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Genetic Variability and Association Analysis for some Forage and Seed yield Related Traits in F_4 and F_5 Generations of Oat (*Avena sativa* L.)

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ABSTRACT: The present investigation was conducted to estimate genetic variability and association analysis on progenies from seven different crosses of oat in F_4 and F_5 generations. The analysis of variance revealed sufficient genetic variability among the genotypes for all the traits under study. Highest magnitude of PCV and GCV along with high heritability and high genetic advance was recorded for fresh fodder yield per plant, dry matter yield per plant, grain yield per plant and crude protein yield per plant in both generations. Significance and high direct effects towards grain yield per plant were shown by days to 75% maturity, harvest index, number of leaves per plant and number of tillers per plant; whereas, by dry matter yield per plant, crude protein yield per plant, leaf area and dry matter per cent towards fresh fodder yield per plant suggesting these traits as the best selection indices to obtain high yielding genotypes of oat.

Keywords: Oat, variability, heritability, genetic advance, correlation, path coefficient.

INTRODUCTION

Oat (*Avena sativa* L., 2n=6x=42) is an important cereal fodder crop constituent of family Gramineae. It is primarily grown during the *Rabi* season under both irrigated and rainfed conditions. About 10 million hectares of cultivated oat (*Avena sativa* L.) is planted each year, yielding approximately 23 million metric tonnes of grains worldwide (USDA, 2020-21). In India, oat is grown as a dual-purpose crop, covering approximately 0.1 million hectares and yielding 35-50 tonnes of green fodder per hectare (Anonymous, 2014). It is grown in many states across the country, including the North Western, southern and eastern states. The crop provides green fodder during winter season in the Himalayan region, when green fodder is scarce which is rich in approximately 10-13% protein and 10-30% dry matter (Priyanka *et al.*, 2021). It is widely adopted by farmers for all types of livestock due to the presence of sufficient soluble carbohydrates which provide good silage along with palatable roughage straw that is also excellent for bedding. Within the regions of Himalayas, this crop incorporates a more extensive flexibility since of its great developing environment and speedy recovery (Sood *et al.*, 2016). Oat grain has long been an important livestock feed, but it is now also being used for human consumption in the form of baby food and breakfast cereal. The main cause of lower milch animal productivity in India is an inadequate supply of high-quality feed and fodder. With the emergence of growing dairy sector in our nation, the oat has captivated the attention of breeders due to its nutritious quality fodder and grains with significant net energy gains as animal feed. Land for agricultural purpose is limited, so forage availability should be raised through increasing the yield per unit area. Therefore, efforts are being made to cultivate high yielding varieties for both forage and grains (Singhal *et al*., 2018). The genetic variability has a significant impact on the success of any breeding programme, as it increases the likelihood of selecting desired genotypes. According to Burton and De Vane (1953) amenability of given character for its improvement is determined by the extent of genotypic variability present in it. Phenotypic and genotypic variance (GCV & PCV), heritability along with genetic advance have been used to assess the magnitude variation. High heritability coupled with high genetic advance for different yield components is found to have a better scope for selecting high yielding genotypes. Knowledge about the correlation relationship between yield and its component traits is helps in eliminating the characters of little or no use during selection but when more number of variables are considered, the association becomes more and more complex. The problem can be resolved by path analysis which emphasizes on the nature and magnitude of direct and indirect contributions of traits and aids in selecting the suitable traits to advance the crop yield (Dewey and Lu 1959). Keeping the above points in context, the present research was conducted to estimate the nature and magnitude of genetic parameters of variability, correlation and path analysis in F_4 and F_5 generations of oat.

MATERIAL AND METHODS

The research material comprises of 29 F_4 and 28 F_5 progenies derived from seven different crosses namely, PLP-1×HJ-8, HJ-8×JPO-46, HJ-8×PLP-1, HJ-8×EC528896, HJ-8× *A. sterilis* cv. HFO-878, HJ-8×KRR-AK-26 and PLP-1× *A. byzantine* cv. HFO-60includingfive checks. During *Rabi*, 2019-20, F_4 progenies were evaluated in Randomized Block Design with three replications. Each treatment consist of 3 rows of 2 m each having row to row spacing of 25 cm and 10 cm for plant to plant. Selection from each progeny was done on the basis of yield and otherdesirable characters and derived F_5 progenies were evaluated during *Rabi*, 2020-21 following the same method undertaken during evaluation of F_4 generation. The observations were recorded on fifteenrandomly selected plants taken from each genotype of each replication for different morphological, yield and its contributing traits, *viz*., days to 50% flowering, plant height (cm), number of tillers per plant, number of leaves per plant, leaf area (cm^2), fresh fodder yield per plant (g), dry matter per cent, dry matter yield per plant (g), days to 75 % maturity, grain yield per plant (g), harvest index (%), 100 grain weight (g), crude protein content (%) and crude protein yield per plant (g). Analysis of variance was carried out as per standard procedure by Panse and Sukhatme, 1985, 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 following Burton and Devane, 1953 and Johnson et al., 1955.Phenotypic, genotypic and environmental correlation coefficients were worked out as per the procedure of Al-Jibouri *et al*. (1958); Dewey and Lu (1959) and path analysis of important yield and component traits was done following Dewey and Lu (1959).

RESULTS AND DISCUSSION

The results from analysis of variance revealed that the mean sum of square due to genotypes was significant for all the traits studied such as days to 50% flowering, plant height (cm), number of tillers per plant, number of leaves per plant, leaf area (cm^2), fresh fodder yield per plant (g), dry matter per cent, dry matter yield per plant (g), days to 75 % maturity, grain yield per plant (g), harvest index (%), 100 grain weight (g); and quality traits *viz*., crude protein content (%) and crude protein yield per plant (g) among all the genotypes in both F_4 and F_5 generations (Table 1). Similar results were also reported by Singh and Singh (2011); Nirmalakumari *et al*., (2013); Premkumar *et al*., (2017); Kumari *et al*., (2017); Chauhan and Singh (2019) which indicated that sufficient variability existed in the present set of material and further genetic analysis and study would be meaningful.

Table 1: Analysis of variance for various traits among oat genotypes in F_4 and F_5 generations.

Traits	Source	Mean sum of squares					
		F_4 generation			F_5 generation		
		Replication	Genotypes	Error	Replication	Genotypes	Error
	df	2	33	66	2	32	64
Days to 50% flowering		0.60	12.00*	1.60	4.04	2.98*	1.24
Plant height (cm)		364.42	679.72*	73.92	603.95	213.51*	46.67
Tillers per plant		5.98	6.37*	1.28	0.75	8.57*	0.83
Leaves per plant		346.86	133.84*	21.73	54.65	88.84*	12.17
Leaf area (cm^2)		22.08	35.27*	8.55	29.01	81.64*	9.48
Fresh fodder yield per plant (g)		147.82	1224.50*	49.32	12.18	670.92*	39.23
Dry matter per cent		0.08	100.97*	3.38	4.46	32.44*	3.64
Dry matter yield per plant (g)		11.50	166.14*	3.39	1.84	62.12*	5.17
Days to 75% maturity		9.45	32.66*	1.74	1.12	13.72*	2.10
Grain yield per plant (g)		0.29	53.70*	2.43	0.29	27.39*	0.91
Harvest index (%)		76.84	66.02*	40.52	18.27	140.8*	26.75
100 grain weight (g)		0.08	0.94*	0.08	0.00	0.33*	0.04
Crude protein content (%)		0.15	1.60*	0.11	0.08	1.51*	0.13
Crude protein yield per plant (g)		0.01	1.88*	0.02	0.01	0.42*	0.01

PCV estimates were greater than GCV estimates for all the traits studied in the both F_4 and F_5 generations, indicating that the apparent variation is the result of both genotypic as well as environmental influences. However, there was little difference in genotypic and phenotypic coefficients of variation, revealing that they are highly heritable and relatively stable in nature. So, phenotypic performance based selection would be effective in improving these traits (Table 2). Similar findings were reported by Singh and Singh (2011); Surje and De (2014); Kumari *et al.* (2017) for all the characters studied indicating the importance of environment on the expression of these characters. Highest magnitude of PCV and GCV (> 20%) in F_4 generation were obtained for dry matter yield per plant (46.36%, 44.97%) followed by crude protein yield per plant (43.83%, 43.25%), dry matter per cent (31.77%, 30.24%), fresh fodder yield per plant (29.58%, 27.88%) and grain yield per plant (28.32%, 26.50%), while high PCV was also observed for number of leaves per plant (24.11%) and number of tillers per plant (20.54%).

Table 2: Estimates of genetic parameters of variability for various characters in F_4 and F_5 generations of oat.

Characters	F_4 generation						F_5 generation					
	General Mean±SE(m)	Range	PCV (%)	GCV (%)	h²bs (%)	GA (% of mean)	General Mean±SE(m)	Range	PCV (%)	GCV (%)	h²bs (%)	GA (% of mean)
Days to 50% flowering	121.07±0.73	116.33-125.33	1.86	1.54	68.44	2.62	122.53±0.64	120-124.33	1.10	0.62	31.92	0.72
Plant height (cm)	97.88 ±4.96	67.05-137.39	16.97	14.52	73.20	25.59	78.33±3.94	63.75-98.64	12.91	9.52	54.37	14.46
No. of tillers per plant	8.40±0.65	5.90-11.59	20.54	15.51	57.05	24.14	8.38±0.53	5.14-12.78	22.05	19.17	75.85	34.33
No. of leaves per plant	31.89±2.69	15.59-42.99	24.11	19.17	63.23	31.40	30.81±2.01	18.51-41.67	19.93	16.41	67.75	27.82
Leaf area (cm^2)	31.38±1.69	23.67-37.55	13.31	9.51	51.02	13.99	31.14±1.78	23.04-43.27	18.60	15.75	71.73	27.48
Fresh fodder yield per plant (g)	70.99±4.06	43.67-145.98	29.58	27.88	88.82	54.12	67.68±3.62	36.26-89.37	23.35	21.44	84.29	40.55
Dry matter per cent	18.86±1.06	6.50-37.45	31.77	30.24	90.58	59.29	17.73±1.10	11.38-23.81	20.51	17.46	72.50	30.63
Dry matter yield per plant (g)	16.38±1.06	9.00-47.55	46.36	44.97	94.12	89.88	12.62±1.31	4.58-21.42	38.94	34.53	78.61	63.06
Days to 75% maturity	160.77±0.76	154.00-165.67	2.16	2.00	85.53	3.80	162.73±0.84	157.33-165.33	1.50	1.21	64.84	2.01
Grain yield per plant (g)	15.60±0.90	8.87-24.65	28.32	26.50	87.53	51.07	14.58±0.55	8.58-19.93	21.40	20.37	90.62	39.94
Harvest index (%)	38.45±3.68	29.6-48.27	18.21	7.58	17.33	6.50	40.88±2.99	25.46-55.70	19.65	15.04	58.54	23.70
100 grain weight (g)	3.12±0.16	2.42-4.91	19.44	17.22	78.43	31.41	3.50±0.11	2.80-4.27	10.48	8.89	71.90	15.53
Crude protein content (%)	11.09±0.19	4.73-12.21	7.04	6.36	81.69	11.84	11.19±0.21	9.87-12.43	6.86	6.06	78.15	11.04
Crude protein yield per plant (g)	1.82±0.07	1.04-9.65	43.83	43.25	97.39	87.93	1.52±0.04	1.00-2.24	24.91	24.52	96.92	49.73

Likewise, highest magnitude of PCV and GCV were recorded for dry matter yield per plant (38.94%, 34.53%) followed by crude protein yield per plant (24.91%, 24.52%), fresh fodder yield per plant (23.35%, 21.44%) and grain yield per plant (21.40%, 20.37%), while high PCV was obtained for number of tillers per plant (22.05%) and dry matter per cent (21.40%) in F_5 generation. Surje and De (2014) also reported high estimates of GCV and PCV for grain yield per plant and green forage yield per plant. The results are in agreement with those obtained earlier by Kapoor *et al*. (2011); Singh and Singh (2011); Surje and De (2014); Revathi *et al.* (2016); Kumari *et al.* (2017); Rani *et al*. (2018); Chauhan and Singh (2019); Rawat *et al.* (2019); Sahu and Tiwari (2020).

Heritability in broad sense (>70%) was highest for crude protein yield per plant (97.39%) followed by dry matter yield per plant (94.12%), dry matter per cent (90.58%), fresh fodder yield per plant (88.82%), grain yield per plant (87.53%), days to 75% maturity (85.53%), crude protein content (81.69%), 100 grain weight (78.43%) and plant height (73.20%) in the F_4 generation. Likewise, in F_5 generation, estimates of heritability were also high for crude protein yield per plant (96.92%), grain yield per plant (90.62%), fresh fodder yield per plant (84.29%), dry matter yield per plant (78.61%), crude protein content (78.15%), number of tillers per plant (75.85%), dry matter per cent (72.50%), 100 grain weight (71.90%) and leaf area (71.73%).

High heritability along with high genetic advance as percent of mean were observed for fresh fodder yield per plant, dry matter per cent, dry matter yield per plant, grain yield per plant, 100 grain weight and crude protein yield per plant in the F_4 generation. Moreover, in F_5 generation, number of tillers per plant, fresh fodder yield per plant, dry matter per cent, dry matter yield per plant, grain yield per plant and crude protein yield per plant showed high heritability along with high genetic advance. Same results were also supported by Singh and Singh (2011); Kapoor *et al.* (2011); Krishana *et al.* (2013). The results indicated that the inheritance of these characters is predominantly controlled by additive gene action and direct selection would be rewarding. Low estimates of heritability along with low genetic advance were recorded for harvest index and days to 50% flowering in F_4 and F_5 generations, respectively, indicating that the selection for these trait would be ineffective due to the presence of non-additive gene action. These results are in accordance with Bind *et al*. (2016); Rani *et al*. (2018); Chaudhary *et al.* (2020).

At phenotypic level, grain yield per plant was significantly and positively correlated with number of tillers per plant, number of leaves per plant and harvest index in both F_4 and F_5 generations (Table 3 and 4), whereas significantly negative with crude protein yield per plant in F_5 generation. Genotypic correlation provides more reliable measure of genetic association between traits than phenotypic correlation. For most traits, the magnitude of genotypic correlations were observed to be higher than their corresponding phenotypic correlations, indicating that there is a strong inherent association between various traits and that genotypes were less influenced by environmental conditions. At genotypic level, grain yield per plant found to be significant and positively correlated with number of tillers per plant, number of leaves per plant and harvest index in both F_4 and F_5 generations. Similar results were also obtained by Deep *et al.* (2019) for tillers per plant, leaves per plant and harvest index; Tessema and Getinet (2020) for tillers per plant and harvest index; Mecha *et al*. (2017) for harvest index; Baye *et al.* (2020) for harvest index, days to 75% maturity, days to 50% flowering and crude protein yield per plant; Kumar *et al.* (2016); Jaipal and Shekhawat (2016) for days to 50 per cent flowering; Gungor *et al.* (2017); Baye *et al*. (2020) for days to maturity with grain yield.

Table 3: Estimates of correlation coefficients at phenotypic and genotypic levels for various traits in F_4 generation of oat.

Characters		Plant height (cm)	Tillers per plant	Leaves per plant	Leaf area (cm^2)	Fresh fodder yield per plant (g)	Dry matter %	Dry matter yield per plant (g)	Days to 75% maturity	Harvest index (%)	100 grain weight (g)	Crude protein content (%)	Crude protein yield per plant (g)	Grain yield per plant (g)
Days to 50% flowering	P	0.649**	0.129	0.130	-0.176	-0.133	-0.350**	-0.125	0.561**	0.020	-0.307**	-0.300**	-0.185	-0.118
	G	0.754**	0.157	0.171	-0.255**	-0.152	-0.450**	-0.136	0.649**	-0.018	-0.424**	-0.463**	-0.217*	-0.149
Plant height (cm)	P		0.157	0.228*	0.277**	0.373**	0.540**	0.429**	-0.637**	0.004	0.143	0.225*	0.478**	0.084
	G		0.155	0.287**	0.325**	0.410**	0.649**	0.476**	-0.705**	0.050	0.177	0.330**	0.548**	0.120
Tillers per plant	P			0.724**	0.053	0.226*	0.188	0.248*	0.090	0.089	-0.024	0.049	0.256**	0.392**
	G			0.880**	-0.104	0.211*	0.206*	0.310**	0.123	0.352**	-0.066	0.065	0.328**	0.582**
Leaves per plant	P				0.046	0.328**	0.329**	0.375**	-0.033	0.180	-0.196*	0.051	0.378**	0.447**
	G				0.068	0.399**	0.384**	0.449**	-0.047	0.264**	-0.254**	0.053	0.473**	0.635**
Leaf area (cm^2)	P					0.432**	0.486**	0.375**	-0.214*	-0.009	0.001	-0.039	0.360**	-0.143
	G					0.494**	0.594**	0.430**	-0.267**	0.103	0.046	-0.037	0.451**	-0.150
Fresh fodder yield per plant (g)	P						0.842**	0.932**	-0.316**	0.099	0.076	-0.015	0.907**	0.064
	G						0.867**	0.962**	-0.332**	0.349**	0.082	-0.026	0.948**	0.073
Dry matter per cent	P							0.870**	-0.465**	0.151	-0.033	0.071	0.865**	0.042
	G							0.892**	-0.515**	0.257**	-0.038	0.075	0.901**	0.054
Dry matter yield per plant (g)	P								-0.300**	0.149	-0.016	-0.007	0.973**	0.082
	G								-0.323**	0.356**	0.000^{NS}	-0.008	0.990**	0.113
Days to 75% maturity	P									-0.042	-0.281**	-0.334**	-0.374**	0.109
	G									-0.028	-0.350**	-0.422**	-0.398**	0.117
Harvest index (%)	P										-0.137	-0.006	0.162	0.418**
	G										-0.280**	-0.084	0.344**	0.817**
100 grain weight (g)	P											0.234*	0.020	0.009
	G											0.260**	0.029	-0.035
Crude protein content (%)	P												0.149	-0.071
	G												0.143	-0.078
Crude protein yield per plant (g)	P													0.076
	G													0.087

$*p \leq 0.05$; and $**p \leq 0.01$

Table 4: Estimates of correlation coefficients at phenotypic and genotypic levels for various traits in F_5 generation of oat.

Characters		Plant height (cm)	Tillers per plant	Leaves per plant	Leaf area (cm^2)	Fresh fodder yield per plant (g)	Dry matter %	Dry matter yield per plant (g)	Days to 75% maturity	Harvest index (%)	100 grain weight (g)	Crude protein content (%)	Crude protein yield per plant (g)	Grain yield per plant (g)
Days to 50% flowering	P	0.373**	0.134	-0.276**	-0.214*	-0.099	-0.199*	-0.150	0.387**	0.024	-0.082	0.203*	-0.052	-0.084
	G	0.320**	0.179	-0.520**	-0.032	-0.147	-0.249*	-0.196*	0.528**	-0.116	-0.262**	0.373**	-0.080	-0.231*
Plant height (cm)	P		0.178	0.113	0.531**	0.040	0.183	0.104	-0.281**	-0.108	0.158	0.045	0.090	-0.048
	G		0.257**	0.124	0.619**	0.122	0.261**	0.177	-0.223*	-0.193	0.360**	0.052	0.138	-0.083
Tillers per plant	P			0.718**	-0.284**	0.201*	0.352**	0.294**	-0.003	0.243*	-0.014	0.178	0.279**	0.318**
	G			0.779**	-0.343**	0.206*	0.410**	0.309**	0.023	0.429**	0.003	0.230*	0.283**	0.389**
Leaves per plant	P				-0.062	0.408**	0.424**	0.443**	-0.014	0.207*	0.039	-0.031	0.323**	0.317**
	G				-0.079	0.425**	0.392**	0.419**	0.022	0.260**	0.049	0.007	0.365**	0.394**
Leaf area (cm^2)	P					0.304**	0.305**	0.309**	-0.111	0.149	0.208*	-0.050	0.219*	0.075
	G					0.364**	0.401**	0.383**	0.013	0.144	0.264**	-0.080	0.269**	0.092
Fresh fodder yield per plant (g)	P						0.734**	0.921**	0.140	0.066	0.057	0.018	0.747**	-0.133
	G						0.822**	0.957**	0.235*	0.034	0.107	0.010	0.796**	-0.170
Dry matter per cent	P							0.925**	0.067	0.142	0.052	0.095	0.743**	-0.036
	G							0.942**	0.109	0.110	0.062	0.108	0.849**	-0.066
Dry matter yield per plant (g)	P								0.105	0.129	0.057	0.031	0.834**	-0.123
	G								0.179	0.085	0.100	0.016	0.913**	-0.171
Days to 75% maturity	P									-0.005	-0.007	0.193	0.125	0.187
	G									0.007	-0.028	0.334**	0.163	0.221*
Harvest index (%)	P										-0.061	-0.069	0.097	0.491**
	G										-0.127	-0.170	0.107	0.597**
100 grain weight (g)	P											0.055	0.035	-0.017
	G											0.037	0.047	-0.002
Crude protein content (%)	P												0.092	0.107
	G												0.077	0.096
Crude protein yield per plant (g)	P													-0.219*
	G													-0.236*

$*p \leq 0.05$; and $**p \leq 0.01$

Fresh fodder yield per plant, at both phenotypic and genotypic level, showed significant and positive correlation with number of tillers per plant, number of leaves per plant, leaf area, dry matter per cent, dry matter yield per plant and crude protein yield per plant in both F_4 and F_5 generations. It was also significant and positively correlated with plant height and harvest index (genotypic level) in F_4 generation but significantly negative with days to 75% maturity. However, in F_5 generation, it was significant and positively correlation with days to 75% maturity. Similar results were also reported by Bibi *et al.* (2012) for green fodder yield with leaf area, number of tillers and dry matter yield; Dubey *et al.* (2014) for dry matter yield, tillers per plant and leaves per plant; Devi *et al.* (2018) for tillers per plant, leaves per plant, dry matter yield per plant and crude protein yield per plant in F_2, F_3 and F_4 generations of oat; Chaudhary *et al*. (2020) for green fodder yield with plant height and dry fodder yield per plant and by Negi *et al.* (2019) for tillers per plant and dry matter yield.

Highest positive direct effects towards grain yield per plant were contributed by crude protein yield per plant, dry matter yield per plant and leaf area at genotypic level followed by harvest index, days to 75% maturity, number of leaves per plant at phenotypic level in F_4 and at both phenotypic and genotypic levels by all these traits in F_5 generation. Furthermore, traits *viz*., leaf area, crude protein content, dry matter per cent also showed positive direct effect towards grain yield per plant in F_5 generation at both phenotypic and genotypic levels (Table 5 and 6).

Table 5: Estimates of direct and indirect effects of various traits ongrain yield in F_4 generation of oat.

Characters		Days to 50% flowering	Plant height (cm)	Tillers per plant	Leaves per plant	Leaf area (cm^2)	Fresh fodder yield per plant (g)	Dry matter %	Dry matter yield per plant (g)	Days to 75% maturity	Harvest index (%)	100 grain weight (g)	Crude protein content (%)	Crude protein yield per plant (g)	Grain yield per plant (g)
Days to 50% flowering	P	-0.161	-0.093	-0.009	-0.046	0.027	-0.023	0.025	0.019	0.140	0.008	-0.045	0.035	0.005	-0.118
	G	-4.889	1.585	-0.015	0.104	-0.146	0.113	3.398	-0.236	-0.468	0.007	0.953	0.771	-1.326	-0.149
Plant height (cm)	P	0.104	0.144	0.011	0.081	-0.043	0.064	-0.038	-0.064	-0.158	0.002	0.021	-0.026	-0.012	0.084
	G	3.684	-2.103	0.015	-0.175	0.187	-0.304	-4.901	0.828	0.507	-0.021	-0.397	-0.551	3.349	0.120
Tillers per plant	P	0.021	0.023	0.070	0.256	-0.008	0.039	-0.013	-0.037	0.023	0.036	-0.004	-0.006	-0.006	0.392**
	G	0.767	-0.326	0.098	-0.536	-0.060	-0.156	-1.557	0.540	-0.089	-0.145	0.149	-0.109	2.004	0.582**
Leaves per plant	P	0.021	0.033	0.051	0.353	-0.007	0.056	-0.023	-0.056	-0.008	0.072	-0.028	-0.006	-0.009	0.447**
	G	0.837	-0.604	0.087	-0.609	0.039	-0.296	-2.901	0.782	0.034	-0.109	0.571	-0.088	2.891	0.635**
Leaf area (cm^2)	P	0.028	0.040	0.004	0.016	-0.154	0.074	-0.035	-0.056	-0.053	-0.004	0.000	0.005	-0.009	-0.143
	G	1.247	-0.684	-0.010	-0.042	0.574	-0.366	-4.484	0.749	0.192	-0.043	-0.103	0.062	2.759	-0.150
Fresh fodder yield per plant (g)	P	0.021	0.054	0.016	0.116	-0.067	0.171	-0.060	-0.138	-0.079	0.039	0.011	0.002	-0.022	0.064
	G	0.743	-0.863	0.021	-0.243	0.284	-0.741	-6.546	1.674	0.239	-0.144	-0.186	0.043	5.792	0.073
Dry matter per cent	P	0.056	0.078	0.013	0.116	-0.075	0.144	-0.071	-0.129	-0.116	0.060	-0.005	-0.008	-0.021	0.042
	G	2.201	-1.365	0.020	-0.234	0.341	-0.643	-7.548	1.552	0.371	-0.106	0.085	-0.125	5.504	0.054
Dry matter yield per plant (g)	P	0.020	0.062	0.017	0.132	-0.058	0.159	-0.062	-0.148	-0.075	0.060	-0.002	0.001	-0.024	0.082
	G	0.664	-1.000	0.031	-0.274	0.247	-0.713	-6.732	1.740	0.232	-0.147	-0.001	0.013	6.052	0.113
Days to 75% maturity	P	-0.090	-0.091	0.006	-0.012	0.033	-0.054	0.033	0.045	0.249	-0.017	-0.041	0.039	0.009	0.109
	G	-3.175	1.482	0.012	0.029	-0.153	0.246	3.889	-0.562	-0.720	0.012	0.788	0.704	-2.434	0.117
Harvest index (%)	P	-0.003	0.001	0.006	0.064	0.002	0.017	-0.011	-0.022	-0.011	0.399	-0.020	0.001	-0.004	0.418**
	G	0.087	-0.105	0.035	-0.161	0.059	-0.258	-1.940	0.620	0.021	-0.412	0.631	0.139	2.102	0.817**
100 grain weight (g)	P	0.049	0.021	-0.002	-0.069	0.001	0.013	0.002	0.002	-0.070	-0.055	0.145	-0.028	-0.001	0.009
	G	2.072	-0.372	-0.007	0.155	0.026	-0.061	0.285	0.001	0.252	0.116	-2.249	-0.433	0.180	-0.035
Crude protein content (%)	P	0.048	0.032	0.004	0.018	0.006	-0.003	-0.005	0.001	-0.083	-0.002	0.034	-0.118	-0.004	-0.071
	G	2.262	-0.695	0.006	-0.032	-0.021	0.019	-0.565	-0.014	0.304	0.034	-0.584	-1.667	0.874	-0.078
Crude protein yield per plant (g)	P	0.030	0.069	0.018	0.134	-0.055	0.155	-0.062	-0.144	-0.093	0.065	0.003	-0.018	-0.025	0.076
	G	1.061	-1.152	0.032	-0.288	0.259	-0.702	-6.798	1.723	0.287	-0.142	-0.066	-0.238	6.112	0.087

*p≤0.05; and **P≤0.01 (Bold values indicate direct effects); Residual effects: Phenotypic (0.56410), Genotypic (0.87717)

Table 6: Estimates of direct and indirect effects of various traits ongrain yield in F_5 generation of oat.

Characters		Days to 50% flowering	Plant height (cm)	Tillers per plant	Leaves per plant	Leaf area (cm^2)	Fresh fodder yield per plant (g)	Dry matter %	Dry matter yield per plant (g)	Days to 75% maturity	Harvest index (%)	100 grain weight (g)	Crude protein content (%)	Crude protein yield per plant (g)	Grain yield per plant (g)
Days to 50% flowering	P	-0.114	-0.010	-0.022	-0.079	-0.042	-0.049	-0.126	0.195	0.119	0.011	0.003	0.018	0.013	-0.084
	G	-0.345	0.024	0.020	-0.215	-0.007	0.079	-0.051	-0.050	0.234	-0.060	0.009	0.087	0.045	-0.231*
Plant height (cm)	P	0.043	0.026	-0.030	-0.032	0.104	0.020	0.116	-0.135	-0.086	-0.048	-0.005	0.004	-0.023	-0.048
	G	0.111	-0.074	0.029	-0.051	0.144	-0.066	0.054	0.045	-0.099	-0.100	-0.012	0.012	-0.077	-0.083
Tillers per plant	P	0.015	-0.005	0.166	0.205	-0.056	0.100	0.223	-0.382	-0.001	0.108	0.001	0.015	-0.071	0.318**
	G	0.062	0.019	-0.114	0.322	-0.080	-0.111	0.085	0.079	0.010	0.222	0.001	0.054	-0.158	0.389**
Leaves per plant	P	0.031	-0.003	0.119	0.285	-0.012	0.202	0.269	-0.574	-0.004	0.092	-0.001	-0.003	-0.082	0.317**
	G	0.180	0.009	-0.089	0.413	-0.018	-0.229	0.081	0.107	0.010	0.135	-0.002	0.002	-0.204	0.394**
Leaf area (cm^2)	P	0.024	0.014	-0.047	-0.018	0.195	0.150	0.193	-0.401	-0.034	0.066	-0.007	-0.004	-0.056	0.075
	G	0.011	-0.046	0.039	-0.032	0.233	-0.196	0.083	0.097	0.006	0.074	-0.009	-0.019	-0.150	0.092
Fresh fodder yield per plant (g)	P	0.011	0.001	0.033	0.116	0.059	0.495	0.464	-1.195	0.043	0.029	-0.002	0.002	-0.190	-0.133
	G	0.051	-0.009	-0.024	0.175	0.085	-0.538	0.170	0.244	0.104	0.018	-0.004	0.002	-0.444	-0.170
Dry matter per cent	P	0.023	0.005	0.058	0.121	0.060	0.363	0.633	-1.199	0.021	0.063	-0.002	0.008	-0.189	-0.036
	G	0.086	-0.019	-0.047	0.162	0.094	-0.443	0.207	0.240	0.049	0.057	-0.002	0.025	-0.474	-0.066
Dry matter yield per plant (g)	P	0.017	0.003	0.049	0.126	0.060	0.456	0.585	-1.297	0.032	0.057	-0.002	0.003	-0.212	-0.123
	G	0.068	-0.013	-0.035	0.173	0.089	-0.515	0.195	0.255	0.079	0.044	-0.003	0.004	-0.509	-0.171
Days to 75% maturity	P	-0.044	-0.007	0.001	-0.004	-0.022	0.069	0.042	-0.137	0.306	-0.002	0.001	0.017	-0.032	0.187
	G	-0.182	0.017	-0.003	0.009	0.003	-0.126	0.023	0.046	0.444	0.003	0.001	0.078	-0.091	0.221*
Harvest index (%)	P	-0.003	-0.003	0.040	0.059	0.029	0.033	0.090	-0.167	-0.002	0.443	0.002	-0.006	-0.025	0.491**
	G	0.040	0.014	-0.049	0.107	0.034	-0.018	0.023	0.022	0.003	0.517	0.004	-0.040	-0.060	0.597**
100 grain weight (g)	P	0.009	0.004	-0.002	0.011	0.041	0.028	0.033	-0.074	-0.002	-0.027	-0.034	0.005	-0.009	-0.017
	G	0.091	-0.027	0.001	0.020	0.062	-0.057	0.013	0.026	-0.012	-0.066	-0.033	0.009	-0.026	-0.002
Crude protein content (%)	P	-0.023	0.001	0.030	-0.009	-0.010	0.009	0.060	-0.041	0.059	-0.031	-0.002	0.086	-0.024	0.107
	G	-0.129	-0.004	-0.026	0.003	-0.019	-0.005	0.022	0.004	0.148	-0.088	-0.001	0.233	-0.043	0.096
Crude protein yield per plant (g)	P	0.006	0.002	0.046	0.092	0.043	0.370	0.470	-1.082	0.038	0.043	-0.001	0.008	-0.255	-0.219*
	G	0.028	-0.010	-0.032	0.151	0.063	-0.428	0.176	0.232	0.072	0.055	-0.002	0.018	-0.558	-0.236*

*p≤0.05; and **P≤0.01 (Bold values indicate direct effects); Residual effects: Phenotypic (0.18002), Genotypic (0.42319)

Table 7: Estimates of direct and indirect effects of various traits onfresh fodder yield in F_4 generation of oat.

Characters		Days to 50% flowering	Plant height (cm)	Tillers per plant	Leaves per plant	Leaf area (cm^2)	Dry matter %	Dry matter yield per plant (g)	Days to 75% maturity	Grain yield per plant (g)	Harvest index (%)	100 grain weight (g)	Crude protein content (%)	Crude protein yield per plant (g)	Fresh fodder yield per plant (g)
Days to 50% flowering	P	0.028	0.072	-0.001	-0.002	-0.015	-0.054	-0.090	-0.031	-0.004	-0.001	-0.032	0.012	-0.016	-0.133
	G	-0.701	0.331	0.064	-0.043	-0.032	0.411	-0.197	-0.029	0.003	0.001	0.059	0.070	-0.087	-0.152
Plant height (cm)	P	-0.018	-0.112	0.001	0.003	0.023	0.083	0.308	0.035	0.003	0.000	0.015	-0.009	0.042	0.373**
	G	0.529	-0.439	-0.063	0.073	0.041	-0.593	0.690	0.032	-0.002	-0.002	-0.025	-0.050	0.219	0.410**
Tillers per plant	P	-0.004	-0.018	0.006	0.008	0.004	0.029	0.178	-0.005	0.012	-0.004	-0.003	-0.002	0.022	0.226*
	G	0.110	-0.068	-0.405	0.223	-0.013	-0.188	0.450	-0.006	-0.010	-0.013	0.009	-0.010	0.131	0.211*
Leaves per plant	P	-0.004	-0.026	0.005	0.012	0.004	0.050	0.269	0.002	0.014	-0.009	-0.020	-0.002	0.033	0.328**
	G	0.120	-0.126	-0.357	0.254	0.009	-0.351	0.652	0.002	-0.011	-0.010	0.035	-0.008	0.189	0.399**
Leaf area (cm^2)	P	-0.005	-0.031	0.000	0.001	0.084	0.075	0.269	0.012	-0.005	0.000	0.000	0.002	0.032	0.432**
	G	0.179	-0.143	0.042	0.017	0.126	-0.542	0.624	0.012	0.003	-0.004	-0.006	0.006	0.181	0.494**
Dry matter per cent	P	-0.010	-0.060	0.001	0.004	0.041	0.153	0.624	0.026	0.001	-0.007	-0.003	-0.003	0.076	0.842**
	G	0.316	-0.285	-0.084	0.098	0.075	-0.913	1.293	0.023	-0.001	-0.010	0.005	-0.011	0.361	0.867**
Dry matter yield per plant (g)	P	-0.003	-0.048	0.002	0.004	0.031	0.133	0.717	0.016	0.003	-0.007	-0.002	0.000	0.085	0.932**
	G	0.095	-0.209	-0.126	0.114	0.054	-0.814	1.450	0.015	-0.002	-0.014	0.000	0.001	0.396	0.962**
Days to 75% maturity	P	0.016	0.071	0.001	0.000	-0.018	-0.071	-0.215	-0.055	0.003	0.002	-0.029	0.013	-0.033	-0.316**
	G	-0.455	0.309	-0.050	-0.012	-0.034	0.470	-0.468	-0.045	-0.002	0.001	0.049	0.064	-0.159	-0.332**
Grain yield per plant (g)	P	-0.003	-0.009	0.003	0.005	-0.012	0.006	0.059	-0.006	0.032	-0.021	0.001	0.003	0.007	0.064
	G	0.105	-0.053	-0.236	0.161	-0.019	-0.049	0.164	-0.005	-0.017	-0.031	0.005	0.012	0.035	0.073
Harvest index (%)	P	0.001	0.000	0.001	0.002	-0.001	0.023	0.107	0.002	0.013	-0.049	-0.014	0.000	0.014	0.099
	G	0.012	-0.022	-0.142	0.067	0.013	-0.235	0.516	0.001	-0.014	-0.038	0.039	0.013	0.138	0.349**
100 grain weight (g)	P	-0.009	-0.016	0.000	-0.002	0.000	-0.005	-0.011	0.015	0.000	0.007	0.104	-0.009	0.002	0.076
	G	0.297	-0.078	0.027	-0.064	0.006	0.034	0.000	0.016	0.001	0.011	-0.140	-0.039	0.012	0.082
Crude protein content (%)	P	-0.008	-0.025	0.000	0.001	-0.003	0.011	-0.005	0.018	-0.002	0.000	0.024	-0.039	0.013	-0.015
	G	0.325	-0.145	-0.026	0.013	-0.005	-0.068	-0.012	0.019	0.001	0.003	-0.036	-0.152	0.057	-0.026
Crude protein yield per plant (g)	P	-0.005	-0.053	0.002	0.004	0.030	0.133	0.698	0.021	0.002	-0.008	0.002	-0.006	0.088	0.907**
	G	0.152	-0.241	-0.133	0.120	0.057	-0.822	1.436	0.018	-0.001	-0.013	-0.004	-0.022	0.400	0.948**

*P≤0.05; and **P≤0.01 (Bold values indicate direct effects); Residual effects: Phenotypic (0.10462), Genotypic (0.01980)

Table 8: Estimates of direct and indirect effects of various traits on fresh fodder yield in F_5 generation of oat.

Characters		Days to 50% flowering	Plant height (cm)	Tillers per plant	Leaves per plant	Leaf area (cm^2)	Dry matter %	Dry matter yield per plant (g)	Days to 75% maturity	Grain yield per plant (g)	Harvest index (%)	100 grain weight (g)	Crude protein content (%)	Crude protein yield per plant (g)	Fresh fodder yield per plant (g)
Days to 50% flowering	P	-0.003	0.002	-0.001	-0.002	-0.011	0.177	-0.278	0.003	-0.004	-0.002	0.001	0.010	0.007	-0.099
	G	-0.055	-0.010	-0.024	0.066	-0.002	0.293	-0.498	-0.020	-0.021	0.009	0.027	0.046	0.041	-0.147
Plant height (cm)	P	0.001	-0.007	-0.001	-0.001	0.027	-0.162	0.193	-0.002	-0.002	0.007	-0.002	0.002	-0.013	0.040
	G	0.018	0.031	-0.035	0.016	0.035	-0.307	0.451	0.008	-0.007	0.014	-0.037	0.007	-0.071	0.122
Tillers per plant	P	0.000	0.001	0.008	0.005	-0.014	-0.313	0.545	0.000	0.015	-0.016	0.000	0.009	-0.040	0.201*
	G	0.010	-0.008	0.136	-0.100	-0.019	-0.483	0.785	-0.001	0.035	-0.032	0.000	0.029	-0.145	0.206*
Leaves per plant	P	0.001	0.001	0.006	0.007	-0.003	-0.377	0.821	0.000	0.015	-0.013	0.000	-0.002	-0.046	0.408**
	G	0.029	-0.004	0.106	-0.128	-0.004	-0.462	1.065	-0.001	0.035	-0.019	-0.005	0.001	-0.187	0.425**
Leaf area (cm^2)	P	0.001	-0.004	-0.002	0.000	0.051	-0.271	0.572	-0.001	0.004	-0.010	-0.003	-0.002	-0.031	0.304**
	G	0.002	0.019	-0.047	0.010	0.057	-0.472	0.973	0.000	0.008	-0.011	-0.027	-0.010	-0.138	0.364**
Dry matter per cent	P	0.001	-0.001	0.003	0.003	0.015	-0.888	1.713	0.001	-0.002	-0.009	-0.001	0.005	-0.106	0.734**
	G	0.014	0.008	0.056	-0.050	0.023	-1.177	2.395	-0.004	-0.006	-0.008	-0.006	0.013	-0.436	0.822**
Dry matter yield per plant (g)	P	0.001	-0.001	0.002	0.003	0.016	-0.821	1.853	0.001	-0.006	-0.008	-0.001	0.002	-0.119	0.921**
	G	0.011	0.005	0.042	-0.053	0.022	-1.108	2.544	-0.007	-0.015	-0.006	-0.010	0.002	-0.469	0.957**
Days to 75% maturity	P	-0.001	0.002	0.000	0.000	-0.006	-0.059	0.195	0.009	0.009	0.000	0.000	0.010	-0.018	0.140
	G	-0.029	-0.007	0.003	-0.003	0.001	-0.129	0.455	-0.037	0.020	0.000	0.003	0.042	-0.083	0.235*
Grain yield per plant (g)	P	0.000	0.000	0.003	0.002	0.004	0.032	-0.228	0.002	0.047	-0.031	0.000	0.005	0.031	-0.133
	G	0.013	-0.003	0.053	-0.050	0.005	0.078	-0.435	-0.008	0.089	-0.045	0.000	0.012	0.121	-0.170
Harvest index (%)	P	0.000	0.001	0.002	0.001	0.008	-0.126	0.238	0.000	0.023	-0.064	0.001	-0.003	-0.014	0.066
	G	0.006	-0.006	0.058	-0.033	0.008	-0.130	0.215	0.000	0.053	-0.075	0.013	-0.021	-0.055	0.034
100 grain weight (g)	P	0.000	-0.001	0.000	0.000	0.011	-0.046	0.105	0.000	-0.001	0.004	-0.013	0.003	-0.005	0.057
	G	0.015	0.011	0.000	-0.006	0.015	-0.073	0.255	0.001	0.000	0.009	-0.102	0.005	-0.024	0.107
Crude protein content (%)	P	-0.001	0.000	0.001	0.000	-0.003	-0.085	0.058	0.002	0.005	0.004	-0.001	0.050	-0.013	0.018
	G	-0.021	0.002	0.031	-0.001	-0.005	-0.127	0.039	-0.012	0.009	0.013	-0.004	0.125	-0.039	0.010
Crude protein yield per plant (g)	P	0.000	-0.001	0.002	0.002	0.011	-0.660	1.545	0.001	-0.010	-0.006	0.000	0.005	-0.142	0.747**
	G	0.004	0.004	0.038	-0.047	0.015	-0.999	2.323	-0.006	-0.021	-0.008	-0.005	0.010	-0.513	0.796**

*$P \le 0.05$; and **$P \le 0.01$ (Bold values indicate direct effects); Residual effects: Phenotypic (-0.02978), Genotypic (0.04000)

Likewise, highest indirect contributions towards grain yield per plant were made *via* crude protein yield per plant, dry matter yield per plant, days to 50% flowering and 100 grain weight at genotypic and by harvest index and number of leaves per plant at phenotypic level in F_4followed dry matter per cent at phenotypic level in F_5 generation. Indirect contributions were also revealed *via* number of leaves per plant and harvest index at both phenotypic and genotypic and levels in F_5 generation. For fresh fodder yield per plant, dry matter yield per plant gave the highest positive direct and indirect contribution in both F_4 and F_5 generation followed by direct effects of crude protein yield per plant and leaf area in F_4 and by number of leaves per plant, leaf area, grain yield per plant and crude protein content in F_5 generation (Table 7 and 8). Similar results were also obtained by Kumar *et al.* (2016) for days to maturity; Sabit *et al*. (2017); Mecha *et al.* (2017); Baye *et al*. (2020) for harvest index; Wagh *et al*. (2018) for crude protein content; Jaipal and Shekhawat (2016) for dry matter yield towards both grain yield and green fodder yield; Negi *et al*. (2019) for dry fodder yield on grain yield and by Chaudhary *et al*. (2020) for leaves per plant and dry fodder yield per plant.

CONCLUSIONS

The analysis of variance revealed significant differences among the genotypes for all the traits in both the generations implying the presence of sufficient genetic variability and scope for selecting promising genotypes with desirable attributes under study. The phenotypic coefficients of variation values were higher than corresponding genotypic coefficient of variation for all the characters studied in both generations. Fresh fodder yield per plant, dry matter yield per plant, grain yield per plant and crude protein yield per plant should be given top priority for their direct selection as they have recorded high magnitudes of phenotypic and genotypic coefficient of variation as well as high heritability along with high genetic advance for successive breeding programme. Correlation and path analysis indicated the significance and high direct effects of traits like days to 75% maturity, harvest index, number of leaves per plant and number of tillers per plant towards grain yield per plant; whereas, significance and high direct effects were also shown by dry matter yield per plant, crude protein yield per plant, leaf area and dry matter per cent towards fresh fodder yield per plant and were also found to contribute indirectly towards grain yield per plant. Therefore, these traits serve as the best selection indices to obtain high yielding genotypes.

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Conflicts of Interest. None.

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