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Multivariate analysis of seed vigour parameters in late sown wheat (*Triticum aestivum* L. em. Thell)

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Abstract
An experiment was conducted to determine variability, correlation, path coefficient and principal component analysis for seed vigour parameters *viz.* standard germination, seedling density, seedling length, seedling dry weight, seedling vigour index I and II, 1000 grain weight and grain yield plot^{-1}. The analysis of variance (ANOVA) revealed a wide range of variation existing in the material studied. The highest phenotypic and genotypic coefficient of variance recorded for seedling vigour index II (21.16 and 20.95, respectively) and, moderate values for seed density, seedling length, seedling dry weight and seedling vigour index I. The maximum value for heritability (broad sense) was found for seedling vigour index II (98.77%) whereas grain yield plot^{-1} had moderately high heritability (62.09%). Significant positive correlation were reported between standard germination and seedling density, seedling length, seedling dry weight, seedling vigour index I, seedling vigour index II and 1000 grain weight and seedling vigour index I estimated highest direct positive effect on grain yield plot^{-1}, followed by seedling vigour index II, 1000 grain weight and seedling density. The principal component (PC1 and PC2) having Eigen value >1 (significant), accounted 64.70% of total variation. Maximum value was explained by component 1 with 50.5% of total variation.

Keywords: Correlation, path analysis, principal component analysis, seed vigour and wheat

Introduction

Wheat (*Triticum aestivum* L. em. Thell), is one among the prime three cereal crops around the world with acreage 215.48 M ha, production 731.5 MT and productivity 33.9 t-ha^{-1} (Anonymous, 2018a) [3]. According to 4th Advance estimate of Directorate of Economics and Statistics (DES) in India, area under wheat cultivation is 29.58 Mha supplying 99.70 MT of production and giving 33.71 q-ha^{-1} productivity (Anonymous, 2018b) [4]. The grain yield is a complex and polygenic trait, greatly affected by the environment. Hence, selection of superior genotypes only on the basis of yield will not be effective. Thus, the selection has to be made on the basis of heritability and association between yield and its attributing traits. Traits with high heritability and high genetic advance should be selected as they are governed by additive gene effect.

The correlation studies together with path analysis provide a clear understanding of the association between yield and its attributing traits. Correlation is useful in revealing the magnitude and direction of relationship between various traits whereas; path coefficient calculates the direct and indirect effect of an independent variable on its dependent variable (Dewey and Lu, 1959) [9].

The Principal Component Analysis (PCA) or canonical root analysis is a multivariate statistical technique, simplifies and analyzes the inter relationship among a large set of variables in term of a relatively a small set of variables without losing any important information of original data set. The first three principal components are often most important in understanding the variation patterns among accessions, characters associated with first three principal components are more useful in differentiating the accessions suggested by Clifford and Stephenson (1975) [7] and corroborated by Guei *et al.* (2005) [11]. PCA is an exploratory tool to identify unknown trends in a multidimensional data set (Hotelling, 1933).

The present study therefore, was conducted to estimate the variability present in material, heritability of traits, association between the traits and grain yield with an aim to utilize the genetic information obtained in developing and selecting superior genotypes and varieties.

Material and Methods

The present investigation was carried out on seed material of genetically diverse 60 bread wheat genotypes including four checks. Seed vigour potential was estimated by taking into consideration six parameters *viz.* standard germination, seed density, 1000 grain weight, seedling length, seedling dry weight, seedling vigour index-I and II. Standard germination test was recorded using "Between the papers" (BP) method. The seedlings dry weight was measured by drying seedlings in hot air oven for 24 hours at 80 ± 1 ^{0}C. The seedling vigour indices were calculated as per the method given by Abdul-Baki and Anderson as follows: Seedling Vigour Index-I = Standard germination (%) × Average seedling length (cm) and Seedling Vigour Index-II = Standard germination (%) × Average seedling dry weight (g).

The ANOVA (Fisher, 1925) [10], heritability, phenotypic coefficient of variance (PCV), genotypic coefficient of variance (GCV), correlation analysis (Al-Jibouri *et al.*, 1958) [2], path analysis (Dewey and Lu, 1959) [9] and principal component analysis was done using OPSTAT software.

Result and Discussion

Variability analysis: The mean sum of square values presented in ANOVA Table 1 was observed to be exceedingly significant for all the traits considered, showing the satisfactory variability present among the genotypes for the characters under study. The values of mean, range, GCV, PCV, heritability and genetic advance as per cent of mean for all characters are introduced in Table 2 and Figure 1, revealed adequate variation for genotypes under investigation. The highest GCV and PCV values were obtained in seedling vigour index II, moderate PCV and GCV values were accounted for seed density, seedling length, seedling dry weight and seedling vigour index I. The value of PCV is nearly equal to the GCV which means that there is less environmental effect on genotypes during the experimentation. The estimation of heritability (broad sense) showed highest values for seedling vigour index II followed by seedling dry weight, standard germination, seed density, seedling length and seedling vigour index I.

Correlation analysis: Correlation between seed vigour parameters presented in Table 3 which clearly reveals that there is positive significant correlation among all the traits namely standard germination, seedling density, seedling length, seedling dry weight, seedling vigour index I, seedling vigour index II and 1000 grain weight. Seedling vigour indexI and 1000 grain weight were found to be positively significantly correlated with grain yield. Almost similar results were obtained by Kumar *et al.* (2017) [13] for standard germination, seedling length, seedling vigour index I, seedling vigour index II and seedling dry weight, Wani *et al.* (2013) for seedling vigour indexand 1000 grain weight and Ball *et al.* (2011) [5] for seed density and standard germination, Dahiya *et al.* (1999) [8] in cotton and Verma *et al.* (1999) [15] in triticale.

Path analysis: Direct and indirect effect of seed vigour parameters on grain yield^{-1} presented in Table 4 is the outcome of path coefficient analysis which states that 1000 grain weight had high direct positive effect on grain yield plot^{-1} but it also has more positive indirect effect on the same through seedling vigour index I and seedling vigour index II. Seed density had positive direct effect and positive indirect effect via seedling vigour index I, seedling vigour index II and 1000 grain weight. Standard germination had negative direct effect on grain yield plot^{-1}, whereas it had positive indirect effect on grain yield plot^{-1} via other seed vigour parameters namely seedling vigour index I & II and 1000 grain weight. Seedling length and seedling dry weight had direct negative effect on grain yield plot^{-1} whereas it has positive direct effect through seedling vigour index I & II on the same.

Table 1: Analysis of variance (ANOVA) for various traits in 60 genotypes of wheat for seed vigour parameters

Source of variation (SV)	Degree of freedom (D.F.)	Mean sum of squares							
		SG	SD	SL	SDW	SVI	SVII	GY/P	TGW
Replication	2	0.32	0.00	0.16	0.000	2138.85	0.44	79638.45	0.12
Genotypes	59	78.06**	0.13**	22.21**	0.07**	279004.81**	711.62**	354382.53**	25.27**
Error	118	1.90	0.00	0.18	0.00	2279.56	4.43	59910.15	1.97

Significant at p = 0.05 SG (%) - Standard germination, SD - Seed density(g/cc), SL - Seedling length(cm), SDW - Seedling dry weight (mg), SV-I – Seedling vigour index I, SV-II – Seedling vigour index II, GY/P - grain yield plot^{-1}, TGW - 1000 grain weight

Table 2: Estimates of mean performance, range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance (GA) as per cent of mean in 60 genotypes of wheat for seed vigour parameters

Traits	Mean	Range		GCV	PCV	h^2 (bs)	GA (5%)
		Minimum	Maximum				
SG	92.55±5.05	70.67	98.00	5.44	5.60	92.92	10.80
SD	1.56±0.21	1.13	2.55	13.46	13.62	97.69	27.42
SL	21.23±2.72	15.91	27.04	12.76	12.92	97.58	25.97
SDW	7.9±0.15	4.7	14.3	18.81	18.95	98.57	38.48
SV(I)	1,969±305.00	1216.98	2614.18	15.41	15.42	97.58	31.37
SV(II)	730.11±15.41	394.5	1384.1	20.95	21.16	98.77	42.75
GY/P	3,107.58±343.70	2193.33	3886.67	10.08	12.79	62.09	16.36
TGW	36.91±2.90	30.40	43.33	7.54	8.45	79.67	13.88

SG (%) - Standard germination, SD - Seed density(g/cc), SL - Seedling length(cm), SDW - Seedling dry weight(mg), SV-I – Seedling vigour index I, SV-II – Seedling vigour index II GY/P - grain yield plot^{-1}, TGW- 1000 grain weight

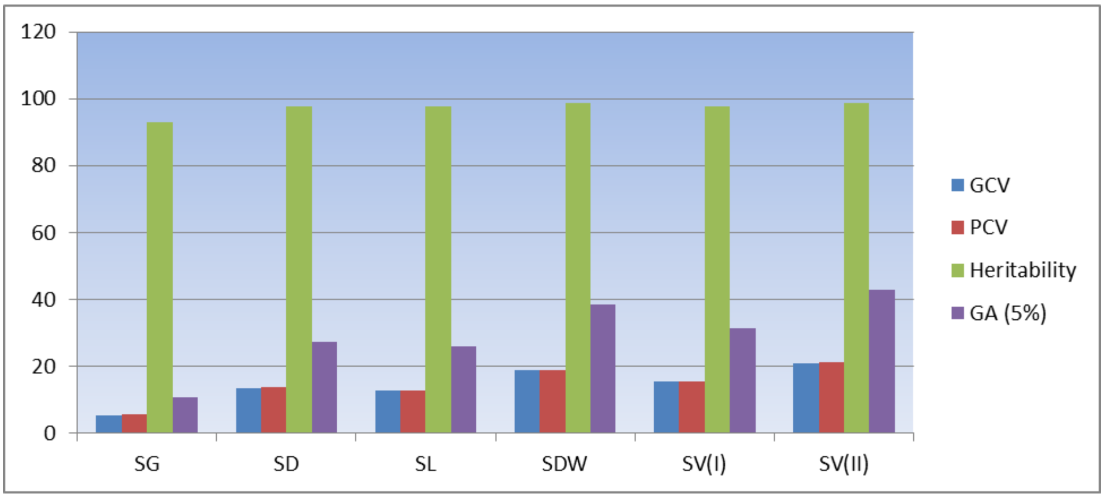

Fig 1: Showing GCV, PCV, Heritability and Genetic Advance for seed vigour parameters

Table 3: Phenotypic correlation coefficients among seed vigour parameters of wheat genotypes

	SG	SD	SL	SDW	SVI	SVII	TGW
SG							
SD	0.233**						
SL	0.363**	0.324**					
SDW	0.340**	0.670**	0.501**				
SVI	0.631**	0.340**	0.951**	0.520**			
SVII	0.534**	0.659**	0.524**	0.975**	0.606**		
TGW	0.257*	0.174*	0.298*	0.352**	0.332**	0.398**	
GY/P	0.126	0.074	0.138	0.111	0.159*	0.131	0.165*

*Significant at p= 0.05, ** Significant at p= 0.01

SG (%) - Standard Germination, SD- Seed density (g cc^{-1}), SL - Seedling length (cm), SDW - Seedling dry weight (mg), SV-I –Seedling vigour indexI, SV-II – Seedling vigour index II, TGW: 1000 grain weight (g), GY/P: grain yield $plot^{-1}$(g)

Table 4: Direct (diagonal) and Indirect (off-diagonal) effects of seed vigour parameters of wheat

	SG	SD	SL	SDW	SVI	SVII	TGW	GY/P
SG	-0.3890	0.0017	-0.2488	-0.1840	0.5816	0.3390	0.0259	0.126
SD	-0.0892	0.0073	-0.2221	-0.3645	0.3135	0.4115	0.0175	0.074
SL	-0.1387	0.0023	-0.6870	-0.2725	0.8764	0.3272	0.0301	0.138
SDW	-0.1300	0.0049	-0.3439	-0.544	0.4797	0.6085	0.0356	0.111
SVI	-0.2412	0.0025	-0.6527	-0.2830	0.9220	0.3789	0.03358	0.159
SVII	-0.2044	0.0048	-0.359	-0.5301	0.5586	0.6240	0.0376	0.131
TGW	-0.0981	0.0012	-0.2042	-0.1915	0.3767	0.2420	0.0390	0.165
Residual effect: 0.075								

SG (%) - Germination percentage, SD - Seed density(g/cc), SL - Seedling length(cm), SDW - Seedling dry weight (mg), SV-I – Seedling vigour index I, SV-II – Seedling vigour index II, TGW 1000 grain weight (g), GY/P: Grain yield $plot^{-1}$ (g)

Principal Component Analysis

By analyzing the Table 5 and Figure 2 it has been cleared that PCA had grouped the wheat variables into eight main components out of which two components showed eigen value >1 and accounted for 64.7% of total variation with yield whereas remaining factors contributes small amount to the total variation. The maximum eigen value was obtained in PC1 i.e. 4.04 and minimum was in PC8 i.e. 0.00. Out of total principal components, PC1 to PC4 were retained with values 50.5%, 14.2%, 12.4% and 10.1% respectively as they contributed more to the total variation. PCA method fastens the selection process in breeding programme and also reduces the cost of selection. The PC1 includes traits *viz.* seedling dry weight, seedling vigour index I and seedling vigour index II and PC2 includes seed density and seedling length as they are main components which are more contributing to the total variation. Similar results were obtained by Bhanupriya *et al.* (2014) and Mohibullah *et al.* (2013) [6, 14].

Table 5: Principal Component Analysis

	Eigen values	Proportion	Cumulative proportion
PC1	4.043	0.505	0.505
PC2	1.136	0.142	0.647
PC3	0.99	0.124	0.771
PC4	0.805	0.101	0.872

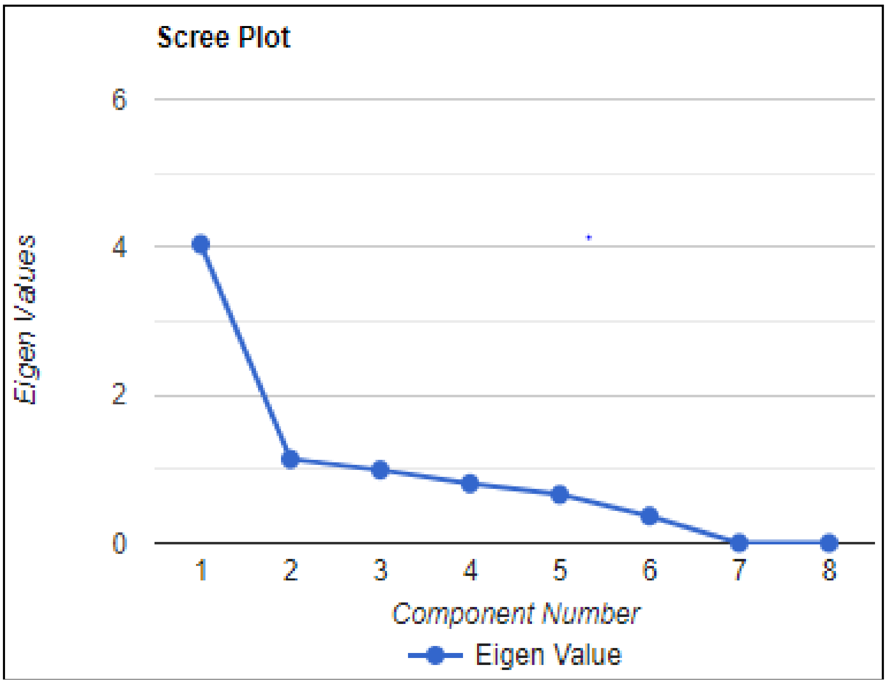

Fig 2: Principal Component Analysis

Conclusion

The moderate to high values of GCV and PCV showed that variability present among the genotypes for the traits studied and selection for these traits will be beneficial. The parameters namely seed density, seedling dry weight, seedling length, seedling vigour index I and seedling vigour index II reported high heritability accompanied with high genetic advance values as per cent of mean indicating that these traits are governed by additive gene effect and direct selection for these traits can be done. Correlation study revealed that the grain yield plot^{-1} had strong positive association with 1000 grain weight and seedling vigour index I which means genotypes showing higher values for these traits will report higher grain yield. Path analysis suggested that there is more direct positive effect by SVI and SVII and also other traits are positively affecting the grain yield plot^{-1} indirectly via these traits which means these traits can be use as selection parameters for high yielding genotypes. Traits in principal component 1 and 2 distinguish between high yield genotype and low yield genotypes as these components are able to serve as bench mark for ascertaining the efficient pattern of genotype between accessions base on these contributing traits.

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