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Heterosis and combining ability analysis for biochemical traits of velvet bean

A. Chinapolaiah*, K. Hima Bindu, V. Thondaiman, V. Keshava Rao, N. Hariprasada Rao and S. Sudheer Kumar

ICAR-Directorate of Medicinal and Aromatic Plants Research, Anand, Boriavi 387 310, Gujarat

ABSTRACT

Velvet bean is an important underutilized medicinal plant widely used in traditional system of medicine. Its seed are rich in protein, minerals and as a major source of biomolecule L-Dopa, which is used for the treatment of Parkinson's disease. Seeds of six parents and 15 hybrids resulting from half-diallel design excluding reciprocals were analysed for various biochemical traits such as L-Dopa, total phenols, total tannins, crude protein and fat. The *sca* variance was greater than *gca* variance for biochemical traits. This indicated that the predominance of non-additive gene action governing the inheritance of these characters. The present study identified hybrids IIHR Selection 2 × Arka Aswini, Arka Aswini × IIHR Selection LP, Arka Dhanvantari × Arka Aswini, Arka Dhanvantari × IIHR Selection 3 with high average heterosis and heterobeltiosis for L-Dopa, total phenols and total tannins. The crosses IIHR Selection 3 × IIHR Selection LP and IIHR Selection 2 × IIHR Selection LP have manifested high heterosis over mid parent and better parent for protein. IIHR Selection 2 was a good general combiner for high L-Dopa and total phenolics. Arka Aswinini was identified as best general combiner for total tannin. Arka Dhanvantari and IIHR Selection 3 were found to be good general combiners for protein and fat. The Hybrids Arka Dhanvantari × Arka Aswini and IIHR Selection 2 × Arka Aswini were best cross combiners for high L-Dopa for pharmaceutical use and Arka Dhanvantari × IIHR Selection 2 for low L-Dopa for food and feed purpose. The cross IIHR Selection 3 × IIHR Selection LP was best specific cross combiner for protein content, which could be used in the future breeding programme of velvet bean.

Key words: *Mucuna pruriens*, combining ability, heterosis, L-Dopa, Parkinson's disease, protein.

INTRODUCTION

An increase in world's population demands high production of food crops to meet the demand of food. Increasing population demands food for consumption which is rich in nutrients. The pressure on production of traditional legumes is increasing to meet the increasing food demand. Exploitation of underutilized wild legume is an alternate means to food legumes to meet the protein in the developed countries. Under these circumstances, underutilized crops rich in nutrients have recently gained worldwide attention as they contain abundant amounts of all the common nutrients required for normal human growth and offer a good scope in this subject (Mal, 10).

Mucuna pruriens (L.) DC is one such underutilized important tropical medicinal plant belonging to *Fabaceae*. *Mucuna* has is wide spread in tropical and sub tropical regions of the world and its seed consists of high protein, fatty acids, minerals, carbohydrates and it's calorific value is considered as an alternate source of protein. Traditionally in India, the matured seeds of velvet bean are consumed by the South Indian hill tribals, the *Kanikkaras* after repeated boiling (Janardhanan and Laxmanan, 7). Its seeds are used for extracting of L-Dopa, which is used for treatment of Parkinson's disease (Nagashayana and Sankarankutty, 12). Consumption of seed as food is a limitation due to some of the antinutrients (Siddhuraju *et al*., 14). Seed of velvet bean contains antinutrient factors such as total free phenolics, tannins, L-Dopa, protease inhibitor, phytic acid, saponins and hydrogen cyanide. Polyphenols and tannins in legumes inhibit the activities of digestive enzymes (Jambunathan and Singh, 6). The seeds having high L-dopa content which can be used in pharmaceutical industries for preparation of drugs to the treatment of Parkinson's disease. Besides this, velvet bean is a potential crop to grow as intercrop in the fruit orchards and plantations for smothering weeds. It is having high nitrogen fixing capacity and can withstand wide variety of soils. It yields about 2-3 tonnes of seeds per hectare and 20-30 tonnes of biomass per hectare. Till date, research on *Mucuna* reported the variability of nutrients and antinutrinents in different accessions of velvet bean. In published literature, no systematic breeding efforts to find out suitable parents, crosses for improvement of velvet bean for seed which is having rich in nutrients and low antinutrient factors for consumption of food as human diet or feed to the livestock have been reported. High seed yield coupled with high

Corresponding author's E-mail: acpolireddy.hortico@gmail.com

antinutrient factors as L-Dopa can be useful in its exploitation for pharmaceutical purpose. Hence, the present investigation was carried out to select suitable parents and hybrids through diallel analysis. The information generated by the present study can be helpful in future breeding programme of velvet bean.

MATERIALS AND METHODS

Six velvet bean genotypes, *viz*., Arka Dhanvantari, IIHR Selection 2, IIHR Selection 3, IIHR Selection 8, IIHR Selection LP and Arka Aswini were used as parents in hybridization programme and their traits are described in the Table 1. The parents used in the study were developed at the Section of Medicinal Crops, IIHR, Bengaluru. Selected parents were crossed in all possible direct crosses in 6 × 6 half diallel mating design excluding reciprocals generating 15 F_1 hybrids. These 15 hybrids along with six parents were laid out in randomized complete block design with three replications and evaluated during *Kharif* season (2014-15) at Central Horticultural Experimental Station (CHES), Hirehalli, a substation of ICAR-IIHR, Bengaluru. Each treatment was represented by 3 rows and each row was 2.7 m in length. Two seeds were sown per hill with a spacing of 90 cm × 50 cm. The crop was raised under irrigated conditions following the recommended package of practices. In each treatment, five competitive plants were randomly selected to record the observations for various quantitative and biochemical traits. The seeds extracted from matured pods were powdered using grinding machine with 0.2 mm size mesh and the seed powder was used for biochemical analysis. All the biochemical estimations were done in triplicates. Nitrogen content was estimated by micro-Kjeldahl method (Humphries, 5) and crude protein content was calculated by applying the formula N × 6.25. Crude lipid content was estimated using Soxhlet's apparatus (AOAC, 1). The L-Dopa was analysed using Ultra High Performance Liquid Chromatography (UHPLC) using the protocol developed by Shivananda *et al*. (15). Total phenols were estimated using FCR method (Bray and Thorpe, 2). Total tannins were estimated according to Makker *et al*. (9) with minor modifications. Analysis of data for general and specific combining ability was carried out the following Griffing's (4) method 2 Model I using software Windostat version 9.2.

RESULTS AND DISCUSSION

The selected velvet bean parents differed from each other morphologically for flower colour, seed size, shape, seed coat colour and biochemical components. Analysis of variance for biochemical traits revealed that mean squares due to genotypes, crosses and parents vs crosses were significant for antinutrient factors, while parent vs crosses were not significant for nutrient factors such as protein and fat (Table 2) indicating presence of considerable variability in the material used in the study. The results showed that the magnitude of *sca* variance was greater than *gca* variance indicating the predominance of non-additive gene action governing the inheritance of L-Dopa, total phenolics, tannins, crude protein and fat. It was evident from *sca* effects that non-additive gene action was predominantly important in the expression of all biochemical traits estimated. Similar results were reported by Kute *et al*. (8) for protein content in mungbean. Mebrahtu and Mohamed (11) reported both additive and non-additive genetic variance effects for protein content, while additive genetic variance for tannin content in common beans.

Table 1. Salient features of parents used in half-diallel mating design.

Parent genotype	Features
Arka Dhanvantari	It is a long duration type (185-190 days). It produces flowers born on long rachis. Flower is purple in colour. No fruiting in basal nodes. It gives seed yield about 4.2 t ha^{-1}. Seed are shiny and black in colour and medium sized.
IIHR Selection 2	Long duration 180-190 days. Flowers born on very long rachis. Flowers light creamy white in colour, seed is medium in size and white in colour.
IIHR Selection 8	Medium duration 150-160 days. Flowers produced on short rachis. Flower is purple in colour. Seed is bold in size with black mottling.
IIHR Selection 3	Medium duration type150-160 days. Flowers produce on short rachis. Flower is purple in colour. Seed is bold and white in colour.
Arka Aswini	It is a short duration type (120-130 days). Flowers are purple in colour on short rachis. It produces fruits on basal nodes. Immature fruits are black in colour.
IIHR Selection LP	Medium duration 140-150 days, flowers are light purple in colour and seed is medium and white in colour.

Table 2. Analysis of variance for combining ability for biochemical characters in velvet bean.

Source	df	L-DOPA (%)	Total phenols (mg/100 g)	Total tannin (mg/100g)	Protein (%)	Fat (%)
Replicate	2	0.01	0.47	0.00	0.30	0.05
Treatment	20	0.97**	136.54**	0.03**	40.21**	0.69**
Parents	5	0.76**	307.20**	0.02**	83.90**	0.73**
Hybrids	14	1.10**	83.08**	0.03**	27.33**	0.49**
Parent vs. Hybrids	1	0.28**	31.63**	0.05**	2.10	3.39
Error	40	0.02	0.34	0.00	1.20	0.04
Total	62	0.33	44.28	0.01	13.76	0.25
GCA	5	0.61**	95.31***	0.02**	16.37**	0.42**
SCA	15	0.23**	28.91**	0.01**	12.41**	0.17**
Error	40	0.01	0.11	0.00	0.40	0.01

*,**significant at 5 and 1% levels

Parental genotypes recorded significant *gca* effects in both positive and negative direction. For high L-Dopa content, IIHR Selection 2 was found to be good general combiner and IIHR Selection 3 was good general combiner for low L-Dopa content. IIHR Selection 2 recorded significantly high *gca* effects and Arka Aswini exhibited with low *gca* effects for total phenolics. Arka Aswini was good general combiner for high tannins and for low tannins, parents IIHR Selection 3 and IIHR Selection LP were good general combiners. The identified superior combiners can be used in further breeding programmes. The genotypes possessing low antinutrient factors can be useful in developing a variety with high seed yield for food for human beings or as feed to the livestock. Whereas, combiners for high L-Dopa antinutrient can be utilised as parents to develop the cultivar with high seed yield coupled with high L-Dopa that can be beneficial for the pharmaceutical industries.

Data recorded for nutrient factors of *Mucuna* seed revealed that the parent Arka Dhanawantari showed highest significant *gca* effects for protein content, IIHR Selection 3 recorded low *gca* effects. IIHR Selection 3 was best general combiner for fat content with significant positive *gca* effects, whereas Arka Dhanawantari recorded low *gca* effects.

For L-Dopa seed content, 12 crosses exhibited significant *sca* effects, in which 6 crosses exhibited significant positive *sca* effects. The hybrids Arka Dhanawantari × Arka Aswini and IIHR Selection 2 × Arka Aswini were best cross combinations for high L-Dopa content and crosses Arka Dhanawantari × IIHR Selection 2 and Arka Dhanawantari × IIHR Selection 3 were best specific combiners for low L-Dopa content in the seed. These can be utilised to develop variety with high L-Dopa suitable for pharmaceutical purpose and genotypes for low L-Dopa content for its exploitation as food and feed. The highest *sca* effects for high L-Dopa and low L-Dopa content manifested by the crosses having high *per se* performance and involving parents with high × high general combiners indicating the additive type of gene action (Table 6). Such crosses can be exploited by simple conventional breeding like pedigree method, which may give stable high performance progenies in next generations. For total phenols, all the crosses except Arka Dhanawantari × Arka Aswini exhibited significant *sca* effects in which 8 crosses recorded significant positive *sca* effects and 6 crosses had shown *sca* effects negative in direction. For high total phenols, IIHR Selection 2 × IIHR Selection LP exhibited high *per se* performance but it showed low *sca* effects indicating that the parents with high mean values may not transmit the superior traits to the their progeny. The crosses Arka Aswini × IIHR Selection LP (8.43), Arka Dhanavantari × IIHR Selection 8 (7.03) were best specific combiners, while for low total phenols, crosses IIHR Selection 2 × IIHR Selection 3 (-7.98) and IIHR Selection 8 × IIHR Selection LP (-5.67) were identified as good specific combiners. Results also revealed that six crosses exhibited significant *sca* effects for total tannins content. The crosses Arka Dhanawantari × Arka Aswini (0.15), IIHR Selection 2 × IIHR Selection 8 (0.12), IIHR Selection 3 × Arka Aswini (0.07) and IIHR Selection 2 × Arka Aswini (0.06) registered significant *sca* effects in positive direction for total tannins. Crosses IIHR Selection 2 × IIHR Selection LP (0.09) and IIHR Selection 8 × Arka Aswini (0.07) recorded significant *sca* effects in negative direction.

For protein content, 10 crosses exhibited significant *sca* effects, in which two crosses were in positive direction and eight crosses were in negative direction. Significant positive *sca* effects were recorded for crosses IIHR Selection 3 × IIHR Selection LP (5.22), and IIHR Selection 2 × IIHR Selection LP (3.94). The hybrid IIHR Selection 3 × IIHR Selection LP, and IIHR Selection 2 × IIHR Selection LP were best specific cross combiners (Table 3) with parents having *gca* status as low × high (Table 6) combiners indicating the involvement of additive and dominance genetic reaction for seed protein content. Hence, the inter crossing of selected segregrants in biparental mating system and recurrent selection procedure followed by pedigree method would improve protein content in these cross combinations. The combination of high × low *gca* status play important role in the expression of positive significant *sca* effects. In a similar study, Mebrahtu and Mohamed (11) reported high *sca* effects in four crosses of common bean. For fat content in the seed, six crosses showed significant *sca* effects and crosses, *viz*., IIHR Selection 8 × IIHR Selection 3 (0.50) and Arka Dhanawantari × IIHR Selection 2 (0.28) recorded significant positive *sca* effects and these were identified as good specific combiners for fat content.

L-Dopa is the important bioactive principle in the seed of velvet bean which is used for the treatment of Parkinson's disease. Relative heterosis ranged from -22.59 to 20.37% and heterobeltiosis from -32.96 to 16.68% (Table 5). For L-Dopa content, 5 crosses exhibited significant positive average heterosis and 7 crosses exhibited significant negative relative heterosis. Positive heterobeltiosis was recorded in 2 crosses, while 7 crosses had negative heterobeltiosis. Both negative as well as positive heterotic crosses can be used in breeding programme as genotypes with low L- Dopa content can be useful as food or feed purpose. High heterotic crosses can be used for development of high L-Dopa variety for pharmaceutical purpose. The relative heterosis for total phenols ranged from -12.83 to 22.56% and eight crosses recorded significant heterosis and six crosses were significant negative in direction. Heterobeltiosis ranged from -16.21 to 5.96% (Table 5) and three crosses had significant positive heterosis and 11 crosses showed significant negative in direction. The cross Arka Aswini × IIHR Selection LP exhibited highest heterosis over mid-parent (22.56%) and better parent (5.96%). The low heterotic cross for the total phenols was recorded in the cross IIHR Selection 2 × IIHR Selection 3 over mid-parent and better parent.

For total tannin content, relative heterosis ranged from -20.80 to 53.56% and was significantly positive in 4 crosses and negative in one cross. Heterobeltiosis for tannins varied from -32.65 to 49.64% (Table 5) and it was significantly positive in two crosses and in negative direction in one cross (IIHR Selection 2 × IIHR Selection LP). The results of heterosis concurred with Mebrahtu and Mohamed (11) who reported heterosis in a study of common beans and ranged from -37 to 43% heterosis over mid parent and -50 to 40% over the better parent. Among the crosses, Arka Dhanvantari × Arka Aswini manifested high heterotic cross over mid-parent (53.56%) and better parent (49.64%) and lowest heterosis was observed in IIHR Selection 2 × IIHR Selection LP. For nutrient factors of *Mucuna* seed, protein is important trait as consumption of food. In crude protein content, the relative heterosis ranged from -32.78 to 31.97% and it was positively significant in six crosses and negative in five crosses. Heterobeltiosis was recorded in the range of -46.39 to 26.64% (Table 5) and it was significant and positive in four crosses and negative in five crosses. Sunil Kumar and Prakash (16) observed similar trend of relative heterosis and heterobeltiosis in the study of mungbean. Similar results were reported by Vaidya *et al*. (17) in mungbean where 14 crosses showed significant positive relative heterosis and highest heterobeltiosis for protein at 6.62%. Das *et al*. (4) reported the range of heterobeltiosis varied from -1.8 to 0.05% in the study of Dolichos bean in which highest heterobeltiosis of 0.05% is vey meagre heterosis compared to this study. Among the crosses, IIHR Selection 3 × IIHR Selection LP have been recorded highest average heterosis (31.97%) and highest heterobeltiosis (26.64%) was recorded in the cross IIHR Selection 2 × IIHR Selection LP (Table 4) . Nassar (14) reported the highest relative heterosis (10.45%) and heterobeltiosis (5.59%) in diallel analysis of soybean, in which 4 crosses exhibited significant relative heterosis and 3 crosses manifested significant positive heterobeltiosis. For fat content, IIHR Selection 8 × IIHR Selection 3 exhibited significant and positive average heterosis and it ranged from -21.07 to 6.96% (Table 5). None of the crosses exhibited significant positive heterobeltiosis for fat content. The highest average heterosis was found in only one cross IIHR Selection 8 × IIHR Selection 3 (6.96%). This finding was contrast to Nassar (13) who reported that 4 and 3 crosses were significant and positive heterosis relevant to over mid and better parents, respectively in soybean.

Information on the nutrient and antinutrient factors in *Mucuna pruriens* is important for plant breeder to select parents for hybridization. From the study, it was found that IIHR Selection 2 was good general combiner for high L-Dopa and total phenolic content. Arka Aswinini was a superior general combiner for total tannin content. Arka Dhanvantari and IIHR Selection 3 were good general combiners for protein and fat, respectively. The hybrids Arka Dhanvantari × Arka Aswini and IIHR Selection 2 × Arka Aswini were best cross combiners for high L-Dopa for pharmaceutical uses. The cross IIHR Selection 3 × IIHR Selection LP was best specific cross combiner for protein. The hybrids IIHR Selection 2 × Arka Aswini, Arka Aswini × IIHR Selection LP, Arka Dhanvantari × Arka Aswini were identified with high average heterosis and heterobeltiosis for L-Dopa, total phenols and total tannins, respectively. In case of protein content of *Mucuna* seed, the crosses IIHR Selection 3 × IIHR Selection LP and IIHR Selection 2 × IIHR Selection LP manifested high heterosis over mid-parent and

Table 3. Estimates of general combining ability effects for biochemical traits in velvet bean.

Parent genotype	L-DOPA (%)	Total phenols (mg/100 g)	Total tannins (mg/100 g)	Crude protein (%)	Fat (%)
Arka Dhanvantari	0.25**	0.12	0.04**	1.88**	-0.37**
IIHR Selection 2	0.30**	5.32**	0.05**	-0.03	-0.09*
IIHR Selection 8	-0.24**	-1.82**	-0.03*	-1.53**	0.00
IIHR Selection 3	-0.34**	-0.11	-0.06**	-1.61**	0.33**
Arka Aswini	0.19**	-5.05**	0.06**	-0.03	0.03
IIHR Selection LP	-0.16**	1.54**	-0.06**	1.33**	0.09*
S.E gi	0.02	0.10	0.00	0.20	0.03
S.E gi-gj	0.03	0.16	0.01	0.31	0.05

*,**significant at 5 and 1% levels

Table 4. Estimates of specific combining ability effects of fifteen cross combinations in velvet bean.

Cross	L-DOPA (%)	Total phenols (mg/100 g)	Total tannins (mg/100 g)	Crude protein (%)	Fat (%)
Arka Dhanvantari × IIHR Selection 2	-0.66**	-0.99**	-0.01	-0.19	0.28*
Arka Dhanvantari × IIHR Selection 8	-0.46**	7.03**	0.01	-2.79**	-0.12
Arka Dhanvantari × IIHR Selection 3	-0.54**	-5.45**	-0.02	-5.69**	-0.17
Arka Dhanvantari × Arka Aswini	0.87**	0.18	0.15**	-2.97**	-0.62**
Arka Dhanvantari × IIHR Selection LP	-0.30**	-3.40**	-0.02	-2.77**	-0.19
IIHR Selection 2 × IIHR Selection 8	0.35**	1.72**	0.12**	-1.28*	-0.11
IIHR Selection 2 × IIHR Selection 3	0.26**	-7.98**	0.01	-1.83**	-0.06
IIHR Selection 2 × Arka Aswini	0.49**	2.98**	0.06*	2.45**	-0.05
IIHR Selection 2 × IIHR Selection LP	0.22**	4.29**	-0.09**	3.94**	-0.50**
IIHR Selection 8 × IIHR Selection 3	-0.38**	-2.11**	0.02	0.57	0.50**
IIHR Selection 8 × Arka Aswini	-0.10	1.04**	-0.07*	0.75	-0.28*
IIHR Selection 8 × IIHR Selection LP	0.16*	-5.67**	-0.02	0.43	-0.17
IIHR Selection 3 × Arka Aswini	-0.03	5.32**	0.07*	1.96**	-0.16
IIHR Selection 3 × IIHR Selection LP	-0.03	1.32**	0.04	5.22**	-0.36**
Arka Aswini × IIHR Selection LP	-0.47**	8.43**	0.02	0.48	-0.19
S.E (Sij)	0.06	0.29	0.02	0.56	0.10
S.E (Sij-Sik)	0.09	0.44	0.04	0.83	0.15
S.E (Sij-Skl)	0.09	0.41	0.37	0.77	0.14

*,**significant at 5 and 1% levels

Table 5. Estimates of heterosis (%) for antinutrient factors L-Dopa, total phenols, tannins crude protein and fat in velvet bean.

Cross	L-DOPA		Total phenols		Total Tannin		Crude Protein		Fat	
	M.P	B.P	M.P	B.P	M.P	B.P	M.P	M.P	M.P	B.P
Arka Dhanvantari × IIHR Selection 2	-16.36**	-22.78**	-2.10**	-7.47**	8.45	4.76	-10.42**	-26.34**	-0.71	-4.19
Arka Dhanvantari × IIHR Selection 8	-19.01**	-29.35**	9.76**	5.13**	14.05	0.73	-24.14**	-37.96**	-7.10*	-10.73**
Arka Dhanvantari × IIHR Selection 3	-22.59**	-32.96**	-11.12**	-12.67**	9.68	-13.14	-32.77**	-46.39**	-7.89**	-16.32**
Arka Dhanvantari × Arka Aswini	17.31**	5.25*	6.34**	-8.58**	53.56**	49.64**	-20.25**	-34.18**	-21.07**	-27.88**
Arka Dhanvantari × IIHR Selection LP	-15.16**	-24.69**	-3.84**	-4.48**	-1.67	-13.87	-15.53**	-29.81**	-13.34**	-21.84**
IIHR Selection 2 × IIHR Selection 8	10.03**	3.41	2.97**	-6.55**	38.10**	18.37	-4.83	-5.48	-5.04	-5.46
IIHR Selection 2 × IIHR Selection 3	6.07*	-1.09	-12.83**	-16.21**	15.42	-10.88	-4.56	-8.23	-4.12	-9.95**
IIHR Selection 2 × Arka Aswini	20.37**	16.68**	11.03**	-8.93**	29.96**	22.45*	16.99**	16.45**	-8.72**	-13.75**
IIHR Selection 2 × IIHR Selection LP	6.80**	2.33	7.13**	0.62	-20.80*	-32.65**	28.31**	26.64**	-16.85**	-22.49**
IIHR Selection 8 × IIHR Selection 3	-17.92**	-18.61**	-5.33**	-10.84**	22.16	7.62	0.23	-2.98	6.96**	0.88
IIHR Selection 8 × Arka Aswini	-0.60	-3.72	10.03**	-1.76*	1.28	-8.46	3.70	2.52	-11.44**	-15.97**
IIHR Selection 8 × IIHR Selection LP	-1.60	-3.56	-5.60**	-9.00**	-4.81	-5.71	7.28*	5.18	-9.79**	-15.57**
IIHR Selection 3 × Arka Aswini	-0.56	-4.46	11.74**	-5.33**	44.76**	16.92	12.23**	7.44	-9.04**	-9.62**
IIHR Selection 3 × IIHR Selection LP	-8.36**	-10.92**	0.45	-1.94**	18.03	4.85	31.97**	25.31**	-12.59**	-13.30**
Arka Aswini × IIHR Selection LP	-9.66**	-10.74**	22.56**	5.96**	15.88	3.85	12.79**	11.84**	-14.34**	-15.57**

better parent, respectively. These crosses can be used in future breeding programme of velvet bean.

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Table 6. List of top superior combiners and their *sca* effects, *per se* performance and *gca* status.

Trait	Cross combination	*sca* effect	*per se* performance	*gca* effect of parents		*gca* status
				male	female	
L-DOPA (%) (High)	Arka Dhanvantri × Arka Aswini	0.87**	5.34	0.24**	0.18**	H × H
	IIHR Selection 2 × Arka Aswini	0.49**	5.01	0.29**	0.18**	H × H
	IIHR Selection 2 × IIHR Selection 8	0.35**	4.44	0.29**	-0.237**	H × L
	IIHR Selection 2 × IIHR Selection 3	0.26**	4.25	0.29**	-0.340	H × L
Low	Arka Dhanvantri × IIHR Selection 2	-0.66**	3.92	0.24**	0.296**	H × H
	Arka Dhanvantri × IIHR Selection 3	-0.54**	3.40	0.24**	-0.340**	H × L
	Arka Aswini × IIHR Selection LP	-0.47**	3.60	0.18**	-0.156**	H × L
	Arka Dhanvantri × IIHR Selection 8	-0.46**	3.58	0.24**	-0.237**	H × L
Total phenols (mg/100 g) (High)	Arka Aswini × IIHR Selection LP	8.43**	76.95	-5.05**	1.53**	L × H
	Arka Dhanvantari × IIHR Selection 8	7.03**	77.37	0.12	-1.81**	L × L
	IIHR Selection 8 × Arka Aswini	5.32**	66.20	-1.81**	-5.05**	H × L
	IIHR Selection 2 × IIHR selection LP	4.29*	83.18	5.32**	1.53**	H × L
Low	IIHR Selection 2 × IIHR Selection 3	-7.98**	69.26	5.32**	-0.11	H × L
	IIHR Selection 8 × IIHR Selection LP	-5.67**	66.08	-1.81**	0.15**	L × H
	Arka Dhanvantri × IIHR Selection 3	-5.45**	66.59	0.12	-0.11	L × L
	Arka Dhanvantri × IIHR Selection LP	-3.40**	70.30	0.12	1.53**	L × H
Total tannins (mg/100 g) High	Arka Dhanvantri × Arka Aswini	0.15**	0.68	0.03**	0.05**	H × H
	IIHR Selection 2 × IIHR Selection 8	0.12**	0.58	0.04**	-0.026*	H × L
	IIHR Selection 3 × Arka Aswini	0.07*	0.50	-0.05**	0.05**	L × H
	IIHR Selection 2 × Arka Aswini	0.06*	0.60	0.04**	0.05**	H × H
Total tannins (mg/100 g) Low	IIHR Selection 2 × IIHR Selection LP	-0.09**	0.33	0.04**	-0.06**	H × L
	IIHR Selection 8 × Arka Aswini	-0.07*	0.39	-0.02*	0.05**	L × H
	Arka Dhanvantri × IIHR Selection 3	-0.02	0.39	0.03**	-0.05**	H × L
	Arka Dhanvantri × IIHR Selection LP	-0.02	0.39	0.03**	-0.06**	H × L
Crude protein (%)	IIHR Selection 3 × IIHR Selection LP	5.22**	29.29	-1.61	1.32**	L × H
	IIHR Selection 2 × IIHR Selection LP	3.94**	29.60	-0.02	1.32**	L × H
	IIHR Selection 2 × Arka Aswini	2.45**	26.75	-0.02	-0.02	L × L
	IIHR Selection 3 × Arka Aswini	1.96**	24.68	-1.61	-0.02	L × L
Fat (%)	IIHR Selection 8 × IIHR Selection 3	0.50**	6.12	0.004	0.33**	L × H
	Arka Dhanvantri × IIHR Selection 2	0.28*	5.10	-0.36	-0.08	L × L
	IIHR Selection 2 × Arka Aswini	-0.05	5.16	-0.088	0.02	L × L
	IIHR Selection 2 × IIHR Selection 3	-0.06	5.46	-0.08	0.33**	L × H

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