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Correlation and Path Coefficient Analysis in Oat (*Avena sativa* L.)

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ABSTRACT

The present study was conducted during winter season of 2009-2010 with 90 diverse genotypes selected from wide range of germplasm being maintained at Forage Research Farm, Punjab Agricultural University, Ludhiana. The genotypes were analysed for genetic variability, correlation and path coefficients. Most of the traits had high mean values. High heritability along with high genetic advance (GA) was recorded for internode length (cm), number of tillers/plant, flag leaf length (cm), plant height (cm), axis length (cm), axis branch number, number of seeds/panicle and seed yield (g)/plant. High estimates of genotypic coefficient of variation and phenotypic coefficient of variation (GCV and PCV) were observed for internode length, number of tillers/plant, axis branch number, number of seeds/plant and seed yield/plant, suggesting that selection based on these characters would facilitate successful isolation of desirable types. Traits like number of leaves, internode length (cm), flag leaf width (cm), axis length (cm), axis branch number and number of seeds/panicle had positive and significant correlation at genotypic as well as phenotypic level with seed yield and the selection based on these traits will result in improving the seed yield in oat. Traits like number of leaves, internode length, flag leaf width, axis length, axis branch number and number of spikelets/panicle showed high direct effect on seed yield/plant. Selection for more number of leaves, axis branches and number of seeds per panicle along with broader flag leaf will be significant for the improvement of seed yield in oat.

Keywords: genetic advance, genotypic coefficient of variation (GCV), heritability, phenotypic coefficient of variation (PCV), seed yield components

INTRODUCTION

Oat (*Avena sativa* L.) is the most important cereal fodder crop grown during *Rabi* season in many parts of the country including North Western, Central and extending up to the parts of Eastern India. Oat (*Avena sativa* L.) ranks sixth in cereal production globally following wheat, maize, rice, barley and sorghum (Choubey and Roy 1996). In many parts of the world oat is grown as multipurpose crop for grain, pasture and forage crop. It is considered to be one of the best dual purpose cereal crops that fit well into the platter of human and cattle as well. Besides green fodder yield, increased seed yield should also be a breeding objective as low seed yields adversely affect the economic availability of seed. The great challenge for oat breeders lies in identifying the genetic make-ups that are superior in seed yield. Seed yield is the result of a number of complex morphological and physiological processes affecting each other and occurring in different growing stages (Dokuyucu and Akkaya 1999).

To reach this goal, the basic requirements are to have adequate information on the extent of variability, heritability, expected genetic gain and degree of genetic association among the different characters. Burton and Devane (1953) suggested that genotypic coefficient of variation GCV together with heritability estimates would give reliable indication about the expected improvement of a trait under consideration. However, McGinnis and Shebeski (1968) have reported the importance of using selection strategies, chiefly for quantitative traits, in highly segregating populations. Intensifying artificial selection for low heritability traits of difficult gene action estimation must be practised in advanced generations with reduced frequency of heterozygosity (Allard 1999). The indirect selection through less complex traits with larger heritability, however, results in larger genetic progress when compared to direct selection. Considerable significance has been devoted to studies involving correlation of traits in breeding programs. The measurement and interpretation of these correlations can result in mistakes on selection strategies (Cruz and Regzzi 1997), since a high correlation can be the result of a third trait or a group of traits affecting these traits. In this scenario, the technique of path analysis has been extensively exploited by many plant breeders to assist in identifying traits that are useful as selection criteria to improve the seed yield of the crop (Dewey and Lu 1959; Miligan *et al*. 1990). Path coefficients have been used to develop selection criteria for complex traits in several crop species (Wright 1921; Dewey and Lu 1959; Fonseca and Patterson 1968; Bhatt 1973; Pandey and Torrie 1973; Ivanovic and Rosic 1983; Gravois *et al.* 1991; Diz *et al.* 1994; Akram *et al.* 2008; Ali *et al*. 2008, 2009; Anwar *et al*. 2009; Wannows *et al*. 2010).

This technique is beneficial in determining the direct influence of one variable on another, and also separates the correlation coefficient into its components (Dewey and Lu 1959; Rodríguez *et al*. 2001). There is rather an agreement among the plant breeders that association among agronomic traits is very important to increase the use of indirect selection to improve the seed yield in oat (Benin *et al*. 2003). In India, not much work has been done on association studies to screen the germplasm for seed yield. An attempt was, therefore, made to estimate the extent of variability for different seed yield contributing traits, magnitude and direction of association among different characters both at genotypic and phenotypic levels and to investigate the direct and indirect effects of yield components on number of seeds per panicle which directly manifests the seed potential of a genotype.

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MATERIALS AND METHODS

The experiment was conducted during *Rabi* season of 2009-2010 with 90 diverse genotypes selected from wide range of germplasm being maintained at Forage Research Farm, Punjab Agricultural University, Ludhiana. The material was grown in augmented design (Federer 1956) in single rows of 5 m length and two checks viz; Kent and OL 9 were repeated after every seven entries to obtain an estimate of the error. Recommended package of practices to raise a good crop was followed. Observations were recorded on five random plants selected from each entry on 14 quantitative variables viz; number of leaves, leaf width (cm), leaf length (cm), internode length (cm), number of tillers per plant, stem girth (cm), flag leaf length (cm), flag leaf width (cm), plant height (cm), axis length (cm), axis branch number, number of spikelets per plant, number of seeds per panicle and seed yield per plant. The data were analysed for variability, divergence, correlation and path coefficient study. Genotypic and phenotypic coefficients of correlation were calculated from genotypic and phenotypic covariances and variances as described by Singh and Chaudhry (1985) and Johnson *et al*. (1955). Direct and indirect effects were calculated by the path coefficient analysis as suggested by Dewey and Lu (1959) at both phenotypic and genotypic levels. Genotypic and phenotypic coefficients were calculated using the formulae as used by Burton and De Vane (1953) and Johnson *et al*. (1955). Heritability in broad sense was estimated as suggested by Burton (1952). The expected genetic advance at 5% selection intensity was calculated by the formula as used by Johnson *et al*. (1955).

RESULTS AND DISCUSSION

Estimates of genetic variability

It is evident from the range of mean values for different traits among the oat genotypes being evaluated (**Table 1**) that these had diverse genetic background. The traits like number of tillers/plant (3.33 – 12.0), leaf length (25.03 – 54.17 cm), flag leaf length (16.33 – 46.33 cm), plant height (53.33 – 121.67 cm), axis branch number (4.0 – 30.0) and seed yield/plant (0.0012 – 0.0202 g) had wide range of mean values.

GCV, phenotypic coefficient of variation (PCV), broad sense heritability (h^2) and genetic advance as percent of mean (GA) are given in **Table 2**. Perusal of data revealed that PCV and the GCV were close for most of the traits except stem girth (cm) and flag leaf width (cm), indicating primarily the genetic control for these traits rather the environment effect alone. Also high estimates of GCV and PCV were observed in internode length, number of tillers/plant, axis branch number, number of seeds/plant and seed yield/plant, suggesting that selection based on these characters would facilitate successful isolation of desirable types. However, the genetic variability together with heritability estimates would give a better idea on the amount of GA expected from selection (Burton 1952). High values of GCV were reported for internode length (cm), number of tillers/plant, axis branch number, number of seeds/plant and seed yield (g)/plant in accordance with the results of Shankar *et al.* (2002). Number of leaves, leaf width (cm), leaf length (cm), stem girth (cm), flag leaf length (cm), flag leaf width (cm), plant height (cm), axis length (cm) and number of spikelets/panicle had low GCV values indicating little scope of genotypes for improvement in these traits. Shankar *et al.* (2002) also reported the low GCV values for traits like Number of leaves, leaf width, stem girth, plant height, supporting our results.

High heritability along with high GA was recorded for internode length (cm), number of tillers/plant, flag leaf length (cm), plant height (cm), axis length (cm), axis branch number, number of seeds/panicle and seed yield (g)/plant. Chaubey and Richaria (1993) and Shankar *et al.* (2002) also reported similar results for many of these characters. Flag leaf width (cm) had lowest heritability followed by stem girth (cm). Traits having high heritability and high genetic advance are supposed to be under control of additive genes, hence, these can be improved by selection based on phenotypic performance (Mondal and Khajuria 2000; Ghosh and Gulati 2001). Traits like number of leaves, leaf width (cm), leaf length (cm) had high h^2 but low values of GA suggesting the involvement of non additive gene action in their inheritance. Traits like number of tillers/plant, flag leaf width, axis branch number and seed yield/plant showed high heritability coupled with high PCV suggesting greater scope for selection of these traits on phenotypic basis.

Genotypic and phenotypic correlation coefficients

Seed yield is a complex character controlled by several components which reflect positive and negative effects on this trait. Yield components of seeds in cereals like oat consist chiefly of traits like number of spikes per unit area, number of spikelets/panicle, number of seeds/panicle (Rasmusson and Chanel 1970). Thus, for achieving rational improvement in seed yield and its components, knowledge of mechanism of association, cause and effect relationship provides a basis for formulating suitable selection methods for the yield components.

Results indicate that number of leaves, internode length (cm), flag leaf width (cm), axis length (cm), axis branch number and number of seeds/panicle had positive and significant correlation at genotypic as well as phenotypic level with seed yield (**Table 3**) and the selection based on these traits will result in improving the seed yield in oat. Lorencetti *et al.* (2006) also reported high and positive correlation (0.69) between seed yield and number of seeds/panicle thus corroborating our findings. Abbott *et al.* (2007) in rescue grass (0.57); Arslan (2007) in safflower (0.67); Bello *et al.* (2010) in maize (0.34); Bhattacharya *et al.* (2007) in wheat (0.54); Nofouzi *et al.* (2008) in rice (0.43) also reported similar results.

Table 1 Estimates of genetic parameters for different traits in oats.

Character	Minimum	Maximum	h^2 (%)	GA %	PCV	GCV	GM
No. of leaves	4.0	7.33	51.53	15.42	14.52	10.43	5.88
Leaf width (cm)	1.53	3.03	59.19	20.95	17.19	13.22	2.15
Leaf length (cm)	25.03	54.17	84.84	24.19	13.84	12.75	42.40
Internode length (cm)	5.83	22.67	73.89	41.53	27.28	23.45	11.45
No. of tillers/plant	3.33	12.0	67.22	43.84	31.66	25.96	6.97
Stem girth (cm)	0.4	1.23	36.06	16.17	21.77	13.07	0.88
Flag leaf length (cm)	16.33	46.33	86.56	37.31	20.92	19.47	30.02
Flag leaf width (cm)	1.23	6.00	9.16	8.80	46.68	14.12	1.90
Plant height (cm)	53.33	121.67	94.50	30.80	15.82	15.38	81.53
Axis length	15.0	46.0	83.65	31.96	18.55	16.96	34.47
Axis branch number	4.00	30.00	84.69	67.25	38.55	35.47	11.63
No. of spikelets/panicle	42.33	125.67	93.60	37.86	19.64	19.00	82.83
No. of seeds/panicle	75.67	281.67	99.44	53.80	26.26	26.19	159.69
Seed yield/plant (g)	0.0012	0.0202	99.65	124.91	60.85	60.74	0.01

h^2 = heritability (broad sense); PCV = Phenotypic coefficient of variability; GCV = Genotypic coefficient of variability; GA % = Genetic advance as percentage of mean; GM = grand mean

Table 2 Genotypic and phenotypic correlation coefficients among various traits of oats.

Characters		No. of leaves	Leaf width (cm)	Leaf length (cm)	Internode length (cm)	No. of tillers/ plant	Stem girth (cm)	Flag leaf length (cm)	Flag leaf width (cm)	Plant height (cm)	Axis length (cm)	Axis branch number	No. of spikelets/ panicle	No. of seeds/ panicle
Leaf width (cm)	G	0.32**												
	P	0.14*												
Leaf length (cm)	G	0.32**	0.41**											
	P	0.22**	0.32**											
Internode length (cm)	G	0.06	-0.01	0.29**										
	P	0.05	-0.01	0.24**										
No. of tillers/plant	G	0.15*	0.22**	0.38**	0.07									
	P	0.09	0.14	0.30**	0.06									
Stem girth (cm)	G	0.47**	0.78**	0.35**	0.13*	0.34**								
	P	0.23**	0.46**	0.27**	0.02	0.17								
Flag leaf length (cm)	G	0.45**	0.34**	0.78**	0.18**	0.43**	0.44**							
	P	0.27**	0.32**	0.72**	0.14*	0.35**	0.29**							
Flag leaf width (cm)	G	0.67**	0.86**	0.39**	0.01	0.11	0.78**	0.27**						
	P	0.06	0.29**	0.14*	0.01	0.04	0.14*	0.13*						
Plant height (cm)	G	0.48**	0.32**	0.41**	0.27**	-0.20**	0.35**	0.16**	0.62**					
	P	0.39**	0.22**	0.37**	0.22**	-0.15	0.21**	0.13*	0.17**					
Axis length (cm)	G	0.02	0.23**	0.15*	0.18**	0.05	0.11	0.02	0.06	0.19**				
	P	0.02	0.18**	0.13*	0.15*	0.02	0.10	0.02	0.07	0.16**				
Axis branch number	G	0.21**	0.16**	0.27**	0.28**	0.04	0.29**	0.03	0.66**	0.41**	0.55**			
	P	0.17**	0.12*	0.23**	0.22**	0.03	0.20**	0.03	0.13*	0.37**	0.50**			
No. of spikelets/panicle	G	0.29**	0.48**	0.22**	0.01	0.22**	0.46**	0.13*	0.27**	0.15*	0.59**	0.39**		
	P	0.23**	0.35**	0.20**	0.01	0.18**	0.31**	0.12*	0.06	0.15*	0.53**	0.35**		
No. of seeds/panicle	G	0.32**	0.22**	0.24**	0.05	0.26**	0.46**	0.20**	0.43**	0.35**	0.16**	0.08	0.29**	
	P	0.23**	0.16**	0.22**	0.04	0.21**	0.28**	0.18**	0.13*	0.34**	0.15*	0.07	0.27**	
Seed yield/plant (g)	G	0.18**	-0.31**	0.00	0.22**	-0.09	-0.23**	0.01	0.20**	0.00	0.14*	0.32**	0.02	0.16**
	P	0.13*	-0.24**	0.00	0.19**	-0.07	-0.13*	0.00	0.10	0.00	0.13*	0.29**	0.02	0.11

Critical value of 'r' at 5% = 0.12 and at 1% = 0.15; G = genotypic correlation coefficient; P = phenotypic correlation coefficient

Table 3 Path coefficient analysis for direct (bold) and indirect effects on seed yield/plant in oats.

Characters	No. of leaves	Leaf width (cm)	Leaf length (cm)	Internode length (cm)	No. of tillers/plant	Stem girth (cm)	Flag leaf length (cm)	Flag leaf width (cm)	Plant height (cm)	Axis length (cm)	Axis branch number	No. of spikelets/ panicle	No. of Seeds/ panicle
No. of leaves	**0.2233**	-0.1822	0.0137	0.0124	-0.0169	-0.0781	0.0429	0.1959	-0.1081	0	0.0247	0.0526	-0.0348
Leaf width (cm)	0.0711	**-0.5694**	0.0178	-0.0004	-0.0244	-0.1297	0.0325	0.2518	-0.0721	0.0256	0.0192	0.0884	0.0236
Leaf length (cm)	0.0704	-0.2333	**0.0434**	0.0614	-0.0416	-0.0588	0.0734	0.1143	-0.0927	0.0173	0.0318	0.0394	0.0261
Internode length (cm)	0.0128	0.0010	0.0124	**0.2142**	-0.0074	-0.0220	0.0170	0.0004	-0.0610	0.0204	0.0330	0.0014	-0.0053
No. of tillers	0.0343	-0.1275	0.0165	0.0146	**-0.1092**	-0.0560	0.0408	0.0315	0.0438	0.0053	0.0046	0.0401	-0.0278
Stem girth (cm)	0.1042	-0.4432	0.0153	0.0282	-0.0367	**-0.1666**	0.0417	0.2278	-0.0790	0.0126	0.0341	0.0846	0.0499
Flag leaf length (cm)	0.1008	-0.1955	0.0336	0.0384	-0.0471	-0.0735	**0.0946**	0.0796	-0.0351	0.0027	0.0033	0.0230	-0.0216
Flag leaf width (cm)	0.1484	-0.4885	0.0169	0.0003	-0.0117	-0.1293	0.0257	**0.2935**	-0.1395	0.0070	0.0775	0.0490	0.0467
Plant height (cm)	0.1069	-0.1825	0.0179	0.0581	0.0213	-0.0586	0.0148	0.1822	**-0.2248**	0.0211	0.0479	0.0276	-0.0379
Axis length (cm)	0.0037	-0.1284	0.0066	0.0385	-0.0051	-0.0186	0.0022	0.0182	-0.0419	**0.1134**	0.0639	0.1089	-0.0176
Axis branch number	0.0471	-0.0935	0.0118	0.0604	-0.0043	-0.0486	0.0027	0.1946	-0.0921	0.0620	**0.1169**	0.0706	0.0088
No. of spikelets/panicle	0.0638	-0.2746	0.0093	0.0017	-0.0239	-0.0769	0.0119	0.0784	-0.0338	0.0674	0.0450	**0.1833**	0.0308
No. of seeds/panicle	0.0716	-0.1242	0.0105	0.0105	-0.0281	-0.0769	0.0189	0.1268	-0.0788	0.0184	0.0095	0.0523	**0.1082**

Leaf width and stem girth exhibited a negative and highly significant correlation with seed yield whereas plant height and leaf length showed no correlation with seed yield. Traits like axis length, axis branch number, number of spikelets/panicle and number of seeds/panicle showed positive and highly significant correlation amongst each other except between axis branch number and number of seeds/ panicle which showed non significant correlation. Nofouzi *et al.* (2008) reported negative correlation (-0.34) between axis length and number of seeds/panicle in wheat, in contrast to our results.

Plant height showed high and positive genotypic correlation with other important yield contributing traits like axis length (0.19), axis branch number (0.41), number of spikelets/panicle (0.15) and number of seeds/panicle (0.35). This was in accordance to the results obtained by Kumar and Vivekanandan (2009) who reported strong correlation of plant height and number of capsules/plant with seed yield. But the observations recorded by Chaubey and Richaria (1993) and Gravios and McNeal (1993) were in contrast to our results as they reported negative correlation between plant height and number of seeds/panicle. At the same time our results showed that taller plants will bear longer axis with more branches, having more number of spikelets and seeds/panicle again negating the conclusion drawn by Chaubey and Richaria (1993) and Gravios and McNeal (1993) that selection for shorter genotypes tends to produce more spikes/plant and more seeds/panicle. None of the yield contributing traits showed negative and significant correlation amongst each other except plant height that showed negative and significant correlation with number of tillers/ plant.

Path coefficient analysis for direct and indirect effects on seed yield/plant

Partitioning of the total correlation coefficient into direct and indirect effects for seed yield per plant showed a high direct effect of many yield contributing traits viz; number of leaves, internode length, flag leaf width, axis length, axis branch number and number of spikelets/panicle on seed yield (**Table 3**). Abbott *et al.* (2007) in rescue grass, Kumar and Vivekananda (2009) in sesame, Nofouzi *et al.* (2008) in durum wheat, Shankar *et al.* (2002) in oat, and Simane *et al.* (1993) in durum wheat had also observed high value of direct effect of number of spikelets/panicle on seed yield.

Negative and high direct effect contributed by traits like leaf width, number of tillers, plant height, however, deluded the positive and direct effect of earlier traits on seed yield.

The positive indirect effects were contributed through most of the traits except leaf width, number of tillers/plant, stem girth, plant height and number of seeds/panicle exerting negative impact on the seed yield/plant. Shankar *et al.* (2002) also reported negative indirect effect of number of tillers/plant on seed yield/plant. High and significant genotypic correlation values of traits like number of leaves (0.18), flag width (0.20), axis branch number (0.32) and number of seeds/panicle (0.16) with seed yield and their high direct effect values on seed yield i.e. 0.2233, 0.2935, 0.1169 and 0.1282, respectively, indicated a true picture of association between these traits.

CONCLUSION

Selection for more number of leaves, axis branches and number of seeds per panicle along with broader flag leaf will be significant for the improvement of seed yield in the material under study. At the same time progress in breeding for enhanced seed yield may be adversely affected by selection for traits like number of tillers/plant, stem girth and leaf width due to a strong negative association of these traits with seed yield.

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