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Research Article

Interspecific hybridization of *Vigna radiata* x *13 wild Vigna* species for developing MYMV donar

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Abstract :
Mungbean (*Vigna radiata* (L.) Wilczek) is having a desirable characters like short duration, high protein, less anti nutritional factors, nitrogen fixing capacity, suitable for inter cropping, making many kinds of foods for higher human consumption and cosmetics products and some of the undesirable characters like low yield, low test weight.The aim of the study is to check crossabil;ity of *Vigna radiata* with all wild *Vigna* species and to create variability through wide hybridization and to develop superior segregants for yield component coupled with pest and disease resistance. The interspecific crosses were attempted with thirteen wild relatives of mungbean (*V. radiata)* were employed with *V. radiata* as male parent. The highest pod set of 25 and crossability of 21.92 per cent was recorded by the cross *V. radiata* x *V. radiata* var. *sublobata* and lowest pod set of 2.0 per cent recorded by the cross *V. radiata* x *V. dalzelliana* in the direct cross combinations. The highest pollen germination 69.72 per cent was recorded by *V. radiata* x *V. radiata* var. *sublobata.* The estimates of pollen fertility was sufficient enough to recover F_2 segregants in all the crosses combination.For all the traits in majority of the crosses, In the F_2 generation the skewness was positive indicating that predominance of dominant alleles. Among the direct crosses *V. radiata x V. mungo* var. *silvestris* exhibited highest value for four characters viz., number of clusters per branch, number of clusters per plant, number of pods per plant and single plant yield. The cross *V. umbellata* x *V. radiata* showed better performance for the characters viz., number of branches and number of clusters in reciprocal direction In advanced generation of *Vigna radiata x Vigna umbellata* cross combination has expressed virus resistance for nine seasons. The same line was tested by agro inoculation for confirmation of resistance and was resulted found effective resistance. This line can be used MYMV donar. Conclusion of the studies are mungbean is highly compatible with other wild *Vigna* species. Donor development for different stress is possible in mungbean.

Key words:
Interspecific hybridization, wild species, MYMV donar,skewness,kurtosis

Introduction

Vigna radiata (L.) wilczek, commonly known as green gram or mungbean is the most widely distributed species among the six Asiatic *Wild Vigna accessions*. It is one of the predominant sources of protein and certain essential amino acids like lysine and tryptophan in vegetarian diets. The basic reason for limited success had been due to the limited variability prevailed among the parents used for hybridization in most of the studies. There had been always possibility of improving the crop by incorporating wild genes to the cultivated species. Stepwise utilization of primary, secondary and tertiary gene pools of this crop can result in tremendous improvement in yield. For utilizing the variability available in the secondary and tertiary gene pools, it is essential to attempt interspecific crosses and to develop viable hybrids. These hybrids need to be critically evaluated as such and in the segregating generations for improvement in yield and yield components. The introgressed materials developed through wide crosses can also contribute as genetic reservoirs for novel genes apart from contributing to the improvement of yield and yield components. With a view to evaluate for attempting interspecific hybridization to generate segregants for better yield, this study was taken up keeping the objectives in mind such as to generate variability through interspecific hybridization involving *Vigna radiata* with species in secondary and tertiary gene pools and to compare the variability created for yield and yield components among segregants generated through interspecific hybridization.

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Materials and methods

For this study the following 13 wild *Vigna* species viz., *V.radiata* var *sublobata, V.mungo* var *silvestris, V .hainiana, V .umbellata, V. vexillata , V.trilobata, V. glabrescense, V. pilosa, V. acconitifolia, V. stipulacea, V. bournea, V. khandalensis and V. dalzelliana* were utilised for direct crosses with *V. radiata* as female and six *Wild Vigna species viz.,* *V.radiata* var *sublobata, V.mungo* var *silvestris, V .hainiana, V .umbellata, V. vexillata and V.trilobata* as male reciprocal cross. *Vigna radiata* and thirteen wild *Wild Vigna species* were raised during Rabi 2001-2002 in a crossing block. The direct and reciprocal crosses were effected following the method suggested by Boling *et al. (*1961) for hybridization. The hybrid plants were tagged based on contrasting traits of their corresponding parents and selfed ones were rejected. The number of hybrid plants survived over germinated seeds were taken to assess the leathality of F_1 hybrids or hybrid lethality. The set seeds from the above mentioned crosses were sown in 2 rows along with one row of male and female parents with a spacing of 50 x 20 cm during summer 2003.Thirteen quantitative traits viz., . Plant height (cm), Number of branches per plant, Length of branches (cm), Days to 50 per cent flowering , Number of clusters per branch, Number of clusters per plant , Number of pods per plant , Pod length (cm), Number of seeds per pod, Hundred seed weight (g) , Grain yield per plant (g),. Dry matter production and Days to maturity were recorded for all hybrids. The pollen fertility analysis was carried out in the parents and their hybrids by acetocarmine staining technique based on the following formula.

$$\text{Pollen fertility} = \frac{\text{No. of viable pollens}}{\text{Total no. of pollens observed}} \times 100$$

The seeds from individual F_1 plants were collected separately and were sown as progeny rows during kharif 2003. Observation for all the quantitative traits as that of F_1 generation except the 50 per cent flowering and days to full maturity were recorded. The descriptive parameters such as mean, range, SE, SD, skewness and kurtosis were computed. The frequency distribution of the F_2 segregants for seven traits that are significantly correlated with single plant yield viz.,, number of branches per plant, length of branch, number of clusters per branch, number of clusters per plant, number of pods per plant and hundred seed weight was examined.

Results

The result of crosses pertaining to crossability, pollen fertility, incompatibility barriers, F_1 and F_2 mean are furnished below.. The result of number of seed set and extent of germination in different interspecific crosses attempted are presented Table 1. In direct cross combinations, the highest pod set of 25 and crossability of 21.92 per cent were recorded by the cross *V. radiata* x *V. radiata* var. *sublobata* and lowest pod set of 2.0 per cent recorded by the cross *V. radiata* x *V. dalzelliana.* 115 pollinations were effected which resulted in 8 (6.95%) pods with 40 shrivelled seeds in the cross Vigna radiata x V. mungo var silvestris (Table 1&2). Germination was 35 % and only seven plants were attained maturity. The hybrid leathality and break down percentage were 50.00 per cent (Table 2). The highest number of crossed seeds of 95 was obtained in the direct cross *V. radiata* x *V. radiata var. sublobata* while lowest seed of 2 in the cross *V. radiata* x *V. dalzelliana* The germination percentage of the cross combination *V. radiata* x *V. radiata* var. *sublobata* is 60 and lowest germination percentage is 16.6 in cross V.radiata x V. dalzelliana. Among the crosses made *V. radiata* x *V. hainiana* recorded the highest hybrid germination is 80.00 per cent . (Table 2). In reciprocal cross combinations, the highest pod set of 21.0 and percentage of the pods set of 11 was recorded by the cross V.hainiana x V. radiata and lowest in V. vexillata x V. radiate pod set is 3.0 and podset percentage is 2.8. The highest germination recorded by the cross V. vexillata x V. radiata is 50 per cent and seven plants were attained maturity and lowest germination per cent of 13.33 per cent was recorded by the *V. umbellata* x *V. radiata* with two plants attained maturity (Table 2). Even though crossability barriers were predominant, it was possible to recover interspecific hybrids from all 13 direct and six reciprocal crosses. The percentage of leathality in the F_1 varied from 10 per cent (*V. radiata* x *V. glabresense*) to 56.14 (*V. radiata* x *V.radiata* var. *sublobata*) and hybrid break down ranged from 13.33 (*V. umbellata* x *V. radiata*) to 80 per cent (*V. radiata x V. mungo var silvestris*) . High percent of hybrid break down (43.86) was observed in the *Vigna radiata x V. radiata var sublobata* cross whereas *Vigna hainiana* x *V. radiata* recorded 100 per cent low and unviability F_1 seed. Higher percentage of hybrid leathality recorded by two crosses namely *V. radiata x V. mungo var. silvestris and Vigna radiata x V. khandalensis* in direct crosses combinations.

In direct cross combinations, the highest pollen germination 69.72 per cent was recorded by *V. radiata* x *V. radiata* var. *sublobata.* The lowest of 22.5 per cent was recorded by the cross V. radiata x V. glabresense. Pollen fertility status of parents and F_1 hybrids in the interspecific crosses of *Wild Vigna accessions* were studied under compound microscope. In the reciprocal cross combinations, the cross V. trilobata x V. radiata recorded the highest pollen germination of 56.78 percent and lowest of 15.0 per cent observed in the cross V. mungo var. silvestris x V. radiata (Table 2). The estimates of pollen fertility was sufficient enough to recover F_2 segregants in all the cross combinations.

The mean performance of parents and their hybrids for 13 quantitative traits recorded in both direct and reciprocal crosses are presented in Table 4. For quantitative traits of direct cross combinations the interspecific cross V. radiata x V. bournea recorded highest mean performance for the traits like plant height (78.0 cm), no. cluster per branch (5.0), no. cluster per plant (12.0) and dry matter production (45.2).The single plant yield of 15 g was recorded by *V. radiata x V. trilobata* and 3.5 g of hundred seed weight recorded by the cross combination is V. radiata x V. pilosa. The cross *V. radiata x V. vexillata* has recorded 8.5 cm for the trait of pod length, while the male parent recorded 16.5 cm. The cross V. radiata x V. stipulacea was observed for 32 days to 50 per cent flowering while many other cross combinations recorded 50 days to 50 per cent flowering (Table 3).

In reciprocal cross combinations, the cross *V. umbellata* x *V. radiata* exhibited high *per se* performance for two traits like number of branches per plant and hundred seed weight For seed yield and no. of seeds per plant , the hybrid of the cross *V.vexillata* x *V. radiata has* registered the highest mean value of 5g per plant and 15.2 among the reciprocal crosses respectively (Table 3). Mean performance of different yield contributing characters of wild *Wild Vigna species* in F_2 segregants of both direct and reciprocal crosses (Table .4). The number of branches per plant ranged from 0.90 (*V.radiata* x *V. vexillata*) to 2.73 (*V. trilobata* x *V. radiata*). The mean value for the length of branches per plant varied from 10.54 (V.radiata x V. vexillata) to 25.20 (V. hainiana x V. radiata) with over all mean of 19.21 for F_2 segregants. The traits viz., number of clusters per branch ranged from 1.00 (*V.mungo var. silvestris* x *V. radiata*) to 4.14 *(V.radiata* x *V. mungo* var. *silvestris)* with the over all mean of 2.37. Number of clusters per plant, number of clusters per plant ranged from 2.20 (*V. vexillata* x *V. radiata*) to 8.50 ((*V. radiata* x *V. mungo* var. *silvestris*) with over all mean of 5.25 among the crosses. Number of pods per plant , the range was found to be between 4.30 (*V.vexillata x V.radiata*) to 27.87 (*V.trilobata* x *V.radiata*) with the over all mean value of 17.15. The cross *Vigna radiata x V. trilobata* recorded highest mean value of 26.88 for number of pods per plant among direct crosses. The hundred seed weight ranged from 1.70 (*V.trilobata x V.radiata*) to 3.43 g (*V.vexillata x V. radiata*) with the over all mean of 2.47 g for F_2 segregants. Single plant yield, the seed yield ranged from 0.93 g (*V.mungo var. silvestris x V.radiata*) to 5.21 g (*V.radiata* x *V. mungo* var. silvestris) with a over all mean of 3.25 g for F_2 segregants. For most of the direct as well as reciprocal crosses, the F_2 progenies revealed high *per se* performance and also exhibited high variability for seven yield contributing traits.

For all the traits in majority of the crosses, In F_2 generation the skewness was positive indicating that predominance of dominant alleles (Table 5), Among the direct crosses *V. radiata x V. mungo* var. *silvestris* exhibited highest value for four traits viz., number of clusters per branch, number of clusters per plant, number of pods per plant and single plant yield. The cross *V. umbellata* x *V. radiata* showed better performance for the traits viz., number of branches and number of clusters in reciprocal direction The cross *V. trilobata* x *V. radiata* recorded the best performance for two traits viz., number of clusters per plant and number of pods per plant.

Discussion

In the present investigation with an objective to transfer useful traits from the wild relatives into greengram, interspecific hybridization was attempted. The extent of crossability, fertility of hybrids and possibility of obtaining superior recombinants in F_2 generation through recombination of genes were studied. The wild relatives of greengram such as *V. umbellata, V. vexillata* and *V. trilobata* possess desirable genes for many yield components coupled with resistance to bruchids and MYMV. Transferring of these genes into cultivated species, could result in development of high yielding resistant types. The use of wild *Vigna accessions* in greengram breeding programme has been difficult because of problems encountered in obtaining successful F_1 hybrids due to crossability barriers. In spite of these difficulties, wide hybridization between *V. radiata* and its wild relatives was successfully accomplished by many workers Renganayaki (1985), Pandae *et al.* (1990), Ganeshram (1993) and Subramanian and Muthiah. (2000). Umamaheswari (2002), Crossability is a pre-requisite for gene transfer in wide hybridization. An understanding of crossability relationship among the species had been helpful not only in choosing methods for producing F_1 hybrids, but also in tracing phylogenic relationship among species.

In the present study, successful pod set was observed in all the 13 interspecific crosses with *Vigna* radiata either as ovule or pollen parent. This result is in agreement with the reports of Ahuja and Singh (1977), Parida and Singh (1985), Gopinathan *et al.* (1986), Egawa *et al.* (1990), Mendioro and Ramirez (1994), and James *et al.* (1999). The percentage of lethality among interspecific hybrids varied from 0.00 to 56.14 per cent . Similar observations on hybrid leathality and inviability were noticed in interspecific crosses involving different *Wild Vigna accessions* by AL- Yasiri and Corijne (1966), Chen *et al.*(1989), Chen *et al.* (1982), Adinarayanamurthy *et al.* (1993), Umamaheshwari (2002), Ganeshram (1993) and Renganayaki (1985). Stebbins (1958) had attributed the hybrid weakness, inviability, lethality and sterility as mechanisms of nature for maintaining the integrity of related species.

In general, the pollen fertility among the direct crosses were higher as compared to their corresponding reciprocal crosses which indicated that the approach using the cultivated species as a female parent is likely to generate better hybrids and segregants . Similar results were also reported by various authors for differential pollen fertility among interspecific crosses of *Wild Vigna accessions* (Pandae *et al.,* 1990, Mendioro and Ramirez, 1994, Ravi *et al.,* 1987, Anandabaskaran and Rangasamy, 1996, Subramanian and Muthiah 2001, Monika *et al.*,2001, Umamaheshwari, 2002 and Sidhu and Satija, 2003). Among crosses , the pollen fertility was highest in the cross *V. radiata* x *V. radiata* var. *sublobata* and this observation support the view of Pandae *et al.*(1990) and Mendioro and Ramirez (1994) that *V. radiata* var. *sublobata* is the probable proginator for *V. radiate.* The range of pollen fertility observed in all the F_1 hybrids was high enough to obtain sufficient viable F_2 segregants. The primary criterion used for the evaluation of hybrids was the *per se* performance for different traits. In the present study, among the crosses, the reciprocal cross *V. umbellata x V. radiata* exhibited high mean value for important traits *viz.,* number of branches per plant, hundred seed weight and dry matter production.

The reciprocal cross *V. vexillata x V. radiata* exhibited higher mean performance for three traits *viz.,* length of pod, number of pods per plant and single plant yield while the hybrid of direct cross of same parents exhibited high value for three traits in the desirable direction *viz.,* length of pod and days to full maturity and 50 per cent flowering. The hybrid of the direct cross *V. radiata* x *V. radiata* var. *sublobata* recorded high *per se* performance for the traits viz., plant height and length of branch while the higher number of clusters per branch and number of pods per plant were recorded in the reciprocal crosses. Hybrid of the cross *V. radiata* x *V. mungo* var. *silvestris* registered higher number of branches per plant, number of cluster per plant and number of pods per plant. For seed yield, the hybrid of the cross *V. radiata* x *V. trilobata* registered the highest mean value among direct crosses. Hence , the segregants that could be recovered from these promising interspecific hybrids might serve as better breeding base for improvement of yield and yield components. Such promising interspecific hybrids were also reported by Umamaheswari (2000), Subramaninan and Muthiah (2001) and Ganeshram (1993).

For most of the direct as well as reciprocal crosses, F_2 progenies revealed high *per se* performance and also exhibited high variability for seven yield contributing traits. For all the traits in majority of the crosses, the skewness was positive indicating that predominance of dominant alleles as opined by Fisher *et al.* (1967) and Darbeshwar Roy (2000). In this situation, selection for traits in the early generation will not be fixable and desirable hence selections, in later generations or by adopting modified breeding procedures such as intermating and also break any undesirable linkages between yield and resistance the segregants may shift the gene action towards additive effects. Since sterility factors will gradually reduce over generations in case of interspecific crosses and more recombined populations will be available for selection, the effecting selection in the later generation will be more effective.

Conclusion

All the wild *Vigna* species are flexible with *Vigna radiata* by means of crossability which shows V, radiata is genetically compatible with all wild Vigna species. Based on the crossability percentage we clearly understood that V. radiata var. sublobata, V. mungo var silvestris, V. hainiana, V. trilobata, V. stipulacea, V. acconitifolia, V. glabrescense , V. khandalensis and V. umbellata are very closely related to *Vigna radiata*. The species V. vexillata, V. bounea, and V. dalzelliana are keep some distance from the *Vigna radiata*. For the improvement of other *Vigna* cultivated species , *Vigna radiata* can be used as bridging species.

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Table.1. The pod set and crossability percentage of *Vigna* species crosses.

Parents	***V. radiata* var. *sublobata***			***V. mungo* var. *silvestris***			***V. haineana***			***V.umbellata***			***V. vexillata***			***Vigna trilobata***		
***V.radiata* (female)**	**Crosses**	**Pod set**	**%**	**Crosses**	**Pod set**	**%**	**Crosses**	**Pod set**	**%**	**Crosses**	**Pod set**	**%**	**Crosses**	**Pod set**	**%**	**Crosses**	**Pod set**	**%**
	114.0	**25.0**	**21.9**	**115.0**	**8.0**	**6.9**	**230.0**	**18.0**	**7.8**	**280.0**	**31.0**	**11.0**	**205**	**8.0**	**3.9**	**110.0**	**8.0**	**7.2**
***V. radiata* (male)**	**225.0**	**15.0**	**6.6**	**105.0**	**5.0**	**4.7**	**190.0**	**21.0**	**11.0**	**152.0**	**8.0**	**5.2**	**105**	**3.0**	**2.8**	**95.0**	**5.0**	**5.2**

Parents	*V. glabrescense*			*V. pilosa*			*V. acconitifolia*			*V. stipulacea*			*V. bournea*			*V. khandalensis*			*V. dalzelliana*		
***V.radiata* (female)**	**Crosses**	**Pod set**	**%**	**Crosses**	**Pod set**	**%**	**Crosses**	**Pod set**	**%**	**Crosses**	**Pod set**	**%**	**Crosses**	**Pod set**	**%**	**Crosses**	**Pod set**	**%**	**Crosses**	**Pod set**	**%**
	100	**8.0**	**8.0**	**50**	**2.0**	**4**	**100**	**2.0**	**2.0**	**100**	**11.0**	**10.0**	**100**	**5.0**	**5.0**	**25**	**2.0**	**8.0**	**100**	**2.0**	**2.0**

Table 2.Germination percentage of parents and F_1 hybrids for direct and reciprocal crosses

Parents and Crosses	No. of crossed seeds obtained/ no. of seeds per parent	No. of seeds germinated	Hybrid leathality (%)	% of hybrid break down	% of germination	No. of seedlings attained maturity
V.radiata	50	48	-	-	96.00	45.00
V.radiata var *sublobata*	30	15	-	-	50.00	12.00
V.mungo var *silvestris*	20	05	-	-	25.00	4.00
V .hainiana	50	30	-	-	60.00	25.00
V .umbellata	50	45	-	-	90.00	35.00
V. vexillata	25	18	-	-	72.00	9.00
V.trilobata	25	20	-	-	80.00	15.00
V. glabrescense	50	50	-	-	100.00	50.00
V. pilosa	08	06	-	-	75.00	3.00
V. acconitifolia	25	20	-	-	80.00	13.00
V. stipulacea	30	22	-	-	73.33	15.00
V. bournea	25	15	-	-	60.00	8.00
V. khandalensis	08	06	-	-	75.00	2.00
V. dalzelliana	06	05	-	-	83.33	3.00
V.rad x V.rad var sublobata	95	57	56.14	43.86	60.00	25.00
V.rad x *V.mungo* var *silvestris*	40	14	50.00	50.00	35.00	7.00
V. radiata x *V. Hainiana*	50	40	37.50	62.50	80.00	25.00
V. radiata x *V.umbellata*	28	07	28.58	71.42	25.00	5.00
V. radiata x *V.vexillata*	26	13	38.46	61.54	50.00	8.00
V. radiata x *V. Trilobata*	40	10	20.00	80.00	25.00	8.00
V. radiata x *V. glabrescense*	25	10	10.00	90.00	40.00	9.00
V. radiata x *V. pilosa*	12	03	33.34	66.66	25.0	2.00
V. radiata x *V. Acconitifolia*	15	08	12.50	87.50	53.3	7.00
V. radiata x *V. stipulacea*	18	09	11.22	88.88	50.0	8.00
V. radiata x *V. Bournea*	12	05	20.00	80.00	41.6	4.00
V. radiata x *V. khandalensis*	08	02	50.00	50.00	25.0	1.00
V. radiata x *V. Dalzelliana*	06	01	0.00	100.00	16.6	1.00
V.rad var *sublo* x *V.radiata*	25	04	25.00	75.00	16.00	3.00
V.mungo var *silv* x *V.radiata*	18	05	40.00	60.00	27.77	3.00
V.hainiana x *V.radiata*	52	10	40.00	60.00	19.23	6.00
V.umbellata x *V.radiata*	15	02	0.00	100.00	13.33	2.00
V.vexillata x *V.radiata*	18	09	22.22	77.78	50.00	7.00
V.trilobata x *V.radiata*	19	06	16.67	83.33	31.57	5.00

Table 3. Pollen fertility percentage of parents and F1 hybrids of interspecific crosses for *Wild Vigna accessions*

Parents and Hybrids	Pollen fertility (%)
V. radiata	**87.84**
V. radiata* var. *sublobata	**75.65**
V. mungo* var .*silvestris	**70.23**
V. hainiana	**81.75**
V. umbellata	**82.58**
V. vexillata	**69.54**
V. trilobata	**65.85**
V.radiata x ***V. radiata sublobata***	**69.72**
V. radiata x ***V.mungo* var. *Silvestris***	**60.00**
V. radiata x ***V. Hainiana***	**59.25**
V. radiata x ***V.umbellata***	**41.38**
V. radiata x ***V.vexillata***	**51.30**
V. radiata x ***V. Trilobata***	**43.5**
V. radiata x *V. glabrescense*	**22.5**
V. radiata x *V. pilosa*	**42.5**
V. radiata x *V. Acconitifolia*	**66.5**
V. radiata x *V. stipulacea*	**68.5**
V. radiata x *V. Bournea*	**55.3**
V. radiata x *V. khandalensis*	**52.3**
V. radiata x *V. Dalzelliana*	**35.5**
V.radiata* var. *sublobata* x *V.radiata	**49.86**
V. mungo* var. *Silvestris* x *V.radiata	**15.00**
V.hainiana x ***V.radiata***	**38.33**
V.umbellata x ***V.radiata***	**40.11**
V.vexillata x ***V.radiata***	**32.06**
V.trilobata x ***V.radiata***	**56.78**

Table.4. Mean performance of parents and hybrids both direct and reciprocal crosses

Parents	PHT	NOB	BRL	DFF	NCB	NOC	NPP	POL	NSP	HSW	SPY	DMP	DFM
V.radiata	45.5	3.0	38.5	38.0	4.0	10.0	45.0	8.80	12.0	3.8	5.85	25.5	65.0
V.radiata var sublobata	25.8	2.0	15.0	40.0	2.0	5.0	18.0	5.27	6.0	2.5	2.8	9.5	68.0
V.mungo var silvestris	15.0	1.0	10.5	42.0	2.0	8.0	10.0	3.5	5.0	2.5	1.5	4.2	70.0
V .hainiana	29.0	3.0	24.0	37.0	4.0	10.0	25.0	6.50	10.	2.2	4.2	5.8	66.0
V .umbellata	67.0	3.0	52.0	58.0	4.0	10.0	21.0	5.5	4.5	5.4	4.4	18.6	95.0
V .vexillata	25.0	1.0	14.0	55.0	1.0	3.0	8.0	16.5	15.5	4.2	4.8	8.8	85.0
V .trilobata	35.0	5.0	45.0	50.0	8.0	12.0	55.0	5.3	6.0	2.8	3.8	6.5	75.0
V.radiata xV.rad var. sublobata	44.0	2.0	29.0	42.0	2.0	5.0	30.0	5.5	8.0	2.4	1.5	10.7	70.0
V.radiata* x *V.mungo* var. *silvestris	39.0	3.0	15.0	40.0	2.0	7.0	35.0	5.5	11.0	2.0	1.8	4.0	68.0
V. radiata* x *V. hainiana	27.0	1.0	18.0	39.0	3.0	5.0	29.0	5.8	10.0	2.5	3.8	5.3	69.0
*V.*radiata x V.umbellata	65.0	2.0	20	38.0	3.0	8.0	14.0	6.2	5.0	3.2	4.3	23.0	35.0
V. radiata* x *V .vexillata	28.0	2.0	18.0	38.0	3.0	5.0	21.0	8.5	9.0	3.2	3.8	20	65.0
V. radiata* x *V. trilobata	25.0	2.0	10.0	48.0	2.0	4.0	15.0	7.5	8.0	2.8	15.0	3.0	68.0
***V. radiata* x** *V. glabrescense*	45.0	3.0	15.0	50.0	2.0	6.0	15.0	8.5	9.0	3.2	5.6	35.0	80.0
***V. radiata* x** *V. pilosa*	68.0	1.0	18.0	45.0	2.0	5.0	12.0	6.5	6.0	3.5	5.0	25.2	65.0
***V. radiata* x** *V. acconitifolia*	35.0	2.0	8.0	35.0	2.0	4.0	15.0	4.5	4.0	2.8	3.8	18.2	65.0
***V. radiata* x** *V. stipulacea*	25.0	3.0	10.0	32.0	2.0	5.0	12.0	3.5	4.0	1.9	2.5	12.2	60.0
***V. radiata* x** *V. bournea*	78.0	3.0	25.0	50.0	5.0	12.0	18.0	6.8	7.0	2.5	5.0	45.2	85.0
***V. radiata* x** *V. khandalensis*	30.0	1.0	7.0	35.0	2.0	8.0	11.0	3.5	3.0	3.2	2.1	15.0	60.0
***V. radiata* x** *V. dalzelliana*	55.0	3.0	15.0	50.0	3.0	12.0	18.0	2.5	3.0	1.5	1.2	25.0	80.0
V.radiata* var.*sublobata* x *V.radiata	25.3	2.0	18.5	45.0	3.0	8.0	35.0	6.5	8.6	3.5	2.5	15	69.0
V.mungo* var .*silvestris* xV .*radiata	18.4	2.0	12.2	48.0	2.0	6.0	26.0	3.2	3.3	2.8	1.8	18.3	72.0
V. hainiana* x *V.radiata	29.5	4.0	21.5	38.0	3.0	8.0	33.0	6.8	10.2	2.5	3.2	19.5	65.0
V .umbellata* x*V .radiata	48.5	4.0	36.8	55.0	3.0	8.0	28.0	5.8	6.6	5.5	3.5	25.6	85.0
V . vexillata* x *V.radiata	20.6	1.0	13.4	58.0	1.0	3.0	6.0	15.3	15.2	5.0	5.0	12.5	92.0
V.trilobata* x *V.radiata	18.5	1.0	12.5	42.0	2.0	3.0	18.0	4.5	5.0	2.5	2.5	8.0	69.0

PHT- Plant height (cm), BRL- Branch length (cm), DFF- Days to fifty percent flowering, NCB- Number of cluster per branch, NOC- Number of cluster per plant, NPP- Number of pods per plant, POL- Pod length, HSW- Hundred grain weight, SPY-Single plant yield, DMP- Dry matter production, DFM- Days to full maturity.

Table. 5. Mean performance of the yield contributing characters among F_2 families of interspecific crosses

Crosses	NOB	BRL	NCB	NOC	NPP	HSW	SPY
V.radiata* x *V . radiata* var. *sublobata	1.52	15.22	1.60	4.56	16.68	2.08	1.81
V.radiata* x *V. mungo* var.*silvestris	1.07	14.64	4.14	8.50	21.86	2.94	5.21
V.radiata* x *V.hainiana	2.00	22.68	2.20	7.83	23.75	2.32	4.39
V.radiata* x *V.umbellata	2.00	15.45	3.20	5.80	15.00	3.20	4.10
V. radiata* x *V. vexillata	0.90	10.54	1.63	3.18	12.00	2.35	3.17
V. radiata* x *V. trilobata	2.50	21.00	4.00	8.12	26.88	1.88	3.13
V. radiata* var. *sublobata* x *V.radiata	1.75	21.37	2.37	4.50	14.25	2.50	2.93
V.mungo* var. *silvestris* x *V.radiata	1.20	12.00	1.00	2.60	8.30	2.46	0.93
V.hainiana* x *V.radiata	2.20	25.20	1.60	4.00	23.60	2.23	4.61
V.umbellata* x *V.radiata	1.50	24.75	2.25	4.08	9.17	3.31	1.44
V. vexillata* x *V.radiata	1.40	22.00	1.40	2.20	4.30	3.43	4.99
V. trilobata* x *V.radiata	2.73	21.93	3.86	8.20	27.87	1.70	3.16
Mean	**1.71**	**19.21**	**2.37**	**5.25**	**17.15**	**2.47**	**3.25**

Table 6. Skewness and Kurtosis of yield contributing characters among F_2 families of interspecific crosses

Crosses	NOB		BRL		NCB		NOC		NPP		HSW		SPY	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
V.radiata* x *V . radiata* var. *sublobata	0.81	1.06	0.72	1.86	0.57	0.86	1.41	2.58	1.24	2.64	2.19	7.72	1.93	5.15
V.radiata* x *V. mungo* var.*silvestris	-0.02	0.30	-0.27	-0.45	3.37	11.97	2.98	9.66	3.52	12.82	-1.15	3.30	3.71	13.81
V.radiata* x *V.hainiana	1.05	1.92	-1.22	0.27	0.81	-0.97	0.23	-0.42	0.18	-0.43	0.71	-0.29	-0.03	-1.26
V.radiata* x *V.umbellata	-0.18	1.56	-0.12	-0.04	0.18	-0.59	0.35	0.65	0.12	-0.23	0.58	0.54	-0.02	-1.20
V. radiata* x *V. vexillata	-0.15	1.86	-0.52	-0.08	0.23	-0.96	0.69	0.77	0.15	-1.13	0.52	0.67	-0.09	-0.88
V. radiata* x *V. trilobata	0.46	-0.83	-0.67	-0.17	1.43	2.00	0.39	1.13	1.31	0.26	0.27	-0.30	0.61	-1.72
V. radiata* var. *sublobata* x *V.radiata	0.40	-0.22	0.44	-1.04	0.48	0.42	0.49	-0.99	-0.87	1.87	-0.38	0.22	-0.60	0.38
V.mungo* var. *silvestris* x *V.radiata	1.77	1.40	0.43	-1.13	0.00	0.00	1.95	4.18	0.18	-0.81	-0.65	-0.57	-0.12	-1.59
V.hainiana* x *V.radiata	-0.51	-0.61	-0.13	0.00	-0.60	-0.62	0.00	-0.30	0.59	-2.98	0.29	-0.73	1.06	1.12
V.umbellata* x *V.radiata	1.06	0.35	0.33	-0.26	0.97	0.37	1.23	1.47	0.45	-1.01	-2.64	8.30	0.90	-0.32
V. vexillata* x *V.radiata	0.48	-2.27	0.53	-0.53	0.16	0.48	1.77	1.40	-0.74	-1.60	-0.74	-0.64	0.03	-1.64
V. trilobata* x *V.radiata	0.55	-1.13	0.63	-0.58	0.29	-0.83	0.97	0.39	0.55	-0.80	-0.49	0.00	-0.49	0.00
Mean	**0.54**	**0.17**	**0.02**	**-0.19**	**0.70**	**1.16**	**1.10**	**1.81**	**0.60**	**0.80**	**--0.19**	**1.61**	**0.63**	**1.19**