AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION
A. PRIMARY: Agriculture
B. SECONDARY: Legume Crops

2. TITLE AND SUBTITLE
Regressions, correlations, and combining ability in mungbeans (Vigna radiata/L./Wilczek)

3. AUTHOR(S)
Yohe, J. M.; Poehlman, J. M.

4. DOCUMENT DATE: 1975
5. NUMBER OF PAGES: 10 p.
6. ARC NUMBER: ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Department of Agronomy, University of Missouri, Columbia, Missouri 65201

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)
(In Tropical Agriculture, v. 52, no. 4, pp. 343-352)

9. ABSTRACT

Five mungbean (Vigna radiata (L.) strains, selected for their diverse plant characteristics and origins, were evaluated for ten variables in a diallele experiment using repression coefficients, correlations, and combining ability estimates. Repression coefficients were high, indicating large additive effects for most of the variables. Yield was correlated positively with number of pods per plant, number of seeds per pod, 1000-seed weight, and plant size as measured by plant height and branch length, and negatively correlated with virus score. Negative correlations of yield with late flowering and mildew score were not significant. Genetic variability among F plants for the ten variables was accounted for largely by highly significant general combining ability (GCA) effects, although specific combining ability (SCA) effects were observed for five traits. GCA effects were much larger than SCA effects, SCA effects being not significant in general, suggesting that the variables are controlled predominantly by loci with additive gene effects. Hence, classical breeding systems which made use of additive genetic variance would be effective here.

10. CONTROL NUMBER: PN-AAB-837

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Beans
Combining
Correlations
Mungbeans?
Regression analysis

13. PROJECT NUMBER

14. CONTRACT NUMBER: CSD-1921 211(d)

15. TYPE OF DOCUMENT

AID 890-1 (4-74)

PN-AAF-527

REPRINTED FROM

TROPICAL AGRICULTURE

THE JOURNAL OF THE FACULTY OF AGRICULTURE (IMPERIAL COLLEGE OF TROPICAL AGRICULTURE) UNIVERSITY OF THE WEST INDIES

Published on behalf of the Faculty by
IPC SCIENCE AND TECHNOLOGY PRESS LTD
GUILDFORD
1975

Regressions, correlations, and combining ability in mung beans (Vigna radiata (*L.*) *Wilczek*)*

J. M. YOHE† and J. M. POEHLMAN

Department of Agronomy, University of Missouri, Columbia, Missouri 65201, U.S.A.

Five mung bean (*Vigna radiata* (L.) Wilczek) strains, selected for their diverse plant characteristics and origins, were evaluated for ten variables in a diallele experiment using regression coefficients, correlations, and combining ability estimates. Regression coefficients were high, indicating large additive effects for most of the variables. Yield was positively correlated with number of pods per plant, number of seeds per pod, 1000-seed weight, and plant size as measured by plant height and branch length, and negatively correlated with virus score. Negative correlations of yield with late flowering and mildew score were non-significant. Genetic variability among F_1 plants for the ten variables was largely accounted for by highly significant general combining ability (*GCA*) effects, although specific combining ability (*SCA*) effects were observed for five traits. *GCA* effects were much larger than *SCA* effects, *SCA* effects being non-significant in general, suggesting that the variables are predominantly controlled by loci with additive gene effects. Hence, classical breeding systems which made use of additive genetic variance would be effective here.

INTRODUCTION

BREEDING improvement of the mung bean (*Vigna radiata* (L.) Wilczek) has been limited mostly to examination of varietal differences and selection within local strains. Genetic investigations of the mung bean likewise have been sparse and few of these have been devoted to economic characters or to type of gene action such as would be useful to the breeder in developing a hybridization programme.

Genetic variability within the mung bean species has been studied by BANKS (1958), BHARGAVA *et al.* (1966), GUPTA and SINGH (1970), SINGH and MALHOTRA (1970b) and YOHE and POEHLMAN (1972). Each reported a sufficiently wide range of genetic variability in economically important

* Contribution from the Department of Agronomy, University of Missouri, Columbia, U.S.A., based on a Thesis submitted by the senior author in part fulfilment of the requirements or the Ph. D. degree, and published as Missouri Agricultural Experiment Station Journal Series No. 7188.
† Present address: Crop Improvement Research Center, Office of Rural Development, Suwom, Korea 170.

characters to be useful in a mung bean breeding programme. The heritabilities of several quantitative characters in five mung bean crosses were examined by EMPIG *et al.* (1970). Broad sense heritabilities in the F_2 ranged from 71·2 per cent for days to maturity to 8·6 per cent for seed yield. Among the yield components, seed weight had the highest heritability (51·2 per cent) followed by pods per plant (24·6 per cent), and seeds per pod (10·0 per cent).

SINGH and BHATNAGAR (1965) studied the relationship of flowering date to maturity and obtained a correlation of 0·78 between them. SINGH and MALHOTRA (1970a) using multiple regression analysis, indicated that pods per plant, seeds per pod and seed size were the most important characters determining yield in mung beans. CHANDEL *et al.* (1973) reported that days to flower, pods per plant, pods per peduncle and seed weight had direct positive effects on yield in mung beans. From a diallele cross with mung beans SINGH and JAIN (1971a) estimated combining ability and gene effects for yield and the two yield components, seeds per pod and pods per plant. They reported both general combining ability (*GCA*) and specific combining ability (*SCA*) effects to be important for all of the traits and that grain yield and the two yield components were influenced by both additive and non-additive gene action. In a separate report SINGH and JAIN (1971b) stated that *GCA* was important for pod length, whereas both *GCA* and *SCA* were important in determination of seed size.

In 1970, we grew 321 mung bean strains from the United States Department of Agriculture mung bean germplasm collection and noted considerable variation among the strains in yield, flowering date, plant size, seed size and disease reaction (YOHE and POEHLMAN, 1972). In the development of a mung bean breeding programme it would be useful to have information on the combinations of these characteristics that would be associated with high yield. To obtain this information we initiated the investigations reported here. Our specific objectives were to obtain estimates of heritability, to examine the relationships among characters, and to measure estimates of general and specific combining ability for each of the ten variables under study.

MATERIALS AND METHODS

Five strains of mung bean, M101, M304, M317, M299, and M277 (accession numbers of the Missouri Agricultural Experiment Station; United States Department of Agriculture Plant Introduction (P.I.) numbers are listed in *Table 1*) selected for diverse plant characteristics, were used as parental lines in a diallele experiment. Comparative data for the parent varieties are presented in *Table 1*. Crosses were made in all possible combinations, excluding reciprocals, to produce a 5×5 diallele. The five parents and ten single crosses were grown in 1971 in a randomized complete block design with five replications at the Agronomy Research Center, Columbia, Missouri. A plot consisted of eight plants in a single row with spacings of 1·5m between rows and 45cm between plants within the row. Seeds were inoculated with a commercial culture of rhizobium before planting. A herbicide, chloramben, was applied at the time of planting at the rate

Table 1. Comparative performance for ten variables of five mung bean parent cultivars used in a diallele cross (data for three years, 1970–72, at Columbia, Missouri)

USDA P.I. No.	*Missouri accession No.*	*Origin*	*Yield (kg/ha)*	*No. of pods per plant*	*No. of seeds per pod*	*1000-seed weight (g)*	*Days to first flower*	*Days to first ripe pod*	*Plant height (cm)*	*Branch length (cm)*	*Virus* score*	*Mildew† score*
271401	M101	India	1938	103	12·3	73	52	72	50	55	0·7	2·6
273487	M304	Korea	1150	76	13·0	56	51	72	59	46	15·7	4·1
298915	M317	China	1712	109	13·7	64	53	75	70	62	20·3	3·9
271405	M299	India	665	67	10·0	37	42	58	39	30	8·3	5·0
246130	M277	Madagascar	471	39	9·8	43	61	81	66	52	43·0	3·8

* Visual estimation of virus symptoms on the basic of 1 (highly resistant) to 100 (highly susceptible

† Visual rating for mildew on leaves at maturity based on a score of 1 (highly resistant) to 5 (highly susceptible)

of 3·37 kg/ha. Pods were harvested separately from each plant and dried at a temperature of 35°C. Observations were recorded on each plant for the following variables. Yield (g): weight of threshed cleaned seed. Pod number per plant: number of mature pods. Seed number per pod: mean of 10 randomly selected pods. 1000-seed weight (g): weight of 100 randomly selected seeds × 10. Days to first flower: number of days from planting to first open flower. Days to first ripe pod: number of days from planting to first ripe pod. Plant height (cm): height of the main axis. Branch length (cm): length of the first or lower lateral branch. Virus score: visual estimate on the basis of 1 (no symptoms) to 100 (highly susceptible). Virus symptoms were identified by leaf mosaic, leaf crinkling, plant stunting, and flower abortion. Identification of the specific virus (or viruses) could not be made. Mildew score: visual rating of mildew on leaves at maturity on the basis of 1 (resistant) to 5 (highly susceptible). Regressions of the means of the F_1 plants on their respective mid-parent means were calculated to give an estimate of heritability in the narrow sense according to FALCONER (1960). Phenotypic correlation coefficients were calculated among all variables. Combining ability analyses were computed according to GRIFFING (1956) Method 4, Model I, since only one set of F_1 plants was included. A separate 'parent *versus* F_1' comparison was made since parents were not included in the calculation of combining ability effects.

RESULTS AND DISCUSSION

Regression coefficients

Regression coefficients of mid-parents with F_1 means for the ten variables in the five parent diallele are listed in *Table 2*. High regression coefficients with values approaching 1·0 were obtained for pods per plant, 1000-seed weight, days to first ripe pod, branch length, and mildew score, indicating strong additive gene effects for these variables. These data support results reported by BHARGAVA *et al.* (1966), EMPIG *et al.* (1970), and SINGH and MALHOTRA (1970a). Regression coefficients with *b* exceeding 1·0 were obtained for yield, days to first flower, and plant height indicating both additive and non-additive gene effects for these variables. The regression

Table 2. Regression coefficients of mid-parent with F_1 mean for ten variables in a five parent diallele cross with mung beans

Variable	*Midparent-progeny regression, b*
Yield	1·666 ± 0·117*
Pods per plant	0·766 ± 0·166*
Seeds per pod	0·220 ± 0·173*
1000-seed weight	0·709 ± 0·096*
Days to 1st flower	1·085 ± 0·183*
Days to 1st ripe pod	0·923 ± 0·151*
Plant height	1·317 ± 0·234*
Branch length	0·911 ± 0·216*
Virus score	0·484 ± 0·129*
Mildew score	0·994 ± 0·252*

* Significant at the 0·05 level of probability when $n = 50$

Table 3. Correlation coefficients among ten variables in a five parent diallele cross of mung beans

Variable	*Yield*	*No. of pods per plant*	*No. of seeds per pod*	*1000-seed weight*	*Days to first flower*	*Days to first ripe pod*	*Plant height*	*Branch length*	*Virus score*	*Mildew score*
Yield	1·000									
No. of pods per plant	0·878*	1·000								
No. of seeds per pod	0·601*	0·474*	1·000							
1000-seed weight	0·764*	0·473*	0·574*	1·000						
Days to 1st flower	−0·051	−0·304*	0·025	0·201	1·000					
Days to 1st ripe pod	−0·137	−0·383*	−0·028	0·141	0·983*	1·000				
Plant height	0·432*	0·367*	0·349*	0·443*	0·525*	0·467*	1·000			
Branch length	0·607*	0·554*	0·382*	0·543*	0·371*	0·300*	0·900*	1·000		
Virus score	−0·630*	−0·633*	−0·497*	−0·406*	0·409*	0·496*	−0·165	−0·261*	1·000	
Mildew score	−0·117	0·027	−0·073	−0·261*	−0·410*	−0·380*	−0·130	−0·190	−0·106	1·000

* Significant at the 0·05 level of probability

coefficients for seeds per pod and virus score were low, indicating some additive effects for these variables. EMPIG *et al.* (1970) reported the broad sense heritability (*BSH*) of seeds per pod was lower than *BSH* for the other yield components, pods per plant and 1000-seed weight.

Correlation coefficients

Correlation coefficients among the ten variables in the five parent diallele cross of mung beans are reported in *Table 3*. Yield was positively correlated with each of the primary components of yield, pods per plant, seeds per pod, and 1000-seed weight. Positive correlations were obtained also among the yield components. Yield is generally considered to be complex in its inheritance and low in heritability. Primary components of yield may be less complex in inheritance and the heritability of the components would generally appear to be greater than for yield *per se*. The high correlation between yield and its primary components, in general, support the heritability studies in the assumption that a major portion of the genotypic variance is additive. It also suggests that selection for each yield component will contribute towards yield improvement.

Correlations of yield with the maturity variables, days to flower and days to first ripe pod, were negative and non-significant. The significant negative correlations between number of pods per plant and days to flower and days to ripe pods suggest that earlier plants had more time in which to set pods.

The variables concerning plant size, plant height and branch length, were positively correlated with yield, the primary yield components (pods per plant, seeds per pod, and seed weight) and the variables concerned with maturity (days to flower and days to first ripe pod). Plant size is important because it provides the physical capacity to support a large number of pods and generate a higher yield. Plant size may be associated with late maturity because a delay in flowering would result in a longer period of vegetative growth.

Yield and the components of yield were significantly and negatively correlated with virus score, indicating that the virus disease adversely affected the expression of each component as well as total yield. An increase in virus also delayed flowering as shown by the positive correlation between days to flower and virus score. The effect of mildew on yield and the yield components was less pronounced than the effect of the virus, a weak negative correlation with seed weight being the only correlation with mildew that was significant. The mildew disease developed late in the season after many of the pods had been formed, so the effect of mildew on pods per plant and seeds per pod was small but mildew did reduce seed weight.

Diallele analyses

All of the variables showed highly significant genotypic differences in the analysis of variance of the diallele population (*Table 4*). The genetic variability among F_1 plants for all variables was accounted for largely by highly significant *GCA* effects. Although *SCA* effects were observed for five variables, the *GCA* effects were much larger in magnitude indicating

Table 4. Mean squares for ten variables in a five parent diallele cross of mung beans

Source of variation	*Degrees of freedom*	*Yield per plant*	*No. of pods per plant*	*No. of seeds per pod*	*1000-seed weight*	*Days to first flower*	*Days to first ripe pod*	*Plant height*	*Branch length*	*Virus score*	*Mildew score*
Replications	4	148·8	970·9	4·0	8·2	4·5	6·6	17·3	45·4	40·5	34·8**
Entries	14	3872·9**	6914·1**	18·0**	576·6**	259·5**	246·6**	496·9**	364·0**	669·4**	24·8**
Parents	4	5378·1**	8697·7**	36·7**	1216·4**	277·8**	341·3**	381·0**	434·4**	1371·2**	10·5
F_1 plants	9	3272·7**	4157·8**	9·5**	336·5**	272·7**	216·2**	522·7**	304·4**	331·1**	32·4**
GCA	4	7049·5**	7917·4**	18·7**	704·4**	563·6**	450·6**	1067·6**	575·3**	478·4**	57·5**
SCA	5	251·4	1150·9	2·2	42·3*	40·0*	28·6*	86·8*	87·8	213·2**	12·4
Parents vs. F_1 plants	1	3251·5**	24585·4**	19·5**	177·7**	67·3	141·3**	729·1**	618·1**	907·2**	15·6
Error	56	127·9	543·3	2·9	16·5	12·5	10·9	35·6	39·2	66·0	5·9

* Significant at the 0·05 level of probability
** Significant at the 0·01 level of probability

Table 5. Estimates of general combining ability effects for ten variables in a five parent diallele cross of mung beans

Variable	Parent					Standard error		Least significant difference	
	M101	*M304*	*M317*	*M299*	*M277*	*1*†	*2*‡	*1*†	*2*‡
Yield	35·262*	−4·881*	3·243*	−21·104*	−12·520*	2·613	4·131	5·236	8·278
No. of pods per plant	39·962*	−14·658*	−3·261	−6·265*	−15·777*	5·384	8·512	10·789	17·058
No. of seeds per pod	1·030*	0·830*	−0·080	−1·787*	−0·153	0·225	0·619	0·451	1·241
1000-seed weight	8·918*	0·497	2·147*	−10·059*	−1·503*	0·938	1·483	1·880	2·973
Days to 1st flower	0·153	0·400	1·333*	−9·503*	7·617	0·816	1·290	1·634	2·584
Days to 1st ripe pod	−0·154	0·418	1·262*	−8·418*	6·892	0·761	1·203	1·525	2·411
Plant height	1·643*	−4·643	5·140*	−11·834	9·694*	1·378	2·179	2·761	4·366
Branch length	4·529	−3·629*	1·979	−8·911*	6·032	1·446	2·287	2·899	4·583
Virus score	−7·433*	3·360	−4·185*	1·959	6·299	1·876	2·966	3·760	5·945
Mildew score	−0·062*	−0·019	0·067	0·064	−0·051*	0·018	0·028	0·036	0·056

* Significant at the 0·05 level of probability
† SE 1 and LSD 1 = standard error and least significant difference between effect and zero
‡ SE 2 and LSD 2 = standard error and least significant difference between two effects

the absence of average *SCA* effects of practical significance, except possibly for virus score.

Estimates of *GCA* effects associated with each of the parent varieties for the ten variables are presented in *Table 5*, along with the appropriate standard errors and LSD values. As measured in the diallele, *GCA* variance is composed of additive plus part of the additive interaction variances. *SCA* variance is composed of dominance and remaining interaction variances. On the basis of this assumption the present results are in agreement with those of SINGH and JAIN (1971a, b) who found that most of the total genetic variability for a number of characters in mung bean crosses was due to additive effects of genes. Here, the occurrence of significant *SCA* effects for five variables suggests that the genetic variation present for those variables was due in part to non-additive effects. However, since *GCA* variation was generally much greater than the *SCA* variation, we may conclude that the variables are predominantly controlled by loci with additive gene effects. Hence, classical breeding systems which make use of additive genetic variance would be effective for modification of the components of yield and other variables discussed here.

Considering estimates of the *GCA* effects for yield and the components of yield, the best parent among the present set was M101. Selection for increased number of seeds per pod, or 1000-seed weight, within populations arising from the crosses M101 × M304 and M101 × M317, respectively, might be expected to result in improved yield since M101 and M317 exhibited the highest *GCA* effects for 1000-seed weight.

Since M299 was the only parent having negative (earliness) *GCA* effects for early flowering and early pod maturity, the crosses involving this parent should provide a relatively broad range of segregants from which plants with earlier flowering and pod maturity could be selected.

The parent M277 has the highest *GCA* effect for plant height. Both M299 and M304 have negative *GCA* effects for branch length indicating that selections from their progenies should have shorter branches. Thus the crosses M277 × M304 and M277 × M299 should provide a broad range of segregants from which erect types with shorter branches could be selected. This was borne out by segregants selected in the F_2 population of the M277 × M304 cross, which were grown the following season.

In this study, strains M101 and M317 were the only parents having negative (resistance) *GCA* effects for the expression of virus symptoms. Progenies of crosses involving these two parents should offer an opportunity for selecting lines with improved virus resistance. Strains M101 and M277 had significant negative (resistance) *GCA* effects for mildew and would provide the best parents among those studied to contribute genes for mildew resistance to their progenies.

ACKNOWLEDGEMENT

This research was conducted with financial support received from the United States Agency for International Development.

(*Received January 1975*)

REFERENCES

BANKS, D. J. (1958). 'A classification of certain characteristics of mungbean strains as an aid to improvement'. *M.S. Thesis* Oklahoma State University, Stillwater (unpubl.)

BHARGAVA, P. D., JOHRI, J. N., SHARMA, S. K. and BHATT, B. N. (1966). 'Morphological and genetic variability in green gram'. *Indian J. Genet. Plant Breed.* **26**, 370–373

CHANDEL, K. P. S., JOSHI, B. S. and PANT, K. C. (1973). 'Yield in mungbeans and its components'. *Indian J. Genet. Plant Breed.* **33**, 271–276

EMPIG, L. T., LANTICAN, R. M. and ESCURO, P. B. (1970) 'Heritability estimates of quantitative characters in mungbean (*Phaseolus aureus* Roxb.)'. *Crop. Sci.* **10**, 240–241

FALCONER, D. S. (1960). *Introduction to Quantitative Genetics*. Ronald Press, New York

GRIFFING, B. (1956). 'Concept of general and specific combining ability in relation to diallel crossing systems'. *Aust. J. Biol. Sci.* **9**, 463–492

GUPTA, M. P. and SINGH, R. B. (1970). 'Genetic divergence for yield and its components in green gram'. *Indian J. Genet. Plant Breed.* **30**, 212–221

SINGH, B. and BHATNAGAR, P. S. (1965). 'Correlation studies in mungbean'. *Indian J. Genet. Plant Breed.* **25**, 105–107

SINGH, K. B. and JAIN, R. P. (1971a). 'Analysis of diallel cross in *Phaseolus aureus* Roxb.'. *Theoret. Appl. Genet.* **41**, 279–281

SINGH, K. B. and JAIN, R. P. (1971b). 'Combining ability for pod length and seed size in mungbean'. *Indian J. Genet. Plant Breed.* **31**, 145–148

SINGH, K. B. and MALHOTRA, R. S. (1970a). 'Estimates of genetic and environmental variability in mung. (*Phaseolus aureus* Roxb.)'. *Madras Agric. J.* **57**, 155–159

SINGH, K. B. and MALHOTRA, R. S. (1970b). 'Interrelationships between yield and yield components in mungbean'. *Indian J. Genet. Plant. Breed.* **30**, 244–250

YOHE, J. M. and POEHLMAN, J. M. (1972). 'Genetic variability in the mungbean, *Vigna radiata* (L.) Wilczek'. *Crop Sci.* **12**, 461–464