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Effect of Population Density and Planting Configuration on Canopy Development and Reproductive Effort in Mungbean (*Vigna radiata* (L.) Wilczek)

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Abstract: A field experiment was conducted to determine the influence of population density and planting arrangement on vegetative and reproductive growth of mungbean. The experiment was conducted with six levels of population densities (10, 20, 30, 40, 50 and 60 plants m^{-2}) each at three levels of configuration (1:1, 1:2.5 and 1:5 rectangularity). Accumulation and distribution of dry matter to different components of plants were determined. Leaf area of each plant was measured at each sampling date and the mean leaf area per plant was calculated. Using the data on the leaf area and dry matter Leaf Area Index (LAI) and Specific Leaf Mass (SLM) were determined. Reproductive Effort (RE) was calculated using dry matter of flowers as well as fruits and seeds. Grain yield and yield contributing characters were recorded at maturity. Leaf area per plant increased over time almost parabolically regardless of planting density and configuration. On land area basis, however, LAI increased progressively with increasing planting density. Specific leaf mass decreased with increasing population density while planting configuration exerted no significant influence on SLM. Specific leaf mass showed similar relationship with dry matter and yield. Reproductive effort decreased linearly with increase in population density. The effect of planting configuration on RE was variable.

Key words: Density, configuration, leaf area, specific leaf mass, reproductive effort, mungbean.

INTRODUCTION

Food legumes are the major sources of vegetable proteins in the diets of most Bangladesh people. Among the food legumes grown in Bangladesh mungbean (*Vigna radiata* (L.) Wilczek) ranks third in terms of area and production[1] and contributes about 11.49% of pulse production[2]. However, the yield of mungbean is comparatively low compared to that of cereals and some other pulses. The low yield of mungbean is attributable to its short growth duration, particularly the slow rate of dry matter allocation prior to flowering, unfavorable canopy structure[3], non-responsive to applied inputs and management conditions[4,5] etc. Among the agronomic practices that influence crop growth and seed yield, plant population stands prominent.

Yield is the function of total dry matter production which in turn depends almost wholly on the canopy photosynthesis. Radiation intercepted by the leaf surface and the efficiency of its use in developing biomass govern the total dry matter production. The proportion of intercepted radiation is determined by plant architecture which is genetically determined and by the rate at which canopy closes. The rate of canopy development is affected by management practices. Studies carried out at the International Rice Research Institute[6] suggests that in order to hasten canopy closure and increase radiation interception planting geometry (configuration) and density has a large bearing. Agronomic management that promotes vegetative growth ensuring early canopy closure helps maximize radiation interception.

The pattern of resource allocation in plants and its regulation is of great practical importance to agriculturists and horticulturists. Biomass distribution provides a general approach for allocation studies, but it is important that equivalent comparisons are made, e.g. in relation to the inclusion of flower parts and supporting structures as well as seeds and fruits. Thompson and Stewart[7] proposed that the term Reproductive Effort (RE) should be used to cover investment in all reproductive structures. In grain legumes, the vegetative, reproductive and ripening phases overlap each other. Dry matter partitioning between vegetative and fruiting structures of indeterminate plants may be regulated either by competition between vegetative and fruiting structures or simply by the dominance of developing pods. Dry matter partitioning and more particularly its consequence on yield, is often assessed by determining the reproductive effort[8]. However, the use of reproductive effect in crop plants is rather uncommon. Since planting density and configuration are reported to have influence on size structure and developmental biology of plants[9-11], it is

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conceivable that these management factors influence the reproductive effort in mungbean plants. Therefore, the present study was designed to examine the effect of population density and planting configuration on the (a) canopy development and (b) reproductive effort of mungbean.

MATERIALS AND METHODS

A field experiment was conducted at the Bangabandhu Seikh Mujibur Rahman Agricultural University farm during early summer (Kharif I) season. The soil of the experimental plot was silty clay of red brown terrace under Salna series. The pH of the soil was 6.5[12]. The experimental site is characterized by hot-humid subtropical climate with abundant rainfall during monsoon season extending from May through September while the remaining part of the year evaporative demand exceeds rainfall[13]. The mean atmospheric temperature ranges from 11.9 (January) to 34.4^{0}C (July).

The experimental land was ploughed by a tractor and rotovator. A fertilizer dose of 20 kg N, 15 kg P and 20 kg K ha^{-1} as urea, TSP and MP, respectively was applied basally at final land preparation and incorporated well into the soil. Six levels of planting densities each at three levels of configuration formed the treatment variables. Different configurations were created by varying the rectangularity keeping the density constant. The treatment combinations were arranged as follows:

D_1: 10 plants m^{-2} i.e. 1000 cm^2 plant^{-1}
- D_1C_1: 31.50 x 31.50 cm (1:1)
- D_1C_2: 20.00 x 50.00 cm (1:2.5)
- D_1C_3: 15.00 x 66.50 cm (1: 5)

D_2: 20 plants m^{-2} i.e. 500 cm^2 plant^{-1}
- D_2C_1: 22.50 x 22.50 cm (1:1)
- D_2C_2: 14.00 x 35.50 cm (1:2.5)
- D_2C_3: 10.00 x 50.00 cm (1: 5)

D_3: 30 plants m^{-2} i.e. 333 cm^2 plant^{-1}
- D_3C_1: 18.25 x 18.25 cm (1:1)
- D_3C_2: 11.50 x 28.25 cm (1:2.5)
- D_3C_3: 8.00 x 41.52 cm (1: 5)

D_4: 40 plants m^{-2} i.e. 250 cm^2 plant^{-1}
- D_4C_1: 15.81 x 15.81 cm (1:1)
- D_4C_2: 10.00 x 25.00 cm (1:2.5)
- D_4C_3: 7.00 x 35.71 cm (1: 5)

D_5: 50 plants m^{-2} i.e. 200 cm^2 plant^{-1}
- D_5C_1: 14.14 x 14.14 cm (1:1)
- D_5C_2: 9.00 x 22.22 cm (1:2.5)
- D_5C_3: 6.25 x 32.00 cm (1: 5)

D_6: 60 plants m^{-2} i.e. 167 cm^2 plant-1
- D_6C_1: 12.90 x 12.90 cm (1:1)
- D_6C_2: 8.00 x 20.87 cm (1:2.5)
- D_6C_3: 5.80 x 28.80 cm (1: 5)

The experiment was laid out in a Factorial Randomized Complete Block design with three replications. Unit plot size was 4x3 m. Seeds were sown in rows as per treatment. Seeds were pre-soaked for 3 h before sowing. Light irrigation was applied one day after sowing. The variety used in this study was NM 92, an advanced line obtained from the Asian Vegetable Research and Development Center (AVRDC). Seedlings emerged by 4 days after sowing and gap filling was done using even aged seedlings on the following day of emergence (DAE). At first trifoliate stage seedlings were carefully thinned to retain one seedling per hill. Soil mulching and hand weeding were done twice- at 13 and 21 days after sowing (DAS). Irrigation was applied twice- at 15 and 25 DAS. Insecticide (Ripcord) was sprayed on four occasions to keep the insect infestation to a minimum. Urea at the rate of 20 kg N ha^{-1} was side dressed at 20 DAS.

Recording of data:

Sampling for dry matter partitioning: Plant samples were taken at weekly interval beginning at DAE. Three plants from each of the lower density treatments- 10, 20 and 30 plants m^{-2} and 5 plants from each of high density treatments- 40, 50, 60 plants m^{-2} were sampled. Plants were cut at the base, put in polythene bag to prevent desiccation of leaves and were brought to the laboratory.

Leaf area: Leaf area of each plant was measured at sampling date with an automatic leaf area meter (Model AAM-7, Hayashi Dehnco Co. Ltd., Tokyo, Japan) and the mean leaf area per plant was calculated.

Dry matter accumulation: Plant parts were separated into stem, petiole, leaf and reproductive organs and oven dried at 70^{0}C for 72 h. Weights of individual components were recorded. Using the data on the leaf area and dry matter, the following growth parameter was derived:

Leaf area index, LAI = L_A/G_A
Specific leaf mass, SLA = L_W/L_A
Where,
L_A= Leaf area
G_A= Ground area
L_W= Leaf weight

Harvest data: At maturity plants were harvested by picking the pods. The variety being a determinate one[14], the picking was done only once. Five plant samples were uprooted from each plot at maturity to record yield parameters viz, pods plant^{-1}, pod length, seeds per pod, 1,000 seed weight. Total biomass of 5 plant sample was determined following standard procedure and harvest index (HI) was calculated as follows:

HI = (Seed yield)/(Total biomass) x 100

Analysis of data: Data on plant characters were subjected to analysis of variance (ANOVA). Means were compared by Least Significance Difference test. Functional relationships between reproductive and vegetative growth characters were determined using regression analysis. The parameters considered to be least influenced by plant characters were used as independent variables.

RESULTS AND DISCUSSIONS

Mungbean plants were grown during kharif I (March-May) season and the general growth condition of the crop was good. However, previous studies[15] on the seasonal variations in mungbean production suggested that the kharif II (August-October) planting resulted in better crop growth and higher seed yield compared with kharif I season. Weather conditions during the growing season were generally favorable for crop growth except for one occasion in late April when heavy rain coupled with strong wind tended to cause some minor damage to the crop (data not shown).

Statistical analyses revealed that there was a significant density effect for all parameters considered. Furthermore, all parameters were significantly affected by sampling date. The effect of planting configuration was, however, variable.

Leaf area: Dry matter production of a crop plant depends almost wholly on the amount and pattern of photoactive radiation (PhAR) intercepted and absorbed by the crop and the efficiency of the crop to use the absorbed radiation. The interception of PhAR by a crop surface is the function of leaf area and the posture of the leaves on the plant (i.e. canopy structure).

Leaf area per plant increased over time almost parabolically regardless of planting density or configuration (Fig. 1 and 2). It is evident that increasing population density tended to depress leaf area per plant right from the early vegetative stage. Reduction in leaf area per plant was due to interplant competition within the community. The competition intensified during reproductive and early pod fill stage (i.e., 28 and 33 DAE). The trend persisted during the remaining part of the growing season. Maximum leaf area was recorded at the pod development phase (i.e. 33 DAE) in all the treatments, after which it declined sharply, indicating limitations of source when it is required mostly. Decrease in leaf area during pod maturity stage might be due to senescence of leaves associated with the remobilization of the stored metabolites from the leaf to the pod wall tissues. Similar results in chickpea were found by Prasad *et al*.[16]. They reported that with the onset of flowering and fruit development, there is a decline in vegetative dry weight. This is partly due to loss of leaves and petioles and partly to the mobilization of the stored metabolites from the stem to the pod wall tissues. Leaf area is an important component having a large bearing on the physiological processes controlling yield and dry matter production[17]. Seed yield on a broader sense depends on the size, duration and activity of source and

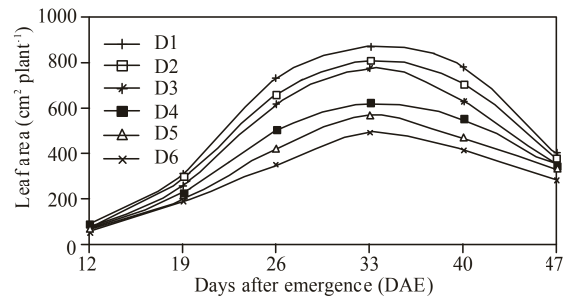

Fig. 1: Leaf area of mungbean plant as affected by different density treatments.

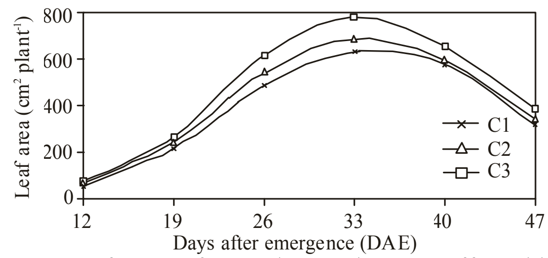

Fig. 2: Leaf area of mungbean plant as affected by planting configuration.

sink capacity. Source size and activity regulate the rate of dry matter accumulation.

When leaf area is viewed as Leaf Area Index (LAI), multiplying per plant area and ground area, the scenario changes abruptly (data not shown). LAI increased linearly with increasing population density, although from 26 DAE onwards density greater than 50 plants m^{-2} (D_5) resulted in no appreciable increase in LAI. Our results are in consistent with the results of Gowda and Kaul[18] who reported that LAI in mungbean can be increased by increasing plant population density.

Specific Leaf Mass: It indicates the photosynthetic rate of a crop through RuDPase activity[19]. Seasonal changes in specific leaf mass (SLM) due to planting systems are presented in Table 1. SLM declined markedly at the second sampling (19 DAE) and from third sampling (26 DAE) it continued increasing reaching the highest at 47 DAE. Almost similar SLM in mungbean genotypes were recorded at AVRDC[19]. The decline in SLM at second sampling might be due to the fact that the sampling corresponded to late vegetative phase when demand for photosynthates was more in triggering from vegetative to reproduction. Except in first sampling, SLM decreased with increasing population density although the difference between D_1 and D_2 was not appreciably great. Planting configuration exerted no significant influence on SLM (data not shown).

Specific leaf mass correlated well with total dry matter (g $plant^{-1}$) and seed yield per plant (g). SLM at 40 DAE gave a best fit simple linear regression with total dry matter (TDM) and yield suggesting that as SLM increased, TDM and yield also increased linearly

Table 1: Specific leaf mass (SLM) (mg cm^{-2}) of mungbean as influenced by different density treatments

Density (Plants m^{-2})	Specific leaf mass (SLM) (mg cm^{-2}) at successive sampling dates 12 DAE	19 DAE	26 DAE	33 DAE	40 DAE	47 DAE
10	3.29	3.03	3.91	4.99	6.86	8.02
20	3.26	3.02	3.86	4.99	6.68	7.92
30	3.23	2.95	3.78	3.99	6.05	7.61
40	3.22	2.92	3.67	3.87	5.70	7.13
50	3.18	2.78	3.66	3.81	5.52	6.75
60	3.17	2.58	3.63	3.67	5.44	5.60
CV (%)	5.76	4.54	3.38	4.74	3.26	3.08
$LSD_{0.01}$	NS	0.125	0.121	0.120	0.189	0.212

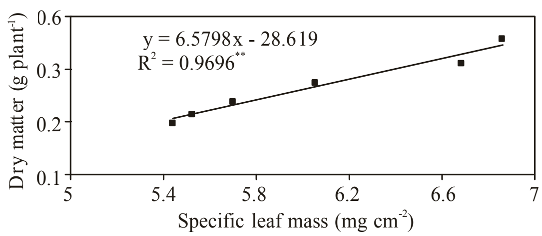

Fig. 3: Functional relationship between specific leaf mass and dry matter in mungbean

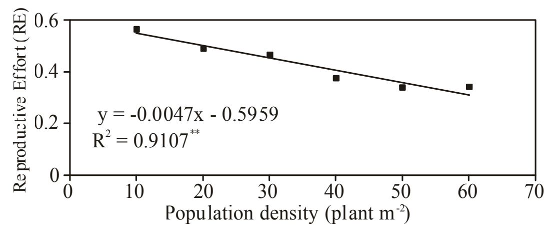

Fig. 5: Functional relationship between population density and reproduction effort in mungbean.

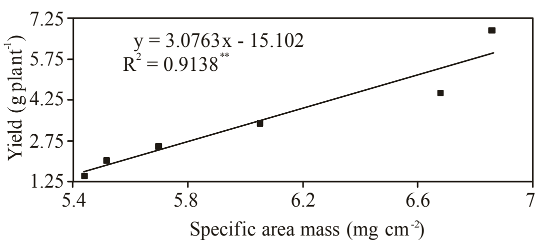

Fig. 4: Functional relationship between specific leaf mass and grain yield in mungbean

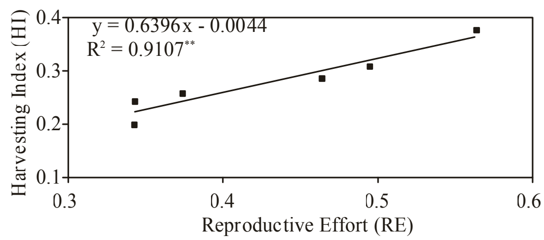

Fig. 6: Functional relationship between population density and harvest index in mungbean.

(Fig. 3 and Fig. 4). Kuo *et al.*[20] pointed out those cultivars that are early maturing and/or have higher specific leaf mass have a high harvest index. This implies that excessive vegetative growth in the late maturing types does not add to seed weight. Part of the stored assimilates in the lower leaves are remobilized to pods during later stages of growth. Over 90% of the variation in TDM and yield could be explained from the variation in SLM at 40 DAE (Fig. 3 and 4).

Reproductive effort: Various theories proposed to explain resource allocation patterns assume that vegetative and reproductive processes compete for a common pool of resources and that an increase in one activity necessarily results in a proportional decrease in the other activity[21]. Biomass allocation to reproductive organs, particularly seeds and pods in the case of mungbean, provides a comprehensive measure to reproductive output. Reproductive output is a crucial measure of plant productivity and fitness. In the present study reproductive effort was calculated using aboveground structures alone and assuming that the proportion of biomass aboveground was relatively constant over the comparisons being made among the treatments. Reekie and Bazzaz[8] observed that for *Agropyron repens* reproductive effort calculated based on the aboveground biomass was a good indicator of the allocation on a total plant basis across a wide range of environments.

Values of reproductive effort plotted against planting density are presented in Fig. 5. It is apparent that reproductive effort decreased linearly with increase in population density. The results indicate that as the population density increases the plant competition constrains reproductive allocation, although reproduction did not reduce the overall growth of the mungbean plant. In *Plantago coronopus*, an annual, Waite and Hutchings[22] showed that reproductive allocation significantly decreased from 47 to 31% with increasing density. The effect of planting configuration on RE was variable. A simple linear regression analysis using reproductive effort as independent variable and harvest index as dependent variable showed a significantly positive relationship. Plotting of harvest index against reproductive effort suggested that the harvest index was highly dependent on reproductive effort and over 90% variation in harvest index could be explained from the variation in harvest index (Fig. 6).

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