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Genetic Variability and Trait Association Studies on Yield and Pod Shattering Attributing Traits in MAGIC Population of Soybean (*Glycine max* (L.) Merrill)

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ABSTRACT: Pod shattering is one of the major constraints in soybean that could reduce the yield potential considerably in tropical and subtropical areas. As a consequence, the management of pod shattering is of great importance for achieving higher productivity. Hence there is a need of assessing the extent of variability and association studies in recently developed tailor made source of germplasm *i.e.*, MAGIC population which has undergone heavy genetic recombinations. Keeping these points in view, the present investigation was carried out to assess the genetic variability and association studies in 60 soybean MAGIC lines along with six checks for 15 quantitative traits. The ANOVA found that all the traits differed significantly for different source of variations. The higher estimates of PCV and GCV were found for pod shattering, seed yield per plant, number of branches per plant and plant height. The measure of broad sense heritability was found high for most of the traits and lowest (51.4 %) for harvest index. High heritability coupled with high genetic advance was observed for plant height, number of branches per plant, pod wall thickness, weight of pods, weight of seeds per pod, hundred seed weight, seed yield per plant and pod shattering indicating that these traits are governed by additive gene effects and direct selection of soybean MAGIC lines based on these traits would be effective. The association studies revealed that seed yield per plant have positive correlation with days to 50% flowering, harvest index, number of pods per plant, days to maturity, pod width, pod wall thickness, weight of seeds per pod and hundred seed weight and negative association with plant height, number of branches, number of clusters, pod length and pod shattering while, Pod shattering has significantly negative correlation with pod wall thickness and pod width. From the results, it is revealed that an increase in pod wall thickness and pod width will reduce the incidence of pod shattering and reduce the yield losses.

Keywords: Soybean, MAGIC, Pod shattering, Augmented design, Correlation and path coefficient.

INTRODUCTION

Soybean, a “golden bean” is thought to have been domesticated 5,000 years ago in East Asia, which scatters its seeds via pod dehiscence (Hymowitz and Singh 1987). Although this characteristic is important for wild species adaptation to natural habitats, it reduces soybean yields significantly. Pod shattering, a physiological feature that can severely reduce seed yield is a major hindrance to soybean production in tropical and sub-tropical ecosystems (Krisnawati and Adie 2017). Yield losses due to shattering can range from 34 to 99% (Tiwari and Bhatnagar 1991), depending on the variety's susceptibility, environmental factors (temperature and relative humidity), pod morphology and anatomyand the length of the harvest delay after maturity (Zhang and Boahen 2010; Krisnawati and Adie 2017; Gaikwad, 2018).

The success in increasing soybean resistance to pod shattering is determined by the availability of genetic diversity, an understanding of the genes controlling shattering resistance and an efficient selection method. In order to adopt proper selection methods, there must be variability in the plant population before starting any crop improvement programme (Dhanwani *et al.*, 2013). As phenotypic variation is influenced by environmental factors, selection based on it alone is erroneous. To understand the genetic makeup of the experimental population, it is needed to split overall variability into several components. In assessing variability at the genotypic and phenotypic levels, genetic parameters such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) are quite useful. In addition, partitioning observed variability into heritable and non-heritable components is necessary for effective selection (Yadawad *et al.*, 2015). As a result, the parameter heritability is employed to calculate the heritable component of total variation, but it is insufficiently informative for proper selection. As a result, heritability along with genetic advance can help in determining genetic gain under selection (Johnson *et al*., 1955).

Furthermore, due to the repeated use of the same parents during the hybridisation technique Indian soybean cultivars have a very narrow genetic base (Bharadwaj *et al*., 2002). As a result, a multi-way hybrid such as MAGIC (Multi-parent Advanced Generation Inter Cross) can add variability to the crop gene pool as it is a highly variable and diverse source of germplasm which undergoes high genetic recombination events. The genetic parameters in various soybean cultivars were studied by Chandrawat *et al*. (2017); Guleria *et al*. (2019); Jain *et al*. (2018); Joshi *et al*. (2018); Koraddi and Basavaraja (2019); Kumar *et al.* (2018); Neelima *et al.* (2018). But, an in-depth study is required on soybean MAGIC lines which is of current importance. Hence, the present study was carried out which deals with the assessment of phenotypic coefficient of variation, genotypic coefficient of variation, heritability and genetic advance in soybean MAGIC lines for yield and pod shattering attributing traits.

Grain yield in soybeans, as in other crops is a complicated trait that is influenced by a number of factors. The study of direct and indirect effects of yield and its components provides the basis for the subsequent breeding programme and thus a gain in bean production may be more effectively tackled on the basis of yield component performance and selection for highly associated traits. Knowledge of character correlations is extremely useful in breeding programmes since, it allows the breeder to easily determine which characters to employ as selection indices. Path co-efficient analysis determines the direct and indirect effects of one variable on another, enabling the correlation co-efficient to be divided into direct and indirect effect (Dewey and Lu 1959)

MATERIALS AND METHODS

The field study was carried out inARS (Agricultural Research Station) Adilabad, Hyderabad during *Kharif* 2021. The experimental material consisted of 60 soybean MAGIC lines with 6 checks Basara, KDS-726, KDS-753, AISB-50 (tolerant) and JS-335, JS-9305 (susceptible). All the entries were evaluated in Augmented Randomised Block Design (RBD) by keeping inter and intra-row spacing of 45 and 10 cm respectively. Evaluation of MAGIC lines for pod shattering was carried out in oven dry method at 40°C for 8 hour and 25°C for 16 hours alternatively for 7 days. The observations were recorded for 15 yield and its attributing traits and subjected to statistical analysis.

Statistical Analysis. The statistical analysis was carried out using R package "augmented RCBD" software version 4.2.Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were estimated as per suggested by Burton and Devane (1953), heritability and genetic advance were calculated as per Johnson *et al*., 1955. Correlation coefficients (Falconer, 1981) and Path coefficient analysis was done according to Wright (1921); Dewey and Lu (1959) to estimate the direct and indirect effects.

RESULTS AND DISCUSSION

ANOVA and Genetic parameters: The analysis of variance revealed a significant difference among the MAGIC lines for all the 15 traits for different source of variations. The block effect (unadjusted) and the treatment effects (adjusted and unadjusted) were significant indicating the presence of considerable amount of genetic variability. Similarly, the effects due to checks, varieties and checks *vs*. varieties were significant indicating that the MAGIC lines were significantly different from checks. However, the adjusted block effects were non-significant for different traits related to yield and pod shattering under field condition indicating homogeneity of evaluation blocks. It provides ample opportunity for the breeder in the selection of lines having traits in the desirable direction. This is in agreement with the result obtained by Koraddi and Basavaraja (2019).

The magnitude of variability is estimated by the parameter PCV and GCV which suggests the phenotypic and genotypic components of variation respectively. The value of PCV was found higher than the corresponding GCV for all the characters. But, a narrow gap between the PCV and GCV was observed indicating a lower influence of environmental factor in the expression of selected traits. Thus, selection of the genotypes for these characters would be beneficial. Similar results were obtained by Neelima *et al*. (2018).

Higher estimates of PCV and GCV were recorded in pod shattering % (38.97, 38.69), Seed yield per plant (30.81, 30.80), Number of branches per plant (28.41, 28.34) and plant height (22.75, 22.73). The results suggesting the presence of sufficient variability among the MAGIC lines for these traits which can be selected directly or may be utilised in future breeding programmes. A moderate value of PCV and GCV was recorded for Hundred seed weight (15.74, 15.11), Weight of seeds per pod (14.98, 13.47), pod wall thickness (20.4, 16.1) and pod weight (15.4, 14.67) and days to fifty % flowering (12.70, 10.55) which is similar to the result obtained by Karnwal *et al*. (2009); Kumar *et al*. (2018). The measure of PCV and GCV was found lower for Harvest index (10.00, 9.57), pod width (7.22, 7.10), pod length (10.03, 8.21), number of pods per plant (9.80, 9.54), Number of clusters per plant (12.43, 7.65) and days to maturity (7.12, 6.57). It shows presence of lower variability in the selected MAGIC lines for these traits indicating a good scope for their further improvement. Similar results were obtained by Chandrawat *et al*. (2017); Dubey *et al*. (2015); Guleria *et al*. (2019); Mahbub *et al*. (2015) for days to maturity.

Variability exists among the genotypes for several traits can be better exploited when they are heritable in nature. The majority of the traits had a high broad sense heritability, according to the results (Table 1). It shows that these traits are least influenced by environmental effects and genetic improvement through selection may be effective. The results are consistent with Akram *et al*. (2016); Chandrawat *et al*. (2017); Guleria *et al*. (2019); Malek *et al*. (2014). A moderate value (51.42 %) of heritability was observed in harvest index which is in conformity with the findings of Jain *et al.* (2018); Koraddi and Basavaraja (2019).

Genetic advance refers to the improvement of the mean genotypic value of the selected lines over the mean genotypic value of the parental population. It is usually expressed as a percent of the mean. Selection based on broad sense heritability alone is misleading as it is not sufficiently informative about the existence of gene action (additive/non-additive) and involvement of other factors in the expression of traits. Thus, heritability along with genetic advance together is helpful in predicting genetic gain under selection (Johnson *et al*., 1955). The estimates of genetic advance as percent of mean was found highest for pod shattering % (79.25) followed by seed yield per plant (63.51), number of branches per plant (58.34), plant height (46.87), hundred seed weight (29.93), pod weight (28.82), pod wall thickness (26.22), weight of seeds per pod (24.98). The lowest value was observed for number of clusters per plant (9.70) followed by days to maturity (12.51), pod length (13.84), pod width (15.92), days to fifty percent flowering (18.08), number of pods per plant (19.17) and harvest index (19.72). Among all the characters, high heritability along with high genetic advance as percent of mean was observed for plant height, number of branches per plant, pod wall thickness, weight of pods, weight of seeds per pod, hundred seed weight, seed yield per plant and pod shattering % indicating predominance of additive gene action and a limited role of environment in the expression of these traits. Hence, these traits are fixable in nature and selection on the basis of these traits would be effective.

Traits like days to 50 % flowering, days to maturity, number of pods per plant, pod length, pod weight exhibited high heritability with moderate genetic advance as percent of mean suggesting the combining or conditional role of additive and non-additive gene action in governing these traits and high heritability may have resulted from favourable influence of environmental factors. Thus, the selection of these traits may not be beneficial. Similar findings were reported by Akram *et al*. (2016) for days to 50 percent flowering. A moderate estimate of heritability with lower estimates of genetic advance as percent of mean was observed for number of clusters per plant indicating predominance of non-additive gene action and direct selection for these traits may not be rewarding. Hence, recombination breeding may be useful for the improvement of these traits.

Correlation and path analysis studies. The trait association of fifteen traits were assessed through correlation and path analysis (Table 2 and 3, Fig. 1). The results revealed that seed yield per plant trait have significant positive correlation with days to fifty % flowering, harvest index and number of pods per plant. Similar results of positive correlation of seed yield with number of pods per plant were recorded by Reziazed *et al*. (2001); Gohil *et al*. (2003); Saharan *et al*. (2006); Faisal *et al*. (2006); Sonwane *et al*. (2006). It have non-significant positive correlation with days to maturity, pod width, pod wall thickness, weight of seeds per pod and hundred seed weight. There was non-significant negative association with plant height, number of branches, number of clusters, pod length and pod shattering percentage.

The trait association analysis revealed that pod shattering has significantly negative correlation with pod wall thickness and pod width. This finding is in agreement with Adeyeye *et al*. (2014); Bhatia and Tiwari (1994). There was non-significant positive correlation with days to fifty percent flowering, pod weight, weight of seeds per pod and hundred seed weight and non-significant negative correlation with days to maturity, plant height, number of branches, number of clusters, number of pods per plant, pod length and harvest index.

Since the anatomical and morphological trait of pod was considered have important role in resistance to pod shattering in soybean, a path coefficient analysis was used to quantify the relation between pod shattering with pod characters. Pod shattering has recorded a negative direct effect on plant yield mainly influenced by the negative indirect effects through days to fifty percent flowering, pod width, pod wall thickness, pod weight, weight of seeds per pod and hundred seeds weight. There was an indirect positive effect from days to maturity, plant height, number of branches, number of clusters, number of pods per plant, pod length and harvest index. The traits days to fifty % flowering, number of pods per plant, pod weight, weight of seeds per pod, hundred seed weight and harvest index could be used for selection in yield improvement as they have positive direct effect on total plant yield.

Table 1: Mean, variability, GCV, PCV, heritability (broad sense), genetic advance and genetic advance as per cent of mean for 15 characters in MAGIC lines of soybean (*Glycine max*(L.) Merrill).

Sr. No.	Characters	Mean	Range		Coefficient of variation (%)		Broad sense heritability (h^2) (%)	Genetic advance	Genetic advance as % of mean (5%)
			Minimum	Maximum	Genotypic	Phenotypic			
1.	Days to 50% flowering	36.83	27.00	46.00	10.55	12.70	69.02	6.65	18.08
2.	Days to maturity	100.63	85.00	112.00	6.57	7.12	85.15	12.59	12.51
3.	Plant height (cm)	59.88	36.80	101.80	22.73	22.75	99.89	28.06	46.87
4.	Number of branches per plant	3.77	2.00	7.00	28.34	28.41	99.55	2.20	58.34
5.	Number of clusters per plant	11.16	8.00	16.00	7.65	12.43	37.81	1.09	9.7
6.	Number of pods per plant	58.70	42.20	77.00	9.54	9.80	94.82	11.25	19.17
7.	Pod length (mm)	3.45	2.78	4.60	8.21	10.03	66.87	0.48	13.84
8.	Pod width (mm)	5.07	4.06	6.10	7.10	7.22	90.8	0.809	15.92
9.	Pod wall thickness (mm)	0.21	0.15	0.40	16.10	20.40	62.31	0.06	26.22
10.	Pod weight (g)	0.54	0.68	0.30	14.67	15.40	90.72	0.16	28.82
11.	Weight of seeds per pod (g)	0.40	0.21	0.51	13.47	14.98	80.86	0.10	24.98
12.	Hundred seeds weight(g)	13.27	7.72	17.03	15.11	15.74	92.15	3.97	29.93
13.	Seed yield per plant	15.37	8.60	23.90	30.80	30.81	99.91	9.76	63.51
14.	Harvest index	38.38	30.40	45.30	9.57	10.00	51.42	7.57	19.72
15.	Shattering Percentage (%)	55.66	8.00	100.00	38.69	38.97	98.58	44.14	79.25

Table 2: Correlation coefficients of yield and pod shattering attributing traits.

	DFF	DM	PH	NB	NC	NPP	PL	PW	WT	PWt.	WSPP	HSW	HI	SP	SYP
DFF	1	0.516**	0.036	0.062	0.045	0.042	0.136	0.238	0.310 *	0.087	0.086	0.103	0.216	0.001	0.327 **
DM		1	0.007	-0.105	0.159	0.160	0.101	0.114	0.081	0.115	0.192	0.162	0.127	-0.163	0.105
PH			1	0.306*	0.206	0.085	-0.224	-0.001	0.161	-0.041	-0.009	-0.015	0.017	-0.235	-0.051
NB				1	0.277 *	0.219	-0.206	-0.162	-0.004	-0.275 *	-0.247 *	-0.216	0.051	-0.097	-0.139
NC					1	0.203	-0.002	-0.245*	-0.089	-0.242	-0.197	-0.143	-0.011	-0.106	-0.056
NPP						1	-0.002	-0.201	-0.030	-0.192	-0.181	-0.216	-0.051	-0.073	0.264 *
PL							1	0.249 *	0.174	0.206	0.249 *	0.133	-0.151	-0.207	-0.015
PW								1	0.380**	0.468**	0.507**	0.448**	-0.003	-0.106*	0.113
WT									1	0.221	0.259*	0.148	0.212	-0.021*	0.148
PWt.										1	0.934**	0.896**	-0.047	0.103	0.166
WSPP											1	0.845**	-0.061	0.068	0.181
HSW												1	-0.058	0.007	0.112
HI													1	-0.085	0.424**
SP														1	-0.146
SYP															1

DFF – Days to 50 percent flowering, **DM**- Days to maturity, **PH**- Plant height, **NB**- Number of branches, **NC**- Number of clusters, **NPP**-Number of pods per plant, **PL**- Pod length, **PW**- Pod width, **WT**-Pod wall thickness, **PWt**. - Pod weight, **WSPP**- Weight of seeds per pod, **HSW**- Hundred seeds weight, **SYP**- Seed yield per plant, **HI**- Harvest index, **SP**- pod shattering percentage.

Table 3: Path coefficient analysis of yield and pod shattering attributing traits.

	DFF	DM	PH	NB	NC	NPP	PL	PW	WT	PWt.	WSPP	HSW	HI	SP
DFF	**0.4186**	0.2179	0.0172	0.0144	0.0211	0.0227	0.0630	0.1045	0.1353	0.0479	0.0467	0.0529	0.0841	0.0087
DM	-0.1084	**-0.2083**	-0.0023	0.0254	-0.0339	-0.0351	-0.0235	-0.0261	-0.0198	-0.0279	-0.0432	-0.0369	-0.0243	0.0303
PH	-0.0055	-0.0015	**-0.1338**	-0.0384	-0.0278	-0.0120	0.0287	-0.0007	-0.0222	0.0036	-0.0003	0.0006	-0.0016	0.0299
NB	-0.0045	0.0160	-0.0376	**-0.1311**	-0.0337	-0.0241	0.0310	0.0251	0.0067	0.0430	0.0392	0.0346	-0.0104	0.0181
NC	0.0041	0.0132	0.0169	0.0208	**0.0810**	0.0168	0.0004	-0.0191	-0.0064	-0.0176	-0.0142	-0.0103	-0.0014	-0.0078
NPP	-0.0126	-0.0390	-0.0208	0.0426	0.0480	**0.2314**	-0.0037	0.0420	0.0018	0.0342	0.0326	0.0415	0.0149	0.0117
PL	-0.0307	-0.0230	0.0438	0.0482	-0.0010	-0.0033	**-0.2043**	-0.0546	-0.0408	-0.0496	-0.0574	-0.0342	0.0343	0.0350
PW	-0.0025	-0.0012	0.0000	0.0019	0.0023	0.0018	-0.0026	**-0.0099**	-0.0039	-0.0048	-0.0052	-0.0046	0.0002	-0.0013
WT	-0.0286	-0.0084	-0.0147	0.0045	0.0069	0.0007	-0.0177	-0.0352	**-0.0885**	-0.0235	-0.0264	-0.0167	-0.0162	-0.0013
PWt.	0.0103	0.0120	-0.0024	-0.0294	-0.0194	-0.0133	0.0218	0.0435	0.0238	**0.0897**	0.0843	0.0810	-0.0074	0.0137
WSPP	0.0560	0.1040	0.0011	-0.1500	-0.0880	-0.0707	0.1411	0.2626	0.1497	0.4715	**0.5018**	0.4296	-0.0469	0.0585
HSW	-0.0535	-0.0750	0.0018	0.1118	0.0537	0.0760	-0.0710	-0.1974	-0.0802	-0.3824	-0.3628	**0.4237**	0.0370	-0.0225
HI	0.0684	0.0397	0.0042	0.0271	-0.0060	-0.0220	-0.0572	-0.0073	0.0623	-0.0280	-0.0318	-0.0297	**0.3406**	-0.0361
SP	-0.0064	0.0449	0.0690	0.0427	0.0295	0.0157	0.0529	-0.0402	-0.0046	-0.0471	-0.0360	-0.0164	0.0327	**-0.3086**
SYP	0.3047	0.0911	-0.0579	-0.0947	-0.0632	-0.2782	-0.0411	0.0874	0.1133	0.1090	0.1274	0.0676	0.4356	-0.1716
Partial R^2	0.1275	-0.0190	0.0077	0.0124	-0.0051	0.0644	0.0084	-0.0009	-0.0100	0.0098	0.0639	-0.0287	0.1484	0.0530

DFF – Days to 50 percent flowering, **DM**- Days to maturity, **PH**- Plant height, **NB**- Number of branches, **NC**- Number of clusters, **NPP**-Number of pods per plant, **PL**- Pod length, **PW**- Pod width, **WT**-Pod wall thickness, **PWt**. - Pod weight, **WSPP**- Weight of seeds per pod, **HSW**- Hundred seeds weight, **SYP**- Seed yield per plant, **HI**- Harvest index, **SP**- pod shattering percentage

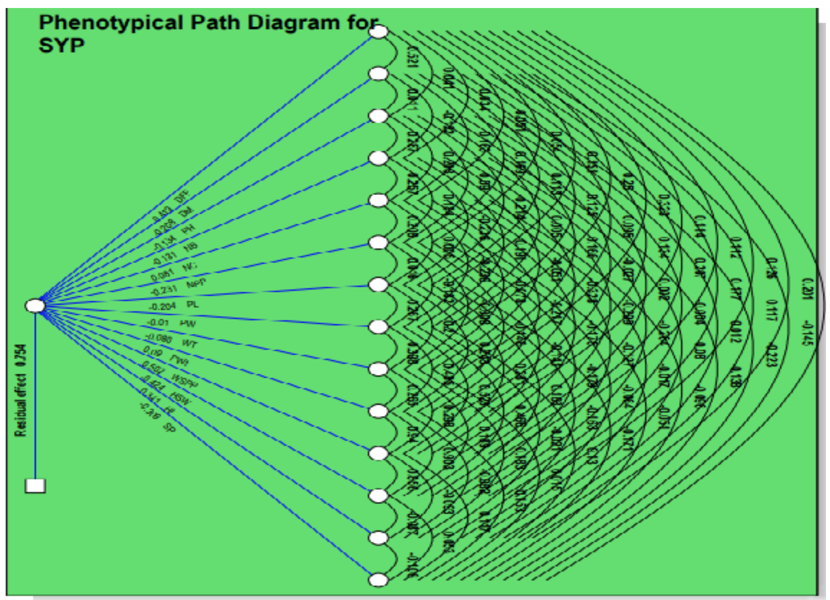

Fig. 1. Phenotypical path diagram.

FUTURE SCOPE

From the findings of the present investigation, it can be concluded that a substantial amount of genetic variation exists in the selected soybean MAGIC lines since they exhibited a wide range of variation for all the characters. Higher estimates of genetic parameters like PCV, GCV, broad sense heritability and genetic advance were observed for pod shattering percentage, seed yield per plant, number of branches per plant indicating predominance of additive gene action. Thus, these traits can be fixable and should be given priority in the selection of soybean MAGIC lines in future crop improvement programs. The traits days to fifty % flowering, number of pods per plant, pod weight, weight of seeds per pod, hundred seed weight and harvest index could be used for selection in yield improvement as they have positive direct effect on total plant yield. As pod shattering has significant negative correlation with pod wall thickness and pod width, these traits can be used for indirect selection for pod shattering tolerance breeding programmes.

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Conflict of Interest. None.

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