Response of Cowpea (*Vigna Unguiculata* L) Varieties to Defoliation

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Abstract

Loss of foliage in cowpea (Vigna unguiculata [L] Walp) as a result of field physiological disorders and/or diseases is detrimental to the growth and development of the crop in both tropical and sub-tropical areas. Field studies on effects of defoliation in cowpea were conducted at the University for Development Studies, Tamale in Northern Ghana during the 2015 and 2016 cropping seasons. Four cowpea varieties, namely Songotra, Padituya, Binaaba and Sanzi were subjected to the following five levels of defoliation: 0 %, 25 %, 50 %, 75 % and 100 %. The treatment combinations were replicated three times in randomised complete block design. Results indicated that the varieties differed from each other in terms of vegetative growth and yield responses to defoliation. The overall best grain yielder was Padituya whilst Binaaba was the poorest in terms of grain yield. Up to 50 % defoliation of any of the four varieties was not observed to be detrimental to growth and grain production.

Keywords: Cowpea Varieties, Experimental Defoliation, Growth, Grain Yield

Introduction

Cowpea (*Vigna unguiculata* [L] walp) is a major staple food crop grown in sub-Saharan Africa, especially in the dry savannah regions of West Africa. It is known to be the most economically significant African traditional legume (Valenzuela and Smith, 2002; Langyintuo *et al.*, 2003). Cowpea plays a critical role in the lives of millions of people in Africa and other parts of the world. According to IITA (2007), about 7.6 million tonnes of cowpea are produced annually on about 12.8 million hectares of land worldwide. Cowpea contains 20-25 % of protein, about twice the protein content of most cereals. The leaves, immature pods and seeds are all used as food, and this is an indication that when the crop is given a careful attention, it would be able to support 850 million people in the world, and the high incidence of undernourishment in sub-Saharan Africa would reduce (FAO, 2006).

In Ghana, the crop is widely cultivated under rainfed conditions mainly in the savannah and transitional agro ecological zones, but the bulk of the grain is produced in the northern part of the country (CSIR-SARI, 2012). Cowpea yields in Ghana are among the lowest in the world, averaging 310 kg ha^{-1} (Ofosu-Budu *et al*., 2007) and efforts made to improve the production of the crop include the introduction of high yielding varieties (Addo-Quaye *et al*. 2011). Available literature indicates that defoliation in cowpea especially in areas where farmers do not protect their crops adequately from field physiological disorders, diseases or herbivores, has contributed to poor yields. McNaughton (1983) stated that factors such as timing, type and extent of defoliation as well as the availability of resources in the environment to support growth may influence plants' response to defoliation. Rockwood and Lobstein (1994) demonstrated that in plants, defoliation may decrease growth and reproduction, increase mortality or reduce the leaf area available for photosynthesis. Ida *et al*. (2012) studied the effects of defoliation in *O. sericea* and reported that the phenomenon reduced photosynthesis and reproductive performance of the plants especially during flowering.

Defoliation in plants is not always disadvantageous but could be advantageous (Barimavandi *et al.,* 2010). For instance, Meyer (2011) reported that delayed leaf senescence and compensatory photosynthesis characterised defoliation in *Solidago altissima*. Hossain *et al.* (2006) and Mondal (2007) observed that defoliation reduced the abortion of flowers and immature pods and thereby increased seed yield in cowpea and mungbean, respectively. It has been established that plants would store more resources to support growth and reproduction when they are defoliated or subjected to other stresses (Chapin *et al*., 1990). Information regarding the response of cowpea to defoliation in Ghana is either scanty or unavailable according to the available literature. The present study was conducted to investigate growth and yield response of cowpea to defoliation in Nyankpala located within the Guinea savannah agroecology of Ghana.

Materials and Methods

Site Description

The studies were conducted during the 2015 and 2016 cropping seasons at the University for Development Studies, Nyankpala Ghana on latitude 09° 25' N and longitude 0° 58'W at an altitude of 183m above sea level. The experimental area lies within the interior Guinea savannah of Ghana and has total annual rainfall of about 1022 mm which is mainly evenly distributed from May to October with a peak in August or September in each year. The area has an average minimum temperature of 25°C and maximum average temperature of 35°C (Lawson *et al*., 2013). The place is characterised with natural vegetation dominated by grasses with few shrubs. The soils of the area are brown, moderately drained sandy-loam and free from concretions. They are very shallow with hardpan under the top few centimetres and were derived from Voltaian sandstone and classified as Nyankpala series (Plinthic Acrisol) according to FAO (1988). The area is characterised by grassland vegetation interspersed with short trees such as *Parkia biglobosa*, and *Azadirachta indica*. Commonly located weed species include *Centrosema pubescens*, *Cyperus difformis* and *Striga hermontheca*.

Land Preparation and Field Layout

In both the 2015 and 2016 seasons, the experimental fields were slashed and ploughed. Plant species that were not properly buried were removed. The area was lined and pegged into experimental units. A total field dimension of 72 m x 26 m was used and each experimental unit measured 5 m x 4 m. There were three replications, and each was separated from the other by an alley of 1.5 m. Plots were separated from each other by a distance of 1m.

Experimental Design

The study made use of a 4 x 5 factorial experiment in each season. Seeds of the following cowpea genotypes: Songotra, Padituya, Binaaba and Sanzi were planted by dibbling at a depth of 3.5 cm. Three seeds per hill were planted at a distance of 20 cm x 60 cm. The seedlings were thinned to two per stand after 5 days of emergence. Seedlings of the four cowpea genotypes were subjected to 25 %, 50 %, 75 % and 100 % levels of defoliation with undefoliated (0 %) plants from each genotype serving as control. Treatment combinations were replicated three times in randomised complete block design.

Data Collection

Both growth and yield parameters were collected for analysis in each experimental season. Data collected at the vegetative phase of the plants included plant height, number of branches, number of leaves and chlorophyll content. At harvest, data on number and length of pods, hundred seed weight, number of seeds per pod, number of pods per plant and total grain yield were also collected. A total of ten tagged plants sampled from each experimental plot were considered for data collection.

Data Analysis

Averages were computed for data collected on each parameter for the two years prior to subjecting them to analysis of variance (ANOVA) using Genstat statistical package 12th edition, and means separated using the Least Significant Difference (LSD) approach at 5% level of probability.

Results

Vegetative Growth

The influence of variety, defoliation or variety x defoliation on plant height of cowpea was not significant ($P > 0.05$). The trends in variation with respect to number of branches and number of leaves were similar. In each of these two parameters, the effect of variety was significant ($P < 0.05$) whilst the single effect of defoliation or the combined influence of variety and defoliation (variety x defoliation) was not significant ($P > 0.05$) (Figures 1 and 2). Genotype Binaaba recorded significantly ($P < 0.05$) higher number of branches (Figure 1) or number of leaves (Figure 2) than any of the other three genotypes especially from 4 to 8 weeks after planting. Variation in number of branches and number of leaves for Songotra, Padituya and Sanzi were not significantly different ($P > 0.05$).

Figure 3 shows that chlorophyll content varied significantly ($P < 0.05$) with variety especially at 6 and 8 weeks after planting. The effect of defoliation or variety x defoliation on chlorophyll content, however, was not significant ($P > 0.05$). At 6 or 8 weeks after planting, genotype Songotra recorded significantly ($P < 0.05$) higher chlorophyll content than Binaaba whilst genotypes Padituya and Sanzi recorded significantly the same ($P > 0.05$) chlorophyll content.

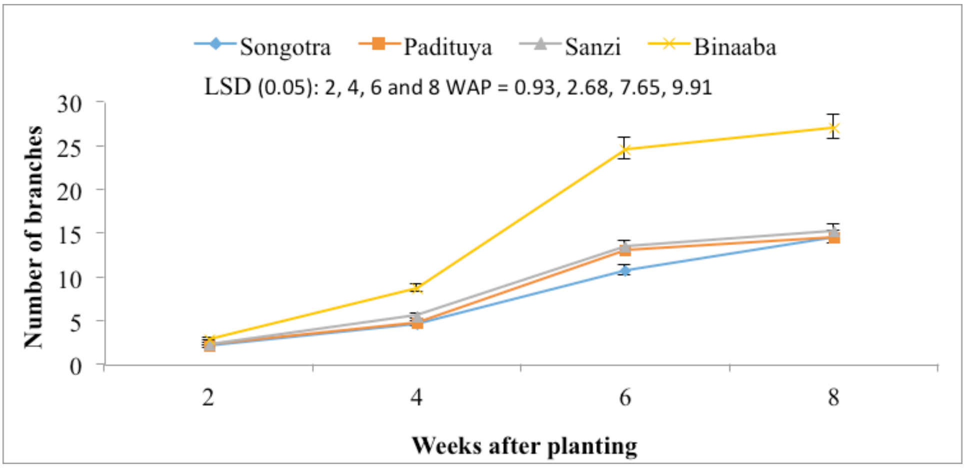

Figure 1: Variation in number of branches formed by the cowpea varieties during field studies in the 2015 and 2016 cropping seasons at Nyankpala. Bars indicate mean ± standard error of the means.

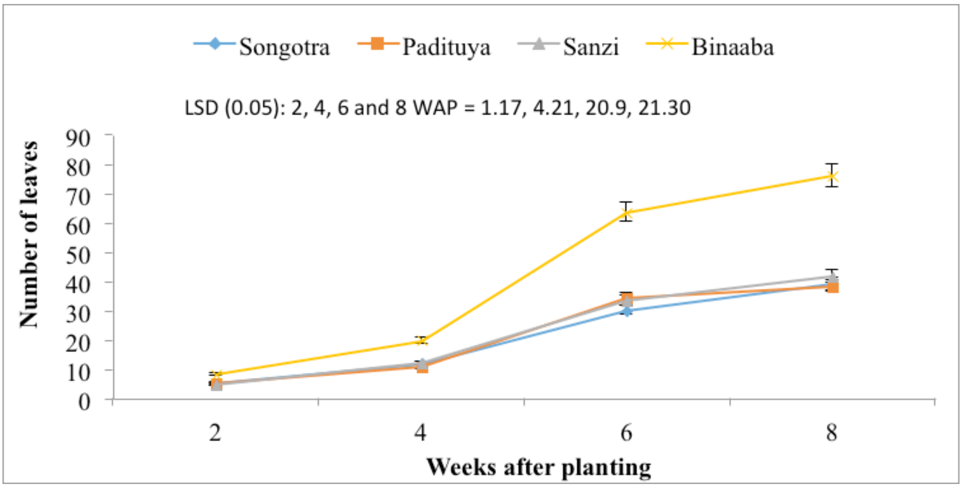

Figure 2: Changes in number of leaves produced by the cowpea varieties during field studies in the 2015 and 2016 cropping seasons at Nyankpala. Bars indicate mean ± standard error of the means.

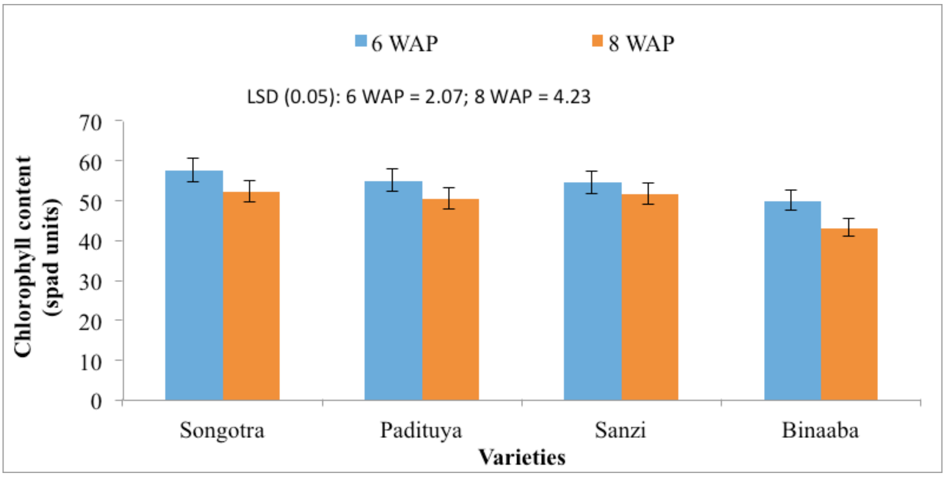

Figure 3: Trend in chlorophyll content of the cowpea varieties during the experimental period. Bars indicate mean ± standard error of the means.

Yield and Yield Components

Variety x defoliation was significant ($P < 0.05$) for number of pods per plant and number of seeds per pod. The undefoliated plants from Songotra and 50% defoliated plants from Padituya recorded significantly ($P < 0.05$) the highest average number of pods per plant. Pod yield recorded from genotype Sanzi was significantly ($P < 0.05$) similar to that of Songotra and Padituya. Padituya and Binaaba at 100 % defoliation recorded values that were not significantly ($P > 0.05$) different from each other. These two genotypes at 100 % defoliation recorded the lowest number of pods per plant (Table 1).

Number of seeds per pod also varied significantly ($P < 0.05$) for the combined effect of variety and defoliation (Table 2). Plants defoliated at 50 % from Padituya and undefoliated plants from Songotra significantly ($P < 0.05$) recorded the same average and highest number of seeds per pod while the undefoliated plants from Binaaba recorded significantly ($P < 0.05$) the least value of this parameter (Table 2).

Table 1: Effects of variety and defoliation on pod numbers of cowpea during the experimental period

Levels of defoliation					
Cowpea variety	0%	25%	50%	75%	100%
Songotra	11.67	11.00	8.33	7.67	7.33
Padituya	8.00	9.84	11.67	7.33	4.33
Sanzi	11.33	9.40	8.67	7.67	6.33
Binaaba	6.33	7.33	8.33	5.67	5.00

LSD (0.05): Variety x Defoliation = 3.72

Table 2: Variation in number of seeds per pod of four cowpea varieties in response to defoliation during the experimental period

Levels of defoliation					
Cowpea variety	0 %	25%	50 %	75 %	100 %
Songotra	13.33	10.83	10.33	11	7.67
Padituya	10.00	11.16	14.33	10.67	9.67
Sanzi	10.00	8.83	9.67	9.00	5.33
Binaaba	5.33	6.66	8.00	11.33	8.33

LSD (0.05): Variety x Defoliation = 3.87

The interaction between variety and defoliation varied significantly ($P < 0.05$) for pod length; hundred seed weight and grain yield (Tables 3 – 5). Songotra and Padituya at 0 %, 25 % and 50 % defoliations and Binaaba at 75 % defoliation recorded significantly ($P > 0.05$) the same values of pod length. Padituya at 50 % and Sanzi at 100 % defoliations recorded significantly ($P < 0.05$) the highest and lowest pod length, respectively (Table 3).

The variation in the response to defoliation of cowpea of seed weight and total grain yield are reported in Tables 4 and 5, respectively. The two parameters varied significantly ($P < 0.05$) among the varieties and defoliation regimes. Padituya at 0 %, 25 % and 50 % levels of defoliation recorded significantly ($P > 0.05$) the same but highest values in seed weight and total grain yield (Tables 4 and 5). Seed and grain yields recorded by Binaaba at all levels of defoliation were significantly ($P > 0.05$) the same and the least among the varieties (Tables 4 and 5).

Table 3: Variation in pod length (cm) in response to changes in defoliation of four cowpea varieties during field experimentation

Levels of defoliation					
Cowpea variety	0 %	25 %	50 %	75 %	100 %
Songotra	14.40	13.61	12.83	11.23	11.20
Padituya	13.00	14.70	16.40	12.63	12.20
Sanzi	12.43	12.38	12.33	11.43	10.03
Binaaba	10.90	11.21	11.53	13.60	11.87

LSD (0.05): Variety x Defoliation = 4.78

Table 4: Influence of variety x defoliation on hundred seed weight (g) of four cowpea varieties during experimentation

Levels of defoliation					
Cowpea variety	0 %	25%	50 %	75 %	100 %
Songotra	19.33	19.85	20.37	18.47	20.4
Padituya	28.03	27.75	27.47	25.27	24.33
Sanzi	18.93	18.26	17.6	18.53	16.83
Binaaba	16.13	15.76	15.4	17.53	16.00

LSD (0.05): Variety x Defoliation = 2.96

Table 5: Variety x defoliation effect on total grain yield (t/ha) of four cowpea varieties during field experimentation

Levels of defoliation					
Cowpea variety	0 %	25%	50 %	75 %	100 %
Songotra	15.01	14.45	13.89	11.68	12.04
Padituya	18.07	17.635	17.20	15.61	11.68
Sanzi	12.14	12.09	12.04	12.1	11.75
Binaaba	10.62	10.93	11.25	11.87	8.92

LSD (0.05): Variety x Defoliation = 3.04

Discussion

The study revealed that variety, and not defoliation influenced vegetative growth. Variety Binaaba was the best genotype in terms of leaf production but was the poorest in terms of seed and/ or grain yield. Leaves are the major sources that supply assimilates to sinks such as developing organs, young pods and seeds (Barimavandi *et al*., 2010). Even though Binaaba was the best leaf producer, the high leaf production of this genotype did not reflect in its grain production. This result is in support of the findings of Matikiti *et al*. (2009) who made a similar observation on cowpea in Zimbabwe. The data provided on seed and grain yield indicated that Padituya was the best seed or grain producer whilst Binaaba was the poorest. Binaaba possibly might have channeled more of its photoassimilates for the growth and production of shoots rather than grain. Data on chlorophyll content also showed that Binaaba recorded the least chlorophyll content among the four varieties studied. The important role of chlorophyll in plants during photosynthesis cannot be overemphasised. Chlorophyll plays a major role in the photosynthetic activities of plants. The low grain production of Binaaba might also be attributed to its low chlorophyll content. Koike *et al*. (2004) observed a clear positive correlation between chlorophyll content and photosynthetic rate of some certain plant species. Thus in general, high chlorophyll content may increase the photosynthetic rate of plants and this may also imply high productivity of the plant species.

Yield responses to defoliation of the varieties were remarkable. In almost all the varieties studied, components of yield and total grain yield measured from plants defoliated at 50 % were highest or comparable with the undefoliated control. The observation made here is in agreement with that of Barimavandi *et al*. (2010) who reported that defoliation in plants is not always disadvantageous but could be advantageous. The increased yields of the 50 % defoliated plants, among other reasons might have been due to compensatory regrowth and photosynthesis that occurred following defoliation and this is in accordance with the finding of Meyer (2011). According to this author, compensatory photosynthesis resulted from defoliation of some forest species. The present study indicates that the overall best grain yielders were undefoliated Padituya plants, or plants from this genotype defoliated at 25 % or 50 %, whilst Binaaba was the lowest yielding in terms of grain production.

In general, plants completely defoliated were more adversely affected by defoliation than those subjected to mild (25 or 50 %) defoliation. According to Gustafson *et al*. (2006), defoliation may cause yield reductions by affecting the photosynthate production and its distribution into various parts of the crop depending on the intensity of defoliation. Plants completely defoliated might have recorded a more drastic reduction of their photosynthetic apparatus as compared to those from mild defoliations. Thus the production of photoassimilates and their subsequent translocation from foliage to roots from such plants might have been greatly affected. The completely defoliated plants were placed at a competitive disadvantage position relative to those from mild defoliation regimes (Vargas – Ortiz *et al*., 2013). The photosynthetic products of plants subjected to complete defoliation might have been redirected towards the development of new leaves at the expense of the reserves stored for growth and reproduction. The results obtained from this study are consistent with those of Saidi (2007) and McNaughton (1983) who explained that type and extent of defoliation may influence the responses of plants to the stress. According to Chen *et al*. (2017) when plants lose their tissues or organs as a result of stresses, they generally use their stored compounds to replace the tissues through regrowth of shoots.

Reductions in yield parameters were higher in genotypes Sanzi and Binaaba than Padituya and Songotra. Sanzi and Binaaba are local unimproved varieties whilst Padituya and Songotra are improved varieties. The two groups of varieties used in the study possess different structural characteristics and adaptability to various areas. Padituya was derived from genotype SARC-122-2 prior to its release. It is medium maturing genotype with erect canopy architecture. It has moderate resistance to aphids, leaf curl and Striga (CSIR-SARI, 2008). Songotra was also developed from genotype IT97K-499-35. It is also a medium maturing variety that is also erect and is resistant to Striga, aphids and leaf curl. Sanzi and Binaaba are, however landraces. They are tolerant to drought and most pests and diseases that may attack the improved varieties (CSIR-SARI, 2012). They have determinate and spread growth habit. The improved varietal morphological characteristics of the Padituya and Songotra might have conferred to them tolerance to the effects of defoliation. Data provided indicate that plants from the undefoliated control (0%) and those from the partially defoliated regimes (50 %) exhibited similar yield responses. The result implies that up to 50 % defoliation resulting from physiological disorders and /or diseases of these varieties may not cause any serious damages to their growth and yield.

Conclusion

The varieties differed from each other in terms of vegetative growth and yield responses to defoliation. The overall best grain yielders were the undefoliated Padituya plants, or plants from this genotype defoliated at 25 % or 50 %. Binaaba, even though produced the highest number of leaves and branches, was the poorest grain yielder. Defoliation of the cowpea varieties up to 50 % is not detrimental to growth and grain production.

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