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Effect of defoliation at vegetative stage on dry mass production and yield in cowpea

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Abstract

Different degrees of defoliation (0%, 33%, 66%, and 100%) treatments were employed at vegetative stage (55 days after sowing) to investigate their effects on dry mass (DM) production, pod and seed yield in a cowpea (var. Fallon-1). The results revealed that DM was the highest in control (74.3 g/plant) and it decreased significantly with increasing degree of defoliation. Results further showed that pod yield was similar between control and 33% defoliation treatments (average of 31.2 g/plant) and seed yield followed a trend similar to that of pod yield in these treatments (average of 20.5 g/plant). It may be concluded that cowpea variety like Fallon-1 may sustain partial defoliation at vegetative stage without affecting pod and seed yield. The practical implication of the results in relation to pest and disease control, and fodder yield is also discussed.

Keywords: Defoliation, Canopy structure, DM partitioning, Pod and Seed yield, Cowpea

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp.) is an important grain legume crop in the tropics and sub-tropics. Cowpea is a minor vegetable crop in Bangladesh. Cowpea is popularly called 'Fallon' and the crop is an important and well-known pulse for the people of the district of Feny, Bhola, and Chittagong in Bangladesh. It is highly nutritious pulse, containing 24-28% protein, 26% carbohydrate and 32% minerals (Anonymous, 1984). The area under crop and production were 475000 acres and 158000 metric tons respectively in 2000-2001 (BBS, 2001).

Fodder shortage and protein deficiencies are acute in Bangladesh. Farmers would not cultivate fodder crops replacing rice, obviously, for the essentiality and profitability of the latter. Therefore, any fodder crop must fit into existing cropping pattern without affecting rice cultivation. Further, most of our rural people suffer from protein malnutrition. Hence, by growing dwarf cowpea variety like Fallon, farmer would benefit in two ways by getting protein from young pod and dry seed in one hand and fodder from leaf and shoot on the other.

In Bangladesh, the yield of cowpea is low (1.1-1.4 t/ha) compared to that of the other countries (Biswas, 2000). Cowpea yield is depended upon the number of pods/plant, number of seeds/ plant and individual seed weight. The individual seed weight and seed yield of cowpea depend upon the photosynthetic capacity of the plant (source) as well as on the capacity of seed (sink) to accumulate the increased supply of assimilate. Defoliation influences the plant canopy structure by changing morphology and physiology of the crop thereby affecting the yield and its yield components (Osumi *et al.*, 1998). Variation in the supply of assimilate through defoliation may influence the number of pod , size of seed and ultimately yield (Biswas, 2000).

There is a general trend that pulses often possess excessive vegetative growth and cause reduction in dry matter production and yield due to shading effects (Ezedinma, 1973; Patel *et al.,* 1992) in one hand and utilizing reserves as a respiratory burden of those parasitic leaves on the other (Beevers and Cooper, 1964). Defoliation up to certain limit may, therefore, be useful to overcome this problem of excessive vegetative growth. Therefore, clipping of some source (leaves) may even increase yield in one hand and clipped leaves would be used as fodder on the other (Fakir and Biswas, 2001). So, investigations are needed to quantify and to determine the stage of defoliation in cowpea. Therefore, this research project may be a potential one to address fodder shortage and protein deficiency in Bangladesh.

Cowpea plants subject to the attack of diseases and various leaf eating insects. This results in loss of photosynthetic surface mainly leaf area. Effects of such reduction in source size on yield were investigated in abroad (Pandey, 1983; Pandey and Singh, 1984; Jayaramireddy *et al.,* 2000). Little researches on flower production, pod and seed yield, DM partitioning and physiological activities have carried out in Bangladesh (Chowdhury, 1999; Hossain, 2000; Chowdhury *et al.,* 2001). Information on the effects of defoliation on total DM production and yield in recommended variety like Fallon is very scanty in Bangladesh (Biswas, 2000; Fakir and Biswas, 2000). There is, therefore, a need to conduct research in this regard under local condition with the following objectives: i) to determine the effect of degree of defoliation on canopy structure; and ii) to investigate the magnitude of defoliation on DM production, pod and seed yield.

Materials and Methods

The experiments were conducted at the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh (at 24°75′ N latitude and 90° 75′ E longitude), during the period from November 1999 to April 2000 with the following treatments employed at vegetative stage (55 days after sowing, DAS): i) control (0%, no leaflet was clipped), ii) 33% defoliation (terminal leaflets of fully expanded pinnately trifoliate leaves were clipped), iii) 66% defoliation (two lateral leaflets of fully expanded pinnately trifoliate leaves were clipped), and iv) 100% defoliation (all leaflets of fully expanded pinnately trifoliate leaves were clipped). The agro-climatic conditions of the experimental site during the study period is shown in Appendix I.

The experiment was laid out in a randomized complete block design (RCBD) with three replications. The land was divided into three blocks with each block subdivided into 4 plots where 4 clipping treatments were assigned at random. The plot to plot distance was 0.25 m and block to block distance was 1.0 m. The unit plot size was 4.0 m × 1.25 m. Seeds of cowpea (*Vigna unguiculata* (L.) Walp.) var. Fallon-1 were collected from the previous experiment of Prof. Dr. M.S.A. Fakir, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh. Three seeds of cowpea were handsown at 5 cm depth at a spacing 50 cm × 25 cm. Gap filling, irrigation, weeding and pest and disease control practices were done as and when necessary. Number of days required to bud initiation, 50% flowering and pod maturity were recorded. The pods were harvested at 80-90% pod maturity (brown pod). Five plants in each replication from central guarded rows were sampled and harvested for collecting necessary data. Roots were extracted carefully between 20 and 30 cm soil depth. Separated plant parts were oven-dried at 80°C ± 2 for 48 h and weighed. The harvest index was calculated by dividing dry grain weight by total dry mass from entire plot. The oven dry weights of grain and other plant parts were obtained from sun-dried samples. Total dry mass of plant was recorded excluding root mass.

All collected data were analyzed and the mean differences were compared by Duncan's Multiple Range Test (DMRT), (Gomez and Gomez, 1984) using the statistical computer package program MSTAT.

Results and Discussion

Phenology: The effect of defoliation at vegetative stage on number of days required to bud initiation (BI), number of days required to 50% flowering ($Flow_{50}$) and number of days required to 80-90% pod maturity (Pod_{mat}) were significant ($P \leq 0.05$) (Table 1). The number of days required to reach BI was earlier in 33%, 66% defoliation and control (average of 74 days) than that in 100% defoliation treatment (101 days). The number of days required to reach $Flow_{50}$ and number of days to Pod_{mat} followed a trend similar to that of BI.

Table 1. Effect of defoliation at vegetative stage (55 days after sowing) on the number of days required to bud initiation (BI), 50% flowering ($Flow_{50}$) and pod maturity (Pod_{mat}) in cowpea (var. Fallon-1) under field condition

Degree of defoliation	Days to BI	Days to $Flow_{50}$	Days to Pod_{mat}
0% (control)	72.3 b	91.3 b	135.3 b
33%	72.7 b	91.8 b	136.3 b
66%	77.3 b	99.3 b	143.3 b
100%	101.3 a	119.7 a	167.3 a
$Lsd_{0.05}$	11.7	10.1	11.59

In a column, numbers followed by different letter(s) vary significantly at $P \leq 0.05$ in DMRT

Canopy structure: Different degrees of defoliation at vegetative stage had significant ($P \leq 0.05$) effects on canopy structure (main stem length, number of branches and leaves, and inflorescence production) (Table 2). Main stem length was greater in control and 33% defoliation treatments (average of 74 cm) than in the 66% defoliation (57 cm) and 100% defoliation (42 cm). The number of branches and inflorescence per plant was the highest in control and it decreased with increasing degree of defoliation. In contrast, the number of leaves per plant was much greater at 100% defoliation (35) than in the others (average of 4.3).

Table 2. Effect of defoliation at vegetative stage (55 days after sowing) on canopy structure at pod maturity in cowpea (var. Fallon-1) under field condition

Degree of defoliation	Main stem length (cm)	Branches/plant (no.)	Leaves/plant (no.)	Inflorescence/plant (no.)
0% (control)	77.0 a	7.2 a	3.0 b	32.0 a
33%	71.0 a	6.7 b	4.0 b	30.0 ab
66%	57.0 b	6.3 c	6.0 b	27.0 b
100%	42.0 c	6.0 d	35.0 a	21.0 c
$Lsd_{0.05}$	5.99	0.26	4.42	3.05

In a column, numbers followed by different letter(s) vary significantly at $P \leq 0.05$ in DMRT

Dry mass production and yield: The effect of defoliation on total dry mass (TDM) production and its allocation into different plant parts was significant (Table 3). TDM production and dry mass partitioning into root, stem plus petiole plus peduncle, and pod and seed growth decreased with increasing degree of defoliation. In contrast, DM partitioning into leaf increased with increasing magnitude of defoliation. Harvest index also varied significantly ($P \leq 0.05$) with the clipping treatments. It was higher in 33% and 66% defoliation (average of 24.5%) than in control and 100% defoliation (average of 22.7%).

Table 3. Effect of defoliation at vegetative stage (55 days after sowing) on dry mass production and its partitioning into different plant parts in cowpea (var. Fallon-1) under field condition

Degree of defoliation	Dry mass per plant						Harvest index[†]
	Root (tap + lateral) (g)	leaf (g)	Stem+petiole+ peduncle (g)	Pod (g)	Seed (g)	Total dry mass (g)	
0% (control)	1.3 a	1.3 c	40.0 a	31.7 a	20.7 a	74.3 a	22.8 b
33%	1.2 b	1.4 c	35.0 b	30.6 a	20.2 a	68.2 b	24.8 a
66%	1.2 c	2.5 b	26.0 c	25.6 b	16.4 b	55.3 c	24.2 a
100%	1.0 d	7.2 a	20.0 d	20.6 c	13.3 c	48.8 d	22.7 b
Lsd $_{0.05}$	0.04	1.0	2.77	3.9	0.94	3.8	1.05

In a column, numbers followed by different letter(s) vary significantly at $P \leq 0.05$ in DMRT,
[†] Per plot basis.

The effect of defoliation on pod and seed yield was significant (Table 4). Generally pod and seed weight/plant was higher in control and 33% defoliation treatment than in the others. Dry pod weight/plant was greater in control and 33% defoliation treatment (average of 31.2) than in the 100% defoliation (20.6 g) and 66% defoliation (25.6 g). Dry seed weight/plant followed a trend similar to dry pod weight/plant. Estimated dry pod and seed yield (t/ha) followed a trend also similar to that of dry pod weight/plant (Table 4).

Table 4. Effect of defoliation at vegetative stage (55 days after sowing) on pod and seed yield, total dry mass (TDM) production and yield attributes in cowpea (var. Fallon-1) under field condition

Degree of defoliation	Dry pod weight/ plant (g)	Dry seed weight/ plant (g)	Dry pod yield (t/ha)	Dry seed yield (t/ha)	TDM (t/ha)	Pod/ plant (no.)	Pod length (cm)	Seeds/ pod (no.)	100-seed mass (g)
0% (control)	31.7 a	20.7 a	2.09 a	1.38 a	3.96 a	22.0 c	16.3 a	15.2 a	10.9 a
33%	30.6 a	20.2 a	2.04 a	1.35 a	3.4 b	25.0 b	16.2 a	14.8 ab	10.9 a
66%	25.6 b	16.4 b	1.71 b	1.09 b	2.81 c	27.0 a	13.5 c	13.0 c	9.4 b
100%	20.6 c	13.3 c	1.37 c	0.91 c	2.6 c	17.0 d	14.9 b	14.6 b	10.7 a
Lsd $_{0.05}$	3.87	0.94	0.151	0.098	0.277	2.07	0.91	0.44	0.22

In a column, numbers followed by different letter(s) differ significantly at $P \leq 0.05$ in DMRT

Yield contributing characters were also significantly ($P \leq 0.05$) affected by different defoliation treatments (Table 4). Number of pod/plant was greater in 66% defoliation (27) than in 33% defoliation (25), control (22) and 100% defoliation (17.0). Pod length was the highest in control and 33% defoliation (average of 16.2 cm) and the lowest in 66% defoliation (13.5 cm) with pod length being intermediate in 100% defoliation (14.9 cm). Number of seed/pod was fewer in 66% defoliation than in the others.

Fodder yield: The amount of clipped leaf (fodder) was significantly affected by the defoliation treatments (Table 5). Generally, fodder or forage yield was increased with increasing degree of defoliation with the highest fodder yield was obtained at 100% defoliation and lowest at 33% defoliation (Table 5). Both green and dry fodder yield followed a similar trend.

Table 5. Effect of defoliation at vegetative stage (55 days after sowing) on fodder and seed yield in cowpea (var. Fallon-1) under field condition

Degree of defoliation	Clipped green leaf/plot (no.)	Yield of clipped green fodder/plot (g)	Yield of clipped dry fodder/plot (g)	Yield of clipped green fodder (t/ha)	Yield of clipped dry fodder (t/ha)
0% (control)	0.0 d	0.0 d	0.0 d	0.0 d	0.0 d
33%	550.0 c	470.0 c	65.0 c	0.94 c	0.13 c
66%	930.0 b	780.0 b	95.0 b	1.56 b	0.19 b
100%	1950.0 a	1635.0 a	227.0 a	3.27 a	0.45 a
$Lsd_{0.05}$	152.2	142.7	19.23	0.30	0.01

In a column, numbers followed by different letter(s) vary significantly at $P \leq 0.05$ in DMRT

Appendix I. Monthly record of air temperature, relative humidity, rainfall and sunshine hour during the study period from November 1999 to April 2000 at Bangladesh Agricultural University, Mymensingh, Bangladesh

Year	Month	Monthly average air temperature (°C)			Monthly average rainfall (mm)	Monthly average relative humidity (%)	Average sunshine (hr/day)
		Maximum	Minimum	Average			
1999	November	30.47	18.48	24.47	0.60	80.96	9.05
	December	27.46	14.06	20.81	0.00	81.00	8.67
2000	January	24.21	12.13	18.17	18.00	80.54	5.99
	February	25.11	13.95	19.53	20.00	73.34	7.06
	March	29.91	18.93	24.42	73.50	77.45	6.92
	April	31.06	22.02	26.54	317.50	72.20	6.75

Source: Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Defoliation alters phenology, morphology, and dry mass production and partition (Biswas, 2000) as is evidenced in the present study (Table 1-4). Leaf is the major source of assimilate supply for developing vegetative organs, and young pods and seeds in cowpea (Wien and Summerfield, 1984). Leaf removal, may, therefore, influence yield through photosynthate production and its distribution into plant parts depending on the magnitude of clipping of leaves. Yield obtained with partial defoliation, such as 33%, at vegetative stage was similar to that of control (no defoliation) indicating little effect on yield by 33% leaf removal (Table 3). Such partial defoliation reduced components of canopy structure (main stem length, number of branches and inflorescence) (Table 2). Increase degree of defoliation increased the number of leaf production with the highest being at 100% defoliation (35). It was possibly due to the greater number of nodes in branches, which have provided loci for increased number of leaves in 100% defoliation than in the others. However, partial defoliation (33% and 66%) increased the number of dry pod/plant (Table 4). Such increase of pod number may be due to the increased flower production and/or increased pod set. Data on this aspect were not collected. However, investigation in this aspect is on progress. Number of pods/plant is the principal component of yield (Chowdhury *et al.,* 2001) but this increased number of pods/plant decreased dry pod and seed weight/plant in 66% defoliation (Table 4). This was perhaps due to the other components of pod yield such as pod length, number of seed/pod and 100-seed mass were not increased accordingly (Table 4). In contrast, the pod and seed weight/plant remains unaffected by 33% defoliation. The reasons again being the components of dry pod and seed yield such as number of seeds/pod; 100-seed mass and pod length remained unaffected by 33% defoliation. This resulted in similar pod and seed yield between 33% defoliation and control. The present findings are in agreement with the results of Ezedinma (1973), Demooy and Demooy (1989) and Jayaramireddy *et al.* (2000) who obtained insignificant influence on yield by partial to moderate (20%-67%) defoliation at pre-flowering stage. In contrast, Panday (1983) obtained reduction in yield by continuous 33.3% defoliation at vegetative stage .The reduction was primarily through fewer pods/plant and seeds/pod. The present result contradicts with findings of Pandey (1983) and this was due to continuous removal of leaf, which may have caused reduced assimilate supply to pod. In the current study, source leaves were removed only once at 55 days after sowing. So there was chance to compensate by producing new leaves.

Increasing the magnitude of defoliation at vegetative stage from 33 to 66%, the yield was decreased (Table 3, 4). The mechanism of reduction in yield by 66% defoliation was due to fewer seeds/pod, shorter pod and smaller seed size (Table 4). The increased number of pods/plant was not enough to offset the negative effects of other yield components (Table 4). In cowpea, some of the leaves are generally shaded by other leaves (Ezedinma, 1973) and many of the mature leaves may not actively contribute to assimilate production despite they respire (Beevers and Cooper, 1964). Further, partial defoliation can increase photosynthetic rate of the remaining leaves (Geiger, 1976; Ghosh and Sengupta, 1986). Dry mass partitioning into plant parts was also affected by different degrees of defoliation (Table 3). Dry mass partitioning into stem growth was decreased with increasing degree of defoliation since assimilate produced during early vegetative stage of growth are used in the growth of stem and leaves (Enyi, 1975). In contrast, there is considerable evidence that seed yield in cowpea depends on post flowering photosynthesis (Wien and Tayo, 1978; Bewley and Black, 1994).

Loss of leaves through insect attack, disease and other environmental hazards reduces assimilatory surface. The loss of such assimilatory leaf surface to a smaller degree may result in insignificant reduction in yield as is indicted by partial defoliation (33%) at vegetative stage (Table 3, 4). Therefore, it is not wise to spray pesticide for controlling pests in a variety like Fallon-1 at moderate loss of leaf surface since 33% defoliation does not affect yield. These results seem to indicate that yield may not be affected by limitation of 'source' when 33% defoliation is imposed. This further means that photosynthate produced by the rest of the leaves and other green plant parts of the 33% defoliated cowpea plants (variety Fallon-1) seems enough to feed the developing pod and seed. Yield in Fallon-1 does not seem to be, therefore, limited by source, rather yield remained unaffected by management of the source, i.e., by defoliation of 33% at vegetative stage. In Bangladesh, fodder shortage is acute. The farmers are not capable to produce fodder crops replacing rice/wheat/pulse crops. This experiment would be a viable alternative approach to meet up the fodder shortage in Bangladesh as partial to moderate defoliation provided green fodder (3.0-6.0 t/ha) (Table 5). So, partial defoliation in cowpea (variety Fallon-1) benefits in two ways by producing similar yield in one hand, and by providing fodder on the other. Removal of leaf in such way may labour intensive. Investigation is urgently needed whether 33% leaf removal could be done either from base or top of the plant employing little labour. Currently investigations in these regards are on progress. It may be concluded that of the different degrees of leaf removal, 33% defoliation at vegetative stage (55 DAS) decreased TDM/plant whereas yield remained unaffected.

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