Electronic Journal of Plant Breeding, 8(3): 980-985 (September 2017) DOI: 10.5958/0975-928X.2017.00130.2
ISSN 0975-928X

Research Note

Correlation studies for yield components in oats germplasm

R. Premkumar[1*], A. Nirmalakumari[2] and C.R. Anandakumar[3]
[1]RVS Agricultural College, Thanjavur, Tamil Nadu – 613 402, India.
[2]Centre of Excellence in Millets, Athiyandal, Thiruvannamalai, Tamil Nadu – 606 603, India.
[3]Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu – 641 003, India.
E-mail: premmelb@gmail.com

(Received: 05 April 2017; Revised: 10 Aug 2017; Accepted: 20 Aug 2017)

Abstract
Forty eight oats genotypes were evaluated in a Randomized Complete Block Design to analyse the existence of variation and correlation among yield and yield components during, *rabi*, 2013 - 2014. In this study, based on the experimental data, ANOVA was worked out for different characters. The variability parameters *viz*., mean, range, standard error of difference (SEd) and critical difference (CD) were worked out. The plant height exhibited highest mean square value 620.81** than other characters which signified at 0.01 probability level. Among forty eight genotypes, TNAs 48 showed highest total number of tillers per plant (13.67), number of productive tillers per plant (10.00), groat weight per primary panicle (0.96g), kernel weight per primary panicle (0.81g) and fodder yield per plant (50.99g), followed by TNAs 20 for panicle exertion (18.23cm), single plant groat yield (8.89g) and single plant kernel yield (5.70g) and TNAs 22 for thousand groat weight (57.81g) and thousand kernel weight (56.00g) than other genotypes included in this study. Among the characters studied, groat weight per primary panicle and kernel weight per primary panicle showed the least SEd (0.15) value followed by single plant kernel yield (0.57g), single plant groat yield (0.68g) and days to 50% flowering (0.77) which showed the least influence by environmental variations. Hence, the selection of genotype with higher groat weight and kernel weight per panicle will be a fruitful exercise. According to correlation coefficient analysis, single plant kernel yield was positive and significantly correlated with days to 50% flowering, total number of tillers per plant, number of productive tillers per plant, panicle exertion, groats weight per primary panicle, kernel weight per primary panicle and single plant groat yield. Hence, these traits should be used as selection criteria to improve oats genotypes with higher grain yield potential.

Key words
Oats, Correlation coefficient, Genotypes, Groat, Kernel, Variation, Yield

Oats (*Avena sativa* L.) originated from Mediterranean region, is an important dual (grain and fodder) purpose annual crop of *rabi* season. It belongs to family poaceae and ranks sixth in production among all cereal crops next to wheat, maize, rice, barley and sorghum in the world scenario. Among the oats genomes, white oats (*Avena sativa*) and red oats (*Avena byzantiana*) are cultivated. All over the world, oats was cultivated over 10.29 million hectares with a production of 20.49 million tonnes. The major oats growing areas are between 40^0 and 60^0N latitudes (Asia, Europe and North America), whereas a small proportion of production originates from southern hemisphere also (South America, Australia and New Zealand).

Oats (2n=6x=42) is a natural allopolyploid evolved through cycles of interspecific hybridization and polyploidization combining three distinct genomes are *A. sterilis, A. fatua* and *A. sativa.* In recent years, oats production has continuously decreased, whereas the demand for oats for human consumption as food has increased because of dietary benefits of whole grain (Achleitner *et al*., 2008). Improvement of yield and yield components has been the prime objective of breeders besides quality traits and agronomic traits in evolving high yielding oats varieties.

Availability of genetic variability for the component characters was a major asset for initiating a fruitful crop yield improvement program. Arora *et al*. (2008) carried out evaluation and characterization for some morphological traits in 554 germplasm accessions of oats. Raj Bahadur *et al*. (2009) studied oat genotypes to determine the extent of variability for various fodder yield and quality traits under normal and late sown conditions where they found considerable variability existed for all the characters. The first step in a breeding programme is to determine the amount of variation that is present in the characters of economic importance within a large collection of material, in order to define the valuable populations to be considered further. Assessment of the genetic variability can be achieved using morphological measurements and phenotypic characterization (Greene *et al*., 2008). Hence, evaluation of the existence of genetic variability for various yield components and analysis of correlation between various characters towards improvement of yield were taken as the prime objectives of the present study.

An investigation in oats was carried out during *rabi*, 2013-2014 at Indian Agricultural Research Institute, Regional Station, Wellington. A total of 48 genotypes received from IARI, Regional Station, Wellington and Department of forage crops, Centre for Plant Breeding and Genetics, TNAU, Coimbatore and Indian Grassland and Fodder Research Institute, Jhansi were evaluated under field condition using randomized complete block design with three replications. Seeds were sown continuously without plant to plant spacing and with wide spacing of 20-22 cm between rows at 2-4 cm depth. Experimental plot was maintained with good crop stand and uniform plant growth to reduce possibilities of error in making observation. Oats is a highly exhaustive crop and it needs three to four irrigations with 70 kg N and 30 kg P_2O_5/ha for the establishment of good growth and crop stand. The observations were recorded for yield and its component characters *viz*., days to 50% flowering, plant height (cm), total number of tillers per plant, number of productive tillers per plant, panicle length (cm), panicle exertion (cm), number of groats per panicle, groat weight per primary panicle (g), kernel weight per primary panicle (g), thousand groat weight (g), thousand kernel weight (g), fodder yield per plant (g), single plant groat yield (g) and single plant kernel yield (g). Existence of genetic variability and correlation coefficients were worked out from the replicated data of various traits.

Data on yield and yield components for forty eight oat genotypes were taken during *rabi* 2013 - 14 and analysed. Mean values were worked out for fourteen characters and ANOVA for mean square, range, critical difference (CD), standard error of difference (SEd) are presented in Table 1 and 2. Mean genotypic values worked out for forty eight genotypes with fourteen characters indicated that the genotype TNAs 48 showed highest total number of tillers per plant (13.67), number of productive tillers per plant (10.00), groat weight per primary panicle (0.96), kernel weight per primary panicle (0.81) and fodder yield per plant (50.99g), followed by TNAs 20 for panicle exertion (18.23cm), single plant groat yield (8.89g) and single plant kernel yield (5.70g) and TNAs 22 for thousand groat weight (57.81g) and thousand kernel weight (56.00g) were observed. Likewise the lowest mean genotypic value was observed in genotype TNAs 41 for total number of tillers per plant (2.67), number of productive tillers per plant (2.67) and single plant kernel yield (1.04g) followed by TNAs 42 for days to 50% flowering (58.67) and number of groats per panicle (21.00). Analysis of variance showed highly significant variation observed for all the characters studied except groat weight per primary panicle and kernel weight per primary panicle.

According to Peterson *et al*. (2005) knowledge of some of the relationships among different traits can help breeders to optimize some traits simultaneously. Knowledge of correlation that exists among important characters may facilitate proper interpretation of results and provide basis for planning more efficient breeding programme. Correlation between important and may reveal that some of the latter are useful as indicators of one or more of the former. Direct selection for yield is not effective since yield is a complex and quantitatively inherited character with low heritability. Therefore, indirect selection could be made for the component characters contributing to yield through character association as it provides information about the characters that are correlated with each other in improving yield.

According to correlation coefficient analysis (Table 3), single plant kernel yield was positive and significantly correlated with days to 50% flowering, total number of tillers per plant, number of productive tillers per plant, panicle exertion, groats weight per primary panicle, kernel weight per primary panicle and single plant groat yield. These traits were used as selection criteria to improve oat cultivars with higher grain yield. Yanming (2006) and Buerstmayr (2007) reported variations among the oat genotypes for thousand groat weight. Existence of significant positive correlation between two variables showed improvement of one trait will have positive result on another trait. The positive correlation existed between number of productive tillers per plant with single plant kernel yield showed increase in single plant kernel yield was dependent on presence of number of productive tillers. According to Redaelli *et al*. (2008), high seed yield in oat is negatively correlated with plant height and positively correlated with seed weight. Robertson and Frey (1987) indicated grain yield and biomass as selection criteria. Gautam *et al*. (2006) determined a large variation for grain yield among genotypes. In oats, one of the most important traits after grain yield is groat weight. In previous works, Doehlert *et al*. (1999) reported groat weight as an important quality trait in oats, Welch *et al*. (2000) reported variation for groat weight within oat species.

In agriculture, path analyses have been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield (Dewey & Lu, 1959). Path coefficient analysis is done in order to study the direct and indirect effects of individual component characters on the dependent variable yield. Study of path coefficients enable breeders to concentrate on the variable which shows high direct effect on grain yield. Ultimately we can reduce the time in looking for more number of component traits by restricting selection to one or few important traits. The results of path coefficient analysis were given in Table 4. Among the 14 yield component characters seven characters showed positive direct effects. Thousand kernel weight recorded the highest positive direct effect followed by single plant groat yield, groat weight per primary panicle and days to 50% flowering. Yang, (1986); Moradi *et al*.,

(2005) and Bibi *et al*, (2012) found that number of grains per panicle showed the highest direct effect on grain yield of oats genotypes. Our findings are in partial agreement with these results. Negative direct effects were observed for the following characters *viz*., thousand kernel weight, kernel weight per primary panicle, panicle length and number of productive tillers per plant. Bhutta *et al*. (2005) and Bibi *et al*, (2012) also reported negative direct effect of plant height on grain yield. Our findings are in contrast with these results mentioned above.

In this study, we have evaluated existence of variability and correlation between oats genotypes based on grain yield and yield components. Genotypes showed higher performance for some of the yield components, like days to 50% flowering, total number of tillers per plant, number of productive tillers per plant, panicle exertion, groats weight per primary panicle, kernel weight per primary panicle and single plant groat yield which are the important selection criteria for high yield in oats. Our results demonstrate that these traits are more promising as selection criteria for use in oats breeding programs.

Acknowledgement

The authors here by acknowledge the IARI, Regional Station, Wellington for providing seed material and technical support. Also wish to thank Marico Private Limited for providing funds to carry out this research work.

References

Anderson Achleitner, A., Tinker, N.A, Zechner, E. and Buerstmayer, H. 2008. Genetic diversity among oat varieties of worldwide origin and association of AFLP markers with quantitative trait loci. *Theoretical and Applied Genetics*. **117**: 1041-1053.

Arora, R.N., Bisht,S.S., Joshi, U.N. and Jhorar, B.S. 2008. Evaluation and characterization of oat germplasm. *Forage Res*., **34**: 29-32.

Bhutta, W.M., Barley, T. and İbrahim, M. 2005. Path-coefficient analysis of some quantative characters in husked barley. *Caderno de Pesquisa Ser Biologia, Santa Cruz de Sul*., **17**(1): 65-70.

Bibi, Shahzad, A.N., Sadaqat, H.A., Tahir, M.H.N. and Fatima, B. 2012. Genetic characterization and inheritance studies of oats (*Avena Sativa* L.) For green fodder yield. *Int.J.Bio.Pharmacy and Food.Sci*., **1**(4): 450-460.

Buerstmayr, H., Krenn, N., Stephan, U., Grausgruber, H. and Zechner E. 2007. Agronomic performance and quality of oat (*Avena sativa* L.) genotypes of worldwide origin produced under Central European growing conditions. *Field Crops Research*, **101**: 341-351.

Dewey, D.R. and Lu, K.H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J*., **51**(9): 515-518.

Doehlert, D.C., McMullen, M.S. and Baumann, V. 1999. Factors affecting groat percentage in oat. *Crop Science*, **39**: 1858-1865.

Gautam, S.K, Verma, A.K and Vishwakarma, S.R. 2006. Genetic variability and association of morpho-physiological characters in oat (*Avena sativa* L.). *Farm Science J.*, **15**(1): 82-83.

Greene, N.V., Kenworthy, K.E., Quesenberry, K.H., Unruh, J.B. and Sartain, J.B. 2008. Diversity and relatedness of common carpet grass germplasm. *Crop Sci.*, **48**: 2298-2304.

Moradi, M., Rezai, A. and Arzani, A. 2005. Path analysis for yield and related traits in oats. *Journal of Science and Technology of Agriculture and Natural Resources*, **9**(1): 173-180.

Peterson, D.M., Wesenberg, D.M., Burrup, D.E. and Erickson, C.A. 2005. Relationships among agronomic traits and grain composition in oat genotypes grown in different environments. *Crop Sci*., **45**: 1249-1255.

Raj Bahadur, R.N. and Choubey. 2009. Genetic divergence in oat (*Avena sativa* L.). *Forage Res*., **34**: 225-229.

Redaelli, R., Lagana, P., Rizza, F., Li Destri Nicosia, O. and Cattivelli, L. 2008. Genetic progress of oats in Italy. *Euphytica*, **164**(3): 679-687.

Robertson, L.D. and Frey, K.J. 1987. Honeycomb design for selection among homozygous oat lines. *Crop Science*. 27: 1105-1108.

Welch, R.W., Brown, J.C. Wand Leggett, M. 2000. Interspecific and intraspecific variation in grain and groat characteristics of wild oat (*Avena*) species. *Journal of Cereal Sci*., **31**: 271-279.

Yang, H.S. 1986. Studies on the main traits of inter varietals hybrid progenies in indica rice. *Fujan-Agricultural Science and Technology*, **6**: 2-4.

Yanming, M., ZhiYong, L., YuTing, B., Wei, W. and Hao, W. 2006. Study on diversity of oats varieties in Xinjiang. *Xinjiang Agricultural Sci*., **43**(6): 510-513.

Table 1. Mean genotypic values for yield and its attributes in oats

Entries	DFF	PH	TNT	NPT	PL	PE	NGP	GWPP	KWPP	TGW	TKW	FYPP	SPGY	SPKY
TNAs 1	62.67	99.83	8.00	4.67	25.83	4.33	79.67	0.69	0.47	47.96	45.91	31.22	3.17	1.60
TNAs 2	63.33	81.33	9.67	4.33	28.00	5.30	60.00	0.62	0.53	46.19	44.50	48.85	4.90	3.58
TNAs 3	60.67	81.23	8.00	4.00	28.90	3.33	76.33	0.67	0.45	45.47	43.68	43.09	5.13	2.82
TNAs 4	62.33	88.33	5.00	4.67	27.10	5.54	75.00	0.54	0.43	48.59	46.64	43.02	2.76	1.31
TNAs 5	64.67	96.13	5.33	4.67	31.75	3.47	53.00	0.50	0.37	45.73	43.71	47.46	5.19	3.56
TNAs 6	64.00	61.67	9.67	8.67	18.83	3.68	33.33	0.95	0.77	52.55	50.05	43.06	4.46	2.75
TNAs 7	64.67	68.00	9.33	7.33	20.27	1.73	40.67	0.60	0.40	50.01	48.02	37.21	6.09	3.98
TNAs 8	64.33	85.73	7.67	6.00	22.13	3.37	50.00	0.55	0.36	49.88	47.73	38.29	4.44	3.08
TNAs 9	63.67	74.67	8.67	7.67	22.57	3.63	52.00	0.54	0.38	54.04	51.87	35.93	5.20	3.37
TNAs 10	64.33	79.83	6.67	5.67	20.63	5.53	38.00	0.90	0.72	49.09	46.66	35.79	3.12	2.04
TNAs 11	60.00	102.33	5.00	4.67	26.93	8.13	62.67	0.72	0.60	46.07	43.65	46.29	4.96	3.08
TNAs 12	60.33	105.87	5.00	4.00	29.70	5.50	60.67	0.84	0.64	48.63	46.72	37.76	6.10	3.98
TNAs 13	61.33	62.33	4.67	4.00	18.93	2.00	60.33	0.40	0.26	42.72	40.68	43.28	2.76	1.62
TNAs 14	61.00	71.40	6.33	5.67	17.90	5.83	40.33	0.51	0.32	38.39	36.66	34.76	2.31	1.27
TNAs 15	60.67	89.23	7.67	6.67	21.07	7.43	31.00	0.41	0.26	44.27	41.55	48.05	1.88	1.07
TNAs 16	63.00	87.73	5.00	4.33	21.83	10.17	38.33	0.61	0.49	48.45	46.14	42.76	3.66	2.37
TNAs 17	60.67	91.17	6.00	5.00	20.50	12.50	51.67	0.46	0.31	48.17	45.54	34.38	4.59	3.11
TNAs 18	61.67	81.67	7.00	5.67	17.83	11.90	27.33	0.55	0.41	45.70	43.95	34.18	4.33	3.07
TNAs 19	58.67	90.67	10.67	9.33	20.57	12.97	41.67	0.61	0.40	49.42	47.49	36.48	5.51	4.60
TNAs 20	59.33	93.83	6.33	5.67	21.67	18.23	51.67	0.62	0.50	39.80	37.05	33.52	8.89	5.70
TNAs 21	62.33	87.33	5.67	5.33	21.13	10.13	42.00	0.61	0.50	54.69	51.60	42.14	4.93	3.11
TNAs 22	61.00	86.07	6.00	6.00	20.57	12.07	58.67	0.55	0.43	57.81	56.00	44.19	4.94	3.32
TNAs 23	62.00	81.00	5.33	5.00	22.43	12.17	38.67	0.59	0.40	33.92	31.93	35.40	5.16	3.27
TNAs 24	69.67	84.27	7.33	6.00	26.03	7.40	59.00	0.59	0.41	51.63	48.65	41.05	4.93	3.33
TNAs 25	67.33	111.80	5.00	4.00	29.00	10.13	63.33	0.90	0.81	49.37	46.60	46.89	6.23	5.22
TNAs 26	65.67	102.90	4.00	3.33	24.33	13.30	46.00	0.58	0.44	35.34	32.87	34.67	5.43	3.69
TNAs 27	69.00	84.90	6.33	3.33	22.70	9.37	59.33	0.62	0.43	29.25	27.38	32.77	4.66	2.85
TNAs 28	64.67	90.00	6.67	5.00	25.67	9.70	47.00	0.48	0.33	35.96	32.82	31.95	5.05	2.95
TNAs 29	61.67	101.00	6.00	5.33	24.90	14.20	43.67	0.62	0.45	45.79	43.57	35.35	5.65	3.63
TNAs 30	74.33	109.13	7.67	5.67	25.97	11.93	49.00	0.46	0.33	23.89	21.97	36.82	5.03	3.38
TNAs 31	75.67	79.50	6.33	5.00	23.77	8.57	44.33	0.62	0.45	36.53	34.19	43.80	5.45	3.94
TNAs 32	65.33	110.33	5.33	4.33	29.03	11.67	53.00	0.47	0.26	28.91	26.36	42.75	5.36	3.58
TNAs 33	65.33	117.67	6.67	5.67	29.10	10.33	45.67	0.56	0.41	37.85	35.30	40.33	4.54	3.02
TNAs 34	66.00	117.33	6.00	5.00	30.37	11.50	43.67	0.82	0.67	36.91	34.85	38.11	5.04	3.03
TNAs 35	62.00	86.17	6.33	4.67	24.60	4.50	54.00	0.34	0.27	34.83	32.42	36.75	3.95	2.46
TNAs 36	61.00	112.67	5.33	3.33	27.90	11.23	43.67	0.52	0.37	35.49	33.06	42.05	2.88	1.80
TNAs 37	64.00	98.27	4.67	3.67	25.60	6.43	50.33	0.50	0.35	36.20	33.99	40.78	4.87	3.48
TNAs 38	66.67	90.47	6.33	5.33	23.17	9.20	47.00	0.65	0.52	31.06	28.61	34.82	4.55	3.04
TNAs 39	66.33	98.70	7.00	4.67	23.53	13.73	58.33	0.67	0.48	33.83	30.94	32.49	3.75	2.48
TNAs 40	62.00	114.50	4.00	4.00	26.33	16.13	39.00	0.67	0.52	29.82	28.17	28.97	5.60	3.06
TNAs 41	64.00	109.83	2.67	2.67	27.70	8.37	37.33	0.44	0.29	34.83	31.42	35.89	2.40	1.04
TNAs 42	58.67	110.73	5.00	4.33	20.17	14.23	21.00	0.42	0.28	45.64	43.07	40.69	4.48	2.76
TNAs 43	87.67	117.17	8.33	6.67	25.20	8.00	52.33	0.62	0.51	35.67	33.05	47.33	5.42	4.00
TNAs 44	93.67	95.36	10.33	7.00	20.87	6.57	48.00	0.75	0.60	35.52	32.51	35.51	5.52	3.79
TNAs 45	94.67	95.96	7.33	6.33	22.69	9.30	43.33	0.82	0.67	36.77	34.31	35.59	5.73	4.29
TNAs 46	89.67	93.82	6.33	4.67	26.13	6.33	46.00	0.69	0.54	35.11	32.59	36.78	5.53	4.19
TNAs 47	96.33	88.97	6.67	5.33	23.17	7.57	43.67	0.62	0.44	30.54	27.32	33.70	5.29	3.89
TNAs 48	97.00	112.00	13.67	10.00	30.43	4.97	54.00	0.96	0.81	37.82	35.87	50.99	6.09	4.90
Mean	**67.40**	**93.35**	**6.67**	**5.30**	**24.28**	**8.62**	**49.06**	**0.61**	**0.46**	**41.50**	**39.16**	**39.04**	**4.75**	**3.16**
Min	**58.67**	**61.67**	**2.67**	**2.67**	**17.83**	**1.73**	**21.00**	**0.34**	**0.26**	**23.89**	**21.97**	**28.97**	**1.88**	**1.04**
Max	**97.00**	**117.67**	**13.67**	**10.00**	**31.75**	**18.23**	**79.67**	**0.96**	**0.81**	**57.81**	**56.00**	**50.99**	**8.89**	**5.70**
SEd	0.77	3.82	1.03	0.84	1.64	1.42	4.95	0.15	0.15	1.22	1.17	2.35	0.68	0.57
CD (%)	1.53	7.58	2.05	1.68	3.25	2.83	9.82	0.31	0.30	2.42	2.33	4.67	1.35	1.13

DFF- days to 50% flowering, PH- plant height, TNT- total number of tillers per plant, NPT- number of productive tillers per plant, PL- panicle length, PE- panicle exertion, NGP- number of groats per panicle, GWPP- groat weight per primary panicle, KWPP- kernel weight per primary panicle, TGW- thousand groat weight, TKW- thousand kernel weight, FYP- fodder yield per plant, SPGY- single plant groat yield and SPGY- single plant kernel yield

Electronic Journal of Plant Breeding, 8(3): 980-985 (September 2017)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00130.2

Table 2. ANOVA for different characters in oats

S.No	Characters	Mean square		
		Replication (df= 2)	Genotypes (df= 47)	Error (df= 94)
1.	Days to 50% flowering	3.26	329.56**	0.89
2.	Plant height	29.62	620.81**	21.91
3.	Total number of tillers per plant	0.14	11.71**	1.60
4.	Number of productive tillers per plant	0.54	6.76**	1.07
5.	Panicle length	0.27	39.37**	4.04
6.	Panicle exertion	0.68	45.59**	3.06
7.	Number of groats per panicle	10.02	414.97**	36.75
8.	Groat weight per primary panicle	0.05	0.06	0.03
9.	Kernel weight per primary panicle	0.02	0.06	0.03
10.	Thousand groat weight	0.85	195.45**	2.24
11.	Thousand kernel weight	0.43	198.65**	2.08
12.	Fodder yield per plant	0.79	83.70**	8.32
13.	Single plant groat yield	0.15	4.58**	0.69
14.	Single plant kernel yield	0.32	3.12**	0.49

* Significant at P = 0.05, ** significant at P = 0.01

DOI: 10.5958/0975-928X.2017.00130.2

Table 3. Simple correlation coefficients among yield and its components in oats

Traits	DFF	PH	TNT	NPT	PL	PE	NGP	GWPP	KWPP	TGW	TKW	FYPP	SPGY	SPKY
DFF	1.000	0.184	0.419**	0.327*	0.120	-0.157	-0.014	0.374**	0.384**	-0.400**	-0.411**	0.059	0.279*	0.410**
PH		1.000	-0.209	-0.233	0.641**	0.481**	0.022	0.099	0.146	-0.400**	-0.407**	0.051	0.196	0.203
TNT			1.000	0.835**	-0.112	-0.327*	0.058	0.368**	0.320*	0.153	0.160	0.188	0.214	0.321*
NPT				1.000	-0.302*	-0.180	-0.204*	0.331*	0.297*	0.285*	0.287*	0.157	0.228	0.330*
PL					1.000	-0.067	0.459**	0.181	0.206	-0.241*	-0.238	0.317*	0.189	0.169
PE						1.000	-0.326*	-0.098	-0.060	-0.290*	-0.297*	-0.336*	0.305*	0.246*
NGP							1.000	0.117	0.109	0.122	0.132	0.168	0.075	0.039
GWPP								1.000	0.971**	0.152	0.154	0.090	0.362**	0.407**
KWPP									1.000	0.156	0.156	0.173	0.376**	0.430**
TGW										1.000	0.995**	0.320*	-0.054	-0.034
TKW											1.000	0.321*	-0.053	-0.034
FYPP												1.000	-0.055	0.073
SPGY													1.000	0.943*
SPKY														1.000

* Significant at P = 0.05, ** significant at P = 0.01

Table 4. Estimation of direct and indirect effects of path coefficients analysis on grain yield in oats genotypes

Characters	DFF	PH	TNT	NPT	PL	PE	NGP	GWP	KWP	TGW	TKW	FYPP	SPGY
DFF	**0.445**	0.027	-0.016	-0.048	-0.022	-0.026	0.001	0.585	-0.696	1.132	-1.268	0.023	0.309
PH	0.083	**0.143**	0.008	0.035	-0.116	0.076	-0.002	0.143	-0.260	1.159	-1.290	0.019	0.219
TNT	0.202	-0.034	**-0.035**	-0.115	0.024	-0.057	-0.004	0.560	-0.569	-0.487	0.554	0.080	0.245
NPT	0.162	-0.038	-0.030	**-0.133**	0.059	-0.030	0.019	0.532	-0.565	-0.887	0.975	0.060	0.274
PL	0.057	0.098	0.005	0.046	**-0.170**	-0.010	-0.038	0.209	-0.291	0.712	-0.769	0.128	0.222
PE	-0.073	0.070	0.013	0.026	0.012	**0.155**	0.027	-0.166	0.115	0.856	-0.958	-0.132	0.332
NGP	-0.007	0.004	-0.002	0.032	-0.083	-0.054	**-0.077**	0.103	-0.103	-0.350	0.421	0.067	0.101
GWPP	0.261	0.021	-0.020	-0.071	-0.035	-0.026	-0.008	**0.997**	-1.150	-0.643	0.722	0.053	0.592
KWPP	0.261	0.031	-0.017	-0.063	-0.042	-0.015	-0.007	0.965	**-1.188**	-0.660	0.726	0.107	0.613
TGW	-0.179	-0.059	-0.006	-0.042	0.043	-0.047	-0.010	0.228	-0.278	**-2.815**	3.066	0.127	-0.063
TKW	-0.184	-0.060	-0.006	-0.042	0.043	-0.048	-0.011	0.235	-0.281	-2.814	**3.067**	0.127	-0.060
FYP	0.028	0.007	-0.008	-0.022	-0.058	-0.055	-0.014	0.141	-0.342	-0.962	1.053	**0.371**	-0.061
SPGY	0.135	0.031	-0.008	-0.036	-0.037	0.051	-0.008	0.580	-0.716	0.175	-0.182	-0.022	**1.017**

DFF- days to 50% flowering, PH- plant height, TNT- total number of tillers per plant, NPT- number of productive tillers per plant, PL- panicle length, PE- panicle exertion, NGP- number of groats per panicle, GWPP- groat weight per primary panicle, KWPP- kernel weight per primary panicle, TGW- thousand groat weight, TKW- thousand kernel weight, FYP- fodder yield per plant, SPGY- single plant groat yield and SPGY- single plant kernel yield