Influence of Planting Density on the Nitrogen Nutrition and Grain Productivity of Mungbean

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Planting density is one of the most principal factors affecting the grain yield of leguminous plants^{2,3,7}. In over closer spacing, the grain yield was observed to decrease owing to mutual shading. This influence also varied according to the plant type and its photosynthetic activity^{6,7,8,15}. In comparison with the gramineous crops, the leguminous crops such as soybean, adzuki bean, kidney bean, mungbean have long petioles with wide leaflets. This implies that the light-receiving efficiency in these crops was relatively low^{6,9}. Therefore, the grain yield of leguminous crops in comparison with that of other crops could be considered to be greatly susceptible to the effects of high planting density³. Planting density was also known to affect the development of plant organs, nutrient uptake as well as the nodulation and nitrogen fixation of leguminous plants^{3,13}.

Mungbean is an important legume in tropical regions which is intercropped with other crops such as cereals or frequently single cultivated in the drained paddy fields after rice croppings^{12,16}. In order to get the informations for increasing the grain productivity of mungbean, a series of researches on the plant physiological properties as affected by environmental factors were conducted^{18,19,20,21,22}. The present investigation is designed to determine the influence of planting density on the plant growth, grain productivity, nitrogen fixation and nitrogen uptake in field grown mungbean.

Materials and Methods

Mungbean plants (Raipur local variety,

India) were sown zigzag on May 20th, 1981 in three planting densities (8, 14, 28 plants/m²) in two replicated rows (1.2 x 13 m). The inter-row distance was 0.75 m. Three mungbean seeds were sown in each hole and two weeks after germination, they were thinned out to a plant/hill.

A basal fertilizing incorporation to plow layer of urea, superphosphate and potassium chloride was done at the rate of 4 : 10 : 10 kg/10a for N, P₂O₅, K₂O respectively. In each row, two sub-plots (1.2 x 1.2 m) were reserved for grain harvest and the remaining plants were subjected to the investigation of plant growth and nitrogen fixing activity of mungbean root nodules.

The investigation of plant growth was carried out six times throughout their growing cycles, starting from first flowerings until the second grain harvesting stages. After cutting, the aerial part was separated into stem-leaf, shell, grain while root was dug out carefully, washed from adhering soil and submitted firstly to acetylene reduction assay. Nitrogen content of these plant parts was determined by colorimetric method using Nessler's reagent as previously reported¹⁶. Fallen leaves were not investigated. Plant height, leaf area and relative light intensity at the soil surface were determined at the pod filling stage (August 4th), when the vegetative organs were fully developed. Nitrogenase activity of mungbean root nodules was investigated seven times during the growth period using acetylene reduction method^{17,21}. The nodules were then detached from roots, counted and weighed.

In each sampling, five plants were used for

Fig. 1. Effect of planting density on the plant dry matter production per unit area during the growing period of field grown mungbean.

*appearance of first flowering.

A, B, C : 8, 14, 28 plants/m² respectively.

Table 1. Effect of planting density on the plant height, leaf area index and relative light intensity at pod filling stage of field grown mungbean (August 4th).

Planting density (plant/m ²)	Plant height (cm)	Leaf area index	Relative light intensity* (%)
8	98.0	4.35	20.1
14	89.8	5.08	14.7
28	89.5	6.94	5.3

* Relative light intensity at the soil surface in the canopies.

the investigation of growth and nitrogenase activity, and the results shown are the means of them.

During the period of plant growth in field, sprinklers were used for watering at long drought. In general, the growth of mungbean plants were in favorable condition.

Results and Discussion

1. Effect of planting density on the dry matter production

The plant dry matter production per unit area is shown in Fig. 1. The plant dry weights

Fig. 2. Effect of planting density on the dry matter of plant parts of field grown mungbean.

*appearance of first flowering ; A, B, C : 8, 14, 28 plants/m² respectively ; G1, G2 : 1st and 2nd grains ; Sh1, Sh2 : 1st and 2nd shells ; St + L : stem + leaf ; R : root.

in either planting densities slowly increased at early stages of growth, and then rapidly increased from about ten days prior to first flowering to the grain harvesting stage. From first flowering stage, the difference of plant dry weights among the treatments began to largely differ each other. Plant dry weights per unit area increased and markedly differed at the pod filling stage (August 4th), when the growth of mungbean plants reached peak developmental stage. The plant dry weights per unit area were found to increase with increasing planting density.

In this experiment, the highest plant dry weight was 1450 g/m² in the treatment of 28 plants/m². This value was relatively higher in comparison with other grain legumes such as soybean, adzuki bean or kidney bean though the growth conditions were different^{7,9,10,11}).

Table 1 shows some environmental characters at highest developed stage of vegetative

Table 2. Effect of planting density on the grain and pod yields of field grown mungbean.

Planting density (plant/m ²)	Harvest	Plant		Area(m ²)		Pod	
		Pod number (No.)	Grain weight (g)	Pod number (No.)	Grain weight (g)	Grain number (No.)	Grain weight (g)
8	1st	49.4	25.4	395	203	10.9	0.51
	2nd	51.2	13.8	410	110	6.3	0.27
	Total	100.6	39.2	805	313	—	—
	Mean	—	—	—	—	8.6	0.39
14	1st	37.8	18.1	529	254	10.3	0.48
	2nd	27.6	8.2	386	115	6.5	0.30
	Total	65.4	26.3	915	369	—	—
	Mean	—	—	—	—	8.4	0.40
28	1st	22.4	10.6	626	295	10.1	0.47
	2nd	14.6	4.1	409	116	6.3	0.28
	Total	37.0	14.7	1035	411	—	—
	Mean	—	—	—	—	8.2	0.40

Fig. 3. Effect of planting density on the nitrogen distribution in plant parts at two grain harvesting stages of field grown mungbean.

organs as described above. The plant height in low planting density (8 plants/m²) was a little higher than others whereas leaf area index (LAI) increased as the planting density increased. The LAI of the highest planting density (28 plants/m²) was 6.94. The relative light intensities (RLI) at the soil surface in the canopies showed an inverse tendency to LAI. RLI decreased from 20.06 to only 5.26% when planting density in-

creased from 8 to 28 plants/m².

Fig. 2 shows the dry weight of whole plants and each plant part at the different planting densities. Unlike the amounts of dry matter production per unit area shown in Fig. 1, the dry weights of whole plants were higher in the treatment with sparse planting density. This tendency was especially obvious in the aerial parts, in which the stem-leaf comprised more than a half-part of the total plant dry

Fig. 4. Effect of planting density on the efficiencies of grain and grain protein production of field grown mungbean.

weight, followed by the grain yield. Thus, the competition for nutrients and light intensity in sparser planting density was less intense than that of the higher planting densities.

The grain yield and number of pods are shown in Table 2. Both the grain yield and pod number per plant decreased as planting density increased. However, their quantities per unit area increased. On the other hand, the grain weight and grain number per pod at the first and second harvestings were almost the same at the different planting densities. Thus, the main course of high grain yield per plant was due to increases in pod-setting at the low densities.

The grain yield per unit area depends on the grain weight per plant and the number of plants per unit area. In regards to the utilization of field, the grain yield of mungbean was the highest at the closest planting density (28 plants/m²) in this field experiment, and the yield (estimated as 411 kg/10a) was remarkably superior to that of other reports^{5,12,14}. Thus, the suitable planting density for mungbean cultivation could probably be increased to some extent as far as grain production concerned.

2. Effect of planting density on the efficiencies of grain and grain protein production

Since the amount of basal fertilizer applied in the soil is the same per unit area among

Table 3. Effect of planting density on the grain properties of field grown mungbean.

Planting density (plant/m ²)	Harvest	Crude protein content (%)	Thousand grain weight (g)
8	1st	26.5	47.1
	2nd	27.8	42.6
14	1st	27.3	46.7
	2nd	26.9	46.0
28	1st	27.3	46.6
	2nd	27.7	45.1

treatments, the available amount of nutrients to each plant would presumably decrease with increasing planting density¹³.

Fig. 3 shows the plant total nitrogen at the first and second harvesting stages. Similar to the tendency in plant dry weight (Table 2), the amounts of nitrogen accumulated into plants gradually decreased with increasing planting density at either harvesting stage. On the contrary, the amounts of plant total nitrogen per unit area increased with increasing planting density. Although the stem-leaf occupied a major part of the plant dry weights as described before, the ratio of grain nitrogen amount to total plant nitrogen was relatively high. Fig. 4 shows the efficiencies of grain and grain protein production^{18,19,20,21}. The efficiencies of grain protein production were always higher than those of grain production and both of these efficiencies had a slightly declining tendency as planting density increased to 28 plants/m².

Table 3 shows some properties of the harvested grains. The crude protein content in grains was relatively constant at the two harvesting stages and also at the different planting densities. The thousand grain weight also seemed to be almost the same among all the treatments except for the second harvesting at 8 plants/m² plot. Thus, planting density was found to affect to a much more extent the plant growth and nitrogen uptake of mungbean while the grain properties and production efficiencies were mostly unaffected.

Fig. 5. Effect of planting density on the nodulation during the growing period of field grown mungbean.
*appearance of first flowering.
A, B, C : 8, 14, 28 plants/m² respectively.

3. Effect of planting density on the nodulation and nitrogen fixation

The nitrogen fixing capacity of mungbean was generally reported to be lower than in other grain legumes such as soybean and cowpea^{1,4)}. Environmental factors also affect nitrogen fixation of legumes^{2,14)}. As shown in Fig. 5, the nodulation per plant largely fluctuated throughout its growing cycle. Both the nodule fresh weight and nodule number increased rapidly prior to the first flowering and reached maxima at the pod filling stage. The differences in nodulation among the planting densities were not very large though they were higher in sparse plant spacing plots. As shown in Fig. 6, the nitrogenase activity measured by acetylene reduction method also behaved similarly. It was recognized that there was a high positive correlation between the nodule fresh weight and nitrogenase activity of mungbean as reported previously¹⁷⁾.

On the other hand, the nitrogenase activity per unit of fresh nodule weight gradually decreased during growth and was not very different among planting densities.

Table 4 shows the mean values of

Fig. 6. Effect of planting density on the acetylene reducing activity during the growing period of field grown mungbean.
*appearance of first flowering.
A, B, C : 8, 14, 28 plants/m² respectively.

Table 4. Effect of planting density on the means of acetylene reducing activity per plant and per unit area of field grown mungbean.

Planting density (plant/m ²)	Acetylene reducing activity	
	μM C ₂ H ₄ /h/plant	μM C ₂ H ₄ /h/m ²
8	8.02	64.2
14	5.98	83.7
28	5.49	153.7

nitrogenase activities of each treatment with different planting densities throughout the growing period. The nitrogenase activity per plant was high at low planting density (8 plants/m²) but decreased with increasing planting density. On the contrary, the mean nitrogenase activity per unit area increased with increasing planting density.

From these results, it is assumed that the planting density strongly affected the grain productivity and plant growth of mungbean. In comparison between lowest (8 plants/m²) and highest (28 plants/m²) planting den-

sities in this experiment, the decreasing rate per plant was very prominent in grain yield, followed by plant growth. There was a large decrease in the rate and quantity of growth of the aerial parts, but the underground parts, and also nodulation and nitrogen fixing capacity were less influenced.

Summary

Mungbean plants were grown zigzag in an experimental field with three planting densities ; 8, 14, 28 plants/m² in order to investigate the effect of planting density on its plant growth, grain productivity, nitrogen uptake and nitrogen fixing capacity. Plant sampling was carried out six times for investigate the plant growth and the investigation on the nitrogenase activity was carried out seven times from the prior of first flowering until the matured pods derived from the second flowering were fully harvested. The results obtained were as follows :

1) Plant dry matter per unit area increased with increasing planting density while the plant dry matter per plant markedly decreased with increasing density. This decreasing tendency was mainly due to the decrease of stem-leaf production in closer spacing.

2) The grain yield also increased with increasing planting density but the grain components such as number of grains, grain weight per pod and the grain properties such as thousand grain weight and crude protein content did not show significant differences among the different planting densities.

3) The efficiencies of grain and grain protein production slightly decreased with increasing planting density.

4) At the fully developing stage of vegetative organs, leaf area index increased with increase of planting density. On the contrary, relative light intensity at the soil surface in the canopies showed an inverse relationship to increase in planting density.

5) The nodulation and nitrogenase activity per plant decreased with increasing planting density but nitrogen fixation per unit area increased remarkably at closer planting density (28 plants/m²). Large difference in nitrogenase activity per unit nodule fresh weight among the different

planting densities were not observed.

6) Consequently, in a comparison between 8 and 28 plants/m² densities, the decrease in rate per plant in closer spacing was stronger in the order of grain yield > plant growth (aerial part > underground part) > nodulation $\approx$ nitrogen fixation.

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* In Japanese with English summary

[和 文 摘 要]

リョクトウの窒素栄養および子実生産に 及ぼす栽植密度の影響

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リョクトウを3段階の栽植密度条件(8, 14 および 28 本/ m^2 , 1 本立て千鳥植え)下で圃場栽培し, その生育, 子実生産, 窒素吸収および共生窒素固定能に及ぼす栽植密度の影響を経時的に調査した。その結果, 下記のことが明らかとなった。

1. 個体当りの植物体乾物重は栽植密度の増加に伴って低下したが, 単位面積当りの植物体乾物重は上記とは逆に栽植密度の高いものほど大きかった。その主たる原因は密植に伴う個体間の光競合による茎葉生産の抑制によるものと考えられた。
2. 単位面積当りの子実収量も上記と同様に栽植密度の増加に伴って高まったが, 個体当りの着莢数や子実重は逆に栽植密度の増加に伴って低下した。しかし, 一莢当りの子実重, 子実数および千粒重や子実粗タンパク含量等は栽植密度の差異によって大きく影響されなかった。
3. 栄養生長の最盛期における葉面積指数は栽植密度の高いものほど高く, それに対応して植物体地際における相対照度は低下していた。また, 植物体乾物重に対する子実重, 植物体全窒素量に対する子実窒素量の比率で示される子実生産効率や子実タンパク生産効率は栽植密度の増加に伴ってやや低下する傾向がみられた。
4. 植物体当りの根粒着生やアセチレン還元能で示される窒素固定能は栽植密度の増加に伴って低下したが, 単位面積当りの窒素固定能は栽植密度の増加に伴って顕著に高まった。しかし, 単位根粒重当りの窒素固定能は栽植密度の違いによって大きく影響されなかった。
5. これらの結果から密植(28 本/ m^2)と疎植(8 本/ m^2)の場合を比較すると, 栽植密度の影響は子実収量>植物生育量(地上部>地下部)>根粒着生, 窒素固定の順に強く反映すると考えられた。