International Journal of Plant Breeding ©2013 Global Science Books

Analysis of Variability, Correlation and Path Coefficients in Induced Mutants of Glory Lily (*Gloriosa superba* L.)

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ABSTRACT

Variability, correlation and path coefficients for 17 morphological characters were studied on morphologically distinct mutants of *Gloriosa superba* in the second generation of vegetative mutant (VM_2) along with their mother genotypes collected form Mulanur. The maximum GCV (1.24%), PCV (102.02%) was noticed for number of leaves/plant and number of secondary branches/plant. The maximum heritability (89.74%) and genetic advance was recorded for stem girth. The highest and positive correlation for dry seed yield/plant was observed with number of seeds/pod (0.928), number of leaves/plant (0.537), dry pod weight (0.454), fresh seed weight/pod (0.366), fresh pod weight (0.298), plant height (0.282) and number of secondary branches/plant (0.236). The path analysis of component characters on dry seed yield/plant of *G. superba* in the VM_2 generation exerted a direct positive effect through these characters: number of leaves/plant, dry pod weight, number of seeds/pod, fresh seed weight/pod.

Keywords: character association, path analysis, quantitative trait, variability

INTRODUCTION

Gloriosa superba L., a climber belonging to the Colchicaceae family, is a major high value medicinal crop cultivated in Tamil Nadu. Seeds and tubers of *Gloriosa* species contain valuable alkaloids *viz*., colchicine and colchicoside as the major constituents, which are used to treat gout and rheumatism (Nadkarni 1996). Due to the action of colchicine on spindle fibre formation during cell division, the plant has been identified as a potential anti-cancerous drug. On the Indian market, the annual trade estimated is 100-200 million tonnes and the price range is Rs. 600-750/kg (Ved 2007). The genetic variability of Glory lily is low owing to the continued vegetative propagation through tubers which has reduced the vigour, tolerance to biotic and abiotic stress, causing low yields (Rajadurai 2001). The growing demand (600 million tonnes) for the seeds of Glory lily in the international market and the wider popularity it has gained among the Indian farmers necessitates attempts to induce new variability with high yield, high colchicine content, dwarf stature and leaf blight resistant of the plant as well (Ved 2007). Traditional or conventional breeding has not been attempted so far as there are only local ecotypes of *G. superba* under cultivation and genetic wealth is limited. Therefore, generation of variability through mutagenic treatments is of paramount importance for improvement of Glory lily.

Production of a stable quality and quantity of these plants is important to growing world market, which make it necessary to breed varieties with high yield and quality. Seed yield is a quantitative trait and highly affected by environmental factors (Poormohammad Kiani *et al*. 2009). Plant breeders, commonly prefer yield components that indirectly increase seed yield (Yasin and Singh 2010). Correlation of a particular character with other characters contributing to seed yield is of great importance in indirect selection of genotypes for higher seed yield (Choudhry *et al*. 1986; Ali *et al*. 2003). Simple correlation analysis that relates seed yield to a single variable may not provide a complete understanding about the importance of each component in determining seed yield (Dewey and Lu 1959). Path coefficient analysis is a statistical technique of partitioning the correlation coefficients into its direct and indirect effects, so that the contribution of each character to yield could be estimated (Wright 1921; Dewey and Lu 1959). Path coefficient analysis have been widely used in plant breeding programs to determine the nature of the relationships between yield and yield components that are useful as selection criteria to improve crop yield. In most studies involving path analysis, researchers considered the predictor characters as first-order variables in order to analyze their effects over a dependent variable such as yield. This approach might result in multicolinearity for variables, and possibly make difficulties in interpretation of the actual contribution of each variable (Hair *et al*. 1995). Recently the sequential path coefficient analysis has been used by many researchers in different crops (Samonte *et al*. 1998; Mohammadi *et al*. 2003; Das *et al*. 2004; Rasool *et al*. 2007; Feyzian *et al*. 2009; Karuppaiah and Senthil Kumar 2010), for complete identification of impact of independent variables on dependent ones.

Selvaraj (1995) studied the genetic parameters, association analysis and regression analysis in garlic mutants. The results revealed that strong association was noticed for the bulb characters and clove characters on yield. In *Vetiveria zizanioides*, positive and significant correlations were found between oil yield and plant height, fresh and dry root yield in all the evaluation trails. The tendencies of the associations were found very stable and generally not influenced by the clonal selection (Lal and Sharma 2000). In *G. superba*, Rajadurai (2001) noticed higher heritability for plant height, number of pods and fresh weight of seeds. Low doses of mutagens exhibited high coefficient of variation for most of characters in M_1 and M_2 generation.

The aim of the present study was to generate information on character association, direct and indirect influence of characters on seed yield in the induced mutants of Glory lily.

Received: 31 August, 2012. Accepted: 14 November, 2012.

Original Research Paper

MATERIALS AND METHODS

Tubers of *G. superba* collected from Mulanur, Tamil Nadu, were subjected to three doses of gamma irradiation (0.50, 1.00, 1.50 kR at Gamma chamber - 900 installed at the Sugarcane Breeding Institute, Coimbatore), ethyl methyl sulphonate (1.0, 1.5 and 2.0%) and diethyl sulphonate (1.0, 1.5 and 2.0%). The experiment was conducted at the Department of Medicinal and Aromatic Crops, Horticultural College and Research Institute, Coimbatore during the first week of August, 2010 (VM_1 = first generation of vegetative mutant) and first week of August, 2011 (VM_2 = second generation of vegetative mutant). In the VM_2 generation, data was recorded on 18 plant characters *viz.*, plant height, stem girth, no. of leaves/plant, no. of primary branches/plant, no. of secondary branches/plant, no. of flowers/plant, pod length, pod girth, fresh pod weight, dry pod weight, fresh seed weight/pod, no. of seed/pod, 100 fresh seed weight, 100 dry seed weight, dry seed yield/plant, tuber length, tuber girth, tuber weight.

The genotypic and phenotypic variances were estimated and were utilized to estimate the genotypic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV) as suggested by Burton (1952).

Phenotypic and Genotypic coefficient of variation

$$GCV = \frac{\sqrt{\text{Genotypic variance}}}{\text{Mean}} \times 100$$

$$PCV = \frac{\sqrt{\text{Phenotypic variance}}}{\text{Mean}} \times 100$$

The PCV and GCV were classified as per Sivasubramanian and Madhava Menon (1973):

< 10% = Low
10-20% = Moderate
> 20% = High

Heritability

The heritability (h^2) estimates in broad sense were worked out and expressed as percentage as suggested by Allard (1970):

$$\text{Heritability} = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}}$$

The heritability per cent was categorized as suggested by Robinson *et al.* (1949).
0-30% = Low
31-60% = Medium
> 60% = High

Genetic advance

Genetic advance (GA) was calculated by using the formula:

$$GA = k \times h^2 \times P$$

where:
k = Selection differential which is equal to 2.06 at 5% selection intensity
h^2 = Heritability
P = Phenotypic standard deviation

For making comparison, the genetic advance (GA) was expressed as percentage of mean. Genetic advance (GA) as percentage of mean was worked by the following formula.

$$\text{Genetic advance as per cent of mean} = \frac{GA}{\text{mean}} \times 100$$

The genetic advance as per cent of mean was categorized as suggested by Johnson *et al*. (1955):
< 10% = Low
10-20% = Moderate
> 20% = High

Correlation coefficient

The coefficients of simple correlation between various characters were estimated for the different generations in each cross using the following formula:

$$r_{xy} = \frac{Cov_{(xy)}}{\sqrt{Var_{(x)} Var_{(y)}}}$$

where:
r_{xy} = simple correlation co-efficient between x and y
$Cov_{(xy)}$ = covariance between the character x and y
Var $(_x)$ and Var $(_y)$ = variance of characters x and y

Path analysis

Path coefficient analysis was carried out according to Dewey and Lu (1959) by partitioning the genotypic correlation into direct and indirect effects.

Path coefficients	Category
> 1.00	Very high
0.30 to 0.99	High
0.20 to 0.29	Moderate
0.10 to 0.19	Low
0.00 to 0.09	Negligible

RESULTS

The variability measured based on the phenotypic and genotypic co-efficient of variation, heritability and genetic advance for seventeen component characters of yield in VM_2 generation (**Table 1**).

The mutants exhibited a GCV range from 1.24% (number of leaves/plant) to 55.06% (number of secondary branches/plant). The PCV was highest for number of secondary branches/plant (102.02%) but was lowest (1.76%) for number of leaves/plant. Among the characters studied, higher heritability was noticed for stem girth (89.74%) followed by fresh pod weight (82.39%). The genetic advance as %age of mean was highest for stem girth (69.30) followed by number of secondary branches/plant (61.22), while it was the lowest for plant height (1.73).

Correlation studies

The highest and positive significant correlation for dry seed yield/plant (g) was observed with number of seeds/pod (0.928) closely followed by number of leaves/plant (0.537) and dry pod weight (0.454) which was further followed by fresh seed weight/pod (0.366), fresh pod weight (0.298), plant height (0.282) and number of secondary branches/ plant (0.236) (**Table 2**).

Intercorrelation positive significance (residual effect-0.3465 with plant height was observed for several traits, namely number of leaves/plant (0.471), number of seeds/ pod (0.270), tuber length (0.379) and tuber weight (0.309). Similarly number of leaves/plant showed positive significance with number of flowers/plant (0.487), fresh pod weight (0.260), dry pod weight (0.378), number of seeds/ pod (0.549), fresh seed weight (0.323), tuber girth (0.222) and tuber weight (0.216). Number of primary branches/ plant showed positive and significant correlation with number of secondary branches/plant (0.350) and plant girth (0.421) while number of secondary branches/plant exhibited positive and significant correlation with plant girth (0.274), number of flowers/plant (0.253), number of seeds/pod (0.239), 100 fresh seed weight (0.219) and tuber girth (0.230).

A positive and significant correlation was exerted by stem girth (0.219) and number of flowers/plant (0.235) with dry pod weight and fresh 100 seed weight respectively. On the other hand, fresh pod weight exhibited significance in the positive direction with dry pod weight (0.353), number of seeds/pod (0.263), fresh seed weight/pod (0.270) and 100 fresh seed weight (0.202). Dry pod weight exerted a posi-

Table 1 Estimates of variability, heritability and genetic advance of VM_2 generation of glory lily derived from large sized tuber.

Characters	Mean	GCV (%)	PCV (%)	h^2 (%)	GA	GAM
Plant height (cm)	139.15	1.52	2.76	30.29	2.40	1.73
Stem girth	1.66	35.51	37.48	89.74	1.15	69.30
No. of leaves/plant	194.23	1.24	1.76	49.70	3.50	1.80
No. of primary branches/plant	3.26	33.19	49.62	44.73	1.49	45.72
No. of secondary branches/plant	3.45	55.06	102.02	29.13	2.12	61.22
No. of flowers/plant	40.46	2.45	4.91	24.96	1.30	2.52
Pod length (cm)	7.83	6.37	9.14	48.66	3.71	9.16
Pod girth (cm)	7.48	7.88	9.14	74.44	5.33	14.01
Fresh pod weight (g)	11.65	16.57	18.26	82.39	2.43	30.99
Dry pod weight (g)	8.22	9.40	12.85	53.54	1.06	14.17
Fresh seed weight/pod	6.19	21.90	27.42	63.78	4.20	36.02
No. of seed/pod	52.65	27.89	31.57	78.03	4.17	50.74
100 fresh seed weight (g)	10.05	30.84	35.48	75.54	3.42	55.21
100 dry seed weight (g)	3.19	3.06	3.56	73.80	2.85	5.41
Dry seed yield/plant	52.95	19.08	23.24	67.42	3.25	32.28
Tuber length (cm)	10.61	22.87	26.07	76.96	1.32	41.32
Tuber girth (cm)	5.58	2.85	3.86	54.65	2.30	4.34
Tuber weight (g)	57.52	18.76	21.12	78.90	3.64	34.33

tive and significant correlation with number of seeds/pod (0.448) and fresh seed weight/pod (0.316). Similarly, number of seeds/pod, fresh seed weight/pod and 100 fresh seed weight exhibited a positive and significant correlation with fresh seed weight (0.382), 100 fresh seed weight (0.275) and 100 dry seed weight (0.399), respectively.

Significant correlation in the negative direction was observed for pod girth with 100 dry seed weight and tuber girth.

Path analysis

Path coefficient analysis revealed that significant direct effects were observed through plant height (0.282), number of leaves/plant (0.537), number of secondary branches/plant (0.236), fresh pod weight (0.298), dry pod weight (0.454), number of seeds/pod (0.928) and fresh seed weight/pod (0.366) for the dry seed yield/plant (**Table 3**).

The number of seeds/pod exhibited indirect effect *via* plant height, number of leaves/plant, fresh pod weight, dry pod weight and fresh seed weight/pod.

DISCUSSION

Induced mutations are one of the tools used to create wide variability. Since spontaneous mutations occurs at a very low frequency and often do not include the full range of variability, mutations are induced in high frequencies by physical or chemical mutagens (Konzak *et al.* 1961). Achievements in this field have highlighted the utility and usefulness of mutation breeding in crop improvement programme especially wherever there is a narrow genetic variability.

Gustaffson (1963) reported a number of useful and potential viable mutants in many horticulture crops. Wide ranges of physical and chemical mutagens are now commonly used for inducing mutations in many crop plants. Among various mutagens, gamma rays and EMS were found to play a significant role in crop plants inducing genetic changes like inhibition of mitosis that impairs the auxin production and also in causing chromosomal aberrations which ultimately resulted in induction of variability in different plant characters. But there is no conclusive strong evidence for the best and preferable mutagens among the physical and chemical induced mutagens for the improvement of crop plants. However, Swaminathan (1969) suggested that both kinds of mutagens have been effective in inducing mutations in crop plants.

Wang and Liu (2002) clearly mentioned that mutation induction techniques can greatly increase the gene mutation frequency and create new germplasm, new material and new cultivars, meeting the breeding targets in a relatively shorter period.

The most promising aspect of induced mutation in vegetatively propagated crops compared to that of cross breeding method is the ability to change only a few characters of an otherwise good cultivar without altering the other characters (Broertjes 1972). Obviously, mutations are the only reliable mean for creating variability in sterile vegetatively propagated crops. The characters to be considered primarily are those which are rather simply inherited such as compact growth, colour or disease resistance.

Wang and Liu (2002) documented that mutation breeding of vegetatively propagated plants have their unique advantages compared with other kind of crops and other breeding methods. Firstly, the variation frequency increased greatly; which can be of hundred or thousand times higher than natural frequency. Secondly the target mutation appeared, the variation could be rapidly stabilized by vegetative propagation methods to speed up the selection process.

Induction of mutation in polygenic quantitative traits can be well detected by the estimation of variance, genetic advance and other genetic parameters of gamma ray, ethyl methyl sulphonate and di ethyl sulphonate treated population. It is evident from the current study that the analysis of variance indicated significant differences among the treatments for most of the traits.

Estimates of phenotypic coefficient of variation for the selected traits in VM_2 generation were in general slightly higher than the genotypic coefficient of variation indicating the influence of environmental factors on these traits.

In VM_2 generation, PCV was higher than the GCV, thus, revealing a strong association at phenotypic level between the characters. This might be due to the masking effect of environment in modifying the total expression of the phenotypes and hence genotypic expression was reduced. In VM_2 generation, the traits *viz.*, stem girth, number of primary branches/plant, number of secondary branches/plant, fresh seed weight/pod, number of seed/pod, 100 fresh seed weight, tuber length, tuber weight and dry seed yield/plant recorded high PCV and GCV emphasizing these characters to be potentially variable. It was also observed that the differences between PCV and GCV were meagre revealing the fact that these traits were less influenced by the environment. High values of GCV suggested better improvement for selection of traits. However, the estimation of heritable variation with the help of genetic coefficient of variation alone may be misleading. Burton (1952) suggested that the genetic coefficient of variation together with heritability estimates gave a better picture of the extent of heritable variation. Heritability (H2) and genetic advance (GA) estimates were interpreted as low, medium and high as per the classification of Johnson *et al.* (1955). Velmurugan (2007) observed highest PCV for plant height, number of laterals/plant, number of leaves/plant, number of tubers/plant, tuber

Table 2 Effect of mutagens on simple correlation coefficient in VM_2 generation of glory lily derived from large sized tubers.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}
X_1	1.000																	
X_2	0.471**	1.000																
X_3	0.074	0.081	1.000															
X_4	-0.002	0.251*	0.350**	1.000														
X_5	-0.014	0.147	0.421**	0.274**	1.000													
X_6	-0.059	0.487**	0.111	0.253*	0.158	1.000												
X_7	0.115	-0.042	0.037	0.100	0.184	-0.095	1.000											
X_8	-0.097	-0.104	0.187	-0.009	0.155	-0.012	0.099	1.000										
X_9	0.155	0.260**	0.039	-0.027	0.144	0.092	0.084	-0.144	1.000									
X_{10}	0.170	0.378**	0.096	0.019	0.219*	0.068	0.186	-0.033	0.353**	1.000								
X_{11}	0.270**	0.549**	0.063	0.219*	0.128	0.173	0.071	-0.053	0.263**	0.448**	1.000							
X_{12}	0.198	0.323**	-0.039	0.019	0.024	-0.087	0.107	0.095	0.270**	0.316**	0.382**	1.000						
X_{13}	0.047	-0.040	-0.011	-0.239*	-0.183	-0.235*	0.046	0.121	0.202*	0.162	0.061	0.275**	1.000					
X_{14}	0.191	0.020	-0.088	-0.112	-0.101	-0.165	0.147	-0.027	0.043	0.059	0.123	-0.005	0.399**	1.000				
X_{15}	-0.379**	-0.164	-0.104	-0.079	0.106	-0.116	-0.085	0.077	-0.110	-0.077	0.017	0.042	-0.056	-0.063	1.000			
X_{16}	0.109	0.222*	-0.024	0.230*	-0.040	0.146	0.030	-0.225*	-0.013	0.050	0.218*	0.121	-0.111	0.015	-0.150	1.000		
X_{17}	-0.309**	-0.216*	0.166	0.086	0.125	-0.190	0.035	-0.089	0.041	0.048	-0.122	0.007	-0.004	-0.086	0.116	-0.094	1.000	
X_{18}	0.282**	0.537**	0.065	0.236*	0.113	0.125	0.071	-0.105	0.298**	0.454**	0.928**	0.366**	0.087	0.142	0.039	0.168	-0.091	1.000

* Significant at 5% level; ** Significant at 1% level

X_1	Plant height	X_7	Pod length	X_{13}	100 fresh seed weight
X_2	No. of leaves/plant	X_8	Pod girth	X_{14}	100 dry seed weight
X_3	No. of primary branches/plant	X_9	Fresh pod weight	X_{15}	Tuber length
X_4	No. of secondary branches/plant	X_{10}	Dry pod weight	X_{16}	Tuber girth
X_5	Stem girth	X_{11}	No. of seed/pod	X_{17}	Tuber weight
X_6	No. of flowers/plant	X_{12}	Fresh seed weight/pod	X_{18}	Dry seed yield/plant

length, tuber girth in *Coleus forskohlii.*

Estimates of heritability appreciate the proportion of variation. Heritability was in reality a measure of the efficiency of a selection system in separating genotypes. According to Robinson (1966), heritability was classified as low, medium and high. High heritability was indicative of genetic nature of induced mutations (Scossiroli1966 and Farooqi *et al.* 1999). Low heritability and increased genetic advance highlighted the greater role of non-additive genes than additive gene. High genetic advance as % of mean was recorded for stem girth, number of primary branches/plant, number of secondary branches/plant, fresh pod weight, fresh seed weight/pod, number of seed/pod, 100 fresh seed weight, tuber length, tuber weight and dry seed yield/plant. This indicates that selection can be relied upon for improvement of these parameters among the progenies. High genetic advance was governed by additive genes and paves the way for improvement of those characters in individual plant selection (Panse 1957). So the predominance of additive genetic variance in expression of these traits is the most reliable indices for effective selection. Miah and Bhadra (1989) reported high values for expected genetic advance for seeds per pods. Makeen *et al*. (2007) and Sriphadet *et al*. (2005) have also reported moderate to high heritability for various morphological traits in mungbean. Due to high heritability estimates, the traits are expected to remain stable under varied environmental conditions and could easily be improved through selection (Khattak *et al*. 1997; Siddique *et al*. 2006).

High heritability was recorded for stem girth, fresh pod weight, fresh seed weight/pod, number of seeds/pod, 100 fresh seed weight, 100 dry seed weight, dry seed yield/plant, tuber length and tuber weight. It indicates that selection of such characters is easy because of the close correspondence between the phenotype and genotype due to relatively smaller contribution of the environment to genotype. Roychowdhury and Tah (2011) also reported high heritability for plant height and moderate for seeds per inflorescence in case of *Dianthus caryophyllus.*

Association analysis

The ultimate goal of crop improvement in *Gloriosa* is to achieve improved seed yield and colchicine content. Being a complex trait, the seed yield is largely influenced by many associated traits. The information on strength and direction of correlation of these component characters on seed yield and *inter se* association among them would be useful in designing breeding programmes for yield improvement. Genetic association plays a significant role to study the interrelationship and relative contribution of different characters towards crop improvement. As this investigation

Table 3 Effect of mutagens on path analysis in VM_2 generation of glory lily derived from large sized tubers.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}
X_1	0.028	0.023	0.001	-0.001	0.001	0.002	0.001	0.005	0.006	0.006	0.235*	-0.003	0.001	0.002	-0.020	-0.005	-0.001	0.282**
X_2	0.013	0.050	0.001	0.019	-0.004	-0.023	-0.000	0.006	0.011	0.013	0.477*	-0.005	-0.001	0.001	-0.009	-0.112	-0.000	0.537**
X_3	0.002	0.00	0.004	0.026	-0.011	-0.005	0.000	-0.010	0.001	0.003	0.055	0.001	-0.001	-0.001	-0.005	0.001	0.001	0.065
X_4	-0.001	0.012	0.001	0.06	-0.001	-0.012	0.000	0.001	-0.001	0.001	0.190	-0.001	-0.001	-0.001	-0.004	-0.011	0.001	0.236*
X_5	-0.001	0.007	0.001	0.020	-0.027	-0.007	0.001	-0.008	0.006	0.007	0.111	-0.001	-0.005	-0.001	0.005	0.002	0.001	0.113
X_6	-0.001	0.024	0.001	0.019	-0.004	-0.048	-0.000	0.001	0.004	0.002	0.150	0.001	-0.007	-0.002	-0.006	-0.007	-0.001	0.125
X_7	0.003	-0.002	0.001	0.007	-0.005	0.004	0.001	-0.005	0.003	0.006	0.062	-0.001	0.001	0.002	-0.004	-0.001	0.001	0.071
X_8	-0.002	-0.005	0.001	-0.001	-0.004	0.001	0.000	-0.056	-0.006	-0.001	-0.046	-0.001	0.003	-0.001	0.004	0.011	-0.001	-0.105
X_9	0.004	0.013	0.001	-0.002	-0.003	-0.004	0.000	0.008	0.044	0.012	0.229*	-0.004	0.006	0.001	-0.006	0.001	0.001	0.298**
X_{10}	0.004	0.019	0.001	0.001	-0.006	-0.003	0.001	0.001	0.015	0.035	0.390**	-0.004	0.004	0.001	-0.004	-0.002	0.001	0.454**
X_{11}	0.007	0.027	0.001	0.016	-0.003	-0.008	0.000	0.003	0.011	0.016	0.870**	-0.005	0.001	0.001	0.001	-0.011	-0.001	0.928**
X_{12}	0.005	0.016	-0.001	0.001	-0.001	0.004	0.001	-0.005	0.011	0.011	0.332**	-0.015	0.008	-0.001	0.002	-0.006	0.000	0.366**
X_{13}	0.001	-0.002	-0.001	-0.018	0.005	0.011	0.000	-0.006	0.008	0.005	0.053	-0.004	0.030	0.005	-0.003	0.001	-0.000	0.087
X_{14}	0.005	0.001	-0.001	-0.008	0.002	0.008	0.000	0.001	0.001	0.002	0.107	0.001	0.012	0.013	-0.003	-0.001	-0.001	0.142
X_{15}	-0.010	-0.008	-0.001	-0.006	-0.002	0.005	-0.000	-0.004	-0.004	-0.002	0.015	-0.001	-0.001	-0.001	0.054	0.007	0.001	0.039
X_{16}	0.003	0.011	-0.001	0.017	0.001	-0.007	0.000	0.012	-0.001	0.001	0.189	-0.001	-0.001	0.001	-0.008	-0.050	-0.001	0.168
X_{17}	-0.008	-0.010	0.001	0.006	-0.003	0.009	0.000	0.005	0.001	0.001	-0.106	-0.001	-0.001	-0.001	0.006	0.004	0.003	-0.091

* Significant at 5% level; ** Significant at 1% level
Residual effect: 0.3465

X_1	Plant height	X_7	Pod length	X_{13}	100 fresh seed weight
X_2	No. of leaves/plant	X_8	Pod girth	X_{14}	100 dry seed weight
X_3	No. of primary branches/plant	X_9	Fresh pod weight	X_{15}	Tuber length
X_4	No. of secondary branches/plant	X_{10}	Dry pod weight	X_{16}	Tuber girth
X_5	Stem girth	X_{11}	No. of seed/pod	X_{17}	Tuber weight
X_6	No. of flowers/plant	X_{12}	Fresh seed weight/pod	X_{18}	Dry seed yield/plant

would be useful to formulate selection criteria, correlation was studied.

In the present study, dry seed yield/plant was significant and positively correlated with number of seeds/pod, number of leaves/plant, dry pod weight, fresh seed weight/pod, fresh pod weight, plant height and number of secondary branches/plant.

Positive correlation of number of seeds/pod with dry seed yield/plant was reported by Syed and Alam (2005) and Hassan *et al*. (2005) in chickpea and Salehi *et al*. (2008) in *Phaseolus vulgaris.* A positive association of number of branches with dry seed yield was reported by Syed and Alam (2005) and Hassan *et al*. (2005) in chickpea and Chandirakala and Subbaraman (2010) in *Cajanus cajan*. A positive correlation of number of leaves/plant with seed yield/plant was reported by Darvishzadeh *et al*. (2011), while Vidhya and Sunny (2002) reported positive correlation of pod weight with seed yield in long bean.

This analysis revealed that selecting plants with more plant height, number of secondary branches/plant, number of leaves/plant, number of seeds/pod, dry pod weight, fresh seed weight/pod and fresh pod weight were desirable for future crop improvement programme. The positive inter correlation among the yield components also indicated the possibility of simultaneous improvement of seed yield.

Path analysis

Correlation coefficient between any two characters would not give a complete picture for a parameter like yield which is controlled by several other traits, either directly or indirectly. In such situations, path coefficient analysis furnishes a means of measuring the direct effect of each trait as well as the indirect effect *via* other characters on yield. So information on the direct and indirect effect on yield is important which is explicable by path analysis as proposed by Wright (1921) and illustrated by Dewey and Lu (1959). The interrelationships of the component characters on yield provide the likely consequences of their selection for simultaneous improvement of desirable characters with yield.

In the VM_2 generation, high and positive direct effect on dry seed yield/plant from various yield traits *viz.*, number of leaves/plant, dry pod weight, number of seeds/pod, fresh seed weight/pod was observed. Moderate positive direct effects from plant height, fresh pod weight towards the dry seed yield/plant was observed. Since the correlation of these characters with yield is positive, preference should be given to these characters in the selection programme to isolate superior mutants with genetic potential for improving yield (Viswanathan *et al.* 1993). A direct effect of number of branches with seed yield/plant was reported by Sarwar and JafarHussain (2010). The number of seeds/pod had high direct effect on dry seed yield/plant. Indirect positive effects of dry pod weight, fresh seed weight/pod on dry seed yield/plant was recorded by Hassan *et al*. (2005), Salehi *et al*. (2008) and Chandirakala and Subbaraman (2010). Direct effect of pod weight with seed yield/plant was reported by Vidhya and Sunny (2002).

The direct and indirect effect of the path analysis revealed that the plant height, number of leaves/plant, number of seeds/pod, fresh pod weight, dry pod weight and fresh seed weight/pod were considered as important selection indices for yield improvement.

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