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A study of canopy structure and dry mass production in short duration pigeonpea morphotypes

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Abstract: A field experiment was conducted at Mymensingh (24°75′N, 90°50′E) to investigate morphological structure of shoot and root, dry mass production and its partitioning to plant parts, and their relationship in four short duration pigeonpea (*Cajanus cajan*) morphotypes. Results revealed that there were genetic variations in canopy structure of shoot and root. Of the morphotypes, ESD-36 (Extra short duration # 36) possesses more compact shoot canopy and larger taproot than in the others. Results of correlation study showed that seed yield could be increased by increasing shoot, root and total dry mass production in short duration pigeonpea.
Key words: Morphology, Dry mass, *Cajanus cajan*

Introduction

Pigeonpea ('arhar') (*Cajanus cajan* (L.) Millsp.) is the fifth most important pulse crop in the world. It is mainly a subsistence crop in the tropics and subtropics. The drought tolerance ability makes it an important crop in the semi-arid tropics (SAT). Pigeonpea is a minor grain legume in Bangladesh, mainly grown in the northwestern part of the country (Virmani *et al.*, 1991). This perennial woody multipurpose shrub could be utilized in the agro forestry system of Bangladesh (Mostafa and Fakir, 2008). Pigeonpea is utilized in multipurpose ways *viz.*, dry split cotyledons as 'dhal', green leaves and young branches as fodder, stem and branches as fuel wood, crushed dry seed as a animal feed and matured green seed as vegetable (Fakir, 2003; Fakir and Islam, 2007).

Pigeonpea is covering an area of about 30,000 hectares in 2006-07, which produced 19,000 tons with an average yield of 0.60 ton ha^{-1} (BBS, 2008). Bangladesh possesses about 0.27 million-hectare homestead area and 222597 km internal road. It is said that the total 'ail' (border of rice field) area in Bangladesh is about equal to the greater 'Bogra' district. That means the total ail area is about 288500 hectare. It is possible to bring some these lands under social forestry programme with pigeonpea cultivation. Pigeonpea production in the 'ail' of rice field may, therefore, contribute significantly in providing relief from deficient pulse crises in Bangladesh (Fakir and Islam, 2007).

Crop productivity, in general, depends on the photosynthetic rate and canopy architecture of the crop. Biomass and yield in crop plants largely depends on the function of leaf area development and photosynthetic activity. High photosynthetic rates generally are capable of producing high level of biomass (Misa *et al.*, 1994: Patel *et al.*, 2000). A high degree of plant spread with usually spreading and semi spreading type is regarded as an effective attributes to grain yield and biomass accumulation (Rahman, 2000). Grain yield per unit area is a function of yield of individual plants and population density. At wider spacing, plant develops more branches but the contribution of secondary and tertiary branches towards grain yield is substantial. At closer spacing, mainstem contributes more than primary and secondary branches (Rahman, 2000). Physiological basis of yield and biomass improvement in pigeonpea depends on the canopy structure, root growth and yield attributes and their interrelationships (Rahman, 2000). These attributes are very important in Agroforestry system since intercropping of various crops like pigeonpea in Agroforestry system are done in the tropical and subtropical regions of Asia, Africa and Caribbean.

There is very few study of root growth in pigeonpea in Bangladesh (Rahman, 2000). Therefore, there is a need to study root growth, canopy structure and their interrelationships with DM production and yield under Mymensingh condition. There is also little information on the DM partitioning into different plant parts especially in short duration pigeonpea (Rahman, 2000; Mostafa and Fakir, 2008). The present research was, therefore, conducted i) to investigate variation in morphological structure of root and shoot; ii) to study DM production and partitioning into different plant parts; and iii) to envisage relationships between the above and TDM, and seed yield in four short duration pigeonpea morphotypes.

Materials and Methods

The experiment was conducted at the field laboratory, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, between November, 1999 and April, 2000 at 24°75' N latitude and 90°50' E longitude at the elevation of 18 m above the sea level. The topography of experimental field was medium high land belonging to the Sonatola soil series of grey flood plain soil type under the Agro-ecological zone-9 (AEZ-9) named old Brahmaputra flood plain (FAO, 1988). The soil was silty loam imperfectly to poorly drained permeability. Seeds of the four determinate short duration (SD) pigeonpea morphotypes were collected from International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), India. Of the morphotypes two were short duration (SD-13 and SD-15) and the other two were extra short duration (ESD-19 and ESD-36) morphotypes. Again two were high yielding morphotypes (SD-13 and ESD-19) and the other two were low yielding ones (SD-15 and ESD-36). Urea @ 8 g/plot, Triple Super Phosphate @ 10 g/plot and Muriate of Potash @ 6 g/plot were applied as source of nitrogen, phosphorus and potassium respectively. Moreover, well decomposed cowdung @ 2.5 kg/plot was also applied to the plots. Before planting, plots were dug and soils were exposed to sun seven days before sowing. The field experiment was laid out in a randomised complete block design (RCBD) with three replications. The total experimental plot was divided into three blocks. Each block was then subdivided into 4 plots (4 m × 0.5 m) where 4 treatments (4 morphotypes) were allotted at random. The blocks were 1 m apart and the distance between unit plots was 0.5 m. Pigeonpea seeds were hand sown at 5 cm depth at a spacing of 50 cm × 30 cm on November 8, 1999. Emergence of seedlings commenced at 10 days after sowing (DAS). Thinning was done at 15 DAS keeping one healthy seedling at each hill. Standard intercultural practices were followed (Rahman, 2000). The plots were harvested separately at 70-80% dry pod maturity between March 18 and April 20, 2000. The plants from central guarded rows were sampled and harvested for collecting yield and yield attributes. The harvested crop of each plot was bundled separately, tagged properly and brought to the laboratory for further observation. Prior to harvesting four plants were selected randomly from each plot and dug carefully for collecting data on root characters. Plants parts were separated and oven dried (80 ± 2^0C) for 48 hours and their corresponding dry matter (DM) were weighed and recorded. Harvest index (HI) was estimated following the method of Donald *et al*. (1976).

Results

Canopy structure: Significant ($P\leq0.05$) variation existed in different components of canopy structure between the four morphotypes (Table 1). For example, the morphotype SD-13 was taller and thicker than the others. In contrast, ESD-36 had fewer primary (1°) branches (8.3) than in the SD-13 and SD-15 (average of 10.9). In SD-13, 1° branch angle was less wider (42.6°) but canopy spreading was greater (15.2 cm) than the others. Fewer internodes were observed in ESD-36 (7.0) than the others (average of 12.13 cm).

Table 1. Canopy structure in four morphotypes of short duration pigeonpea

Morphotype	Plant height (cm)	Stem diameter (cm)	Primary branch (no.)	Primary branch angle (°)	Internode (no.)	Canopy spreading (cm)
SD-13	91.0a	1.25a	11.0a	42.6b	10.0a	15.2a
SD-15	75.0b	0.87b	10.9a	47.1a	9.9a	11.7b
ESD-19	57.0 c	0.65 b	9.4 ab	47.4 a	8.4 a	12.4 b
ESD-36	35.0 d	0.48 c	8.3 b	47.5 a	7.0 b	9.2 c

Figure with uncommon letter(s) in a column differ significantly at ($P\leq0.05$)

Root characteristics: Variation in different root characters existed (Table 2). In SD-13, for example, taproots were longer and wider but it had fewer primary lateral roots but greater secondary lateral root than in the others (Table 2). In contrast, total length of primary plus lateral root and total root DM were smaller in ESD-36 than in the others. Total root dry mass/plant was greater in SD-13 (11.8 g) than SD-15 and ESD-19 (average of 5.9 g) and ESD-36 (2.1 g).

Table 2. Root characteristics in four morphotypes of short duration pigeonpea

Morphotype	Taproot Length (cm)	Tap root diameter at 5 cm base (cm)	Primary lateral (no.)	Secondary lateral (no.)	Total length of primary lateral root (cm)	Total length of primary plus lateral (cm)	Total root dry mass (g/plant)
SD-13	35.2 a	1.12 a	9.0b	9.6 a	90.7 a	125.9 a	11.8 a
SD-15	30.1 b	0.93 b	12.2 a	6.2 b	88.2 ab	118.3 ab	5.6 b
ESD-19	26.9 b	0.81 b	13.5 a	3.5 c	64.6 b	91.5 b	4.2 b
ESD-36	25.5 b	0.57 c	5.3 c	1.0 d	27.4 c	52.9 c	2.1 c

Figure with uncommon letter(s) in a column differ significantly at ($P\leq0.05$)

Dry mass production and partitioning: Dry mass partitioning into different organs of the plant was significant ($P\leq0.05$) (Table 3). Dry mass partitioning into root growth was greater in SD-13 (11.8 g) than in the SD-15 and ESD-19 (average of 4.9 g) and ESD-36 (2.1 g) (Table 3). Dry mass allocation into pod and seed growth followed a trend similar to that of root growth. Pattern of dry mass distribution into leaf and stem plus branch development was similar and followed the ranking of SD-13>SD-15>ESD-19>ESD-36. Shoot DM and total DM also followed the preceding pattern. Harvest index was significantly ($P\leq0.05$) greater in ESD-36 (32.06 %) than in the ESD-19 (25.07%) and SD-15 and SD-13 (average of 21.35%).

Correlation: Pod and seed yield showed significant and positive correlation with plant height (r = 0.97** and 0.91** for pod and seed yield, respectively), stem diameter (r = 0.98**, 0.97**), primary branch number (r = 0.77**, 0.71**), canopy spreading (r = 0.96**, 0.94**), tap root length (r = 0.94**, 0.94**), root dry mass (r = 0.97**, 0.99**), leaf dry mass (r = 0.98**, 0.99**), shoot dry mass (r = 0.99**, 0.99**), number of branches/stem (r = 0.99**, 0.99**) and total dry mass/plant (r = 0.99**, 0.99**). In contrast, pod and seed weight was negatively associated with primary branch angle. It means erect branches may be suitable for increased seed yield.

Table 3. Total dry mass production (TDM) and DM partitioning into plant parts in four morphotypes of short duration pigeonpea

Morphotype	Dry mass allocation (g/plant)							
	Root	Leaf	Branches & stem	Pod	Seed	Shoot	TDM	HI†
SD-13	11.8 a (9.4)	25.5 a (20.5)	50.7 a (40.5)	36.6 a (29.4)	26.8 a (21.5)	112.6 a	124.6 a	21.5c
SD-15	5.6 b (8.2)	12.9 b (18.8)	27.0 b (39.3)	23.0 b (33.6)	14.4 b (21.0)	63.2 b	68.5 b	21.0c
ESD-19	4.2 b (8.6)	7.5 c (15.1)	17.9 c (36.3)	19.8 b (40.0)	12.6 b (25.5)	46.3c	49.4 c	25.07b
ESD-36	2.1 c (9.6)	3.0 d (13.7)	6.9 d (31.6)	9.8c (44.9)	7.3 c (33.5)	20.5 d	21.8 d	32.06a

Figure with uncommon letter(s) in a column differ significantly at ($P \leq 0.05$). †: Includes root mass, Figure within parenthesis indicates percentage of the total dry mass (TDM)

Table 4. Correlation of pod, seed and TDM yield with morphological and yield attributes in pigeonpea

Independent variable / Dependent variable	Plant height (cm)	Stem Diameter (cm)	Primary Branch (no.)	Primary Branch angle (°)	Canopy spreading (cm)	Tap root length (cm)	Root dry mass (g)	Leaf dry mass (g)	Branch / stem (dry mass)	Shoot dry mass (g)	TDM/ plant	Seed dry mass
Shoot dry weight	0.96**	0.42**	0.87**	-0.91**	0.94**	0.98**	0.99**	0.99**	0.99**	-	0.33**	0.99**
Root dry weight	0.92**	0.98**	0.75**	-0.73**	0.93**	0.94**	-	0.99**	0.99**	0.99	0.99**	0.99**
TDM	0.95**	0.98**	0.79**	-0.70**	0.94**	0.95**	0.99**	0.99**	1.00**	1.00**	-	0.99**

** indicates significant at 1% level of probability

Discussion

Total DM production depends on assimilatory or leaf surface (Patel *et al.*, 2000). The high yielding morphotype, SD-13, had the highest TDM. This was, perhaps, due to greater DM partitioning into leaf (Table 3) since increased leaf surface may have provided greater photosynthetic area (Patel *et al.*, 2000). The greater assimilate may have, thus, partitioned into root and other vegetative organs and produced the greatest TDM (Table 3). Increased DM partitioning into seed growth was not indicated by moderate or high HI (Table 3). In contrast, very low yielding morphotype, ESD-36, produced the highest HI since HI is the ratio of seed DM to TDM. These results indicated that selection of seed yield on the basis of HI may be misleading (Fakir *et al*.,1997; Donald *et al*., 1976). From the results, it was observed that SD-13 was a high yielding morphotype. The morphotype SD-13, with thicker and wider tap root, greater root mass, may be suitable under drought condition since increased root growth had been advocated as an index of better growth under drought condition (Chloupek and Rod, 1992). There were variation not only in root canopy but also shoot canopy (Tables 1, 2). For example, the morphotype ESD-36 having a compact canopy and may be advantageous for realizing increasing yield under high density planting. In contrast other morphotypes characterised by spreading to semi-spreading canopy structure may be suitable for wide spacing. Similar result was also reported by Fakir (1997), Rahman (2000) and Hossain (2001) in pigeonpea.

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