Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2021; 10(3): 181-186
Received: 02-03-2021
Accepted: 05-04-2021

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Genetic variability, correlation and path analysis studies in adzuki bean germplasm

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Abstract
In the present study, one hundred and fifty-one genotypes of adzuki bean were assessed at the experimental farm of the Department of Organic Agriculture, CSKHPKV, Palampur in Augmented design during *Kharif*, 2019 to estimate the extent of association, direct and indirect effects of the characters on yield and its component traits. Analysis of variance revealed that mean sum of squares due to treatments were significant for all the traits under study except plant height. Correlation studies showed that seed yield had significant positive correlation with days to 80% maturity, primary branches per plant, seeds per pod and pods per plant while, Path studies revealed that primary branches per plant, seeds per pod, pods per plant and days to 80% maturity have high direct effects on yield. Principal component analysis (PCA) indicated that first four PCs contributed 60.78% to the total variability for ten agronomic traits. First PC (F1) contributed maximum towards the variability (23.64%) followed by F2 (14.94%), F3 (11.84%) and F4 (10.36). Sufficient amount of variation was observed in the genotypes based on parameters of variability, principal component analysis, correlation and path analysis which could be utilized by researchers in various breeding programme of this crop.

Keywords: Variability, adzuki bean, germplasm, breeding, conservation

Introduction
Adzuki bean (*Vigna angularis* (Willd.) Ohwi and Ohashi) is an important food legume crop in East Asia. It is being cultivated in China, Japan, South Korea, Taiwan, Bhutan, India, Nepal, South America, New Zealand and Africa. China is the largest producer of adzuki bean in the world with an estimated production of about 260 thousand tons in the year 2019-20 (Anonymous 2019) [1]. In India, it is considered as an underutilized crop and its cultivation is limited to the North-eastern and Northern hill zones. It occasionally grows in Kangra, Chamba, Mandi and Sirmour districts of Himachal Pradesh.

It is a self-pollinated crop with chromosome number 2n=22 belonging to family *Leguminosae*. It is a bushy type of annual vine with trifoliate leaves, usually 30-40 cm tall, determinate and late maturing. It is known to have different types of seed coat colour which is mostly wine red but they can be buff, black, white, speckled purple or mottled. Adzuki bean is a very tolerant crop which can sustain heavy rainfall and can grow in all types of soil. It is a multipurpose grain legume mainly cultivated for food, fodder and green manure. They are consumed in the form of seed and flour while immature pods and leaves are utilized as vegetable (Dua *et al*. 2009) [7]. In India, it is used as a pulse crop but in China and Japan it is widely used in a variety of foods like desserts, adzuki milk, cake, porridge, adzuki rice, jelly and ice cream.

The success of any breeding program depends on the nature and magnitude of genetic variability present in the genotypes, nature of association among different characters and their relative contribution to yield. Better understanding of the contribution of component traits can be obtained through correlation. Based upon genotypic and phenotypic correlation, the breeder would be able to decide the breeding methods to be used to exploit desirable and break the undesirable associations. Correlation coefficients are very useful in quantifying the size and direction of trait associations but can be misleading, if the high correlation between two traits is due to indirect effect of other traits. Path coefficient is a standardized partial regression coefficient that helps in partitioning the correlation coefficient into direct and indirect effects of various traits towards dependent variable, and also helps in indirect selection (Wright 1921) [14]. Each correlation coefficient between a predictor variable and the response variable is divided into its component parts: the direct effect or path coefficient for the predictor variable and indirect effects which involve the product of a correlation coefficient between two predictor variables with the appropriate path coefficient in the path diagram (Dewey and Lu 1959) [5]. By determining the interrelationships among yield components, a better understanding of both the direct and indirect effects of the specific components can be attained

(Chaudhary and Joshi 2005) [4]. In adzuki bean, most of the work done is related to molecular aspects and less of morphological evaluation. Thus, present investigation was conducted to study this pulse crop on morphological basis for better understanding of crop diversity, its conservation and to explore the gene pool of adzuki bean for breeding purposes.

Materials and Methods

The experimental material for the present study comprised of 151 adzuki bean genotypes along with 2 checks namely Local Totru and HPU-51 from NBPGR, Shimla, and were evaluated for various quantitative traits in Augmented Block Design during *Kharif*, 2019. Each entry was raised in one rowed plot of 3m length with row to row and plant to plant spacing of 30cm and 10cm, respectively in 15 blocks. Each block consisted of 12 genotypes including 2 checks and the checks were allotted randomly in each block. The crop was raised following standard package of practices. Data was recorded on five randomly choosen plants for the traits *viz*., plant height (cm), primary branches per plant, clusters per plant, pods per cluster, pods per plant, seeds per pod, 1000-seed weight (g) and seed yield per plant (g) while, for days to 50% flowering and days to 80% maturity data was recorded on plot basis. Data obtained with respect to various traits were analyzed for ANOVA according to Federer (1956). Estimation of parameters of variability *viz*., phenotypic and genotypic coefficient of variation was done as per Burton and DeVane (1953) whereas, heritability in broad-sense and genetic advance were calculated as Burton and DeVane (1953) and Johnson *et al*. (1955) [10]. Correlation coefficient between yield and its components was calculated according to the method given by Fisher and Yates (1963) [9]. Path analysis which is an excellent means of studying direct and indirect effects of inter-related components of a complex trait was calculated according to Al-Jibouri *et al*. (1958) [2] and Dewey and Lu (1959) [5]. Principal Component Analysis was computed using the statistical software StatistiXL version 1.10

Results and Discussion

Analysis of variance

Perusal of the data on analysis of variance (ANOVA) revealed that mean sum of squares due to blocks were significant for all the traits under study except pods per cluster when the analysis was done ignoring the treatments; however, when the analysis was done eliminating the treatments, mean sum of squares due to blocks were significant for traits *viz*., clusters per plant and seed yield per plant (g). The mean sum of squares due to treatments (ignoring and eliminating blocks), genotypes and checks vs. genotypes were significant for all the traits under study except plant height, while the mean sum of squares due to checks were significant for all the traits except days to 80% maturity indicating the presence of considerable amount of genetic variability for these traits (Table 1).

Estimates of parameters of variability

The estimates of mean, range and parameters of variability *viz*., phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broad sense (h^2_{bs}) and genetic advance (GA) expressed as percentage of mean for different traits are presented in Table 2 and described below:

a) Coefficients of variation

Phenotypic coefficient of variation (PCV) were higher than their respective genotypic coefficient of variation (GCV) for all the traits studied which indicated that the apparent variation is not only due to genotypes but also due to considerable influence of environment on the performance of genotypes.

High PCV (>20%) values were observed for primary branches per plant and pods per cluster. Moderate PCV (10-20%) was observed for clusters per plant, pods per plant, seeds per pod, 1000-seed weight and seed yield per plant while, low PCV (<10%) was observed for days to 50% flowering, days to 80% maturity and plant height. High GCV (>20%) values were observed for pods per cluster and primary branches per plant. Moderate GCV (10-20%) was observed for clusters per plant, pods per plant, seeds per pod, 1000-seed weight and seed yield per plant. Low GCV (<10%) was observed for days to 50% flowering, days to 80% maturity and plant height. Similar results were observed by Kumar *et al*. (2014) in adzuki bean where phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all the traits. The PCV and GCV estimate were high for plant height, pods per plant, seed yield per plant and 100 seed-weight.

b) Heritability in broad sense (h^2bs)

The present study revealed that heritability in broad sense was high (>70%) for all the traits under study except plant height revealing lesser influence of environment and greater role of genetic component of variation. Thus, selection for these traits on the basis of phenotypic expression would be more effective and can be relied upon. Low heritability (<40%) was observed for plant height indicating that this trait was highly influenced by the environmental factors. Dhobhal and Rana (1997) [6] observed that estimates of heritability were high for all the traits except plant height in adzuki bean, which is in agreement with the present study. Kumar *et al*. (2014) [12] observed high heritability for days to flowering, days to maturity, 100-seed weight and seed yield per plant. The results suggested that the yield components in adzuki bean are less influenced by environmental conditions and high heritability values of these traits indicated that the variation observed was mainly under genetic control and less influenced by environment.

c) Genetic advance (GA)

Genetic advance expressed as percentage of mean was observed highest (>30%) for pods per cluster followed by primary branches per plant, clusters per plant, 1000-seed weight and pods per plant. Moderate genetic advance (20-30%) was observed for seeds per pod and seed yield per plant while, low genetic advance (<20%) was observed for days to 50% flowering, days to 80% maturity and plant height.

For predicting reliable estimates of additive and non-additive effects, heritability should be considered in conjugation with genetic advance (Johnson *et al*., 1955) [10]. On this consideration, high heritability (>70%) coupled with high genetic advance (>30%) was found for primary branches per plant, clusters per plant, pods per cluster, 1000-seed weight and pods per plant indicating the presence of high additive gene effects providing scope for the improvement of these traits through hybridization and selection. High heritability (>70%) with moderate genetic advance (20-30%) was observed for seeds per pod and seed yield per plant. High heritability (>70%) coupled with low genetic advance (>20%) was observed for days to 50% flowering and days to 80% maturity indicating the role of non-additive gene action and selection for these traits would be less effective.

Correlation coefficient and Path analysis

Study on association of various yield attributing traits is essential for accumulating the optimum contribution of such traits to yield. In the present study, the estimates of correlation coefficient and path analysis were computed for 10 different morphological, yield and its component traits to determine the traits on which selection can be emphasized (Table 3) and the results obtained are discussed as under:

Seed yield showed significant positive correlation with days to 80% maturity, primary branches per plant, seeds per pod and pods per plant indicating that selection through these traits would be effective. Days to 50% flowering showed significant and positive correlation with days to 80% maturity, primary branches per plant, pods per plant and seeds per pod. Days to 80% maturity exhibited significant and positive correlation with plant height, primary branches per plant, seeds per pod and seed yield per plant. Primary branches per plant showed significant and positive correlation with seeds per pod and seed yield per plant. Similarly, significant positive correlation was observed for pods per plant with clusters per plant, pods per cluster and seed yield per plant. Seeds per pod showed significantly positive correlation with seed yield per plant. Clusters per plant was significantly positively correlated with pods per cluster.

Path coefficient (Wright 1921; Dewey and Lu 1959) [14, 5] is quite helpful in determining the relative importance of direct and indirect influence of each component trait. The present investigation was therefore, aimed to estimate the direct and indirect effects of different traits on seed yield per plant (Table 4). The direct effect were observed to be positive and high for primary branches per plant (0.22), seeds per pod (0.22) followed by pods per plant (0.14) and days to 80% maturity (0.10). Clusters per plant (0.12), pods per cluster (0.11) and plant height (0.08) did not showed significant positive correlation with seed yield but they exhibited high direct effect. Since all these traits except 1000-seed-weight showed high direct effects, thus they can be considered for direct selection for high seed yield.

Kumar *et al*. (2014) [12] observed positive correlation of seed yield with days to flowering, plant height, pods per plant and seeds per pod. Kaga *et al*. (2008) [11] found that stem length, branch number, leaf size, 100-seed weight, pod length, pods per plant and seed number per pod had significant correlation with total seed number which was used as an index of seed productivity. Based on the association studies in the present study it could be observed that all the yield traits proposed by Wallace *et al*. (1993) have been speculated to be important traits for selection in plants and are suitable characters for indirect selection in adzuki bean.

Principal Component Analysis (PCA)

Principal component analysis (PCA) showed that the first four Eigen vectors are the most important as they have Eigen values more than one. First principal component (F1) explained 23.64 per cent of the total variation, which was mainly contributed by number of primary branches per plant, days to 50% flowering, days to 80% maturity, seed yield per plant and seeds per pod. F2 accounted for 14.94 per cent variation and was attributed by all the traits. F3 contributed 11.84 per cent of the total variance through plant height, pods per cluster, seed yield per plant and seeds per pod. F4 contributed 10.36 per cent to the total variability and was accounted by most of the traits except primary branches per plant, seed yield per plant, clusters per plant and seeds per pod. Eigenvalues and proportion of accounted variance for each variable have been shown in Table 5.

The first two principal components biplot including loadings of the various characters along with the genotypes is presented in Fig. 1. This figure indicates that the PCA showed a clear differentiation between most of the adzuki bean genotypes from each other.

Table 1: Analysis of variance of adzuki bean genotypes for yield and related traits

Mean sum of squares								
Traits	Blocks		Treatments		Checks	Genotypes	Checks vs Genotypes	Error
	Ignoring treatments	Eliminating treatments	Ignoring blocks	Eliminating blocks				
Df	14	14	152	152	1	150	1	14
Days to 50% flowering	81.62**	2.56	30.97**	23.69**	20.83**	26.58**	698.58**	1.76
Days to 80% maturity	32.84**	7.26	19.91**	17.55**	4.03	19.29**	128.51**	4.32
Plant height	236.69**	75.65	70.42	55.59	696.59**	66.43	42.87	49.97
Primary branches/plant	3.42**	0.32	1.31**	1.02**	1.54*	1.17**	21.11**	0.29
Clusters/plant	12.12**	0.54*	11.42**	10.36**	238.57**	9.45**	80.11**	0.21
Pods/cluster	0.28	0.15	1.57**	1.56**	6.26**	0.93**	93.03**	0.21
Pods/plant	148.07**	7.86	54.99**	42.08**	26.89**	51.11**	665.43**	7.39
Seeds/pod	1.63**	0.26	1.60**	1.47**	12.16**	1.35**	28.57**	0.16
1000-seed weight	129.40**	4.10	345.00**	333.50**	10584.40**	278.90**	26.50*	3.50
Seed yield/plant	7.57**	0.88*	3.74**	3.13**	12.94**	2.89**	122.53**	0.33

* Significant at $p \leq 0.05$ ** Significant at $p \leq 0.01$

Table 2: Estimates of parameters of variability for various traits in adzuki bean genotypes

S. No.	Traits	Mean	Range	PCV (%)	GCV (%)	Heritability h^2bs (%)	Expected GA (% of mean)
1.	Days to 50% flowering	68.36	54.27- 82.77	7.54	7.29	93.38	14.51
2.	Days to 80% maturity	109.28	100.17-125.67	4.02	3.54	77.61	6.43
3.	Plant height	85.16	46.82-102.54	9.57	4.76	24.78	4.89
4.	Primary branches/plant	3.72	1.59-6.59	29.10	25.30	75.58	45.31
5.	Clusters/plant	15.97	7.46-22.06	19.25	19.04	97.80	38.79

6.	Pods/cluster	3.21	1.0-6.1	30.01	26.47	77.78	48.08
7.	Pods/plant	36.40	14.41-58.31	19.64	18.16	85.54	34.61
8.	Seeds/pod	7.74	4.43-11.38	15.01	14.10	88.27	27.29
9.	1000-seed weight	90.90	58.14-162.54	18.37	18.26	98.75	37.37
10.	Seed yield/plant	12.66	7.91-16.51	13.43	12.64	88.51	24.49

Table 3: Estimates of correlation coefficient among various yield and morphological traits in adzuki bean

Traits	Days to 50% flowering	Days to 80% maturity	Plant height	Primary branches/plant	Clusters/ plant	Pods/ cluster	Pods/ plant	Seeds/ pod	1000-seed weight	Seed yield/ plant
Days to 50% flowering	1	0.53**	-0.05	0.53**	-0.18*	-0.04	0.27**	0.20*	0.02	0.09
Days to 80% maturity		1	0.09**	0.28*	-0.13*	-0.01	-0.16*	0.24*	-0.02	0.16*
Plant height			1	-0.16*	-0.01	0.10	-0.02	0.04	-0.07	0.08
Primary branches/ plant				1	-0.06	-0.01	-0.23*	0.18*	-0.07	0.23*
Clusters/plant					1	0.16*	0.51**	0.04	0.02	0.07
Pods/cluster						1	0.20*	-0.05	0.05	0.10
Pods/plant							1	-0.09	0.10	0.15*
Seeds/ pod								1	-0.05	0.27**
1000-seed weight									1	-0.03
Seed yield/plant										1

**Significant at p<0.01 * Significant at p<0.05

Table 4: Estimates of direct (diagonal) and indirect effects on seed yield for different traits in adzuki bean

Traits	Days to 50% flowering	Days to 80% maturity	Plant height	Primary branches/ plant	Clusters/ plant	Pods/ cluster	Pods/plant	Seeds/pod	1000-seed weight	Correlation with yield
Days to 50% flowering	-0.14	0.05	0.00	0.12	-0.02	0.00	0.04	0.04	0.00	0.09
Days to 80% maturity	-0.06	0.10	0.01	0.06	-0.02	0.00	0.02	0.05	0.00	0.16*
Plant height	0.01	0.01	0.08	-0.04	0.00	0.01	0.00	0.01	0.00	0.08
Primary branches/ plant	-0.07	0.03	-0.01	0.22	-0.01	0.00	0.03	0.04	0.00	0.23*
Clusters/plant	0.02	-0.02	0.00	-0.01	0.12	0.02	-0.07	0.01	0.00	0.07
Pods/cluster	0.01	0.00	0.01	0.00	0.02	0.11	-0.03	-0.02	0.00	0.10
Pods/plant	0.04	-0.03	-0.01	-0.05	0.06	0.02	0.14	-0.02	0.00	0.15*
Seeds/ pod	-0.03	0.03	0.00	0.04	0.01	-0.01	0.01	0.22	0.00	0.27**
1000-seed weight	0.00	0.00	-0.01	-0.02	0.00	0.01	-0.01	-0.01	0.01	-0.03

Residual Effect = 0.919 *Significant at p<0.05

Diagonal bold values denote direct effects and remaining indirect effects **Significant at p<0.01

Table 5: Eigenvectors for the ten components of quantitatively measured traits

Eigenvectors Variable										
	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**	**F10**
Eigenvalue	2.36	1.49	1.18	1.04	0.94	0.90	0.69	0.60	0.43	0.35
Variability (%)	23.64	14.94	11.84	10.36	9.43	9.03	6.9	6.00	4.32	3.53
Cum. (%)	23.64	38.58	50.41	60.77	70.21	79.24	86.14	92.14	96.47	100
Days to 50% flowering	0.51	0.08	-0.25	0.21	-0.17	-0.18	-0.07	-0.13	-0.03	0.74
Days to 80% maturity	0.43	0.18	0.01	0.29	-0.09	-0.40	0.02	0.59	-0.13	-0.41
Plant height	-0.02	0.11	0.71	0.39	-0.01	-0.26	-0.31	-0.39	0.09	-0.03
Primary branches/plant	0.44	0.16	-0.29	-0.13	-0.24	0.21	-0.25	-0.47	0.25	-0.48
Clusters/plant	-0.27	0.56	-0.16	-0.24	-0.07	-0.22	-0.27	-0.14	-0.63	-0.01
Pods/cluster	-0.11	0.41	0.06	0.46	-0.35	0.49	0.48	-0.03	-0.10	-0.00
Pods/plant	-0.38	0.43	-0.22	0.01	-0.1	-0.31	-0.03	0.14	0.70	0.09
Seeds/pod	0.28	0.31	0.19	-0.38	0.42	-0.22	0.62	-0.25	0.06	-0.02
1000-seed weight	-0.07	0.06	-0.40	0.53	0.70	0.07	-0.11	-0.14	-0.04	-0.10
Seed yield/plant	0.22	0.39	0.29	-0.20	0.30	0.51	-0.37	0.37	0.12	0.19

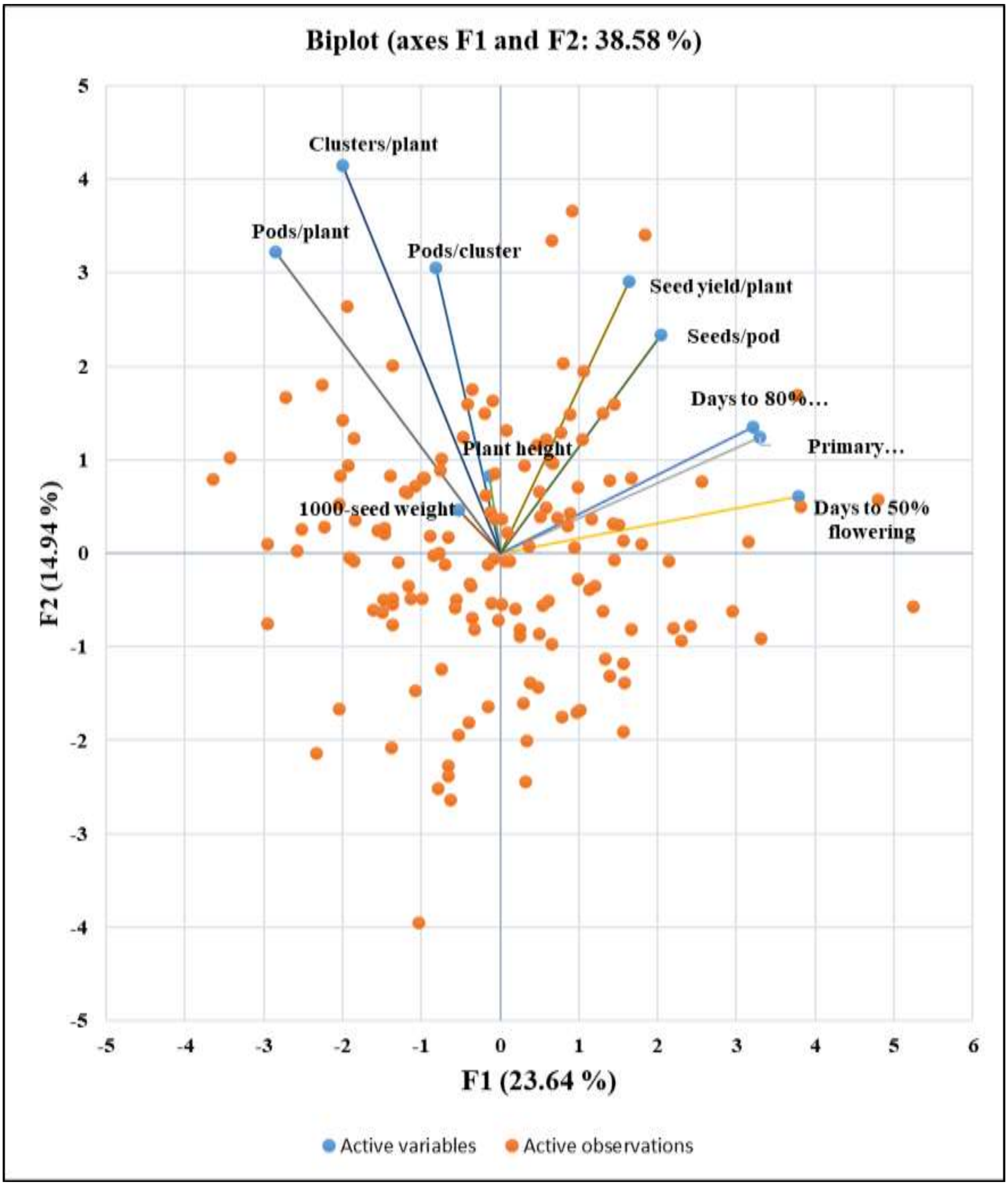

Fig 1: Biplot of different variables with 153 observations on PC F1 and F2

Conclusion

In the present study, analysis of variance revealed considerable variation among genotypes and thereby presenting scope for improvement through hybridization and selection. Estimates of parameters of variability indicated The correlation coefficients are in determining the components of a complex trait like seed yield but an exact picture of the relative importance of direct and indirect influence of each component trait which is not provided by such studies as these estimates provide nature and magnitude but not its cause. Investigation on genetic variability and correlation study between yield and its components of genotypes on rice may increase the opportunity to exploit its potential which will help meet the demand of high grain yield and nutrition supply.

Author Contributions

Conceptualization of research, Designing of the experiment (Neelam Bhardwaj); Execution of field experiments and data collection, Analysis of data and interpretation, Preparation of the manuscript (Anjali).

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