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Effect of Population Density and Planting Configuration on Dry Matter Allocation and Yield 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 configuration on dry matter allocation and yield performance 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. At maturity, grain yield and yield contributing characters were recorded. Population density decreased plant size, but the effect was offset when converted to per unit area basis. Seed yield per plant decreased progressively with the increase in planting density. Significant variation in the number of pods per plant and seeds per pod due to differences in population density caused the variation in seed yield. Planting at higher rectangularity (1:5) out yielded other planting configurations. Planting density and configuration caused similar effect on harvest index.

Key words: Density, configuration, dry matter, yield, harvest index, mungbean

INTRODUCTION

Mungbean (*Vigna radiata* (L.) Wilczek) is an important grain legume in Bangladesh. It is rich in proteins and minerals. The crop is grown widely and the dry seeds are consumed as soup or dahl. Sprouted mungbean seeds provide a succulent and nutritious vegetable, rich in protein, minerals and vitamins[1].

The productivity of mungbean being low, it often cannot compete with high yielding cereals and high valued vegetable crops. There have been considerable efforts towards national and regional levels; but the yield remains low. Old varieties/landraces degenerated and new varieties have been released. For the newly released varieties package of practices has been evolved. However, the experimental evidence of agronomic practices that influence crop growth and seed yield, plant population stands prominent. Yield is the function of total dry matter production and its favorable partition into seeds. Radiation intercepted by the leaf surface and the efficiency of its use in developing biomass governs the total dry matter production.

Yield is very sensitive to plant density. Under ideal growing conditions, optimum plant density is that which allows full light interception to be achieved prior to pod formation, but that which avoids excessive vegetative growth. It has been shown that optimal planting density for higher seed yield should be around 50-60 plants m^{-2}[2]. However, optimum planting density varies with cultivar and growing season[3,4].

Although the yield of mungbean is generally lower than other legumes[5], a fairly high yield potential has been reported[6,7]. Yields more than 3 t ha^{-1} have been reported in many trials[8,9] but in Bangladesh the average yield is about 540 kg ha^{-1}[10]. Much of the improved yield potential of modern cultivars has come from increasing the portion of total growth that a crop partitions to seed i.e. harvest index. High mungbean yield is thus determined by larger total dry matter as well as high harvest index[11].

Grain yield per unit area is a function of yield of individual plants and population density. Both yield and yield attributes are markedly influenced by population density. At wider spacing the plant develops more branches, but the contribution of secondary and tertiary branches towards grain yield is negligible[12]. Variation in grain yield was mainly due to an increase in the number of pods $plant^{-1}$ which was accentuated by the increasing pod bearing branches at lower density[1]. Likewise, planting configuration influenced significantly the yield and yield attributes except seed size in mungbean[13].

The present study was designed to examine the effect of population density and planting arrangement on the (a)

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accumulation and distribution of dry matter into the mungbean plant and (b) yield and yield attributes 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[14]. 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[15]. The mean atmospheric temperature ranges from 11.9 (January) to 34.4°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. 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 12 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. Plant parts were separated into stem, petiole, leaf and reproductive organs and oven dried at 70°C for 72 h. Weights of individual components were recorded.

Harvest data: At maturity plants were harvested by picking the pods. The variety being a determinate one[16], the picking was done only once. For recording yield data an area of 1 m^2 from the center of the plot was harvested. From beyond the harvest area, 5 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:

$$HI = (\text{Seed yield})/(\text{Total biomass}) \times 100$$

Analysis of data: Data on plant characters, yield and yield parameters were subjected to analysis of variance (ANOVA). Means were compared by Least Significance Difference test. Functional relationships between yield parameters and growth characters were determined using simple correlation and regression analysis.

RESULTS AND DISCUSSION

Mungbean plants were grown during Kharif I (March-May) season and the general growth condition of the crop was good. However, previous studies[17] 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

Table 1: Influence of planting configuration on dry matter production of mungbean (g plant^{-1})

Days after emergence (DAE)	Dry matter (g plant^{-1}) for different configuration		
	1:1	1:2.5	1:5
12	0.27	0.29	0.33
19	0.98	1.03	1.12
26	3.10	3.41	3.89
33	5.68	6.26	7.00
40	9.66	10.21	11.01
47	9.79	10.70	11.55

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.

Total dry matter (TDM) accumulation: Accumulation of total dry matter increased progressively over time attaining the highest amount at physiological maturity (Table 1). The rate of increase, however, varied depending on the growth stage. Dry matter (g plant^{-1}) was the highest in case of 1:5 rectangularity while square planting showed the minimum. This might be due to better exploitation of growth resources in 1:5 configurations as sparse population improves biological yield potential.

There were significant variations in TDM among the density treatments except at early vegetative stage. The influence of population density was first apparent at around flowering stage (i.e. between 26 and 33 DAE) and the differences among the treatments persisted throughout the growth period. It appears that until the plants attained about 3 leaf stage and within the range of planting densities, intra-specific competition was not expressed, for the plants were too small to exhibit competition for growth resources. From 26 DAE onward, the size of plants decreased progressively with the progressive increase in planting densities (Table 2). As expected the sparsely populated plants had accumulated more dry matter than the densely planted ones. The magnitude of difference between the highest and the lowest total dry matter was, however, less than the differences in population densities. Bonan[18] reported that in annual plant populations mean plant mass decreased with higher stand densities. Similarly Hamid[12] in cowpea and Rahman *et al.*[19] in mungbean showed that dry matter yield per plant decreased progressively with increasing density.

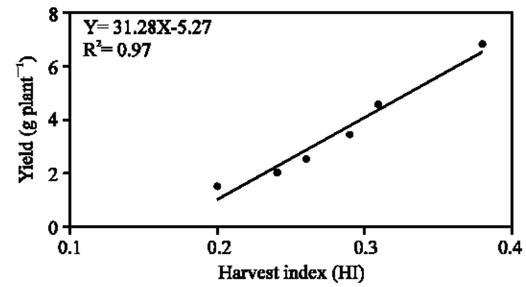

Fig. 1: Functional relationship between yield (g plant^{-1}) and harvest index (HI) in mungbean

Although per plant dry matter decreased with the increase in planting density (Table 1 and 2), the TDM per unit area continued to increase with the increasing population density; and within the population densities used, the dry matter yield per unit area did not decline or plateau (Table 3). Present results compare favorably with those of Muchow and Charles-Edwards[20] who observed significant, positive linear trends of dry matter production in three varieties of mungbean to increasing density.

Table 2 shows the density dependent variation in total dry matter accumulation over time. It seems that plants grown at closer spacing met with intra-specific competition right from the vegetative stage and that persisted throughout the growing season. Regression analysis using dry matter data against density for individual sampling dates indicates that as plant ages the slope values increases sharply (Table 4). Steeper slope toward the sampling dates corresponding to reproductive and pod fill stages is indicative of intense competition. This is rather expected because as the size of the plant increase, competition for growth resources also increases.

The changes in dry matter in individual components were influenced by planting density (Table 5). It is apparent that although the shape of the overall growth curve remained similar for all the planting densities, the changes with time varied appreciably depending on the densities. The differences were also related with phasic changes. The changes across the density treatments was not apparent until the second sampling (i.e.19 DAE) but at third sampling, which corresponded with reproductive stage, planting density exerted significant influence on dry matter accumulation in different components. Dry matter accumulation in reproductive organ and stem of the sparsely populated plants was relatively more than it was for crowded plants. Phasic changes were also somewhat delayed due to plant competition.

Yield and yield attributes: Population density influenced significantly all the yield parameters except seed size (Table 6). Likewise, planting configuration exerted

Table 2: The density dependent variation in total dry matter accumulation in mungbean over time

	Total dry matter (g plant^{-1}) accumulation on successive dates					
Density (Plants m^{-2})	12 DAE	19 DAE	26 DAE	33 DAE	40 DAE	47 DAE
10	0.37	1.36	4.69	9.05	16.03	17.28
20	0.34	1.27	4.13	8.42	13.14	14.18
30	0.30	1.12	3.94	6.58	10.60	11.57
40	0.28	0.98	3.15	5.44	8.53	9.30
50	0.25	0.82	2.67	4.65	7.29	7.79
60	0.23	0.70	2.26	3.97	6.15	6.68
CV (%)	8.06	9.12	4.56	7.84	10.45	8.80
$LSD_{0.01}$	0.06	0.12	0.20	0.64	1.38	1.26

Table 3: Dry matter production of mungbean (g m^{-2}) as influenced by population density

	Dry matter (g m^{-2}) for different density treatments					
Days after emergence (DAE)	D_1	D_2	D_3	D_4	D_5	D_6
12	3.70	6.80	9.00	11.20	12.50	13.80
19	13.60	25.40	33.60	39.20	41.00	42.00
26	46.90	82.60	118.20	126.00	133.50	135.60
33	90.50	168.40	197.40	217.60	232.50	238.20
40	160.30	262.80	318.00	341.20	360.50	369.00
47	172.80	283.60	347.20	372.00	389.50	400.80

Table 4: Intercept (α) and slope (β) values of the regression equations giving best fit to total dry matter accumulation plant^{-1} as influenced by population density over time

Sampling (DAE)	Intercept (α)	Slope (β)	R^2
12	0.394	-0.003	0.990
19	1.521	-0.014	0.995
26	5.205	-0.050	0.985
33	10.137	-0.108	0.974
40	17.192	-0.197	0.967
47	18.577	-0.213	0.970

significant influence on nearly all the attributes (Table 7). Seed yield is the function of pods per plant, number of seeds per pod and seed size[1]. Pod length is usually a varietal character and varies depending on the environmental condition. Pod length by itself does not contribute directly to the yield, but there is often a close relationship between the number of seeds per pod and pod length.

In the present study, the number of pods ranged between 5.3 and 11.2, a two-fold variation, across planting density treatments. Number of pods per plant decreased almost linearly with the increase in density. Mackenzie *et al.*[21] also showed that as populations of mungbean were increased, pods per plant decreased. Similarly, increase in density also decreased pod length. Seeds per pod correlated strongly (r = 0.98) with pod length. As the size of the pod decreased, the number of seeds per pod also reduced (r = 0.99). The number of seeds per pod varied from 6.8 to 13.1 across the density. Seed size remained unaltered due to population density. Reddy and Reddi[22] also reported that among the yield attributes, seed size is the stable character under wide range of plant populations. Seed yield per plant differed greatly depending on planting density. It varied from 6.82 to 1.51 g plant^{-1} for 10 and 60 plants m^{-2}, respectively. This result suggested that yield per plant

Table 5: Accumulation of dry matter in different components of mungbean at varying population densities

	Dry matter (g plant^{-1}) for population density (D)			
Days after emergence (DAE)	Leaf blade	Stem	Petiole	Reproductive organs
D_1				
12	0.27	0.07	0.03	0.00
19	0.94	0.29	0.14	0.00
26	2.84	1.14	0.59	0.12
33	4.12	2.81	0.86	1.26
40	5.34	3.63	1.12	5.94
47	3.09	3.35	1.08	9.73
D_2				
12	0.24	0.07	0.03	0.00
19	0.87	0.26	0.14	0.00
26	2.52	0.95	0.54	0.12
33	4.02	2.70	0.84	0.87
40	4.77	3.45	1.07	3.85
47	2.97	3.14	1.02	7.02
D_3				
12	0.20	0.07	0.03	0.00
19	0.75	0.25	0.12	0.00
26	2.35	0.93	0.54	0.12
33	3.09	2.25	0.78	0.45
40	3.80	2.92	0.88	3.00
47	2.61	2.72	0.86	5.37
D_4				
12	0.20	0.07	0.02	0.00
19	0.66	0.22	0.11	0.00
26	1.83	0.78	0.46	0.09
33	2.40	2.03	0.67	0.34
40	3.13	2.74	0.81	1.85
47	2.42	2.64	0.76	3.47
D_5				
12	0.18	0.05	0.02	0.00
19	0.54	0.19	0.09	0.00
26	1.52	0.72	0.36	0.07
33	2.14	1.65	0.57	0.29
40	2.55	2.31	0.67	1.63
47	2.22	2.27	0.63	2.67
D_6				
12	0.17	0.05	0.02	0.00
19	0.47	0.15	0.08	0.00
26	1.27	0.59	0.32	0.07
33	1.79	1.49	0.49	0.20
40	2.25	2.19	0.58	1.12
47	1.57	2.16	0.55	2.28

Table 6: Yield and yield attributes of mungbean as influenced by different density treatments

Population density (Plants m^{-2})	Pods $plant^{-1}$	Pod length (cm)	Seeds pod^{-1}	Seed size (mg)	Seed yield $plant^{-1}$ (g)	Seed yield ha^{-1} (Kg)	Harvest index (HI)
10	11.20	8.55	13.12	46.01	6.82	682.00	0.38
20	9.82	7.61	10.02	45.81	4.50	900.22	0.31
30	8.81	7.24	8.60	45.58	3.45	1035.00	0.29
40	7.30	6.64	7.85	45.33	2.56	1024.44	0.26
50	6.63	6.64	6.96	44.81	2.06	1031.11	0.24
60	5.26	6.41	6.78	44.75	1.51	906.67	0.20
CV (%)	7.87	3.53	8.20	2.25	5.60	5.58	3.49
$LSD_{0.01}$	0.84	0.33	0.94	NS	0.25	66.75	0.03

Table 7: Yield and yield attributes of mungbean as influenced by different planting arrangements

Planting configuration	Pods $plant^{-1}$	Pod length (cm)	Seeds pod^{-1}	Seed size (mg)	Seed yield $plant^{-1}$ (g)	Seed yield ha^{-1} (Kg)	Harvest index (HI)
1:1	7.60	6.97	8.68	44.97	3.14	838.56	0.27
1:2.5	8.08	7.18	8.76	45.40	3.40	913.78	0.28
1:5	8.84	7.40	9.23	45.78	3.91	1037.39	0.29
CV (%)	7.87	3.53	8.20	2.25	5.60	5.58	3.49
$LSD_{0.01}$	0.58	0.23	NS	NS	0.18	47.20	0.02

decreases gradually as plant population per unit area is increased. Present results are also supported by Rahman *et al.*[19]. They noted that mungbean plants sown at low density produced significantly higher dry matter and yield per plant.

Harvest index, or the proportion of seeds to total aboveground biomass, was generally low which varied between 0.20 and 0.38. Increase in population density generally tended to decrease harvest index. It might be due to the fact that mungbean plants grown at higher densities failed to produce seed[12] even though biomass production was similar. Planting configuration exerted significant influence on most yield parameters (Table 7). Pods per plant and pod length generally increased linearly with the increase in rectangularity. Seeds per pod and seed size were found non-responsive to planting arrangement. Seed yield per plant varied from 3.14-3.91 g following the trend similar to pods per plant. Singh and Singh[13] demonstrated that planting patterns 1:2 and 1:4 gave significantly higher pods per plant, seeds per pod and grain yield than 1:1 planting pattern but seed size did not vary significantly. They concluded that rectangular planting proved better than square planting pattern in mungbean. Rectangularity also influenced harvest index (HI) significantly; greatest rectangularity (1:5) giving the largest HI value (0.29). Plotting of yield per plant against harvest index suggested that the seed yield was highly dependent on harvest index and over 96% variation in yield could be explained from the variation in harvest index (Fig. 1).

When the yield per plant is converted into seed yield per unit area, the difference across density is narrowed. It varied from 68.2-103.10 g m^{-2}. Seed yield per unit area tended to increase up to 30 plants m^{-2} and further increase in density did not result any further increase in yield per unit area. A density of 60 plants m^{-2} rather tended to decrease seed yield. This is parabolic response and according to Holliday[23] this type of response can be fitted to the quadratic equation. Hamid[12] reported that in mungbean the yield-density function based on grain yield per unit area followed a quadratic relationship. However, Muchow and Charles-Edwards[20] found that the seed yield of mungbean remained relatively unresponsive to a wide range of plant densities from 10-50 plants m^{-2}.

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