves to pods, which is crucial during the pod filling stage, and also impacts root-shoot signaling. Furthermore, Boote et al. (2002) pointed out that plants subjected to early defoliation experience developmental delays, which result in a poor synchronization between flowering and resource availability, ultimately leading to abortion of the flowers and pods.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The findings clearly demonstrated that defoliation has a significant effect on both vegetative growth, as measured by vine length, and reproductive output, as measured by the average number of pods per plant and average weight of seeds per plant. The 0% defoliation treatment had consistently recorded the highest vine length, pod number and yield, while the 75% defoliation treatment resulted in a significantly reduced growth and yield. The results also showed that cowpea plants also tolerate up to 25% defoliation without a substantial decrease in growth and yield.

6.2 Recommendations

Based on the findings of this study, it is recommended that farmers avoid high levels of leaf removal in cowpea production, as excessive defoliation, particularly at 50% and 75%, was shown to significantly reduce both growth and yield. Minimal or no defoliation (0–25%) should therefore be practiced in order to maintain optimum plant performance. Since natural defoliation in the field is often caused by insect pests and diseases, it is important for farmers to adopt integrated pest management (IPM) practices, such as the use of resistant varieties, cultural practices, and timely pesticide application, to minimize leaf loss. Furthermore, plant breeders should focus on developing cowpea varieties with tolerance to partial defoliation and enhanced resilience under stress, using variety IT18 as a benchmark for future selection. Farmer training on canopy management should also be prioritized to raise awareness on the negative impact of excessive leaf removal, whether from pest damage, poor crop management, or overgrazing. In addition, good agronomic practices such as adequate fertilization, irrigation, and timely weeding should be encouraged to enhance recovery in cases where minor defoliation occurs. Finally, further research is recommended to explore the effects of defoliation at different growth stages, assess varietal differences in tolerance, and investigate interactions between defoliation and abiotic stresses such as drought and nutrient limitations.

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APPENDICES

Appendix 1: Analysis of variance (ANOVA) Tables for vine length

Variate: vine_length_week_3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	3	0.04500	0.01500	0.18	
replication.*Units* stratum					
treatment	3	36.30500	12.10167	141.45	<.001
Residual	9	0.77000	0.08556		
Total	15	37.12000			

Variate: vine_length_week_6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	3	2.283	0.761	0.70	
replication.*Units* stratum					
treatment	3	243.062	81.021	74.16	<.001
Residual	9	9.833	1.093		
Total	15	255.178			

Variate: vine_length_week_9

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
plot stratum	3	1.3025	0.4342	1.78	
plot.*Units* stratum					
treatment	3	412.2625	137.4208	564.10	<.001
Residual	9	2.1925	0.2436		
Total	15	415.7575			

Variate: vine_length_week_12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	3	0.1419	0.0473	0.33	
replication.*Units* stratum					
treatment	3	812.6419	270.8806	1903.70	<.001

Residual	9	1.2806	0.1423		
Total	15	814.0644			

Variate: vine_length_week_15

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
replication stratum	3	2.932	0.977	0.42	
replication.*Units* stratum					
treatment	3	1488.277	496.092	213.01	<.001
Residual	9	20.961	2.329		
Total	15	1512.169			

Appendix 2: Analysis of variance (ANOVA) Tables for pod number

Variate: pod_number

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
plot stratum	3	4.6269	1.5423	1.91	
plot.*Units* stratum					
treatment	3	300.7519	100.2506	124.35	<.001
Residual	9	7.2556	0.8062		
Total	15	312.6344			

Appendix 3: Analysis of variance (ANOVA) Tables for grain yield

Variate: yield_g_plant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
plot stratum	3	2.282	0.761	0.49	
plot.*Units* stratum					
treatment	3	820.062	273.354	176.83	<.001
Residual	9	13.912	1.546		
Total	15	836.257			