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RESPONSE OF COWPEA (*VIGNA UNGUICULATA* L.) TO SIMULATED LEAF HERBIVORY AND RATE OF APPLICATION OF NPK 15:15:15 IN THE GUINEA SAVANNAH AGROECOLOGY OF GHANA

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Abstract
Field studies were conducted at the University for Development Studies during the 2013 and 2014 cropping seasons to determine the combined effects of NPK 15:15:15 and experimental defoliation on growth and yield of cowpea. Seeds of cowpea cultivar 'Songotra' were planted and fertilized with 15, 20 or 25 kg/ha of NPK 15:15:15 three weeks after planting (WAP). At 4 WAP, the plants were subjected to 50, 75 or 100% defoliation. The unfertilized (0 kg/ha NPK 15:15:15), or undefoliated plants (0% defoliation) served as control treatments. Treatment combinations were replicated four times in randomized complete block design. Results indicated that plants from the 50% defoliation regime that were fertilized with 20 or 25 kg/ha of the fertilizer had the best performance in terms of growth and total grain yield. Thus in the Guinea Savannah agroecology of Ghana, 50% defoliation of cowpea during cultivation is not detrimental to growth and grain production, provided nutrients equivalent to 20 - 25 kg/ha of NPK 15:15:15 can be applied as fertilizer to the crop 3 WAP.

Keywords: Cowpea, Defoliation, Simulated leaf herbivory, NPK 15:15:15 application, Growth and yield.

Introduction

Cowpea (*Vigna unguiculata* L. Walp.) is an important food legume and an integral part of traditional cropping systems in the semi-arid regions of the tropics (Singh *et al*., 2003). Cowpea is of very vital importance to the livelihood of several millions of people especially in the central and western part of Africa. The haulms can be utilized as a supplement for livestock production and its inclusion in the diet of sheep has no deleterious effects while improving the haematological and serum biochemical variables (Anele *et*. *al*., 2010). Cowpea, like other grain legumes improve soil fertility through biological nitrogen fixation and increases soil conservation through greater ground cover (Lithourgidis *et al*., 2011). Some varieties can fix up to 46 - 103 kg N ha^{-1} annually (Sanginga *et al*., 2003). The young leaves, immature pods and peas are used as vegetables in their fresh forms. Most people especially in the rural areas derive food, animal feed and cash income from the crop. IITA (2007) reported that about 7.6 million tonnes of the crop was produced on about 12.8 million hectares of land worldwide. Countries producing cowpea in West Africa are Nigeria, Mali, Burkina Faso and Senegal. Nigeria is the highest producer with 4 million hectares of land under cultivation, followed by Niger with 3 million hectares (Blade *et al*., 1997). Cowpea is adapted to warm weather and requires less rainfall than most crops, and this explains why it is cultivated in the semi arid and arid regions of lowland tropics where soils are poor and rainfall is limited (Mortimore *et al*., 1997). Best yields of the crop are obtained in well drained sandy loamy soils to clay loam soils with a pH range of 6 - 7 (Dujge *et al*., 2009).

Farm animals may feed on cowpea growing in the field especially in the case of unfenced backyard farms or gardens, and the production of the crop, like many other field crops, is bedeviled with disease and pest infestation. Especially, herbivores may defoliate cowpea plants causing yield losses at harvest. A considerable number of Lepidopteran larvae have been reported to be feeding on cowpea leaves, skeletonizing and sometimes defoliating the plants (Allen *et al*., 1996). Severe defoliation resulting from leaf spot may cause subsequent loss in growth and yield of the crop. In crop production, defoliation may be advantageous as well as disadvantageous (Abdi *et al.,* 2007; Barimavandi *et al.,* 2010) but according to Rahman *et al.* (2008), it is the intensity of defoliation that affects growth and/or the grain yield of crops. During defoliation, as may also occur in other stresses to which plants may be subjected, food reserves may be stored or produced in the plant to support growth and reproduction. Vargas-Ortiz *et al*. (2013) reported that stem and root **carbohydrate reserves** are used to support the growth of shoots in defoliated plants.

Studies conducted in Nyankpala indicated that the cowpea variety 'Songotra' was very efficient in leaf regrowth after it had been defoliated (Ghanney, 2012). This variety had a high rate of leaf recovery when subjected to 100% defoliation. It is also known that carbon starvation occurs in plants as a result of depletion of stored reserves during refoliation (Machado *et al*., 2013). This implies that fertilizer/nutrient application during or after defoliation will enhance the growth of plants and increase the yield of the crop. The need to determine the amount of fertilizer to be applied to defoliated crops in order to enhance productivity has been felt over the years. This work was therefore carried out to determine the combined effect of defoliation and NPK 15:15: 15 application rate on growth and yield of cowpea in Nyankpala in the Guinea Savannah Agroecology of Ghana.

Materials and Methods

Site Description

The study was conducted during the 2013 and 2014 cropping seasons at the University for Development Studies, Nyankpala, in the Northern Region of Ghana. The experimental site is located on an altitude of 183 m, latitude 09^o 25' N and longitude 0^o 58'W. Rainfall in the study area is evenly distributed from May to October with a peak in August or September in each year. The total annual rainfall is about 1022 mm. The average minimum temperature is 25˚C whilst the maximum average temperature is 35˚C (Lawson *et al*., 2013). The area lies within the interior Guinea savannah agroecology of Ghana and is characterized with natural vegetation, dominated by grasses with few shrubs. The soils of the area are moderately drained and are free from concretions; they are shallow with hardpan under the top few centimetres and were derived from Voltaian sandstone. The soils, according to FAO (1988), are classified as Nyankpala series or Plinthic Acrisol. The area has grassland vegetation and it is interspersed with short trees such as *Parkia biglobosa*, and *Azadirachta indica* and weed species such as *Centrosema pubescens*, *Cyperus difformis* and *Striga hermontheca.*

Land preparation, experimental design and planting

The experimental field was ploughed and harrowed. A total of 48 plots were laid out using tape measure, cutlass, hoe, garden lines and pegs. Seeds of improved cowpea variety 'Songotra' were obtained from the Council for Scientific and Industrial Research - Savannah Agricultural Research Institute, Nyankpala, Ghana and planted. Plants were fertilized with 15, 20 or 25 kg/ha of NPK 15:15:15 3 WAP, and at 4 WAP, they were subjected to 50, 75 or 100% defoliation. The unfertilized (0 kg/ha NPK 15:15:15), or undefoliated plants (0% defoliation) served as control treatments. Treatment combinations were replicated four times in randomized complete block design. Seeds were planted at a spacing of 20 x 60 cm on beds of sizes 2 m x 2.5 m prepared using a hoe at planting depth of 2 cm.

Data collection and analysis

In the 2013 season, data were taken on the following parameters: number of leaves, plant height, chlorophyll content and number of branches at 2 weekly intervals starting from 2 to 8 WAP. In the 2014 season, parameters considered for data collection were number of pods per plant, number of seeds per pod, pod length, 100 seed weight and total grain yield. The data were subjected to Analysis of Variance using GenStat (Discovery Edition) and where significant differences were observed among treatments, LSD (5%) was used to separate the treatment means.

RESULTS

Plant Height

The main effects of defoliation, NPK 15:15:15 and the interaction of the two factors significantly ($P < 0.05$) influenced plant height at 8 WAP (Table 1). Plants applied with 20 kg/ha of NPK 15:15:15 and subjected to 50% defoliation grew the tallest, whilst the unfertilized control (0 kg/ha) that were completely defoliated (100%) recorded the least height (Table 1).

Table 1: Height (cm) recorded of cowpea plants fertilized with NPK 15:15:15 and subjected to defoliation

	NPK 15:15:15 levels (kg/ha)				
Defoliation (%)	0	15	20	25	Means
0	21.86	22.3	23.08	18.45	21.42
50	22.77	22.62	25.67	23.52	23.64
75	18.75	20.92	21.53	20.5	20.42
100	17.85	19.78	20.4	19.91	19.49
Means	20.31	21.4	22.67	20.6	

Field Data, 2014 LSD (0.05): Defoliation = 1.84; NPK 15:15:15 = 1.84; Defoliation x NPK 15:15:15 = 3.68

Number of Leaves

Main effects of defoliation, NPK 15:15:15 and the interaction of both factors significantly ($P < 0.05$) influenced number of leaves at 8 WAP (Table 2). Plants subjected to 75% defoliation and applied with 25 kg/ha of NPK 15:15:15 produced the highest number of leaves whilst plants completely defoliated (100%) but fertilized with 15 kg/ha of NPK 15:15:15 recorded the least number of leaves (Table 2).

Table 2: Leaf number of cowpea plants fertilized with NPK 15:15:15 and subjected to defoliation during cultivation

	NPK 15:15:15 levels (kg/ha)				
Defoliation (%)	0	15	20	25	Means
0	43.00	32.00	38.00	37.00	37.50
50	34.00	33.00	35.00	31.00	33.25
75	37.00	35.00	31.00	49.00	38.00
100	31.00	28.00	41.00	31.00	32.75
Means	36.25	32.00	36.25	37.00	

Field Data, 2014, LSD (0.05): Defoliation = 3.88; NPK 15:15:15 = 3.88; Defoliation x NPK 15:15:15 = 11.76

Number of Branches

At 8 WAP, number of branches varied significantly ($P < 0.05$) for the main effects of defoliation (Fig 1). The single effect of NPK 15:15:15 application and the interaction effects were, however, not significant ($P > 0.05$).

The undefoliated plants (0% defoliation) recorded significantly (P < 0.05) the highest number of branches whilst plants from the three defoliated regimes had the same number of branches.

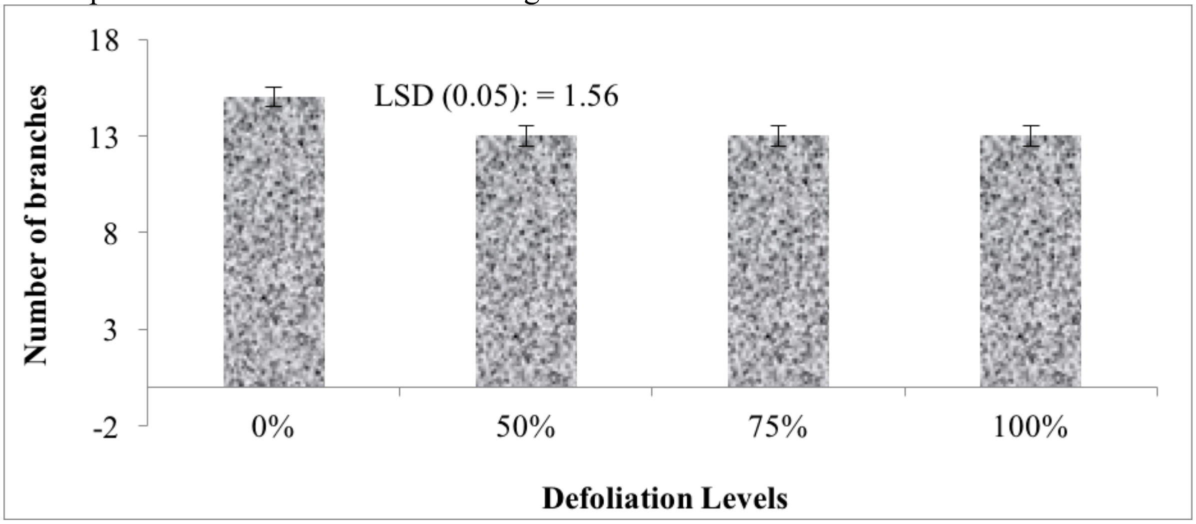

Fig 1. Effects of defoliation on number of branches of cowpea during cultivation

Chlorophyll Content

At 8 WAP, chlorophyll content varied significantly (P < 0.05) for the main effects of NPK 15:15:15. However, the single effect of defoliation and the interaction effects were not significant (P > 0.05). Plants that received application from 20 kg/ha significantly produced the highest value of chlorophyll whilst those fertilized with 15 and 25 kg/ha NPK 15:15:15 had the same chlorophyll content. Those fertilized with 0 kg/ha produced the lowest chlorophyll content (Fig 2).

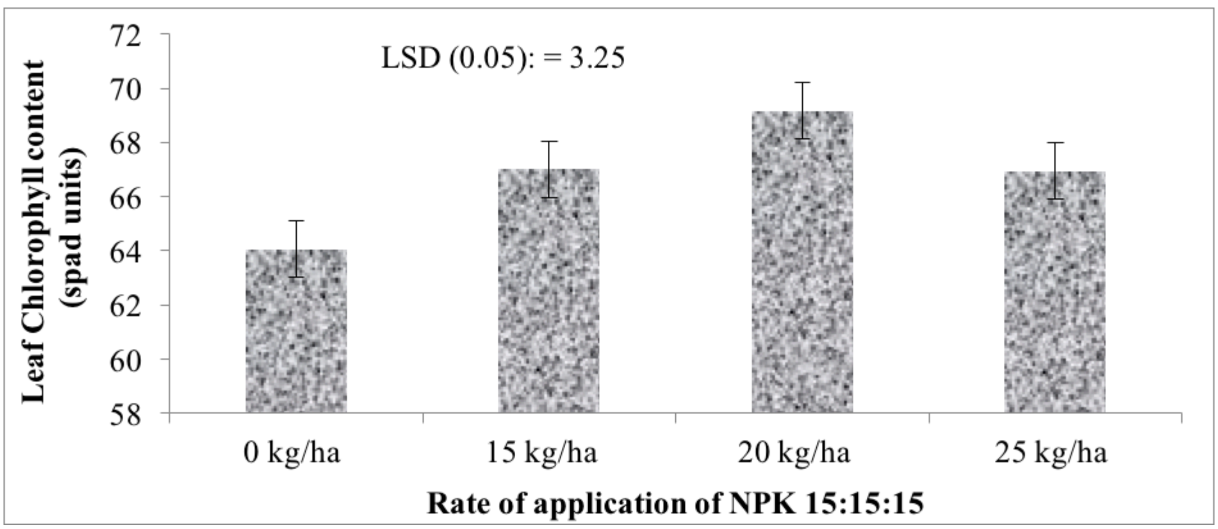

Fig 2: Effects of NPK 15:15:15 application rate on chlorophyll content of cowpea plants

100 Seed Weight

Main effects of defoliation and NPK 15:15:15 were highly significant (P< 0.001). For the single effects, plants defoliated at 50% had the highest seed weight. In terms of fertilizer application, plants fertilized with 25 kg/ha recorded the highest seed weight. The interaction between the levels of the two factors was also significant (P < 0.05). In each nutrient regime, plants defoliated at 50% recorded the highest 100 seed weight. But the overall highest in seed weight was recorded when plants were fertilized with 25 kg/ha of NPK 15:15:15 and subjected to 50% defoliation (Table 3) whilst plants that were not fertilized (0 kg/ha) but completely defoliated recorded the least seed weight.

Table 3: Hundred seed weight (g) of cowpea plants fertilized with NPK 15:15:15 and subjected to defoliation

	NPK 15:15:15 levels (kg/ha)				
Defoliation (%)	0	15	20	25	Means
0	20.03	22.56	24.04	24.21	22.70
50	22.06	25.08	25.81	27.31	25.07
75	18.12	20.61	20.91	21.73	20.34
100	17.49	20.52	21.61	22.15	20.44
Means	19.43	22.19	23.09	23.85	

Field Data, 2014, LSD (0.05): Defoliation = 0.54; NPK 15:15:15 = 0.54; Defoliation x NPK 15:15:15 = 1.09

Number of Pods per Plant

Table 4 shows that, the number of pods per plant varied significantly (P < 0.05) for defoliation. Similarly, main effect of NPK 15:15:15 was highly significant (P< 0.001). The interaction between the two factors was also significant (P < 0.05) for this trait. The overall highest number of pods per plant was recorded by plants fertilized with 25 kg/ha of NPK15:15:15 and subjected to 50% defoliation, whilst the undefoliated plants defoliated at 100% recorded the lowest number of pods per plant.

Table 4: Number of pods per plant recorded of cowpea in response to NPK 15:15:15 fertilizer application and defoliation

	NPK 15:15:15 levels (kg/ha)				
Defoliation (%)	0	15	20	25	Means
0	7.00	12.00	12.00	12.00	10.75
50	8.00	11.00	11.00	13.00	10.75
75	7.00	11.00	12.00	9.00	9.75
100	7.00	11.00	11.00	11.00	10.00
Means	7.25	11.25	11.50	11.25	

Field Data, 2014, LSD (0.05): Defoliation = 1.08; NPK 15:15:15 = 1.08; Defoliation x NPK 15:15:15 = 2.18

Number of Seeds per Pod

Main effects of defoliation and NPK 15:15:15 were significant at (P< 0.05) and (P< 0.001), respectively. The interaction between the two factors was also significant (P < 0.05). The highest number of seeds per pod was recorded by undefoliated plants fertilized with 20 kg/ha of NPK 15:15:15, while plants defoliated at 100% but not fertilized (0 kg/ha) produced the lowest number of seeds per pod (Table 5).

Table 5: Number of seeds per pod of cowpea recorded in response to NPK 15:15:15 fertilizer application and defoliation

	NPK 15:15:15 levels (kg/ha)				
Defoliation (%)	0	15	20	25	Means
0	9.00	13.00	15.00	13.00	12.5
50	9.00	10.00	11.00	13.00	10.75
75	8.00	12.00	12.00	8.00	10.00

100	7.00	12.00	11.00	10.00	10.00
Means	8.25	11.75	12.25	11.00	

Field Data, 2014, LSD (0.05): Defoliation = 1.78; NPK 15:15:15 = 1.78; Defoliation x NPK 15:15:15= 3.58

Grain Yield

Total grain yield followed similar pattern as 100 seed weight. The interaction between levels of the factors was significant ($P < 0.05$). In each nutrient regime, plants defoliated at 50% recorded the highest grain yield. Plants fertilized with 25 kg/ha of NPK and subjected to 50% defoliation produced the highest grain yield while those that were not fertilized (0 kg/ha) but subjected to 100% defoliation recorded the lowest grain yield (Table 6).

Table 6: Grain yields (kg/ha) of cowpea recorded in response to NPK 15:15:15 fertilizer application and defoliation during cultivation.

	NPK 15:15:15 levels (kg/ha)				
Defoliation (%)	0	15	20	25	Means
0	321.6	363.42	384.8	390.02	364.96
50	358.18	402.78	426.78	436.66	405.94
75	294.56	333.44	335.66	352.00	328.92
100	287.74	335.26	355.52	352.64	332.78
Means	315.34	358.72	375.52	382.84	

Field Data, 2014, LSD (0.05): Defoliation = 8.64; NPK 15:15:15 = 8.64; Defoliation x NPK 15:15:15 = 17.28

Discussion

Leaves supply assimilates to sinks such as young pods and seeds (Barimavandi *et al*., 2010). Defoliation at 100 and 75% implies that plants from these regimes suffered a more drastic removal of their photosynthetic apparatus as compared to those from mild defoliation (50%). Thus the production of photoassimilates and their subsequent translocation from foliage to roots from such plants was greatly affected. Highly defoliated plants were therefore placed at a competitive disadvantage relative to those from mild defoliation regime (Vargas - Ortiz *et al*., 2013) and this explains the observed reduction in growth of these plants. Similarly, the altered resource allocation in these plants (Najar *et al*., 2014) and reduction in carbohydrates reserves of the plants probably led to a reduction in their root growth. In general, not much energy from reserved carbohydrates was available for growth and maintenance because reserved energy was invested in refoliation (Jing, 2012). Results of the present study therefore indicated that highly defoliated plants *were more damaging and detrimental to the growth and yield of plants as compared to mild (50%) defoliation and thus confirming the observation made by Ibrahim et al. (2010) that* the response of plants to defoliation may depend on the type and extent of the stress to which the plant is subjected. The data from the study suggest that food reserves of highly defoliated plants might have been used for vegetative growth instead of the reserves being channelled to enhance productivity. This agrees with the finding of Hochwender *et al*. (2012) who indicate that during refoliation new stem buds are activated to produce new leaves at the expense of root growth and resources are utilized for growth of remaining plant tissues, particularly the leaves.

Machado *et al*. (2013) reported that during defoliation there is carbon starvation because reserves are depleted as a result of refoliation. Plants from highly defoliated regimes might have used more food reserves than those from undefoliated control and mild defoliations during refoliation and this explains the significant reductions in growth and yield of the former as compared to the latter. According to O'Connor (2013) the act of refoliation is a part of plants genetic make-up. Plants use up stored reserves during this process, and reallocation of food reserves for the production of more leaves might occur in highly defoliated plants. *The relatively high leaf regrowth from plants defoliated at 75% and fertilized with 25 kg/ha of NPK 15:15:15 demonstrates the importance of macronutrients supply to plants during defoliation. The implication of this result is that cowpea can* respond to shoot losses by exhibiting compensatory regrowth of leaves when the soil is fertile. The result agrees with the observation that defoliated plants in a resource - rich environment showed much more compensation than those in a resource - limited environment (Erbilgin *et al*., 2014). Oyarzabal and Oesterheld (2009) also reported that high levels of phosphorus reserves in the soil can confer tolerance to defoliation to plants by promoting compensatory growth under P deficiency. Plants, after defoliation, might have depended on mobilisation of stored reserves for refoliation and later, on current photosynthesis once new leaves were developed. All these must have taken place as a tolerant mechanism to maintain fitness (Ruiz *et al*., 2002). Physiological adjustments in these plants enhanced their ability to overcome loss of the photosynthetic tissues. Refoliation following defoliation implies a reduction in the stored reserves and this would have major consequences on the subsequent growth and development of the cowpea plant. *Nutrients application was important to* replenish the nutrients lost by the plant during vegetative regrowth.

The present study also revealed that plants from 50% defoliation regime significantly produced the highest seed and grain yield especially when they were supplemented with 25 kg/ha of NPK. *In cowpea production, plants may be defoliated by herbivores during cultivation. L*eaves of the crop may also be cut to feed farm animals especially during the early stages of growth of the legume (Alzouma, 1989). Field grown leguminous plants such as cowpea may also be cut and incorporated into soils as green manure to improve soil physico - chemical properties (Bayorbor *et al*., 2006). The present study has indicated that in all cases, plants can be defoliated up to 50%, but growth and grain production would not be negatively affected provided nutrients up to 25 kg/ha of NPK 15:15:15 would be applied three weeks after planting the legume.

Conclusion

Results from the study showed that defoliation at higher levels had great effects on growth and yield of cowpea. However, loss of cowpea leaves up to 50% of the total number of leaves in the canopy is not detrimental to the growth, seed or grain production provided up to 25 kg/ha of NPK 15:15:15 is applied three weeks after planting.

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