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<https://doi.org/10.5109/24040>

出版情報 : 九州大学大学院農学研究院紀要. 38 (1/2), pp.81-88, 1993-12. Kyushu University
バージョン :
権利関係 :

Characterization of Mungbean (*Vigna radiata* (L.) Wilczek) Genotypes for Yield and Yield Components

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(Received July 20, 1993)

Seventy seven mungbean genotypes collected from different Asian countries were evaluated on yield and yield components in relation to phenological characteristics. Growth period of the genotypes ranged from 61 to 87 days. Based on the days to maturity, the genotypes were grouped into early, medium and late. Flowering period was between 29 to 38 days. Mean air temperature during the growth period of the genotypes was around 24 to 25°C. The cumulative air temperature ranged from 1481 to 2210°C. The solar radiation was between 12 to 13 MJ/m². There were large variations among the genotypes for seed yield per plant (5.3 g to 29.9 g). Seed yield had a close significant relationship with seeds per plant than 100-seed weight. Seeds per plant related more closely to pods per plant than seeds per pod. Other yield components without seeds per plant and pods per plant were not significantly associated with yield. 100-seed weight had negative significant relationship with seeds per plant and pods per plant. Seeds per plant and pods per plant had significant relationship with plant height and number of main branch per plant. Harvest index (HI) was also significantly related with yield. Therefore, it is considered that selection of genotypes with higher pods per plant, higher seeds per plant and higher HI is effective for breeding of high yielding genotypes.

It is clear from the growth status in this experiment that, this crop can be successfully cultivated in the West-Southern part of Japan during summer.

INTRODUCTION

Mungbean contains 3 times more high quality protein than the cereals. The crop is tropical to sub-tropical in nature and can be successfully grown between 25-30°C. It can sustain under 40°C; but the seeds do not germinate or the growth is stunted below 20°C of day and night temperature.

Mungbean shows highly flexible performance depending on the location of growing. As a result, the yield and other morphophysiological traits of the same genotypes become highly unpredictable. Results from International Mungbean Nursery Yield Trials indicate that the major factors influencing mungbean yield is in the order of environment(E) > genotype(G) > (E) x (G) interaction and out of these factors environment only contributes 60-80% (Imrie *et al.*, 1981; Imrie and Shanmugasundaram, 1987). In the tropical and sub-tropical regions, mungbean is highly infested with yellow mosaic virus. Therefore, the field evaluation of the genotypes seems to be disturbed. In Japan, during the growth period we did not find any incidence of viral disease. Therefore, evaluation of genotypes in a disease free environment as in Japan seems to be highly effective to get potentiality of the genotype.

Mungbean is not grown as a commercial crop in Japan and hence remains as an unknown crop to most of the people. But adzuki bean which belongs to the same genus

as that of mungbean, is widely cultivated all over Japan. Till now, sporadic attempts (Trung and Yoshida, 1982; Trung and Yoshida 1985; Francisco and Maeda, 1989a; Francisco and Maeda 1989b; Hamid et al., 1990) have been made to carry out some research on mungbean, but none of them were on the characterization of the yield and yield components of the crop which is the ultimate goal of improvement. So, this study was undertaken to characterize different mungbean genotypes under the same environmental conditions.

MATERIALS AND METHODS

The 77 genotypes used in this study were collected from 10 different countries (Bangladesh, Taiwan, India, Pakistan, Philippines, Nepal, Thailand, Indonesia, Srilanka and China) of Asia. Plants were grown in 8 L pots (one plant/pot) on May 24, 1991. There were 3 replications per genotype. Sandy loam soil mixed with 5 g of compound chemical fertilizer (N:P:K=16:16:16) were used in each pot. Five pre-germinated seeds were sown in order to get uniform plant stand. At two leaf stage of the plant, thinning of the seedlings was done to keep one plant per pot. Watering and mulching was done as and when necessary. Phenological characteristics such as date of flowering, plant height, date of maturity were recorded for each genotype. Also, yield and yield components such as yield per plant, number of seeds per plant, 100-seed weight, number of seeds per pod, number of pods per plant, pod length, were recorded at harvest of the crop. Harvest index (HI) was calculated by the formula:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

The grouping on yield and yield components of the genotypes were done based on "Mean \pm Standard deviation".

Climatic data were obtained from the Fukuoka Meteorological Station, Fukuoka.

RESULTS

In all the genotypes, the germination was uniform and all the genotypes had completed their growth cycle including the production of harvestable seeds. However, there were large variations in days to flower and days to maturity among the genotypes (Table 1). The number of days to flower ranged from 29 to 38 days after emergence. Only 4 (E 6, E 22, P 127 and 7703) genotypes (5.2% of the total) among those flowered the earliest (29 DAE). About 36.4% of the total genotypes had flowered between 33 and 34 days after emergence. As to the number of days to maturity, similar trend among the genotypes was recognized. It ranged from 61-87 days. From the results, ten genotypes (13.0%) were identified as early maturing genotypes; while, 16.0% of the genotypes were grouped as late maturing genotypes. The genotype 880138 was harvested at the earliest (61 days after emergence) and genotype 880032 was harvested as the last one at 87 days after emergence. Among the genotypes 50.6% were harvested between 71 to 75 days after emergence. The mean air temperature for days to flower

Table 1. Mean and cumulative air temperatures and mean solar radiation for days to flower and maturity of mungbean genotypes.

Days of flower					Days to maturity						
C	F	Temp.°C (mean)	Temp.°C (cumulative)	Mean solar rad. (MJ/m ²)	C	F	Temp.°C (mean)	Temp.°C (cumulative)	Mean solar rad. (MJ/m ²)		
29-30	4	22.1	641.8	-663.9	12.2	61-65	14	24.5	1481.3	-1599.1	12.9
31-32	8	22.1	685.6	-708.0	12.0	66-70	10	24.8	1628.8	-1744.7	13.3
33-34	29	22.2	729.8	-758.2	12.1	71-75	39	25.0	1774.7	-1876.1	13.3
35-36	21	22.5	780.4	-812.3	12.2	76-80	12	25.0	1899.9	-2000.3	13.5
37-38	15	22.7	839.5	-864.4	12.0	81-85	1	25.0	2052.1	-2182.8	13.6
...	.	...	...	...	...	86-90	1	25.1	2155.6	-2209.8	13.8

C, Class (days) ; F, Frequency (number of genotypes).

Table 2. Frequency distribution of total dry weight (TDW), plant growth rate (PGR), seed yield per plant and harvest index (HI) of mungbean genotypes.

TDW (g/plant)		PGR (g/plant/day)		Seed yield/plant(g)		HI(%)	
C	F	C	F	C	F	C	F
16.0 – 24.9	7	0.20 – 0.29	2	5.0 – 8.0	6	18.0 – 25.0	4
25.0 – 33.9	29	0.30 – 0.39	11	8.1 – 11.0	5	25.1 – 32.0	1
34.0 – 42.9	23	0.40 – 0.49	26	11.1 – 14.0	7	32.1 – 39.0	7
43.0 – 51.9	14	0.50 – 0.59	17	14.1 – 17.0	21	39.1 – 46.0	20
52.0 – 60.9	4	0.60 – 0.69	14	17.1 – 20.0	17	46.1 – 53.0	25
...	...	0.70 – 0.79	6	20.1 – 23.0	12	53.1 – 60.0	18
...	...	0.80 – 0.89	1	23.1 – 26.0	5	60.1 – 67.0	2
...	...	...	...	26.1 – 29.0	3	...	...
...	...	...	...	29.1 – 32.0	1	...	...
\bar{X}	36.2	0.51		16.9		46.5	
Std	8.9	0.13		5.1		9.4	
CV (%)	24.7	24.8		30.2		20.3	

C, Class; F, Frequency (number of genotypes); \bar{X} , Mean; Std, Standard deviation; CV, Coefficient of variation.

did not vary widely and was around 22°C; for days to maturity it was between 24 to 25 °C. The cumulative air temperature for total growth period varied largely. Eighteen percent of the genotypes had cumulative air temperature between 1481-1599.1°C and 1.3% had 2155.6 - 2209.8 °C. Most of the genotypes (50.6%) had cumulative air temperature between 1774.7-1876.1°C. Mean solar radiation did not vary to a large extent for both days to flower and days to maturity and it was between 12 to 14 MJ/m² (Table 1).

Table 2 elucidates the range of growth and seed yield of the genotypes evaluated. Total dry weight (TDW) ranged from 17.0 to 58.2 g/plant. Most of the genotypes concentrated in the range of 25 to 34. Plant growth rate (PGR) ranged from 0.27 to 0.86 g/plant/day. Yield per plant ranged from a minimum of 5.3 g to maximum 29.9 g.

Table 3. Frequency distribution of yield components of mungbean genotypes

No. of Seeds per plant	100-seed weight(g)		No. of seeds per pod		No. of pods per plant		Pod length (cm)		No. of main branch		Plant height (cm)		
	C	F	C	F	C	F	C	F	C	F	C	F	
101 -200	7	2.0 - 3.0	7	7.1 - 9.0	3	11.0 -20.0	9	5.1 - 6.0	3	1.0 -2.0	1	35.0 -40.0	5
201-300	14	3.1 - 4.0	34	9.1-11.0	35	20.1-30.0	20	6.1 - 7.0	28	2.1-3.0	17	40.1-45.0	14
301-400	18	4.1 - 5.0	7	11.1 -13.0	37	30.1 - 40.0	11	7.1 - 8.0	16	3.1 - 4.0	38	45.1 -50.0	21
401 -500	6	5.1 - 6.0	6	13.1 -15.0	1	40.1 - 50.0	8	8.1 - 9.0	7	4.1 - 5.0	19	50.1 -55.0	15
501-600	10	6.1 - 7.0	9	15.1 - 17.0	1	50.1 - 60.0	18	9.1 -10.0	10	5.1 -6.0	1	55.1 -60.0	13
601 -700	12	7.1 - 8.0	9	...	...	60.1 -70.0	11	10.1 -11.0	9	6.1 -7.0	1	60.1 -65.0	7
701 -800	8	8.1 - 9.0	4	...	...	...	...	...	...	...	...	65.1 - 70.0	2
801-900	2	9.1-10.0	1	...	...	...	...	...	...	...	...	...	...
\bar{X}	451.2	4.8	11.1	40.4	7.9	3.8	52.4						
Std	198.7	1.8	1.3	16.6	1.5	0.8	8.3						
CV (%)	44.0	37.5	11.8	41.1	18.3	21.8	15.9						

C, Class; F, Frequency (number of genotypes); \bar{X} , Mean; Std, Standard deviation; CV, Coefficient of variation.

The number of genotypes in the lowest yield class (5-8 g) was 10.4% of the total; and only one genotype (1.3%) was in the highest yield group. Harvest index ranged from 18.5% to 65.2%. About 30% of the genotypes had harvest index between 46.1 to 53.0%.

Table 3 represents frequency distribution, mean, standard deviation and coefficient of variation of some of the yield components of mungbean. For 100-seed weight, number of the genotypes in the smallest seeds group was 7, which was 9.0% of the total. Most of genotypes (44.0%) were in the range of 3.1-4.0 g. About 26.0% of the genotypes had 30.1 to 40.0 pods per plant and 23.3% of the genotypes had 50.1 to 60.0 pods per plant.

The correlation coefficients shown in table 4 are, among the growth, environmental conditions and seed yield. TDW had positively significant relationship with PGR and seed yield. Mean temperature, cumulative temperature and mean solar radiation had significant relationship with days to flower and days to maturity. Harvest index (HI) had significant correlation with only seed yield, seeds per plant and pods per plant. It indicates that HI together with TDW (Table 4) is important for yield production of mungbean.

Table 5 shows relationships between seed yield and yield contributing characters. Yield components in mungbean are primarily seeds per plant, seed weight, pods plant and seeds per pod. Seed yield had related more to seeds per plant than 100-seed weight. The seeds per plant related more closely to pods per plant and seeds per pod. Other yield components, without seeds per plant and pods per plant were not significantly associated with yield. Furthermore, pods per plant and seeds per plant had significant relationships with plant height and number of main branch per plant. Also there was a low correlation between seed yield and plant height. On the other hand, seeds per plant had a negative relationship with 100-seed weight and pod length. Similarly, 100-seed weight had a negative significant relationship with pods per plant.

Table 4. Correlation coefficient among growth, environmental factors and seed yield of mungbean genotypes.

	PGR	Seed yield	HI	Days to flower	Days to maturity	Mean solar radiation	Mean temperature	Cumulative temperature
TDW	0.947***	0.731***	-0.041 ^{ns}	0.269**	0.179 ^{ns}	0.164 ^{ns}	0.135 ^{ns}	0.178 ^{ns}
PGR		0.697***	-0.034 ^{ns}	0.192 ^{ns}	-0.137 ^{ns}	-0.123 ^{ns}	-0.160 ^{ns}	-0.137 ^{ns}
Seed yield			0.629***	0.140 ^{ns}	0.141 ^{ns}	0.093 ^{ns}	0.079 ^{ns}	0.135 ^{ns}
H I				-0.091 ^{ns}	0.012 ^{ns}	-0.018 ^{ns}	-0.008 ^{ns}	0.008 ^{ns}
Days to flower					0.234*	0.273*	0.277*	0.251 ^{ns}
Days to maturity						0.909***	0.933***	0.998***
Mean solar radiation							0.973***	0.925***
Mean temperature								0.948***

*, **, ***, ns represents significant at 5%, 1%, 0.1% levels and not significant, respectively.

Table 5. Correlation coefficients among the yield and yield contributing characters

	Seeds/plant	100-seed weight	Seeds/pod	Pods/plant	Pod length	No. of main branch	Plant height	Harvest index
Yield/plant	0.641***	-0.141 ^{ns}	0.102 ^{ns}	0.659***	0.063 ^{ns}	0.276*	0.319***	0.631***
Seeds/plant		-0.674***	0.414***	0.954***	-0.553***	0.372***	0.433***	0.331**
100-seed weight			0.263*	-0.650***	0.810***	0.302**	0.338**	0.010 ^{ns}
Seeds/pod				0.135 ^{ns}	-0.012 ^{ns}	0.112 ^{ns}	0.154 ^{ns}	0.016 ^{ns}
Pods/plant					0.614***	0.425***	0.426***	0.352**
Pod length						0.321**	0.321**	0.109 ^{ns}
No. of main branch							0.342**	0.147 ^{ns}
Plant height								0.139 ^{ns}

*, **, ***, ns represents significant at 5%, 1%, 0.1% levels and not significant, respectively.

About 70.1% of the genotypes evaluated, were in the medium group for yield and yield components (Table 6). Only 15.6% of the total genotypes were in the high seed yield group; while 14.3% were in low group for the same parameter. The early maturing (< 66 days) genotypes were 19.5% and late maturing (> 76 days) genotypes were 14.3%. The mean values in table 6 shows that, the yield and yield components in high group were three times more compared to the low group. Table 7 shows the genotypes which are grouped into high, low and medium for seed yield per plant.

DISCUSSION

Solar radiation and temperature are among the most important factors influencing the productivity of the crop. Solar radiation supplies the light energy for the photosynthetic process, modulates the temperature, affects respiration and water loss, and determines the photoperiod. The solar radiation during the summer in Fukuoka appears to be sufficient enough for the successful production of the crop. Air temperature which influences flowering and maturity of the crop also seems to be favorable during summer for growing mungbean in the West-Southern Japanese

Table 6. Mean values of high, medium and low groups of mungbean genotypes for seed yield and yield components.

Group	Yield per plant (g)	Seeds per plant (no.)	100-seed weight (g)	Seeds per pod (no.)	Pod no./ plant (no.)	Pod length (cm)	No. of branch (no.)	Plant height (cm)	Days to* flower	Days to* maturity	Harvest index (%)
High	24.99	721.54	7.55	13.28	63.77	10.05	5.19	66.68	37.8	79.18	59.71
Low	8.31	190.03	2.51	9.03	19.25	6.19	2.2	40.85	30.45	62.38	27.54
Medium	16.99	424.53	4.12	11.12	40.11	7.47	3.77	51.85	34.48	71.94	47.48

*High = Late

Low = Early

Table 7. Mungbean genotypes grouped into high, medium and low classes based on seed yield per plant.

High	Low	Medium			
880144	Mosk 1	VC 3689A	VC 3301A	M 99	VC 2768A
88092	880137	880142	880130	BM-84-1-38-3	VC 3902A
88070	BM-84-2-93-2	880139	E 16	30R (4 * 10)	P 114
880132	MBCB 1	VC 4080A	880141	MBCB 3	BM-84-2-24-1
880138	KPS 2	2709	V 3476	E 11	BM-84-2-7-3
E 10	E 1	VC 2802A	880146	VC 2991A	VC 2917A
880032	9(1 * 10)7	VC 1973A	E 27	BM-84-2-7-1	E 6
Chinese	7703	880140	31R(5*6)15	24(4 * 7)5	E 2
880145	PIMS Viny	VC 3300A	Mosk 2	BM-84-1-6-3	E 19
7715	E22	880134	BM-84-1-60-4	P 128	V 3726
Indonesian	P 127	32 (5 * 4) 12	19R (3 * 5) 2	Pagasa 2	VC 4066A
VC 3741A		VC 3737A	Isd local	VC 4111A	E 8
		BM-84-2-7-3	VC 3890A	BM-84-2-14-1	VC 3117A
		36R (6 * 7) 1	BM-84-2-40-2		

climate. The mean temperature for successful growth of the crop were 22 °C for flowering and 24-25°C for maturity. Also cumulative temperature for flowering ranged from 642-864°C and for maturity it ranged from 1481-2210°C. From the last 50 years observation, it is found that these temperature regimes prevail in Fukuoka during summer from June to September.

PGR is an indication of the conversion efficiency of photosynthesis. There were few genotypes with high PGR and these may be promising genotypes for the improvement of the crop. Significant relationship of TDW and PGR to seed yield indicates that breeding for increase in TDW and PGR may lead to increase in yield of mungbean. Temperature affects the length of the vegetative growth phase and the initiation of flowering. Increase in mean temperature during the vegetative phase hastens flowering (Aggarwal and Phoelman, 1977). Higher air temperature incite flower shading, particularly if there is lack of soil moisture and low humidity. In this study, the low significant relationship between days to flower and mean temperature and solar

radiation may be because of the little genetic variation for this parameter. But on the other hand, there were considerable genetic variations present for days to maturity although the temperature did not vary so much.

The primary yield components of mungbean are seeds per plant, pods per plant, seeds per pod and seed weight; yield of mungbean being the product of these components (Phoelman, 1991). In our study, yield significantly related more to seeds per plant than 100-seed weight. The seeds per plant related more closely to pods per plant. The pods per plant and seeds per plant significantly related to all the yield contributing characters (Table 5). Similar results were also reported in other studies (Singh and Singh, 1973; Rathnaswamy *et al.*, 1978; Satyan *et al.*, 1986). Whereas other reports (Parida and Singh, 1984; Khan, 1985) indicate that there is significant relationship between all the yield contributing characters and yield. Analyzing the reports on yield and yield components, Phoelman (1991) concluded that pods per plant had stronger association with yield as compared with other yield components. The pods per plant also correlates with plant height and number of branches per plant. In this study, plant height and number of branches per plant were associated significantly with yield through pod production (Table 5). Therefore, if we want more number of seeds per plant for higher yield, we have to have more number of pods per plant. This can be made possible by having tall plants with more number of branches. Similar views were also expressed by several authors (Malhotra *et al.*, 1974; Boomikumar and Rathinam, 1981; Satyan *et al.*, 1986).

Harvest index which is an indication of the partitioning of dry matter between grain and other above ground plant organs significantly correlated with yield and pods per plant. Significant correlations among these parameters were also reported by Kuo *et al.*, (1980), Malik *et al.*, (1986), Rathnaswamy *et al.*, (1986). Higher HI represents large physiological capacity (often called sink power or sink capacity) to mobilize photosynthate and translocate it to organs having economic value (Wallace *et al.*, 1972). Therefore, we can say that yield improvement in mungbean can be made by selecting genotypes with higher pods per plant and higher HI.

In this paper, we have tried to characterize the genotypes and have found that large variations occur among genotypes for growth, yield and yield contributing characters. Some genotypes having too much foliage, produced many pods; but the yield performance was poor, while others despite of having small foliage had good performance. We also found that plants with higher HI and more number of pods per plant were necessary to obtain higher yield.

Although till now mungbean is not grown commercially in Japan, through analysis of climatic data in relation to growth and yield, it can be said that mungbean can be successfully grown during the summer in the West-Southern area of Japan. The best growing time is from June to September when the mean air temperature remains above 20°C.

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