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Delineation of selection criterion using pearson correlation and path coefficient analysis in mutant mungbean (*Vigna radiata*) lines

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ABSTRACT

An experiment was conducted at the research farm of Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat to evaluate plant characteristics associated with grain yield and its attributes in mutant mungbean (*Vigna radiata* L.) lines in north Gujarat condition through correlation and path analyses during 2019. Eight independent and 1 dependent variable were evaluated for the character association analysis of the 1200 mutant mungbean lines. The uniform, healthy and dry seeds of mungbean variety GM 4 were treated with 4 different doses of gamma rays at B. A. R. C, Trombay, Mumbai during summer 2019. Selection and evaluation was performed till the M_2 generation and final M_3 generation was grown using augmented design in 21 blocks containing 57 selections and 3 checks. Five plants selected randomly from each replicated lines and subjected to data assortment and analysis using OPSTAT. The seed yield was significantly and positively associated with both number of clusters per plant and number of pods per plant. Same traits, as concluded through the path analysis, had a significant positive direct effect on seed yield. Moderate magnitude of indirect positive effect was detected for number of cluster per plant thorough number of pod per plant (0.162). In order to achieve proper array of relation on seed yield, more traits need to be included in the study, clearly evidenced by the high residual effect of path analysis (0.535). Heatmap interpretation reveals colour grading according to the degree of correlation among the traits. Selection method entered on these 2 traits along with others will be productive to increase seed yield in mungbean.

Keywords: Augmented design, Correlation, Heatmap, Mungbean, Mutation, Path analysis

Mungbean (*Vigna radiata* L.), alias moong or green gram is thought to be originated in India and having 2n = 2x = 22 chromosome number (Naik *et al.* 2020). It is commonly grown across Asia, including South China, Republic of Formosa, Bangladesh, India, Sri Lanka, Pakistan, Thailand, Cambodia, Vietnam and Laos (Karpechenko 1925). Three subgroups of *Vigna radiata* are recognised: two wild (*Vigna radiata* subsp. glabra and *Vigna radiata* subsp. sublobata) and one domesticated (*Vigna radiata* subsp. radiata) (GBIF.org 2022). About 7 million acres are used for mungbean cultivation and 5 million tonnes are produced globally (Nair *et al.* 2019). India produces 54% of the world's mungbeans and accounts for 65% of its production (Anon. 2020). Mungbean is grown on 4.34 million hectares in India and produces 2.12 million tonnes (Productivity - 489 kg per hectare) (Anon. 2020). Gujarat has a total area under cultivation of 1,54,690 hectares, producing 1,10,140 tonnes with a productivity of 711 kg per hectare (Anon. 2021).

Chief reasons among several others reasons for the low productivity of pulses are non-synchronous maturity, long duration, flower drop, unavailability of high yielding genotypes, the low seed replacement rate of improved/high yielding varieties, poor use of plant nutrients and adaption to survival of fittest rather than yield (Reddy 2009). Addition to that in this crop, manual cross pollination and development of hybrid is difficult due to its small cleistogamous flower (Stebbins 1957). The major constrain in attaining higher productivity in mungbean is limited variability which is one of the major constrains for breaking yield plateaus (Kumar *et al.* 2019).

When running a selection programme, it is essential to analyse the coefficients of correlation between the traits which directly or indirectly affect yield (Shood *et al.* 2021). A precise comparative significance of the direct and indirect effect of every attributing trait on yield cannot be obtained solely from a correlation study so we also need to study path analysis (Bhardu and Navale 2011). The results of this study will therefore be utilised to identify the major contributing traits which could be exploited to upsurge yield in mungbean.

MATERIALS AND METHODS

The present study was carried out at the research farm of Sardarkrushinagar Dantiwada Agricultural University,

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Sardarkrushinagar, Gujarat during 2019. The uniform, healthy and dry seeds (moisture 9%) of mungbean variety GM 4 were obtained from Department of Seed Technology, S. D. Agricultural University, Sardarkrushinagar, Gujarat. Mungbean seeds were treated with 4 diverse doses of γ rays (400, 500, 600 and 700 Gy) at B. A. R. C, Trombay, Mumbai during summer 2019. After treatment the seeds were sown at millet research station, S.D.A.U., Deesa during 2019 along with control (GM 4, GAM 5 and K 851). Material was irradiated in Irradiator, named GC 5000, (GC means Gamma chamber and 5000 stands for the volume of a chamber). The source used in irradiator was Cobalt 60. Half life of Cobalt 60 is 5.2713 years. Dose rate of our GC 5000 irradiator is 24 Gy per minute.

The M_1 generation was harvested on single plant basis. Three different varieties of mungbean GM 4, GAM 5 and K 851 were used as a control in M_2 and M_3. The M_3 generation was grown using augmented design (Federer 1956) in 2020. Individual M_2 plant progenies were grown using plant to row method. The control row was repeated once after every 20 rows of M_2 progenies in the experiment (GM 4, GAM 5 and K 851). Quantitative and qualitative traits, viz. days to flowering, days to maturity, plant height (cm), number of clusters per plant, number of pods per plant, pod length (cm), seed yield per plant (g), test weight (g), protein percentage, etc. were recorded for evaluation. Quantitative total crude protein analysis was performed using NIR machine (Wu 2023).

Observations were collected on 5 arbitrarily selected mungbean plants based on each progeny (family) and means were calculated for all the traits excluding days to flowering, days to maturity and test weight which were documented on family plot basis in M_3 generation. Unreplicated data of the M_3 generation were analysed using OPSTAT software (Sheoran *et al.* 1998). Heatmap was generated using Heatmapper; freely available online (http://www.heatmapper.ca/).

RESULTS AND DISCUSSION

Crop improvement programmes heavily rely on the availability of enough diversity and association among various traits, which is a prerequisite for carrying out a successful selection procedure. Being a complicated quantitative trait, seed yield depends on a variety of constituent characters. Therefore, understanding the relationships between various components and their respective contributions is crucial for selection (Okuyama *et al.* 2004, Kumar *et al.* 2020).

Pearson Correlation: Positive significant effect was shown by correlations for pairs of quantitative traits. Heatmap interpretation reveals colour grading according to the degree of correlation and similarity between the same sets of variables for the amount of correlation among the traits (Fig 1). There are two major clusters and six sub clusters of the traits representing degree of dependency on seed yield through colour gradient. Number of pods per plant is falling under same cluster with seed yield with high degree of correlation, followed by number of pods per plant (Fig 1). Protein percentage, pod length and plant height are showing moderate degree of correlation with yield as dividing in II, III and IV cluster separately. Seed index fall under separate cluster with least degree of association followed by days to flowering and days to maturity. Days to flowering and days maturity are showing similarity in correlation amount for seed yield for instance fall in same cluster. Heatmap results are in accordance with the correlation values (Table 1, 2) suggesting authentication of the result through two different analyses.

The genetic architecture of seed yield in mungbean is the complex interaction of different yield attributes. Therefore, prior to developing any selection and crop improvement programme, it is necessary to understand these relationships. The selection of characteristics for seed yield and its contributing traits is based on correlation coefficient analysis, a straightforward technique that shows the strength and direction of the link between various traits. Number of pods per plant (0.511**) and number of clusters per plant (0.506**) are significantly and positively associated with the seed yield. Alom *et al.* (2014), Hemavathy *et al.* (2015), Raturi *et al.* (2015), Gaurav *et al.* (2017), Sarfraz and Vikas (2019), also found similar results for pods per plant and clusters per plant. Selection for number of Singh *et al.* (2021), Parsaniya *et al.* (2022), and Satyanarayana *et al.* (2022) pods per plant and number of cluster per plant in the treated populations will directly increase the yield as suggested by Parsaniya *et al.* (2022), and Satyanarayana *et al.* (2022). The character association arises either due to linkages, pleiotropism or physiological associations. In the induced populations, linkages are expected to be broken and new associations may be recovered. Days to flowering (-0.262**), days to maturity (-0.277**) and seed index

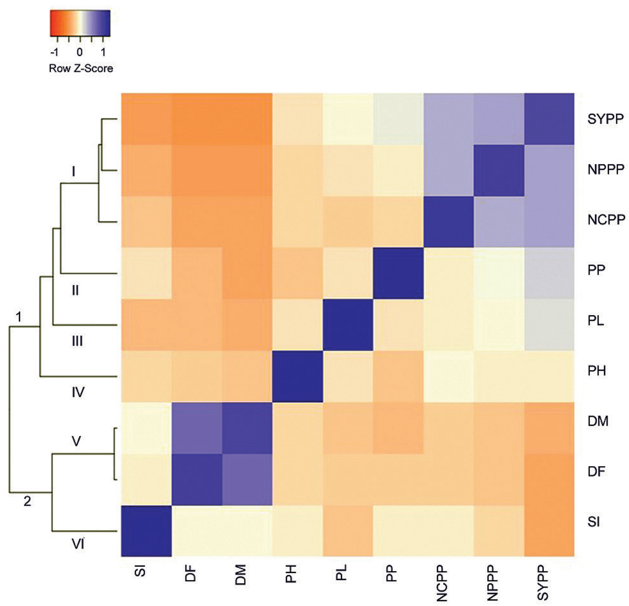

Fig 1 Heatmap signifying degree of correlation and its correspondence among the variables.

Table 1 Pearson correlation between green fruit yield and other traits in mungbean

Character	DF	DM	PH	NCPP	NPPP	PL	PP	SI
DF								
DM	0.763**							
PH	-0.034	-0.085**						
NCPP	-0.114**	-0.099**	0.108**					
NPPP	-0.133**	-0.147**	0.070*	0.482**				
PL	-0.106**	-0.142**	0.030	0.058*	0.104**			
PP	-0.108**	-0.191**	-0.082**	0.074*	0.159**	0.036		
SI	0.051	0.061*	0.011	0.009	-0.055	-0.137**	0.021	
SY	-0.262**	-0.277**	0.086**	0.506**	0.511**	0.189**	0.240**	-0.243**

*Significant at 5% of level of probability; ** Significant at 1% of level of probability.

DF, Days to flowering; DM, Days to maturity; PH, Plant height (cm); NCPP, Number clusters per plant; NPPP, Number of pods per plant; PL, Pod length (cm); PP, Protein percentage; SI, Seed Index (g); SYPP, Seed yield per plant (g).

(-0.243**) had a significant negative correlation with the seed yield per plant. Indirect selection for these characters should be done for yield improvement in mungbean. Rao *et al.* (2006), Singh *et al.* (2009), Alom *et al.* (2015), Hemavathy *et al.* (2015), Gaurav *et al.* (2017), Parsaniya *et al.* (2022) and Satyanarayana *et al.* (2022) all found similar results for days to flowering and days to maturity. Negative correlation with seed index was also observed by Yadav (2022) in mungbean and Miller *et al.* (2020) in cotton. Pod length was showing highly significant but low amount of correlation (0.186**) with seed yield. Similar results for pod length were also observed by Singh *et al.* (2021), Parsaniya *et al.* (2022) and Satyanarayana *et al.* (2022). Alsamadany (2022) in Saudi Arabia and Geetika *et al.* (2022) in Australia recorded a highly significant with high amount of correlation and concluded that pod length is increasing seed yield by accommodating more number of seeds per pod. According to correlation data from the present study, it is possible that the aforementioned characteristics could be enhanced simultaneously as a result of coinheritance. Extent of protein content is the crucial character in pulses as pulses are the chief source of protein for vegetarian cuisine. There was a negative correlation between yield and protein but the magnitude of correlation is very low and it may vary with locations and genotypes (Kumar 1991). Result for the protein percentage (0.240**) was not following the trend in the current study. Indirect selection for these characters should be done in mungbean. Deviation in this result is might be due to error while taking observations or sampling error. The unfavourable associations of some of the component characters may operate as a barrier to the design of a comprehensive selection programme containing these features, thus these aspects must be taken into account when constructing a comprehensive selection programme. Similar deviation in the result for protein percentage was also observed by Singh *et al.* (2021) and Parsaniya *et al.* (2022).

Path analysis: Ever since coefficients of correlation merely reveal the interrelationships between the characters deprived of regard to cause and effect, it gains additional significance when divided in components of indirect and direct effects by path coefficient analysis (Dewey and Lu 1959). Grain yield was deliberated as the dependent variable for analysis, and the other eight characteristics were employed as the causative factors. Table 2 and Fig 2

Table 2 Path coefficient analysis showing direct (diagonal and bold) and indirect effects of different characters on seed yield

Character	DF	DM	PH	NCPP	NPPP	PL	PP	SI	SYPP
DF	-0.090	-0.059	-0.001	-0.038	-0.037	-0.008	-0.016	-0.010	-0.262**
DM	-0.069	-0.077	-0.002	-0.033	-0.040	-0.012	-0.028	-0.012	-0.277**
PH	0.003	0.006	0.032	0.036	0.019	0.002	-0.012	-0.002	0.086**
NCPP	0.010	0.007	0.003	0.336	0.134	0.004	0.011	-0.001	0.506**
NPPP	0.012	0.011	0.0027	0.162	0.278	0.008	0.023	0.011	0.511**
PL	0.009	0.011	0.001	0.019	0.028	0.084	0.005	0.029	0.189**
PP	0.009	0.014	-0.002	0.024	0.044	0.003	0.149	-0.004	0.240**
SI	-0.004	-0.004	0.001	0.003	-0.015	-0.011	0.003	-0.212	-0.243**

*Significant at 5% of level of probability; ** Significant at 1% of level of probability.

DF, Days to flowering; DM, Days to maturity; PH, Plant height (cm); NCPP, Number clusters per plant; NPPP, Number of pods per plant; PL, Pod length (cm); PP, Protein percentage; SI, Seed Index (g); SYPP, Seed yield per plant (g).

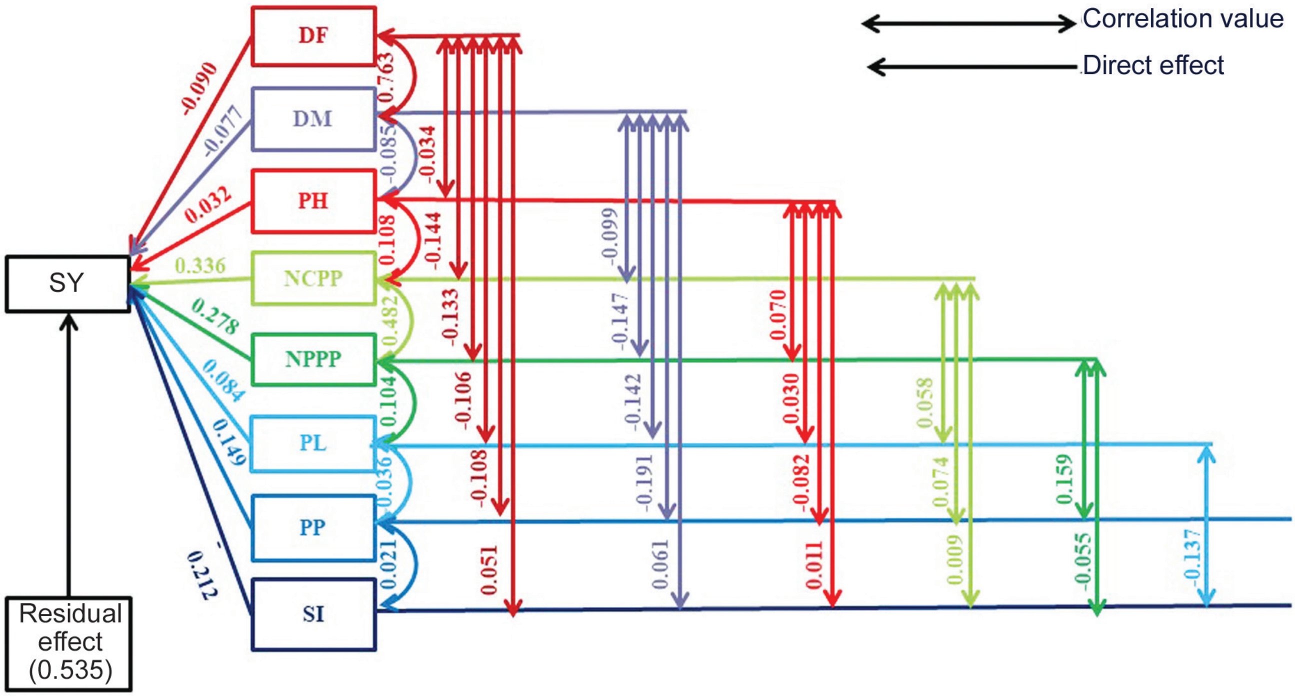

Fig 2 Path diagram representing direct and correlation values.

represent the findings. According to the results of the path analysis, the number of clusters per plant (0.336) and the number of pods per plant (0.278) obligated a significant positive direct influence on seed yield. Rao *et al.* (2006), Singh *et al.* (2009), Alom *et al.* (2015), Hemavathy *et al.* (2015), Raturi *et al.* (2015), Gaurav *et al.* (2017), Sarfraz and Vikas (2019), Singh *et al.* (2021), Parsaniya *et al.* (2022) and Satyanarayana *et al.* (2022) observed the similar results while evaluating their mungbean material and concluded that these traits should be given emphasis for further selection since strong association of these traits with seed yield per plant was recorded. Moderate direct effect was observed for protein percentage (0.149) only while all other traits exerted low magnitude of direct effects. Low magnitude of direct effect was also observed by Alom *et al.* (2015) for all the traits while evaluating 54 genotype of mungbean; Satyanarayana *et al.* (2022) for plant height, number of branches per plant, number of clusters per plant, test weight and days to 50% flowering while evaluating 160 germplasm lines of mungbean at Guntur. Negative direct effect of seed index (-0.212) on seed yield was also observed by Miller *et al.* (2020) in cotton and Yadav (2022) in mungbean. Moderate magnitude of indirect positive effect was detected for number of cluster per plant thorough number of pod per plant (0.162). Moderate level of indirect effect for this traits was also observed by Sarfraz and Vikas (2019) while studying 112 diverse genotypes of mungbean, along with 5 high yielding checks at pantnagar; Singh *et al.* (2021) for 40 genotypes of mungbean and Sineka *et al.* (2021) while evaluating 60 genotypes representing all India. In order to achieve proper array of relation on seed yield, more traits need to be included in the study, as clearly evidenced by the high residual effect of path analysis (0.535). According to the residual effect value, the eight variables under investigation account for only 47% of genetic variations. Dutt *et al.* (2020) reported the high residual effect (0.536) for rice. If the indirectly selected traits have a high heritability as well as association with yield, a larger yield response is obtained. In order to indirect selection to be more effective certain combinations of heritability and correlation coefficient values must be present, according to Searle (1965). Number of pods and clusters per plant had the highest direct impact on yield. Both were also showing a very significant and positive association with seed yield. As a result, selection approaches based on these traits, enhancement will be rewarding for yield and per se performance for other traits (Supplementary Table 1).

Results of this study have clarified the significance of number of pods and number of clusters per plant, which have a very high significant positive association and positive direct effects on yield as well as positive indirect effects on all other traits for seed yield too. Concentrating on these traits in selection process along with other traits such as number of branches per plant, plant height, number of seeds per pod will help in mungbean crop improvement programme to evolve high yielding varieties which will benefit the mungbean growing farmers.

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