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Genetic variability, correlation and path analysis for yield and biochemical traits in velvet bean [*Mucuna pruriens* (L.)]

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Abstract
Mucuna pruriens (L.) is an important medicinal plant and belonging to the family Fabaceae. The seeds of velvet bean are used in Ayurvedic System of Medicine to relief the symptoms of Parkinson's disease. Correlation studies provide information about the relative contribution of various component traits on seed yield per plant and help in effective identification and selection of superior types. Fifteen F_1 crosses resulting from 6 x 6 half diallel design without reciprocals were evaluated for yield and yield attributing traits. Higher estimates of GCV and PCV were recorded for inflorescence length. High heritability coupled with high genetic advance was recorded for dry pod yield per plant, seed yield per plant and these traits were governed by additive gene action hence those traits can be effective to improve the seed yield by selection method. In the present correlation studies, the characters like days taken to 50 percent flowering (rg=0.50*, rp= 0.47*), number of flowers per inflorescence (rg=0.54*, rp=0.51*), number of pods per bunch (rg=0.63**, rp= 0.59**) and dry pod yield per plant (rg=1.00**, rp=0.92**) and seeds per pod (rg=0.53*, rp=0.48*) had exhibited significant and positive association with seed yield per plant at both genotypic and phenotypic levels and number of days taken to maturity had significant negative association with seed yield per plant at both levels. The results suggest the efficiency of direct selection of those contributing traits for seed yield improvement. However, in the path coefficient analysis showed that days taken to 50 percent flowering, number of flowers per inflorescence, pod length, number of pods per bunch, dry pod yield per plant, days taken to maturity and 100 seed weight had exerted direct effect on seed yield. The other traits plant height, inflorescence length, pod width, pod weight, number of bunches per plant and seeds per pod through positive indirect effects on seed yield per plant. For improving the seed yield in velvet bean emphasis should be selection on the characters that are showing direct positive effect on seed yield.

Keywords: Velvet bean, GCV, PCV, heritability, correlation, path analysis, selection

1. Introduction

Mucuna pruriens (L.) is an important underutilized tribal pulse with diploid chromosome number (2n=22) which belonging to the family Fabaceae. It is indigenous to tropical countries like India and in other parts of tropics including Central and South America. It is also called as velvet bean, devil bean, cowhage, kewanch, cowitch and atmagupta (Anonymous, 1985) [3]. It is an annual herbaceous twining climber grows to a height of 3-18 m. It is having trifoliate leaves, bear the flowers on raceme. Mucuna flower colours is varied from creamy white, light purple to deep purple in colour and are self pollinated. Its fruit is pod consist of 4-7 seed oblong ellipsoid seed of various colour viz., white, black, brown and mottled. Mucuna have green or brown colour pod which covered with soft or rigid hairs causing intensive irritation (Leelambika and Sathyanarayan, 2011) [22]. Its seeds are widely used in Ayurvedic system of medicine to the treatment of male fertility, nervous disorders and as an aphrodisiac. Mucuna seed is a constituent of more than 200 indigenous drug formulations. The seeds are rich source of L-Dopa; L-Dopa is a non protein amino acid extracted from the seed of mucuna and used in the treatment of Parkinson's disease. L-Dopa extracted from seeds of mucuna is more effective than the synthetic drug to the treatment of Parkinson's disease. Besides L-Dopa, nicotine, physostigmine, serotonin, bufotenine, choline, N-N dimethyl tryptamine and some indole compounds are the other phytochemicals present in the other parts like roots, stems, leaves of velvet bean (Tripathi and Upadhyay, 2002) [36]. Although all plant parts of mucuna such as leaf, stem, seed and root have been reported to possess medicinal properties but great emphasis has been given to the seed for extraction of high L-Dopa. Hence there is a huge demand for this plant in Indian market and also international drug market to meet the demand for antiparkison drug. Because of this Indian farmers are motivated to take up commercial cultivation (Bammi and Gangadhar Rao, 1982) [6]. In addition to L-Dopa, seeds are rich source of protein, fat, carbohydrate and other minerals but their utilization as a food is limited due to number of antinutrient or antiphysiological factors. Hence to reduce or eliminate the anitinutrient factors in mucuna seeds proper boiling or processing could be followed to use as food or feed. Velvet bean seeds are an alternate source of food or feed to human being or livestock, respectively as a non conventional legume. Velvet bean has been used as food traditionally by certain ethnic groups in India, Philippines, Nigeria, Ghana, Brazil and Malawi (Janardhanan *et al*. 2003) [17]. It is grown in many plantation crops as an inter crop or green manure or cover crop for weed control and to enrich the soil with nutrients. Mucuna is a hardy crop it can tolerate adverse environmental conditions such as drought, low soil fertility and high soil acidity. Mucuna is effective in lowering the nematode population (Queneherve *et al*. 1998) [29]. It gives seed yield about 1.3 to 2.4 t/ha and yield of total biomass is 20-30 t/ha and dry matter was 7-9 t/ha (Carsky *et al*. 1998) [11]. Thus it is considered as one of the most productive legumes of the world (Fujii *et al*. 1991) [13]. Therefore, there is a scope to improve the seed yield of velvet bean by selection method.

Thorough understanding of genetic parameters and the association of plant characters among themselves and with yield is essential for successful crop improvement programme. It enables the breeders to manipulate the expression of these traits in crop improvement. The efficiency of selection for yield mainly depends on the direction and magnitude of association between yield and its components and among themselves. Correlation analysis provides information on the nature and magnitude of the association of different component characters with seed yield, which is regarded as highly complex trait which the breeder is ultimately interested into it. It also helps us to understand the nature of inter-relationship among the component traits themselves. Therefore this kind of analysis could be helpful to the breeder to design selection strategies to improve the seed yield. The total correlation between yield and component characters may be some time misleading, as it might be an overestimate or underestimate because of its association with other characters. Hence, direct selection by correlated response may not be some time fruitful. When many characters are affecting a given character, splitting the total correlation into direct and indirect effects of cause as devised by Wright (1921)[37] would give more meaningful interpretation to the cause of association between the dependent variable like yield and independent variables like yield components. Thus, the correlation and path coefficients in combination can give a better insight into cause and effect relationship between different pairs of characters (Dewey and Lu, 1959) [12].

2. Materials and methods

The materials consist of 15 F_1s of velvet bean seeds were evaluated for yield and biochemical traits. The experiment was conducted at Central Horticultural Experiment Station, Hirehalli a substation of ICAR- Indian Institute of Horticultural Research (ICAR-IIHR), Bengaluru. The crop was raised providing drip irrigation with spacing of 90 cm x 60 cm in randomised block design with three replications. Each treatment represented by 3 rows and each row of 2.7 m length. Two seeds were sown per hill. The gap filling was done one week after germination and thinning was carried out to maintain uniform crop stand and one plant per hill. Crop was raised under support of pandal. One month after germination jute twines are tied to the plants to climb over the pandal. The crop raised under irrigated conditions with all the recommended package of practices were taken up to raise a good crop. The observations such as plant height at flowering stage, days taken to 50 percent flowering, number of flowers per inflorescence, inflorescence length, number of bunches per plant, number of pods per bunch, number of seeds per pod, pod length, pod width, 100 seed weight were recorded five randomly selected plants from each replication and mean was calculated. The matured pods were harvested and seeds were separated from pods. The powder prepared from the seed using grinding machine and sieved the sample by mesh 60 size and used for biochemical analysis. Biochemical estimation was done in using triplicates of seed samples. The crude protein content estimated by multiplying the percentage of Kjeldhal nitrogen by a factor 6.25 (AOAC, 1990) [5]. Crude lipid content estimated using Soxhlet apparatus (AOAC, 2005) [4]. Carbohydrate estimated by calculation of difference method (Muller and Tobin, 1980) [26]. L-Dopa estimated using UHPLC protocol developed by Shivanandha *et al*. (2003) [33]. Total phenol content estimated using Folin Ciocalteu Reagent method (Bray and Thorpe, 1956) [9]. The total tannins were estimated according to Makker *et al*. (1993) [24] with minor modifications.

PCV and GCV was calculated by the method given by Burton (1952) [10] heritability in broad sense and genetic advance was estimated by using method of Lush (1949) [23] and Johanson et al. (1955) [18]. Correlation coefficient was calculated by the method Panse and Sukhatme (1967) [27]. Path coefficient analysis was done by the method described by Dewey and Lu (1959) [12].

3. Results and discussion

3.1 Variability study

Analysis of variance revealed that there was a considerable genetic difference among 15 F_1s for yield and biochemical traits. In the present study the phenotypic coefficient variance was higher than corresponding genotypic coefficient of variation for all the yield and biochemical traits indicating that the role of environmental factors on these traits and it was also reported by Khajudparn and Tantasawat (2011) [20]. The difference between GCV and PCV was narrow for all traits except plant height suggesting little influence of environment on these traits. Higher estimates of GCV and PCV values were recorded for inflorescence length shown in table1. Moderate GCV and PCV were recorded for number of flowers per inflorescence followed by number of pods per bunch. Minimum values of GCV and PCV have been recorded for the shelling percentage followed by carbohydrate content indicated significant role of environment in expression of these characters and selection will be ineffective based on these traits. The heritability values ranged from 38.80 to 99.30 per cent. High heritability was observed for inflorescence length (98.90%), days to 50 per cent flowering (98.40%) followed by number of flowers per inflorescence (98.30%) and total phenol content (98.30%) whereas low heritability recorded for plant height (38.30%). High heritability coupled with high genetic advance was recorded for dry pod yield per plant, seed yield per plant and these traits were governed by additive gene action hence those traits can be effective to improve the seed yield by direct selection method. Similar results reported in cluster bean by Hanchinamani (2003) [14] and in cowpea by Reena and Mehta (2014) [31]. High heritability coupled with moderate genetic advance was noticed for 100 seed weight; days to 50 percent flowering followed by days to maturity indicate these traits are influenced by both additive and non additive gene action thus selection of those traits cannot be effective for improvement of the seed yield. Low genetic advance with low heritability was found for plant height, pod width and shelling percentage suggesting that these traits are governed by non additive gene actions hence selection of these traits are not effective because of it influenced by the environment. Highest value of genetic advance as percent of mean was recorded for the traits inflorescence length, number of flowers per inflorescence, followed by number of pods per bunch. Moderate genetic advance as percent mean was observed in days to 50 percent flowering, seed yield per plant and dry pod yield per plant and least values noticed for the trait shelling percentage.

3.2 Correlation studies

In general genotypic correlation coefficients values are high as compared to their phenotypic correlation coefficients and indicated the association in largely due to genetic reason (Huque *et al*. 2012) [15]. The seed yield was significantly and positively associated with number of flower per inflorescence (0.544, 0.510), number of pods per bunch (0.636, 0.590), dry pod yield per plant (1.001, 0.929) and number of seeds per pod (0.539, 0.488) both phenotypic and genotypic levels whereas days to 50 per cent flowering had significantly correlated with seed yield at phenotypic level only. Similar findings are reported by Basavaraj *et al*. (2018) [7] in velvet bean. The trait days to maturity was significantly and negatively associated with seed yield both phenotypic and genotypic levels whereas the total phenol content had significantly negative association with seed yield at genotypic level (table 2).

Number of days taken to 50 percent flowering was significantly and positively associated with the seed yield per plant at genotypic level (0.500) and phenotypic level (0.477). This was in conformity with results reported by Parveen *et al*. (2011) [28]. It was contradictory to results reported by Jain *et al*. (2013) [16] in fenugreek. The seed yield had significant positive association with number of pods per clusters. These results are in line with conformity with Huque *et al*. (2012) [15] and it was contradictory to Tabasum *et al*. (2010) [35] reported number of pods per cluster had significant negative association with seed yield of mung bean. Significant and positive association was observed between number of seeds per pod with seed yield per plant at both levels i.e. genotypic and phenotypic level (0.539, 0.448), respectively. Similar results were reported by Karasu and Oz (2010) [19] in dry bean, Ali *et al*. (2009) [1] in chickpea. Kumar *et al*. (2010) [21] also reported positive association of number of seeds per pod with seed yield. The present results were in conformity with Anandhi *et al*. (2013) [2] reported in glory lily. Number of days taken to pod maturity had significant negative association with seeds per plant at phenotypic (-0.458) and genotypic (-0.437) level. Similar results were reported in fenugreek (Miheretu Fufa, 2013) [25], field pea (Singh *et al*., 2011) [34]. This finding was in contrast to results reported by Rao *et al*. (2013) [30], Birhan *et al*. (2013) [8] in pigeon pea.

3.3 Path coefficient analysis

Path coefficient analysis revealed that the traits plant height (0.345), days to 50 percent flowering (2.853), pod length (4.093), number of pods per bunch (4.844), dry pod yield per plant (3.362), days to maturity (2.761), 100 seed weight (7.590) and L-Dopa (4.489) content had high direct effect on seed yield per plant at genotypic level and data shown in table 3. Except L-Dopa and plant height similar results have been reported by Reni *et al*. (2013) [32] in blackgram. Karasu and OZ (2010) [19] also reported plant height and 1000 seed weight had high direct effect on seed yield per plant in dry bean. These results are corroborated with results reported by Birhan *et al.* (2013) [8] and Rao *et al*. (2013) [30] in pigeon pea. In a similar study Singh *et al*. (2011) [34] reported that number of pods per plant had highest positive direct effect on seed yield of field pea and Reni *et al*. (2013) [35] reported in black gram. In mung bean Tabasum *et al*. (2010) [35] reported negative direct effects of plant height, clusters per plant and pods per clusters on seed yield per plant. The traits plant height, days to 50 percent flowering, pod length, number of pods per bunch, dry pod yield per plant, days to maturity, 100 seed weight and L-Dopa content had shown low negative direct effect on seed yield per plant at phenotypic level. The characters inflorescence length (-0.374), number of flowers per inflorescence (-3.831) had high direct negative effects, whereas pod width (-1.823), pod weight (-0.485) number of bunches per plant (-0.193), number of seeds per pod (-1.305) and shelling percentage (-1.162) had low direct negative effects on seed yield at genotypic level. The trait pod weight (-0.485, -0.019) had low negative direct effect on seed yield per plant at both genotypic and phenotypic levels. Whereas dry pod yield per plant (3.362) had high direct effect at genotypic level and it had low direct effects (0.732) on seed yield per plant at phenotypic level. The biochemical traits total phenol content (0.100), fat content (2.575) had shown positive direct effect and total tannin (-4.419) had high direct negative effects on seed yield per plant. The seed yield per plant had positive indirect effects through traits plant height, days to 50 percent flowering, inflorescence length, number of flowers per inflorescence, pod length, pod width, number of pods per bunch and seeds per pods.

4. Conclusion

From this study, it can be concluded that day taken to 50 percent flowering, number of flowers per inflorescence, pod length, number of pods per bunch, dry pod yield per plant, days taken to maturity and 100 seed weight had exerted direct effect on seed yield. Therefore improvement of velvet bean seed these traits are most important for selection of elite genotypes and as well as used in crop improvement programme.

Table 1: Estimates of genetic parameters for 21 characters in 15 F_1s in velvet bean

Character	Mean	Range		Genotypic variance	Phenotypic variance	GCV	PCV	Heritability (%)	Genetic Advance	GA as % Mean
		Minimum	Maximum							
Plant height (m)	3.81	2.98	4.61	0.09	0.24	7.93	12.72	38.80	0.39	10.18
Days to 50% flowering	67.46	39.00	109.67	351.11	356.65	27.78	28.00	98.40	38.30	56.77
Inflorescence length (cm)	9.09	1.97	30.49	113.48	114.80	117.25	117.93	98.90	21.82	240.14
No. of flowers /inflorescence	12.06	4.57	30.89	56.21	57.17	62.19	62.72	98.30	15.31	127.02
Pod length (cm)	10.61	7.36	12.65	1.47	1.63	11.42	12.02	90.30	2.37	22.35
Pod Width(cm)	1.97	1.68	2.20	0.01	0.02	5.46	6.58	69.00	0.18	9.35
Pod weight (g)	10.68	6.94	13.63	3.25	3.67	16.88	17.95	88.50	3.50	32.72
Number of bunches/Plant	10.53	8.00	13.34	2.05	3.08	13.60	16.66	66.60	2.41	22.86
No. of pods per bunch	6.30	3.17	12.80	8.90	9.14	47.35	47.98	97.40	6.06	96.26
Dry pod yield/ plant	531.83	290.60	772.27	23551.87	26,391.92	28.86	30.55	89.20	298.65	56.15
No. of seeds/pod	4.90	3.43	5.64	0.41	0.46	12.98	13.78	88.70	1.23	25.17
Seed yield per plant(g)	316.19	172.23	454.47	8235.85	9,302.33	28.70	30.50	88.50	175.91	55.63
Shelling percentage	59.48	56.48	62.23	2.08	4.14	2.43	3.42	50.30	2.11	3.55
Days to maturity	142.10	109.00	177.00	348.20	358.41	13.13	13.32	97.10	37.89	26.66
100 seed weight(g)	138.35	91.33	179.00	729.75	751.81	19.53	19.82	97.10	54.83	39.63
L-DOPA	4.04	3.08	5.34	0.32	0.34	14.01	14.36	95.10	1.14	28.14
Total phenols(mg/g)	72.03	52.95	83.18	45.40	45.74	9.35	9.39	99.30	13.83	19.20
Total tannin(mg/g)	0.44	0.27	0.68	0.01	0.01	22.16	25.27	76.90	0.17	40.02
Protein (%)	24.36	18.94	35.32	13.00	14.21	14.80	15.47	91.50	7.11	29.17
Fat (%)	5.28	4.32	6.17	0.22	0.26	8.83	9.61	84.40	0.88	16.71
Carbohydrate (%)	60.08	54.56	64.75	7.62	9.70	4.59	5.18	78.50	5.04	8.38

Table 2: Correlation coefficients for different growth, yield and yield attributing characters in 15 F_1s of Velvet bean

Character		PH	DF	IL	FI	PL	PW	PWt	BP	PB	DPYP	SP	S	DM	TW	L	Ph	T	P	F	CHO	SYPP
PH	G	1	0.484*	0.303	0.583**	-0.143	-0.134	-0.397	-0.071	0.492*	0.278	0.034	0.048	0.207	-0.678**	0.356	0.237	-0.168	0.267	0.013	0.039	0.278
	P	1	0.274	0.200	0.355	-0.037	-0.191	-0.237	-0.182	0.323	0.134	-0.011	0.148	0.114	-0.405*	0.235	0.165	-0.043	0.234	-0.043	-0.102	0.139
DF	G		1	0.828**	0.884**	-0.553**	-0.761**	-0.826**	-0.558**	0.923**	0.503*	0.151	0.046	0.776**	-0.873**	0.348	0.581**	0.182	0.384	-0.407	-0.291	0.50
	P		1	0.814**	0.870**	-0.520*	-0.637**	-0.776**	-0.455*	0.903**	0.471*	0.138	0.018	0.760**	-0.851**	0.328	0.573**	0.154	0.362	-0.373	-0.250	0.477*
IL	G			1	0.918**	-0.643**	-0.703**	-0.745**	-0.660**	0.920**	0.428	0.067	-0.052	0.841**	-0.772**	0.288	0.433	0.016	0.528*	-0.413	-0.446*	0.422
	P				0.906**	-0.604**	-0.561**	-0.707**	-0.552**	0.906**	0.402	0.071	-0.031	0.827**	-0.757**	0.282	0.425	0.020	0.507*	-0.367	-0.409	0.400
FI	G				1	-0.618**	-0.688**	-0.775**	-0.528*	0.965**	0.561**	0.088	-0.100	0.833**	-0.855**	0.358	0.480*	0.071	0.463*	-0.438*	-0.298	0.544*
	P				1	-0.585**	-0.577**	-0.720**	-0.427*	0.942**	0.512*	0.079	-0.091	0.813**	-0.841**	0.356	0.468*	0.071	0.430	-0.389	-0.259	0.510*
PL	G					1	0.569**	0.686**	0.254	-0.542*	0.026	0.434*	0.427	-0.607**	0.395	-0.605**	-0.198	-0.183	-0.599**	0.216	0.496*	0.070
	P					1	0.463*	0.614**	0.150	-0.496*	0.044	0.391	0.268	-0.578**	0.379	-0.577**	-0.186	-0.106	-0.556**	0.186	0.429	0.059
PW	G						1	0.709**	0.577**	-0.757**	-0.267	-0.346	-0.161	-0.606**	0.791**	-0.312	-0.441*	0.002	-0.326	0.140	0.390	-0.280
	P						1	0.521*	0.454*	-0.593**	-0.170	-0.202	-0.040	-0.491*	0.656**	-0.243	-0.375	-0.047	-0.292	0.102	0.362	-0.188
PWt	G							1	0.457*	-0.763**	-0.189	0.175	0.054	-0.820**	0.806**	-0.346	-0.439*	0.002	-0.546*	0.271	0.508*	-0.169
	P							1	0.360	-0.703**	-0.167	0.173	0.031	-0.756**	0.747**	-0.314	-0.404	0.035	-0.499*	0.234	0.417	-0.172
BP	G								1	-0.582**	-0.002	0.002	0.180	-0.510*	0.532*	-0.286	-0.440*	-0.200	-0.439*	0.353	0.501*	0.002
	P								1	-0.482*	0.000	0.033	0.080	-0.414*	0.415	-0.216	-0.357	-0.165	-0.383	0.277	0.438*	0.002
PB	G									1	0.633**	0.188	-0.032	0.795**	-0.866**	0.271	0.487*	0.120	0.415	-0.443*	-0.296	0.636**

	P									1	0.603**	0.187	-0.010	0.771**	-0.839**	0.264	0.479*	0.096	0.392	-0.415	-0.260	0.590**
DPYP	**G**										1	0.495*	0.040	0.313	-0.442	0.056	0.224	0.270	-0.175	-0.535*	0.362	1.001**
	P										1	0.430	-0.050	0.293	-0.412	0.038	0.215	0.262	-0.179	-0.444*	0.336	0.929**
SP	**G**											1	0.605	-0.020	-0.282	-0.483*	-0.004	-0.328	-0.621**	0.086	0.505*	0.539*
	P											1	0.431	-0.010	-0.270	-0.439*	-0.001	-0.233	-0.549*	0.087	0.410	0.488*
S	**G**												1	-0.016	-0.293	-0.574**	0.063	-0.569*	-0.332	0.654**	0.234	0.031
	P												1	-0.035	-0.163	-0.368	0.054	-0.449*	-0.239	0.366	0.182	0.284
DM	**G**													1	-0.779**	0.152	0.437*	-0.086	0.407	-0.271	-0.302	-0.458*
	P													1	-0.766**	0.139	0.427	-0.070	0.390	-0.242	-0.271	-0.437*
TW	**G**														1	-0.160	-0.604**	0.154	-0.333	0.164	0.271	0.002
	P														1	-0.153	-0.592**	0.121	-0.309	0.143	0.235	0.003
L	**G**															1	0.135	0.690**	0.409	-0.497*	-0.172	0.237
	P															1	0.128	0.579**	0.394	-0.437*	-0.167	0.223
Ph	**G**																1	0.072	0.299	-0.252	-0.302	0.223
	P																1	0.065	0.291	-0.244	-0.268	0.226
T	**G**																	1	0.028	-0.557**	0.120	-0.207
	P																	1	0.031	-0.396	0.031	-0.193
P	**G**																		1	-0.299	-0.901	-0.465*
	P																		1	-0.268	-0.876**	-0.415
F	**G**																			1	0.079	0.392
	P																			1	0.038	0.328
CHO	**G**																				1	0.321
	P																				1	0.215
SYPP	**G**																					1
	P																					1

Table 3: Direct and indirect effect of different traits on seed yield per plant in velvet bean

Character		PH	DF	IL	FI	PL	PW	PWt	BP	PB	DPYP	SP	S	DM	TW	L	Ph	T	P	F	CHO	SYPP
PH	G	0.345	0.167	0.105	0.201	-0.049	-0.046	-0.137	-0.025	0.170	0.096	0.012	0.016	0.072	-0.234	0.123	0.082	-0.058	0.092	0.005	0.013	0.278
	P	-0.024	-0.007	-0.005	-0.009	0.001	0.005	0.006	0.004	-0.008	-0.003	0.000	-0.004	-0.003	0.010	-0.006	-0.004	0.001	-0.006	0.001	0.002	0.139
DF	G	1.381	2.853	2.362	2.522	-1.577	-2.172	-2.356	-1.591	2.633	1.434	0.431	0.131	2.214	-2.491	0.993	1.656	0.518	1.096	-1.162	-0.831	0.507
	P	-0.013	-0.047	-0.038	-0.041	0.024	0.030	0.036	0.021	-0.042	-0.022	-0.006	-0.001	-0.036	0.040	-0.015	-0.027	-0.007	-0.017	0.018	0.012	0.477*
IL	G	-0.113	-0.309	-0.374	-0.343	0.240	0.263	0.278	0.247	-0.344	-0.160	-0.025	0.019	-0.314	0.289	-0.107	-0.162	-0.006	-0.197	0.154	0.167	0.422
	P	0.009	0.039	0.047	0.043	-0.029	-0.027	-0.033	-0.026	0.043	0.019	0.003	-0.001	0.039	-0.036	0.013	0.020	0.001	0.024	-0.017	-0.019	0.401
FI	G	-2.235	-3.388	-3.517	-3.831	2.367	2.637	2.970	2.022	-3.696	-2.148	-0.337	0.384	-3.191	3.274	-1.373	-1.838	-0.271	-1.772	1.680	1.141	0.545**
	P	0.094	0.230	0.240	0.265	-0.155	-0.153	-0.190	-0.113	0.249	0.136	0.021	-0.024	0.215	-0.222	0.094	0.124	0.019	0.114	-0.103	-0.069	0.511*
PL	G	-0.587	-2.262	-2.632	-2.529	4.093	2.328	2.809	1.040	-2.220	0.106	1.778	1.747	-2.484	1.615	-2.477	-0.810	-0.750	-2.453	0.883	2.029	0.070
	P	0.001	0.017	0.020	0.019	-0.032	-0.015	-0.020	-0.005	0.016	-0.001	-0.013	-0.009	0.019	-0.012	0.019	0.006	0.003	0.018	-0.006	-0.014	0.059
PW	G	0.245	1.388	1.281	1.255	-1.037	-1.823	-1.292	-1.052	1.381	0.487	0.630	0.294	1.104	-1.442	0.569	0.803	-0.003	0.594	-0.255	-0.711	-0.280
	P	-0.005	-0.017	-0.015	-0.015	0.012	0.026	0.014	0.012	-0.016	-0.005	-0.005	-0.001	-0.013	0.017	-0.006	-0.010	-0.001	-0.008	0.003	0.010	-0.188
PWt	G	0.193	0.401	0.362	0.376	-0.333	-0.344	-0.485	-0.222	0.370	0.092	-0.085	-0.026	0.398	-0.391	0.168	0.213	-0.001	0.265	-0.131	-0.247	-0.170
	P	0.004	0.015	0.013	0.013	-0.011	-0.010	-0.019	-0.007	0.013	0.003	-0.003	-0.001	0.014	-0.014	0.006	0.008	-0.001	0.009	-0.004	-0.008	-0.172
BP	G	0.014	0.108	0.127	0.102	-0.049	-0.111	-0.088	-0.193	0.112	0.000	-0.000	-0.035	0.098	-0.103	0.055	0.085	0.039	0.085	-0.068	-0.097	0.003
	P	-0.011	-0.027	-0.032	-0.025	0.009	0.027	0.021	0.059	-0.028	-0.000	0.002	0.005	-0.024	0.024	-0.013	-0.021	-0.010	-0.022	0.016	0.026	0.002
PB	G	2.385	4.471	4.458	4.673	-2.627	-3.668	-3.697	-2.818	4.844	3.068	0.913	-0.154	3.851	-4.193	1.314	2.357	0.582	2.012	-2.147	-1.433	0.636**
	P	-0.038	-0.106	-0.106	-0.110	0.058	0.069	0.082	0.056	-0.117	-0.070	-0.022	0.001	-0.090	0.098	-0.031	-0.056	-0.011	-0.046	0.048	0.030	0.591*

DPYP	G	0.935	1.690	1.438	1.885	0.087	-0.899	-0.635	-0.007	2.129	3.362	1.665	0.136	1.052	-1.485	0.188	0.753	0.909	-0.589	-1.799	1.217	1.032
	P	0.098	0.345	0.294	0.375	0.033	-0.125	-0.123	-0.000	0.441	0.732	0.315	-0.036	0.215	-0.301	0.028	0.157	0.192	-0.131	-0.325	0.246	0.929**
SP	G	-0.044	-0.197	-0.088	-0.115	-0.567	0.451	-0.228	-0.002	-0.246	-0.646	-1.305	-0.790	0.026	0.368	0.630	0.005	0.428	0.810	-0.112	-0.658	0.539*
	P	-0.001	0.009	0.005	0.005	0.027	-0.014	0.012	0.002	0.013	0.029	0.069	0.030	-0.001	-0.019	-0.030	-0.000	-0.016	-0.038	0.006	0.028	0.489*
S	G	-0.055	-0.053	0.060	0.117	-0.496	0.187	-0.063	-0.209	0.037	-0.047	-0.703	-1.162	0.019	0.341	0.667	-0.073	0.662	0.386	-0.760	-0.272	0.136
	P	0.018	0.002	-0.004	-0.011	0.032	-0.005	0.004	0.009	-0.001	-0.006	0.051	0.119	-0.004	-0.019	-0.044	0.006	-0.053	-0.028	0.043	0.022	0.054
DM	G	0.573	2.142	2.321	2.299	-1.676	-1.672	-2.263	-1.407	2.195	0.864	-0.056	-0.044	2.761	-2.150	0.419	1.207	-0.237	1.125	-0.747	-0.833	0.315
	P	-0.018	-0.117	-0.127	-0.125	0.089	0.076	0.116	0.064	-0.119	-0.045	0.002	0.005	-0.154	0.118	-0.021	-0.066	0.011	-0.060	0.037	0.042	0.284
TW	G	-5.143	-6.626	-5.862	-6.485	2.995	6.002	6.121	4.037	-6.570	-3.353	-2.140	-2.225	-5.910	7.590	-1.212	-4.588	1.173	-2.527	1.244	2.055	-0.458
	P	0.069	0.144	0.128	0.142	-0.064	-0.111	-0.127	-0.070	0.142	0.070	0.046	0.028	0.130	-0.169	0.026	0.100	-0.020	0.052	-0.024	-0.040	-0.438
L	G	1.599	1.562	1.291	1.608	-2.716	-1.400	-1.551	-1.282	1.218	0.250	-2.167	-2.576	0.681	-0.717	4.489	0.607	3.098	1.838	-2.233	-0.774	0.003
	P	-0.036	-0.051	-0.044	-0.055	0.089	0.038	0.049	0.033	-0.041	-0.006	0.068	0.057	-0.022	0.024	-0.155	-0.020	-0.090	-0.061	0.068	0.026	0.003
Ph	G	0.238	0.584	0.435	0.483	-0.199	-0.443	-0.442	-0.443	0.490	0.226	-0.004	0.063	0.440	-0.608	0.136	1.006	0.073	0.300	-0.254	-0.304	0.238
	P	-0.004	-0.015	-0.011	-0.012	0.005	0.010	0.011	0.010	-0.013	-0.006	0.000	-0.001	-0.011	0.016	-0.003	-0.027	-0.002	-0.008	0.006	0.007	0.224
T	G	0.744	-0.803	-0.069	-0.313	0.809	-0.007	-0.009	0.882	-0.531	-1.194	1.449	2.516	0.379	-0.683	-3.050	-0.319	-4.419	-0.123	2.461	-0.532	0.224
	P	-0.007	0.025	0.003	0.012	-0.017	-0.008	0.006	-0.027	0.016	0.043	-0.038	-0.073	-0.011	0.020	0.094	0.011	0.163	0.005	-0.064	0.005	0.226
P	G	-0.213	-0.306	-0.421	-0.369	0.477	0.260	0.435	0.350	-0.331	0.140	0.495	0.265	-0.325	0.265	-0.326	-0.238	-0.022	-0.797	0.238	0.718	-0.207
	P	0.001	0.002	0.002	0.002	-0.003	-0.001	-0.002	-0.002	0.002	-0.001	-0.003	-0.001	0.002	-0.002	0.002	0.001	0.000	0.005	-0.001	-0.004	-0.193
F	G	0.034	-1.049	-1.063	-1.129	0.556	0.360	0.697	0.909	-1.141	-1.377	0.221	1.685	-0.697	0.422	-1.281	-0.649	-1.434	-0.769	2.575	0.204	-0.466
	P	0.005	0.044	0.043	0.046	-0.022	-0.012	-0.028	-0.033	0.049	0.052	-0.010	-0.043	0.028	-0.017	0.051	0.029	0.047	0.032	-0.118	-0.004	-0.415
CHO	G	-0.018	0.134	0.206	0.137	-0.229	-0.180	-0.234	-0.231	0.136	-0.167	-0.233	-0.108	0.139	-0.125	0.079	0.139	-0.056	0.415	-0.037	-0.461	0.392
	P	-0.003	-0.008	-0.013	-0.008	0.014	0.011	0.013	0.014	-0.008	0.011	0.013	0.006	-0.009	0.007	-0.005	-0.008	0.001	-0.028	0.001	0.032	0.329

*, ** significance at 0.05% and 0.01% probability levels

PH: plant height, DF: days to 50% flowering, IL: inflorescence length, FI: number of flowers per inflorescence, PL: pod length, PW: pod width, PWt: pod weight, BP: number of bunches per plant, PB: number of pods per bunch, DPYP: dry pod yield per plant, SP: seeds per pod, S: shelling percentage, DM: days to maturity, TW: test weight, L: L-Dopa, Ph: total phenol content, T:tannins, P:protein, F: fat, CHO: carbohydrate

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