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Research Article

Association studies for yield and bruchid resistance in mungbean (*Vigna radiata* (L.) Wilczek)

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Abstract
The present investigation was undertaken in 110 mung bean genotypes in alpha lattice design in two replications to estimate the correlation coefficients, direct and indirect effects of various yield contributing traits on grain yield for 18 quantitative traits and nine screening traits against bruchids. The correlation coefficient analysis revealed that single plant yield showed high significant positive correlation with number of pods per plant, followed by number of clusters per plant and hundred seed weight. Path analysis showed that days to 50 per cent flowering and number of pods per plant showed high positive direct effect on single plant yield. The bruchid bioassay resulted in the identification of 12 genotypes with complete resistance to bruchids and all the characters showed high significant positive correlation with each other except for number of eggs laid. Hence, the resistant genotypes identified in this study can be used in resistance breeding programme for bruchids.

Keywords: Mung bean, germplasm, yield traits, correlation, path analysis, bruchid screening

INTRODUCTION

Greengram commonly known as mung bean (*Vigna radiata* (L.)Wilczek) is one of the most important short duration pulse crops grown throughout the year. It is a self-pollinated crop which belongs to the family Fabaceae with chromosome number 2n = 2x = 22. India produces 25% of the global pulses production. In terms of balanced human nutrition, mungbean's protein is an ideal complement to rice because it contains more lysine and tryptophan than urdbean (Parihar *et al.*, 2018). At present productivity of pulses is very low. Yield being a polygenic trait, direct improvement cannot be made. Genetic diversity facilitates breeders to develop varieties for specific traits like quality and yield improvement and tolerance to biotic and abiotic stresses. Consequently, knowledge about traits associated with yield components is important for yield improvement. Breeders widely use association of yield with yield components to assist them in identifying the traits that are useful for selection criteria in yield improvement (Dewey and Lu, 1959). Correlation and path analysis is used to determine the association of yield with other yield contributing parameters. Studies of correlation and path analysis have provided insight into contributions of several characteristics to seed yield (Vandana and Dubey, 1993).

Mungbean production is seriously threatened by an array of destructive pests and diseases, a notable group of which are the storage pests. Among the bruchids, *Callosobruchus maculatus (F.) and Callosobruchus chinensis* (L.) cause heavy loss both in the field as well as in the storage (Bharathi *et al.*, 2017; Majhi and Mogali, 2020). According to Gujar, (1978), the greengram pulse beetle can reduce the weight of seeds from 10 to 95%. The initial infestation of bruchids originates in the field, where the adult beetles lay eggs on green pods. When the seeds are stored the insects continue to feed on them, emerge into adults, which leads to the total destruction of seeds within 3-4 months (Bharathi *et al*., 2017). Keeping this in mind, the present study was conducted in greengram germplasm to assess the correlation coefficient and path coefficient analysis among yield and yield component traits, which helps to find the contribution of different characters to yield and phenotypic screening of germplasm to understand the physical basis of resistance against the pulse beetle.

MATERIALS AND METHODS

The present experiment was carried out in 110 mungbean genotypes during summer 2022-2023 at the research fields of Department of Pulses and bruchid screening was carried out in the laboratory of Department of Plant Genetic Resources, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. The experiment was laid out in alpha lattice design with two replications adopting a spacing of 30 x 10 cm. All agronomic recommendations were followed to maintain good and healthy plants. Five randomly selected plants of mungbean germplasm were tagged and biometrical observations on 18 quantitative traits *viz*., days to initial flowering, days to 50% flowering, plant height (cm), number of primary branches per plant, length of branch (cm), number of clusters per plant, number of clusters per branch, number of pods per plant, number of pods per cluster, pod length (cm), number of seeds per pod, seed length (cm), seed breadth (cm), hundred seed weight (g), days to initial pod colour changes, days to 50% pod colour changes, days to maturity and seed yield per plant (g) were recorded. The mean value was computed for all the quantitative traits and the mean data was subjected to correlation analysis using GRAPES and R software and path analysis using TNAU STAT Software.

Mass culturing of Bruchids: The pure culture of *Callosobruchus maculatus (F.)* was mass reared on fresh susceptible mungbean seeds, maintained at 27±1°C temperature and 65±5% relative humidity to maximize oviposition. After 25-30 days, freshly emerged adults were sub cultured from stock culture and the bruchid population was maintained throughout the study. Infested seeds were replaced with fresh seeds regularly and the freshly emerged adults were used for bruchid bioassay.

Bruchid Bioassay: The bruchid screening was carried out in completely randomized design with two replications by the method developed by Venkataramana *et al.* (2016) with minor modifications. Thirty seeds of each germplasm is taken in transparent plastic containers, five pairs of freshly emerged adults were released in each container and covered with muslin cloth. The containers were maintained undisturbed for 3 days for oviposition. After 3 days, adults were removed, containers with egg-laden seeds are carefully taken out and the number of eggs oviposited on each seed sample were counted. Containers are then incubated at 27±1° C and 65±5% relative humidity and the observations were taken up to the cessation of adult emergence. Observations for bruchid resistance screening included number of eggs laid, number of eggs hatched, hatching percentage (%), number of adult emergence, adult emergence percentage (%), mean developmental period, susceptibility index, initial seed weight (g), final seed weight (g), percent seed weight loss (%), percent seed damage (%) and susceptibility score. The correlation between different parameters of bruchid screening was analysed by using GRAPES and R software.

RESULTS AND DISCUSSION

For effective use of germplasm, information on association of seed yield with different characters is very important for formulating effective crop improvement programme. Studies on correlation and path analysis were undertaken to find the relationship between yield and other yield contributing characters.

Correlation analysis: The correlation coefficient computed for 18 biometrical characters of 110 genotypes are presented in **Table 1.** It was observed that the genotypic correlation was greater than phenotypic correlation for all combination of traits. This indicates that the environmental influence does not alter the degree of association between each characters which confirms the presence of inherent relationship between all characters under study. The results revealed that the seed yield per plant showed high significant positive correlation with number of pods per plant (r=0.488) which is in accordance with the findings of Sreelakshmi and Reddisekhar (2011), Ramakrishnan *et al.* (2018), Sandhiya and Shanmugavel (2018), Sineka *et al.* (2021) and Tejaswini *et al.* (2022) in mung bean. This shows the predominant parallel association of number of pods per plant with single plant yield compared to other characters. Significant positive correlation for single plant yield was observed with number of clusters per plant (r=0.308), number of clusters per branch (r=0.275), hundred seed weight (r=0.275), number of seeds per pod (r=0.229) and number of pods per cluster (r=0.199). These results are in consonance with the results of Ramakrishnan *et al.* (2018), Sandhiya and Shanmugavel (2018), Sineka *et al.* (2021) and Tejaswini *et al.* (2022) for number of seeds per pod; Ramakrishnan *et al.* (2018), Sandhiya and Shanmugavel (2018) and Sineka *et al.* (2021) for number of pods per cluster in mung bean. The results indicated that for increasing the seed yield per plant, more importance should be given for selection of genotypes based on number of pods per plant, number of clusters per plant, number of clusters per branch, hundred seed weight and number of seeds per pod, which in turn improves the yield simultaneously.

Table 1. Genotypic and phenotypic correlation coefficient between yield and its component traits in Mung bean

Traits	DIF	DFF	PH	NPB	LB	NCPP	NCPB	NPPP	NPPC	PL	NSPP	SL	SB	HSW	DIPC	DFPC	DM	SYP
DIF	**1.000**	0.994***	0.755***	0.114	0.562***	-0.066	-0.251**	-0.298**	-0.043	-0.094	-0.313***	-0.041	-0.012	0.000	0.971***	0.945***	0.933***	-0.269**
DFF	0.994***	**1.000**	0.741***	0.091	0.541***	-0.066	-0.247**	-0.304**	-0.046	-0.105	-0.310***	-0.025	0.004	-0.020	0.964***	0.940***	0.924***	-0.260**
PH	0.734***	0.247***	**1.000**	0.354***	0.769***	-0.094	-0.100	-0.079	-0.106	-0.082	-0.224*	-0.080	-0.010	0.168	0.802***	0.796***	0.802***	-0.118
NPB	0.114	0.091	0.025***	**1.000**	0.377***	0.108	0.151	0.250*	0.101	-0.015	0.029	-0.187	-0.082	0.108	0.134	0.141	0.206*	-0.384
LB	0.558***	0.537***	0.769***	0.376***	**1.000**	-0.123	-0.107	-0.023	-0.016	-0.120	-0.269**	-0.106	0.028	0.162	0.591***	0.604***	0.615***	-0.121
NCPP	-0.064	-0.063	-0.056	0.108	-0.123	**1.000**	0.840***	0.622***	0.390***	0.354***	0.325***	0.286**	0.263**	0.261**	-0.325***	-0.332***	-0.344***	0.308**
NCPB	-0.250	-0.247**	-0.095	0.150	-0.107	0.794***	**1.000**	0.538***	0.246**	0.149	0.114	0.291**	0.257**	0.153	-0.278**	-0.243*	-0.279**	0.275**
NPPP	-0.204	-0.208	-0.079	0.218*	-0.023	0.622***	0.470***	**1.000**	0.438***	0.298**	0.259**	0.112	0.104	0.218*	-0.286**	-0.333***	-0.323***	0.488***
NPPC	-0.043	-0.046	-0.106	0.101	-0.016	0.390***	0.246**	0.438***	**1.000**	0.328***	0.395***	0.045	0.059	0.183	-0.224*	-0.282**	-0.322***	0.199*
PL	-0.093	-0.102	-0.081	-0.015	-0.110	0.343***	0.146	0.298**	0.328***	**1.000**	0.550***	0.387***	0.363***	0.237*	-0.097	-0.179	-0.084	0.147
NSPP	-0.313***	-0.290	-0.063*	0.026	-0.257	0.245***	0.105	0.259**	0.395***	0.508***	**1.000**	0.173	0.251**	0.170	-0.286**	-0.348***	-0.272**	0.229*
SL	-0.040	-0.025	-0.080	-0.187	-0.106	0.284**	0.291**	0.079	0.032	0.378***	0.172	**1.000**	0.738***	0.071	-0.032	-0.029	-0.039	0.095
SB	-0.011	0.003	-0.010	-0.082	0.027	0.263**	0.257**	0.065	0.059	0.354***	0.239**	0.738***	**1.000**	0.082	0.006	0.020	0.019	0.058
HSW	0.000	-0.019	0.071	0.108	0.161	0.261**	0.153	0.218*	0.115	0.231*	0.167	0.071	0.081	**1.000**	0.029	0.061	0.030	0.275**
DIPC	0.971***	0.964***	0.207***	0.133	0.587***	-0.325***	-0.277	-0.164	-0.224*	-0.094	-0.273	-0.032	0.005	0.029	**1.000**	0.957***	0.937***	-0.248**
DFPC	0.945***	0.940***	0.796***	0.140	0.599***	-0.332***	-0.243*	-0.220	-0.282**	-0.174	-0.330	-0.029	0.019	0.061	0.956***	**1.000**	0.919***	-0.239*
DM	0.933***	0.924***	0.802***	0.205*	0.610***	-0.344***	-0.279**	-0.190	-0.322***	-0.081	-0.258	-0.039	0.019	0.030	0.936***	0.918***	**1.000**	-0.250**
SYP	-0.269**	-0.260**	-0.011	-0.032	-0.121	0.308**	0.118**	0.488***	0.199*	0.047	0.227*	0.040	0.039	0.101**	-0.078	-0.229	-0.020	**1.000**

*** Correlation is significant at 0.1% level
** Correlation is significant at 1% level
* Correlation is significant at 5% level

DIF- Days to Initial Flowering; LB - Length of Branch; NPPC - Number of Pods Per Cluster; SB - Seed Breadth; DM - Days to Maturity; DFF - Days to 50% Flowering; NCPP- Number of Clusters Per Plant; PL - Pod Length; HSW- Hundred Seed Weight; SYP - Seed Yield per Plant; PH - Plant Height; NCPB - Number of Clusters Per Branch; NSPP- Number of Seeds Per Pod; DIPC - Days to Initial Pod colour Changes; NPB - Number of Primary Branches per plant; NPPP- Number of Pods Per Plant; SL - Seed Length; DFPC - Days to 50% Pod colour Changes

Significant negative correlation of single plant yield was observed with days to initial flowering, days to 50% flowering, days to first pod colour changes, days to 50% pod colour changes and days to maturity. Sreelakshmi and Reddisekhar (2011), Sandhiya and Shanmugavel (2018), Parihar *et al.* (2018) and Majhi *et al.* (2020) reported similar results for days to 50% flowering in mung bean. In accordance with the above results, the decreasing days to 50% flowering and maturity would increase seed yield. This indicates the selection of genotypes for early flowering and maturity is important for achieving high yield in short period of time.

Apart from association of different traits to seed yield, correlation among yield contributing characters also important for elevating seed yield per plant. Among the yield components, plant height showed negative significant correlation with number of seeds per pod, which is concurrence with Zaid *et al.* (2012) and Muralidhara *et al.* (2015) in mung bean. . This implied that short stature plants produce pods with more number of seeds, which in turn increase the yield. Number of clusters per plant showed highly significant positive correlation with number of clusters per branch. Number of pods per plant showed significant positive correlation with number of clusters per plant, number of clusters per branch, number of pods per cluster, pod length and number of seeds per pod. Similar findings have been reported by Sreelakshmi and Reddisekhar (2011), Ramakrishnan *et al.* (2018), Sineka *et al.* (2021) and Tejaswini *et al.* (2022) for pod length in mung bean. This indicates that increase in the number of clusters per plant simultaneously increase number of clusters per branch followed by number of pods per plant, number of pods per branch, pod length and number of seeds per pod, which leads to increase in seed yield per plant. The pod characters *viz.,* number of clusters per plant, number of clusters per branch, number of pods per plant, number of pods per cluster and number of seeds per pod showed significant negative correlation with days to maturity.

Path analysis: The correlation coefficients provide information only on the direct relationship between yield and its component traits but does not show the indirect effects of different yield attributes on yield. Each trait has two paths of action *viz*., the direct influence on yield of plant and indirect effect through components which are not revealed from the correlation studies. The direct and indirect effects of different yield contributing characters on seed yield were presented in **Table 2.** The residual effect was found to be 0.099. This suggests that the contribution level of the component traits was to the tune of 90.10% to single plant yield.

The results revealed high magnitude of positive direct effect of single plant yield on days to 50% flowering (0.965) and number of pods per plant (0.514), moderate positive direct effect was recorded for days to 50% pod colour changes (0.275) and hundred seed weight (0.203), low positive direct effect was recorded for days to maturity (0.172), number of clusters per branch (0.152) and number of seeds per pod (0.121) and negligible positive effect was recorded for plant height (0.08) and seed length (0.029). These results are in agreement with Reshmi Raj *et al.* (2022) for plant height and number of seeds per pod in mung bean. Number of clusters per plant (-0.226), days to initial flowering (-1.429), number of primary branches (-0.122), number of pods per cluster (-0.019), pod length (-0.026), seed breadth (-0.064) and length of branch (-0.084) showed negative direct effect on single plant yield, which is in accordance with Ramakrishnan *et al.* (2018) for number of primary branches in mung bean. Number of clusters per plant registered positive indirect effect through days to 50% flowering, plant height and negative indirect effect through number of pods per plant, pod length, number of seeds per pod and hundred seed weight. Number of pods per plant and number of seeds per pod showed positive indirect effect through number of clusters per plant, pod length, hundred seed weight, seed length, seed breadth and negative indirect effect through plant height, days to 50% flowering. Thus, the positive increase in these characters will simultaneously increase the seed yield per plant indirectly by increasing the number of pods per plant. Hundred seed weight exhibited positive indirect effect on all characters except days to 50% flowering, which showed negative indirect effect.

For the traits, number of clusters per branch and number of pods per plant, the correlation coefficient and direct effect are almost equal. This explains strong and true relationship between them and suggested that direct selection based on these traits will be effective for increasing yield in mungbean.

Phenotypic screening for bruchid resistance: Bruchids are considered as a cosmopolitan pest. Among different species of bruchids, two species *viz., Callosobruchus maculatus* (F.) and *Callosobruchus chinensis* (L.) cause heavy loss in mungbean both in the field as well as in the storage (Bharathi *et al*., 2017; Majhi and Mogali, 2020). For bruchid bioassay, the pure culture of *Callosobruchus maculatus* (F.) was mass reared on fresh susceptible mungbean seeds and the freshly emerged adults were used for the study. The results of the bruchid feeding assay on mungbean germplasm are presented in **Table 3**. Among the germplasm accessions screened, 12 accessions *viz*., AVMU 1607, AVMU 1610, AVMU 1611, AVMU 1622, AVMU 1627, AVMU 1637, AVMU 1646, K.Pudur 3, Kovilpatti, V2709, V2802BG and VRS 550576 showed complete resistance to bruchids. The effect of physical characteristics such as seed colour, seed lusture and seed shape of mung bean seeds towards bruchid infestation were also studied and the classification of mung bean germplasm towards bruchid reaction displayed in **Table 4.** The genotypes that showed complete resistance to bruchids, with no adult emergence, can be declared

Table 2. Direct and indirect effects of different yield contributing traits on seed yield in Mung bean

Traits	DIF	DFF	PH	NPB	LB	NCPP	NCPB	NPPP	NPPC	PL	NSPP	SL	SB	HSW	DIPC	DFPC	DM	Genotypic correlation for seed yield per plant
DIF	**-1.429**	0.959	0.060	-0.014	-0.047	0.075	-0.038	-0.153	0.004	0.002	-0.038	-0.001	0.001	0.000	-0.072	0.260	0.161	-0.269
DFF	-1.420	**0.965**	0.059	-0.011	-0.045	0.074	-0.037	-0.156	0.005	0.003	-0.038	-0.001	0.000	-0.004	-0.072	0.259	0.159	-0.260
PH	-1.078	0.715	**0.080**	-0.043	-0.064	0.021	-0.015	-0.040	0.002	0.002	-0.027	-0.002	0.001	0.034	-0.06	0.219	0.138	-0.118
NPB	-0.163	0.088	0.028	**-0.122**	-0.032	-0.024	0.023	0.105	-0.002	0.000	0.003	-0.005	0.005	0.022	-0.010	0.039	0.035	-0.008
LB	-0.802	0.522	0.061	-0.046	**-0.084**	0.028	-0.016	-0.012	0.000	0.003	-0.033	-0.003	-0.002	0.033	-0.044	0.166	0.106	-0.121
NCPP	0.473	-0.317	-0.008	-0.013	0.010	**-0.226**	0.127	0.320	-0.007	-0.009	0.039	0.008	-0.016	0.053	0.024	-0.091	-0.059	0.308**
NCPB	0.358	-0.238	-0.008	-0.018	0.009	-0.190	**0.152**	0.277	-0.005	-0.004	0.014	0.008	-0.016	0.031	0.021	-0.067	-0.048	0.275**
NPPP	0.426	-0.294	-0.006	-0.025	0.002	-0.141	0.082	**0.514**	-0.008	-0.008	0.031	0.003	-0.006	0.044	0.021	-0.092	-0.056	0.488***
NPPC	0.342	-0.237	-0.008	-0.012	0.001	-0.088	0.037	0.225	**-0.019**	-0.009	0.048	0.001	-0.004	0.037	0.017	-0.077	-0.055	0.199*
PL	0.132	-0.101	-0.007	0.002	0.010	-0.080	0.023	0.153	-0.006	**-0.026**	0.067	0.010	-0.022	0.048	0.007	-0.049	-0.014	0.147
NSPP	0.447	-0.299	-0.018	-0.003	0.023	-0.074	0.017	0.133	-0.007	-0.014	**0.121**	0.005	-0.015	0.035	0.021	-0.096	-0.047	0.229*
SL	0.053	-0.022	-0.006	0.021	0.008	-0.059	0.040	0.053	-0.001	-0.009	0.019	**0.029**	-0.041	0.013	0.002	-0.007	-0.006	0.095
SB	0.016	0.004	-0.001	0.010	-0.002	-0.056	0.037	0.051	-0.001	-0.009	0.029	0.019	**-0.064**	0.016	0.000	0.005	0.003	0.058
HSW	-0.001	-0.019	0.013	-0.013	-0.014	-0.059	0.023	0.112	-0.003	-0.006	0.021	0.002	-0.005	**0.203**	-0.002	0.017	0.005	0.275**
DIPC	-1.388	0.930	0.064	-0.016	-0.049	0.074	-0.042	-0.147	0.004	0.003	-0.035	-0.001	0.000	0.006	**-0.074**	0.263	0.161	-0.248**
DFPC	-1.350	0.907	0.064	-0.017	-0.050	0.075	-0.037	-0.171	0.005	0.005	-0.042	-0.001	-0.001	0.012	-0.071	**0.275**	0.158	-0.239*
DM	-1.333	0.892	0.064	-0.025	-0.051	0.078	-0.042	-0.166	0.006	0.002	-0.033	-0.001	-0.001	0.006	-0.070	0.253	**0.172**	-0.250**

RESIDUE= 0.099

*** Significant at 0.1% level

** Significant at 1% level

* Significant at 5% level

DIF- Days to Initial Flowering; LB - Length of Branch; NPPC - Number of Pods Per Cluster; SB - Seed Breadth; DM - Days to Maturity; DFF - Days to 50% Flowering; NCPP- Number of Clusters Per Plant; PL - Pod Lengt; HSW- Hundred Seed Weight; SYP - Seed Yield per Plant; PH - Plant Height; NCPB - Number of Clusters Per Branch; NSPP- Number of Seeds Per Pod; DIPC - Days to Initial Pod colour Changes; NPB - Number of Primary Branches per plant; NPPP- Number of Pods Per Plant; SL - Seed Length; DFPC - Days to 50% Pod colour Changes

Table 3. Phenotypic screening in mungbean genotypes for the bruchid Callosobruchus maculatus

S. NO.	GERMPLASM	NEL	NEH	HP	NAE	AEP	MDP	SI	PWL	PSD	SUS	SC	LSS	SS
1	AVMU 1607	37.00	3.00	8.11	0.00	0.00	0.00	0.00	0.16	0.00	CR:1	Brownish green	Absent	Drum
2	AVMU 1610	17.00	3.00	17.65	0.00	0.00	0.00	0.00	0.28	0.00	CR:1	Brownish green	Absent	Drum
3	AVMU 1611	49.00	2.00	4.08	0.00	0.00	0.00	0.00	0.08	0.00	CR:1	Brown mosaic	Absent	Drum
4	AVMU 1622	14.00	12.00	14.29	0.00	0.00	0.00	0.00	0.22	0.00	CR:1	Dark green	Absent	Drum
4	AVMU 1627	15.00	2.00	20.00	0.00	0.00	0.00	0.00	1.63	0.00	CR:1	Dark green	Absent	Ovoid
6	AVMU 1637	13.00	10.00	7.69	0.00	0.00	0.00	0.00	0.74	0.00	CR:1	Dark green	Absent	Drum
7	AVMU 1646	31.00	3.00	3.23	0.00	0.00	0.00	0.00	0.30	0.00	CR:1	Dark green	Present	Drum
8	K. Pudur 3	32.00	1.00	6.25	0.00	0.00	0.00	0.00	1.30	0.00	CR:1	Green yellow	Absent	Drum
9	Kovilpatti	9.00	1.00	22.23	0.00	0.00	0.00	0.00	0.72	0.00	CR:1	Dark green	Absent	Drum
10	V2709	61.00	30.00	4.92	0.00	0.00	0.00	0.00	0.19	0.00	CR:1	Darkgreen	Absent	Drum
11	V2802BG	29.00	27.00	13.79	0.00	0.00	0.00	0.00	0.46	0.00	CR:1	Dark green	Absent	Drum
12	VRS 550576	74.00	20.00	4.05	0.00	0.00	0.00	0.00	0.55	0.00	CR:1	Dark green mosaic	Absent	Drum

CR - Completely Resistant

NEL - Number of Eggs Laid; NEH - Number of Eggs Hatched; NAE - Number of Adults Emerged; SI - Susceptibility Index; SS - SUsceptibility Score; SS - Seed Shape; AEP - Adult Emergence Percentage; PWL - Per cent Weight Loss; SC - Seed Colour; HP - Hatching Percentage; MDP - Mean Developmental Period; PSD - Per cent Seed Damage; LSS - Lusture on Seed Surface

as bruchid resistant genotypes and can be utilized as parents in the breeding programs for hybridization followed by selection of superior segregants for yield and bruchid resistance.

Correlation analysis for bruchid screening traits: Among the nine different traits observed during bruchid screening, the susceptibility index showed high significant positive correlation with per cent weight loss followed by adult emergence percentage, per cent seed damage, number of adults emerged, hatching percentage, mean developmental period, number of eggs hatched and non significant positive correlation with number of eggs laid **(Table 5)**. All the characters showed high significant positive correlation with each other except number of eggs laid which exhibited non significant positive correlation with percent weight loss and susceptibility index; negative significant correlation with hatching percentage and adult emergence percentage; non significant negative correlation with mean developmental period and significant positive correlation with number of eggs hatched, number of adults emerged and percent seed damage. This suggests that egg laying alone cannot be considered for determining the criteria for selecting the genotypes for bruchid resistance which is in accordance with the results reported by Duraimurugan *et al.* (2014) in both mung bean and urd bean.

Minimum seed weight loss was one of the resistant factors against bruchids. Even though the genotypes recorded no adult emergence, the minimum per cent seed weight loss was observed which may be due to feeding of the grub. Immediately after hatching, the grub tries to feed on the seed by boring holes on the seed but not able to enter fully into the seed and may die at early stage as an immature grub in its first instar. This may be due to the antibiosis factors present in the resistant seeds inhibiting the complete development of the immature grub into adults. This leads to very minimum weight loss in the seeds and very low adult emergence indicating the presence of resistance mechanism in the seeds against bruchids. The results of the present study were in agreement with the results reported by Dongre *et al.* (1996), Kumar *et al*. (2009) and Indhu (2018) in blackgram, that low seed weight loss and reduction in per cent adult emergence may be due to the presence of some unfavourable biochemical constituents present inside the cotyledons, that directly affect the grub development resulting in prolongation of the developmental period and death of the immature grub. Delay in developmental period causing considerable reduction in seed loss was also observed by Sulehrie *et al*. (2003) during storage of mungbean seeds. Almost all the traits exhibited significant positive correlation with each other . Hence, these bruchid traits were considered to be important in the phenotypic screening for bruchid resistance.

The correlation coefficient and path analysis between yield and its attributing traits worked out in the present study revealed the extent of association with each component traits. From the results, it could be inferred that the yield contributing characters *viz*., number of clusters

Table 4. Reaction of Mung bean accessions to bruchid (*C. maculatus*) bioassay

CLASSIFICATION	Percent damage	Susceptibility score	Nunber of accessions	Frequency of accessions (%)
Completely Resistant or Immune	0	1	12	11
Resistant	1–9	3	7	6
Moderately Susceptible	10–69	5	65	59
Highly Susceptible	70–99	7	25	23
Completely Susceptible	100	9	1	1

Table 5. Correlation coefficient among different bruchid screening traits in Mung bean genotypes

Traits	NEL	NEH	HP	NAE	AEP	MDP	SI	PWL	PSD
NEL	**1.000**								
NEH	0.635***	**1.000**							
HP	-0.232*	0.467***	**1.000**						
NAE	0.482***	0.781***	0.470***	**1.000**					
AEP	-0.289**	0.206*	0.748***	0.563***	**1.000**				
MDP	-0.072	0.296**	0.582***	0.376***	0.489***	**1.000**			
SI	0.012	0.523***	0.756***	0.781***	0.842***	0.689***	**1.000**		
PWL	0.094	0.528***	0.676***	0.668***	0.646***	0.872***	0.893***	**1.000**	
PSD	0.482***	0.781***	0.470***	1.000***	0.563***	0.376***	0.781***	0.668***	**1.000**

*** Significant at 0.1% level
** Significant at 1% level
* Significant at 5% level

NEL- Number of Eggs Laid
NEH - Number of Eggs Hatched
HP - Hatching Percentage
NAE - Number of Adults Emerged
AEP - Adult Emergence Percentage
MDP - Mean Developmental Period
SI - Susceptibility Index
PWL - Per cent Weight Loss
PSD - Per cent Seed Damage

per branch, number of pods per plant, number of seeds per pod and hundred seed weight showed significant positive correlation and positive direct effect with single plant yield. Therefore while designing a breeding strategy more emphasis should be given for the selection of these characters in the mung bean improvement programme for improving the yield potential. The bruchid resistant mung bean genotypes identified through bruchid bioassay can be utilized as donor parents in hybridization programme for developing high yielding cultivars coupled with bruchid resistance.

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REFERENCES

Bharathi, T. D., Krishnayya, P. V. and Madhumathi, T. 2017. Developmental response of *Callosobruchus maculatus* F. and *C. chinensis* L. on different pulse host-grains. *Chemical Science Review Letter*, **6**(22): 786-792.

Dewey, D. R. and Lu, K. 1959. A correlation and path-coefficient analysis of components of crested wheatgrass seed production 1. *Agronomy journal*, **51**(9): 515-518. [Cross Ref]

Dongre, T. K., Pawar, S. E., Thakare, R. G. and Harwalkar, M. R. 1996. Identification of resistant sources to cowpea weevil (*Callosobruchus maculatus* (F.)) in *Vigna* sp. and inheritance of their resistance in blackgram (*Vigna mungo var. mungo*). *Journal of Stored Products Research,* **32**(3): 201-204. [Cross Ref]

Duraimurugan, P., Pratap, A., Singh, S. K. and Gupta, S. 2014. Evaluation of screening methods for bruchid beetle (*Callosobruchus chinensis*) resistance in greengram (*Vigna radiata*) and blackgram (*Vigna mungo*) genotypes and influence of seed physical characteristics on its infestation. *Vegetos,* **27**(1): 60-67. [Cross Ref]

Gujar, T. 1978. Feeding of *Callosobruchus maculatus* F. (Coleoptera: Bruchidae) reared on different foods and temperatures. *J. Stored prod. Res.*, **22**: 71-75.

Majhi, P. K. and Mogali, S. C. 2020. Characterization and selection of bruchid [*Callosobruchus maculatus* (F.)] tolerant greengram [*Vigna radiata* (L.) Wilczek] Genotypes. *Indian Journal of Agricultural Research*, **54**(6): 679-688.

Majhi, P. K.., Mogali, S. C. and Abhisheka, L. 2020. Genetic variability, heritability, genetic advance and correlation studies for seed yield and yield components in early segregating lines (F_3) of greengram [*Vigna radiata* (L.) Wilczek]. *International Journal of Chemical Studies*, **8**(4): 1283-8. [Cross Ref]

Muralidhara, Y. S., Lokesh Kumar, B. M., Uday, G. and Shanthala, J. 2015. Studies on genetic variability, correlation and path analysis of seed yield and related traits in green gram [*Vigna radiata* l. Wilczek]. *International Journal of Agricultural Science and Research*, **5**(3): 125-132.

Parihar, R., Agrawal, A. P., Sharma, D. J. and Minz, M. G. 2018. Character association and path analysis studies on seed yield and its yield attributing traits in mungbean (*Vigna radiata* (L.) Wilczek). *Journal of Pharmacognosy and Phytochemistry*, **7**(1): 2148-2150.

Ramakrishnan, C. D., Savithramma, D. and Vijayabharathi. A. 2018. Studies on genetic variability, correlation and path analysis for yield and yield related traits in greengram (*Vigna radiata* (L.) Wilczek). *International Journal of Current Microbiology and Applied Sciences,* **7**(3): 2753-2761. [Cross Ref]

Reshmi Raj, K. R., Baisakh, B., Tripathy, S. K., Lenka, D., Salini, K. and Mohanty, M. R. 2022. Studies on correlation and path analysis for yield and yield related characters in green gram (*Vigna radiata* (L.) Wilczek). *The Pharma Innovation Journal,* **11**(6): 2392-2395.

Sandhiya, V. and Shanmugavel, S. 2018. Genetic variability and correlation studies in greengram (*Vigna radiata* L. Wilczek). *Electronic Journal of Plant Breeding*, **9**(3): 1094-1099. [Cross Ref]

Sineka, T., Murugan, E., Sheeba, A., Hemalatha, G. and Vanniarajan, C. 2021. Genetic relatedness and variability studies in greengram (*Vigna radiata* (L.) Wilczek). *Electronic Journal of Plant Breeding*, **12**(4): 1157-1162. [Cross Ref]

Sreelakshmi, C. and Reddisekhar, M. 2011. Comparison between correlation and path analysis studies in the full sib progenies and F_3 bulk population among yield and its attributes in two crosses of greengram (*Vigna radiata* L. Wilczek). *Electronic Journal of Plant Breeding*, **2**(2): 258-262.

Sulehrie, M. A. Q., Golob, P., Tran, B. M. D. and Farrell, G. 2003. The effect of attributes of Vigna spp. on the bionomics of *Callosobruchus maculatus*. *Entomologia Experimentalis et Applicata*, **106**(3): 159-168. [Cross Ref]

Tejaswini, K., Malarvizhi, D., Hemavathy, A. T. and Senthil, N. 2022. Character association and path analysis for yield and Yeild contributing traits in greengram [*Vigna radiata* (L.) Wilczek]. *The Pharma Innov J.,* **11**(7): 2654-2657. [Cross Ref]

Vandana, K.. and Dubey, D. K. 1993. Path analysis in fababean. *Federal Board of Intermediate and Secondary Education (FBISE),* **32**: 23-24.

Venkataramana, P. B., Gowda, R., Somta, P., Ramesh, S., Mohan Rao, A., Bhanuprakash, K., Srinives, P., Gireesh, C. and Pramila, C. K. 2016. Mapping QTL for bruchid resistance in rice bean (*Vigna umbellata*). *Euphytica*, **207**: 135-147. [Cross Ref]

Zaid, I. U., Khalil, I. H. and Khan, S. 2012. Genetic variability and correlation analysis for yield components in mungbean (*Vigna radiata* L. Wilczek). *J. Agri. Biol. Sci.,* **7**(11): 1990-199.