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GENETIC STUDY OF YIELD AND YIELD COMPONENTS IN MUNGBEAN [*VIGNA RADIATA* (L.) WILCZEK] GROWN IN DRY AND WET SEASONS

พันธุกรรมของผลผลิตและองค์ประกอบผลผลิตของถั่วเขียวที่ปลูกในฤดูแล้งและฤดูฝน

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ABSTRACT

Six lines of mungbean were crossed in a diallel manner to obtain 15 direct and 15 reciprocal F_1*-crosses. They were planted in dry and late rainy seasons to observe for seed yield. 1,000-seed weight, number of seeds/pod and number of pods/plant. The analyses of variance revealed that all 6 parental lines expressed diversity in both dry and rainy seasons in terms of seed yield/unit area and 1,000-seed weight. Number of seeds/pod showed statistical different only in the dry season while number of pods/plant was significant in the rainy season. Tests of homogeneity among seasons indicated that error variances associated with the 2 seasons were* *heterogeneous in all characters, except 1,000-seed weight. Thus all data were analyzed separately season by season, employing the method 1 model II as suggested by Griffing.[4] The genetical analyses showed that, in dry season, both additive and non-additive gene action were prevalent in controlling yielding ability, 1,000-seed weight and number of seeds/pod. Non-additive gene action also played significant roles in controlling 1,000-seed weight and number of seeds/pod. In the late rainy season, however, only additive gene action was found to be significant in conditioning seed yield, 1,000-seed weight and number of pods/plant.*

Broad-sense heritabilities were estimated from regression of F_2's on F_1's. Yielding ability expressed medium heritability, while 1,000-seed weight and number of pods/plant expressed high and medium heritability, respectively.

บทคัดย่อ

ได้ทำการผสมถั่วเขียว 6 สายพันธุ์แบบพบกันหมด ปลูกทดสอบลูกผสมตรงชั่วแรก 15 คู่ ลูกผสมสลับชั่วแรก 15 คู่ และสายพันธุ์พ่อแม่ในฤดูแล้งและปลายฤดูฝน โดยในปลายฤดูฝน ทำการปลูกลูกผสมชั่วที่ 2 ทั้ง 30 คู่ผสม พร้อมกับลูกผสมชั่วแรก 30 คู่ผสม และพ่อแม่ 6 สายพันธุ์ เก็บข้อมูลผลผลิตต่อพื้นที่ และองค์ประกอบผลผลิตที่สำคัญคือจำนวนฝักต่อต้น จำนวนเมล็ดต่อฝัก และน้ำหนัก 1,000 เมล็ด

การวิเคราะห์ความแปรปรวน ชี้ให้เห็นว่า สายพันธุ์ทั้ง 6 ที่ใช้แสดงลักษณะผลผลิตต่อพื้นที่ และน้ำหนัก 1,000 เมล็ด แตกต่างกันทางสถิติทั้ง 2 ฤดู ในขณะที่ลักษณะจำนวนเมล็ดต่อฝักแสดงนัยสำคัญทางสถิติในฤดูแล้ง และลักษณะจำนวนฝักต่อต้นแสดงนัยสำคัญทางสถิติในปลายฤดูฝนเพียงฤดูเดียว เมื่อทดสอบความเป็นเอกภาพของความแปรปรวนของค่าคลาดเคลื่อนระหว่างฤดูปลูก พบว่ามีเพียงลักษณะน้ำหนัก 1,000 เมล็ดเท่านั้นที่ความแปรปรวนของค่าคลาดเคลื่อนเป็นเอกภาพ จึงทำการวิเคราะห์พันธุกรรมโดยวิธีของ Griffing method 1 model II แยกแต่ละฤดูในทุกลักษณะ เพื่อให้วิธีการวิเคราะห์เป็นไปในแนวทางเดียวกัน ผลการทดลองแสดงว่า ในฤดูแล้ง ยีนทั้งแบบผลบวก (additive gene) และไม่เป็นผลบวก (non-additive gene) มีอิทธิพลต่อลักษณะผลผลิต น้ำหนัก 1,000 เมล็ดและจำนวนเมล็ดต่อฝัก โดยที่ลักษณะน้ำหนัก 1,000 เมล็ดและจำนวนเมล็ดต่อฝัก ควบคุมโดยยีนแบบไม่เป็นผลบวกอีกด้วย ส่วนในปลายฤดูฝน ยีนแบบผลบวกเท่านั้นที่มีอิทธิพลต่อลักษณะผลผลิต น้ำหนัก 1,000 เมล็ดและจำนวนฝักต่อต้น

จากการศึกษาความสามารถในการถ่ายทอดพันธุกรรมแนวกว้างโดยวิธีรีเกรสชัน (regression) ของลูกชั่วที่สองบนลูกผสมชั่วแรก พบว่า ผลผลิตมีความสามารถในการถ่ายทอดลักษณะปานกลาง และองค์ประกอบผลผลิตที่มีการถ่ายทอดลักษณะสูงคือ น้ำหนัก 1,000 เมล็ด ส่วนจำนวนฝักต่อต้น มีความสามารถในการถ่ายทอดลักษณะปานกลาง

INTRODUCTION

Thailand has been the world's largest mungbean exporter for the last 2 decades, but not until 1978 that a mungbean hybridization program was set up in the country. From then on, some of the basic study was conducted to supply information to the breeders so that breeding schemes could be properly set toward the breeding goals. Combining ability study of yield and yield components can reveal gene action controlling the traits and leads to a proper selection plan for mungbean grown in various environments such as wet and dry seasons.

Griffing[4] explained that, without epistasis, general combining ability (GCA) consisted of additive gene action plus parts of dominance gene action while specific combining ability (SCA) comprised only dominance gene action. If epistasis also existed in the genes controlling that traits, both GCA and SCA would include some of its magnitude. Yohe and Poehlman[12] studied on 10 F_1's from 5 diverse parental lines and found that GCA of the lines were significant in yield/plant, number of pods/plant, number of seeds/pod and 1,000-seed weight. SCA was important in only 1,000-seed weight. Swindell and Poehlman[11] reported the significance of GCA in number of seeds/pod but not in number of pods/plant. They found no variation due to SCA in either yield or yield components. Another study by Ramanujum[6] employing partial diallel of 25 F_1's from 10 mungbean lines revealed importance of GCA. Number of seeds/pod and 100 seed weight were inherited mainly through GCA. Variation due to SCA among crosses in most characters was trivial in his study.

Although gene action governing the traits can be interpreted through combining ability analyses, there were particular reports on effects of gene on yield and yield components. Singh and Singh[8,9] advocated that yield and number of pods/plant were largely inherited by dominant gene effect. They also reported that seed size was governed by both additive and dominant gene action, which agreed well with the results of Singh and Jain.[7]

Some investigators employed heritability as a source of information for setting a breeding scheme. Yohe and Poehlman[12] applied regression of F_1's on parental means to investigate heritability of several characters in mungbean. They reported that yield, number of pods/plant and 1,000-seed weight were highly heritable (close to 100%), while number of seeds/pod was least heritable (~22%). The estimates can also relate to generations of mungbean as Empig *et al.*[2] reported that, employing F_2 data, heritabilities of number of pods/plant, number of seeds/pod and yield were rather low while seed size has medium heritability. When the F_3 data were used, seed size was highly heritable, yield was moderately heritable and number of pods/plant was less heritable. Imrie *et al.*[5] regressed 100 seed weight of F_4 on F_3 and reported the heritability in 2 populations to be 31% and 51%.

The present study is investigating combining abilities of high yielding mungbean lines grown in dry and wet seasons. GCA, SCA as well as broad-sense heritability in yield and yield components of the lines are reported.

MATERIALS AND METHODS

Six mungbean lines having merits in various traits were employed in this experiment. Three lines selected from AVRDC, Taiwan, express impressive yield and yet moderately resistant to Cercospora leaf sport and powdery mildew disease under Thailand's condition. They were VC 1560 D from the cross BPI glab. 3//CES 44/ML-3, VC 2778 A from BPI glab. 3//CES 44/ML-3///CES 1D-21/PHLV 18 and VC 1973 A from CES 1D-21/EG-MG-16. Three other lines were obtained from AVRDC in 1980 as F_2-seeds and selected in the country for their high yield with some level of disease resistance. They were VC 2475-77 from the cross EG-MG-16/ML-3//CES 1D-21, VC 2742-13 and VC 2742-26 both from EG-MG-16/ML-3//BPI glab. 3///CES 44/ML-3. All six lines were crossed in all possible combinations to obtain 30 F_1's (15 from direct crosses and 15 from reciprocal crosses). The F_1's and 6 parents were grown in an RCBD with 3 replicates at Suwan Farm Experiment Station of Kasetsart University. The same experiment was conducted twice, one in the dry season, the other in the wet season of 1986. In addition, another trial comprising 30 F_2's and the same parental lines was also carried out in an adjacent plot in the wet season. The F_2 progenies were individually derived from the F_1's in the dry season experiment, so that wet season data from parents, F_1's and F_2's could be employed in parent-offspring regression analyses.

Each treatment was sown in a 4-row plot of 4 m long but data were obtained from only the two middle rows. Row spacing and plant spacing was 50 cm × 12.5 cm with one plant per hill. The fertilizer 16-20-0 (N-P_2O_5-K_2O) was basally applied at 312.5 kg/ha. The herbicide alachlor was applied after planting as preemergence herbicide. Hand weeding was done once in the fourth week after planting. Insects were periodically controlled by spraying monocrotophos.

All important agronomic characters were recorded but only yield per unit area (from 2 harvests), and yield components (number of pods/plant, number of seeds/pod and 1,000-seed weight) were reported.

Statistical and genetical analyses were done in order. Once treatment difference was declared the data were further analyzed according to method 1 model II of Griffing.[4] Combining ability effects were partitioned whenever variation due to GCA, SCA or both were detected. Then broad-sense heritabilities of the character were estimated following regression of F_1's on parents and F_2's on F_1's as advocated in Falconer.[3]

RESULTS AND DISCUSSION

The analyses of variances in all recorded data revealed significant difference in yield/plot and 1,000-seed weight in both dry and rainy seasons. While number of seeds/pod and number of pods/plant were significant in only dry and rainy seasons, respectively. In this study, the latter 2 characters seemed to interact with the environments. Yet error variances from the two environments were not homogeneous. Thus data from each environment rather than from pooled environments were analyzed and presented as the followings.

Yield/plot

Yield/hectare of F_1's and their parents were rather high in the dry season since the experiment was well irrigated. Yet, there was no disease found and the plants were very healthy. F_1 from the cross VC 2745-77 × VC 1973 A was the highest yielder. Its seed yield was 2,163 kg/ha (Table 1). The lowest yielder in this experiment was VC 2742-13 which gave 744 kg/ha. Most F_1's displayed higher yield than the parental average, indicating heterotic effect in yield/unit area of the materials employed in this study. Hybrids having either VC 1973 A or VC 2778 A as a parent displayed high average yield of 1,900 and 1,844 kg/ha, respectively. This implied that they had higher GCA than the other parents.

Yield level from the late rainy season trial was not that impressive, partly due to outbreaks of diseases and insects. The diseases found were powdery mildew and Cercospora leaf spot while the predominant insects were stink bugs and *Heliothis armigera.* The cross VC 2745-77 × VC 2778 A gave the highest yield of 1,131 kg/ha while VC 2742-26 × VC 1560 D gave the lowest yield of 337 kg/ha.

GCA of the six mungbean lines expressed diversity in both seasons while SCA was significant only in dry season experiment. No variation due to reciprocal cross was detected in either season. The variance ratios of GCA/SCA were 1.99 and 6.33 in the dry and wet seasons, respectively. This indicated that genetic variation due to GCA was more important than that due to SCA in conditioning yield/plot in this group of mungbean. The ratio was significant in only the wet season, revealing importance of additive gene action in yield expression in this season. However, the ratio was not significant in the dry season. In the study by Yohe and Poehlman[12] in 5 mungbean lines, it was reported that only GCA was conditioning their yielding ability.

Estimated values of GCA and SCA effects in both seasons are shown in Table 2. In the dry season, VC 2778 A and VC 1973 A expressed high GCA estimate of 68.1 and 45.3, respectively. Progenies derived from them should have higher yield than those derived from the other lines. On the other hand, VC 1560 D and VC 2742-13 tended to give low yielding progenies as they displayed negative GCA of -66.2 and -51.4. The SCA effect was significant in only VC 1973 A × VC 2745-77 indicating that parts of genes controlling yielding ability in this cross were of non-additive type.

GCA estimate in the rainy season was significant in only VC 2745-77 (59.5), while VC 1560 D showed negative GCA (-48.1). Assuming no genotype by environment interaction in this study, VC 2745-77 tended to inherit progenies that express good yield in dry seasons.

Number of pods/plant

Treatment difference in number of pods/plant was significant in only rainy season as shown in Table 3. The F_1 of VC 2745-77 × VC 2742-13 and VC 2742-26 gave the highest and lowest number of pods/plant, 29.9 and 11.6 pods, respectively. The line VC 2745-77 and VC 2742-13 resulted in F_1's that gave higher number of pods/plant when crossed with the other lines.

Variation in number of pods/plant in the rainy season was due only to the lines' GCA. VC 2745-77 was the only line showed significant positive GCA (3.84). VC 2742-13 had a positive GCA of 1.03, which was not significant. The rest 4 lines expressed negative GCA, but was significant in only VC 2742-26 (-1.77). Thus VC 2745-77 was the most desirable line in a breeding program for increasing number of pods/plant, while VC 2742-26 was not desirable.

Number of seeds/pod

Variation in number of seeds/pod was detected in only the dry season experiment. The entry averages were depicted in Table 4. F_1 from the cross VC 2742-13 × VC 1973 A had highest number of seeds/pod of 13.1 while VC 2745-77 had the lowest number of 9.5 seeds. The overall average was 11.7 seeds.

Combining ability estimates in Table 5 showed that VC 1973 A and VC 2778 A tended to give progenies with more seeds/pod. Their GCA's were significant with the value of 0.260 and 0.200, respectively. The lines VC 2745-77 and VC 2742-26, on the other hand, displayed significant negative GCA's of -0.455 and -0.265, respectively. The latter 2 lines were not desirable as far as improving for higher number of seeds/pod.

Variance ratio between GCA to SCA was significant, indicated higher variation due to GCA than to SCA. This was supported by the fact that none of the estimated SCA effects was significant as shown in the upper diagonal of Table 5. The reciprocal effects (lower diagonal) expressed positively significant in the cross VC 2742-26 × VC 1973 A but negatively significant in the cross VC 2742-13 × VC 1973 A.

1,000-seed weight

Seed size is probably the most crucial trait for Thai farmer's acceptance of a cultivar. All mungbean cultivars grown in Thailand bear at least 65 g per 1,000 seeds. The largest seeder in the dry season experiment was the cross VC 2742-26 × VC 1973 A which bore up to 75.1 g per 1,000 seeds (Table 6). VC 2742-13 gave the smallest 1,000 seeds of 53.0 g. The rainy season experiment revealed different results. All entries had smaller seeds than the dry season experiment. VC 2778 A × VC 2742-26 had largest 1,000 seeds of 62.8 g whereas VC 2745-77 was lowest at 50.3 g.

Variation due to GCA and SCA were significant in the dry season while only GCA variance was significant in the rainy season trial. In both environments, variation due to GCA was significantly greater than that due to SCA. The estimated effects of GCA from the dry season agreed well with those from the rainy season, except only in VC 1973 A which displayed positive GCA effect in the dry season but the effect was negative in the rainy season (Table 7). VC 1560 D, VC 2745-77 and VC 2742-13 showed negative GCA effect and thus expected to reduce seed size in their progenies derived from this experiment, VC 2778 A and VC 2742-26, on the other hand, had positively significant GCA for upgrading seed size of their progenies. SCA effects from the dry season testing were positively significant in the cross VC 1560 × VC 2745-77, VC 1973 A × VC 2745-77, VC 2778 A × VC 2742-13 and VC 2742-13 × VC 2742-26, but negatively significant in only F_1 of the cross VC 2745-77 × VC 2742-26.

Broad-sense heritability

Table 8 summarized heritability estimates of yield and yield components based on regression of F_1 on mid-parent in dry and rainy seasons as well as regression of F_2 on F_1 in rainy season. Each calculation resulted in different heritability values. The estimated heritability of 1,000-seed weight revealed similar results in all 3 methods giving the values of 0.83, 0.98 and 0.84, respectively. This indicated that expression of seed size varies only slightly in this experiment. These estimates were greater than what reported earlier by Imrie *et al.*[5]. Broad-sense heritabilities of the other three characters varied according to seasons and estimated generations. Empig *et al.*[2] reported similar results that heritabilities estimated from F_2 were diverse from those estimated from F_3 in all characters studied.

Estimated heritabilities of yield per unit area and number of pods/plant were greater than 1 which considered absurd in definition of heritability. Yohe and Poehlman[12] reported from the results of their study in yield, days to first flower and plant height in 20 mungbean crosses that the regression of offspring on mid-parent method could lead to the estimated values of greater than unity. This always happens when variation within each parental line was rather low. The genetic explanation of high heritability was that correlation between offspring and parents might be controlled by both additive and non-additive gene action. This correlation could be so high that, when regression technique was imposed, the regression coefficient could take the value of greater than unity. This explanation could also apply to the negative estimation in number of pods/plant in the dry season.

Heritability in rainy season gave lower estimates of F_2 on F_1 regression as compared to that of F_1 on mid-parent. Reduction in non-additive gene action was the main season for this discrepancy.

CONCLUSION

Based on the combining abilities studied in yield and yield components (Tables 2, 5 and 7) the superior lines that should be used in mungbean breeding programs in Thailand were VC 1973 A and VC 2778 A. Since these 2 lines were high yielders and had high GCA in yield and yield components. Ahn *et al.*[1] summarized results from the Ninth and Tenth International Mungbean Nursery and concluded that, among 25 mungbean lines and cultivars tested in 21, 23 or 44 locations in Asian countries and the U.S., VC 1973 A and VC 2778 A were the two best yielders. They did not only outyield the other lines in the same tests but also ranked high in yield components, especially 1,000-seed weight which considered crucial in term of farmers' acceptance in Thailand. The merits of these 2 lines were also supported by Srinives *et al.*[10]. They report that VC 1973 A and VC 2778 A were high yielding with impressive yield components. They were also rather stable across 10 tested environments. These 2 lines were finally released as Thai recommended cultivars, Kamphaeng Saen 1 and Kamphaeng Saen 2 in early 1986, and became very popular eversince.

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Table 1. Yield (kg/ha) or 30 F_1 mungbeans and their 6 parents grown in the dry season and rainy season (in parenthesis) of 1986. Figures in the upper and lower diagonal are from direct and reciprocal crosses, respectively.

Parents	VC1560D	VC2778A	VC1973A	VC2745-77	VC2742-13	VC2742-26	Avg.
VC1560D	1,313 (431)	1,763 (644)	1,681 (465)	1,625 (881)	1,625 (694)	1,369 (450)	1,563 (594)
VC2778A	1,706 (756)	1,856 (750)	1,756 (763)	1,963 (856)	1,975 (744)	1,900 (825)	1,856 (781)
VC1973A	1,769 (669)	2,106 (550)	1,875 (656)	1,950 (737)	1,706 (606)	1,894 (713)	1,881 (656)
VC2745-77	1,781 (950)	1,813 (1,131)	2,163 (913)	1,150 (856)	1,831 (1,031)	1,631 (900)	1,731 (963)
VC2742-13	1,413 (694)	1,987 (837)	1,913 (869)	1,656 (781)	744 (663)	1,944 (756)	1,606 (769)
VC2742-26	1,506 (337)	2,137 (769)	1,481 (750)	1,913 (650)	1,769 (606)	1,825 (731)	1,769 (644)
Avg.	1,581 (637)	1,944 (781)	1,813 (737)	1,706 (794)	1,606 (725)	1,763 (731)	1,737 (731)

LSD.05 = 516 kg/ha (274)   LSD.01 = 684 kg/ha (364)

Table 2. Combining ability estimates of yield/plot in 30 F_1 mungbeans and their 6 parents showing GCA (diagonal) and SCA (upper diagonal) from the dry season testing and GCA from the rainy season testing (in parenthesis).

Parents	VC1560D	VC2778A	VC1983A	VC2745-77	VC2742-13	VC2742-26
VC1560D	-66.2** (-48.1**)	-1.9	15.8	60.2	37.2	-68.6
VC2778A		68.1** (19.7)	33.7	1.1	83.6	36.1
VC1973A			45.3 (-15.3)	95.0*	35.8	-78.9
VC2745-77				-7.5 (59.5**)	61.0	9.7
VC2742-13					-51.4* (4.5)	89.1
VC2742-26						11.8 (-20.3)

*, ** : significant at 5% and 1% level of probability, respectively.

Table 3. Mean number of pods/plant of 30 F_1 mungbeans and their 6 parents grown in the rainy season of 1986. Figures in the upper and lower diagonal are from direct and reciprocal crosses, respectively.

Parents	VC1560D	VC2778A	VC1973A	VC2745-77	VC2742-13	VC2742-26	Avg.
VC1560D	13.2	18.0	15.7	20.6	20.1	14.1	16.9
VC2778A	16.9	14.7	13.5	26.0	20.6	17.3	18.2
VC1973A	18.2	17.6	18.1	16.4	19.1	17.7	17.9
VC2745-77	24.5	20.7	22.5	20.5	29.9	26.1	24.0
VC2742-13	20.2	17.9	15.4	22.3	16.5	18.1	18.4
VC2742-26	14.3	16.9	16.1	19.1	19.0	11.6	16.2
Avg.	17.9	17.6	16.9	20.8	20.9	17.5	18.6

LSD.05 = 7.3 pods/plant LSD.01 = 9.7 pods/plant

Table 4. Mean number of seeds/pod of 30 F_1 mungbeans and their 6 parents grown in the dry season of 1986. Figures in the upper and lower diagonal are from direct and reciprocal crosses, respectively.

Parents	VC1560D	VC2778A	VC1973A	VC2745-77	VC2742-13	VC2742-26	Avg.
VC1560D	11.3	12.1	12.1	12.1	12.2	11.7	11.9
VC2778A	11.9	11.9	12.4	11.8	12.5	11.8	12.1
VC1973A	11.9	11.9	11.9	12.2	11.6	12.3	12.0
VC2745-77	11.1	11.8	11.3	9.5	11.8	11.3	11.1
VC2742-13	12.2	11.6	13.1	11.6	11.4	11.6	11.9
VC2742-26	11.5	11.3	10.9	11.1	11.7	11.0	11.3
Avg.	11.7	11.7	11.9	11.4	11.9	11.6	11.7

LSD.05 = 1.0 seed/pod LSD.01 = 1.33 seeds/pod

Table 5. Estimates of GCA (diagonal), SCA (upper diagonal) and reciprocal effects (lower diagonal) of number of seeds/pod in 30 F_1 mungbeans and their 6 parents from the dry season testing.

Parents	VC1560D	VC2778A	VC1973A	VC2745-77	VC2742-13	VC2742-26
VC1560D	0.082	0.015	-0.028	0.245	0.239	0.064
VC2778A	0.050	0.200**	-0.005	0.344	-0.029	-0.121
VC1973A	0.083	0.225	0.260**	0.234	0.178	-0.073
VC2745-77	0.475	0.009	0.441	-0.455**	0.252	0.251
VC2742-13	-0.033	0.433	-0.750**	0.092	0.177	0.036
VC2742-26	0.083	0.267	0.708**	0.083	-0.083	-0.265**

** significant at 1% level of probability

Table 6. Mean 1,000-seed weight (g) of 30 F_1 mungbeans and their 6 parents grown in the dry season and rainy season (in parenthesis) of 1986. Figures in the upper and lower diagonal are from direct and reciprocal crosses, respectively.

Parents	VC1560D	VC2778A	VC1973A	VC2745-77	VC2742-13	VC2742-26	Avg.
VC1560D	63.5 (56.0)	65.3 (56.3)	63.9 (56.7)	60.7 (54.7)	59.8 (51.0)	67.2 (60.5)	63.4 (55.9)
VC2778A	65.6 (53.7)	66.7 (56.5)	70.5 (58.5)	62.4 (53.8)	68.3 (55.3)	73.1 (62.8)	67.8 (56.8)
VC1973A	65.9 (54.2)	71.1 (58.3)	69.9 (55.3)	65.7 (54.0)	61.8 (55.5)	71.5 (60.0)	67.7 (56.2)
VC2745-77	60.6 (51.5)	63.4 (56.2)	63.8 (55.0)	53.4 (50.3)	56.5 (52.3)	61.6 (61.5)	59.9 (54.5)
VC2742-13	59.3 (55.5)	67.4 (59.5)	65.7 (56.5)	55.7 (53.2)	53.0 (51.5)	72.0 (61.0)	62.2 (56.2)
VC2742-26	69.4 (57.8)	72.1 (61.8)	75.1 (58.0)	64.1 (57.0)	74.4 (60.8)	74.1 (62.2)	71.5 (59.6)
Avg.	64.1 (54.8)	67.7 (58.1)	68.1 (56.7)	60.3 (53.8)	62.3 (54.4)	69.9 (61.3)	65.4 (56.5)

LSD.05 = 4.0 g (3.9)   LSD.01 = 5.4 g (5.2)

Table 7. Combining ability estimates of 1,000-seed weight in 30 F_1 mungbeans and their 6 parents showing GCA (diagonal) and SCA (upper diagonal) from the dry season testing and GCA from the rainy season testing (in parenthesis).

Parents	VC1560D	VC2778A	VC1973A	VC2745-77	VC2742-13	VC2742-26
VC1560D	-1.69** (-1.20)**	-0.61	-1.34	2.24*	-1.00	-0.73
VC2778A		2.32** (0.92)*	0.61	0.46	3.26**	-0.41
VC1973A			2.50** (-0.91)*	2.13*	-0.96	0.07
VC2745-77				-5.29** (-2.37)**	-0.83	-2.60**
VC2742-13					-3.17** (-1.22)**	5.61**
VC2742-26						5.33** (3.95)**

*, ** : significant at 5% and 1% level of probability, respectively

Table 8. Broad-sense heritability of yield and yield components of mungbean grown in the dry season (DS) and rainy season (RS) of 1986.

Characters	Broad-sense heritability		
	F_1 on MP, DS	F_1 on MP, RS	F_2 on F_1, RS
Yield/area	0.16 ± 0.12	1.15*± 0.33	0.58*± 0.15
Pods/plant	-0.06 ± 0.22	1.03*± 0.33	0.46 ± 0.14
Seeds/pod	0.39*± 0.15	0.61*± 0.25	0.31 ± 1.9
1,000-seed wt.	0.83*± 0.18	0.98*± 1.21	0.84*± 0.18

MP = mid-parent
* significant at 5% level of probability