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Correlation and path coefficient analyses for grain and fodder yield in F₁ and F₂ generations of oats (*Avena sativa* L.)

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Abstract

The field experiment was conducted in Rabi 2023-24 at Student Instructional Farm, C. S. Azad University of Agriculture and Technology, Kanpur (U.P.). This study aimed to assess the association between grain and fodder yield traits using 10 oats genotypes crossed in a half-diallel design, resulting in 45 F₁ hybrids. The experimental material consisted of 100 treatments (10 parents, 45 F₁s and 45 F₂s) arranged in Randomized Block Design (RBD) with three replications. It was found that seed yield per plant showed positive correlation with plant height, number of tillers per plant, leaf: stem ratio, biological yield per plant and harvest index in both no cut and single cut. Path coefficient analysis revealed positive direct effects towards grain yield per plant were shown by plant height, number of tillers, leaf length, leaf: stem ratio, biological yield per plant and harvest index under no cut, however under single cut with plant height, number tillers per plant, number of leaves per plant, spike length, biological yield per plant and harvest index. Also, positive direct effects on green fodder yield per plant were observed for days to maturity, dry matter yield, biological yield per plant, grain yield per plant.

Keywords: Oats genotypes, grain yield traits, fodder yield, path coefficient analysis, randomized block design (RBD)

Introduction

Oats (*Avena sativa* L.) an annual plant belonging to the Poaceae family is a dual-purpose winter crop grown for grain as well as green fodder purpose. *Avena sativa*, is a hexaploid species (2n=6x=42) with AACCCDD genomic constitution (Rines *et al.*, 2006) [16]. The main oats grown for fodder and grain are *Avena sativa* L., commonly known as white oat, and *Avena byzantina* K. known as red oat. Oats is considered as highly nutritious cereal as it contains relatively high level of lipids (Unsaturated fatty acids), proteins, vitamins, antioxidants such as α-tocotrienol, α-tocopherol, avenanthramides, dietary fiber and also serve as excellent source of β-glucan (Premkumar *et al.*, 2017) [11]. Oats is an important Rabi crop in India, providing abundant and nutritious green fodder, particularly in the northwestern Himalayan region where other fodder crops such as berseem (*Trifolium alexandrinum*) and lucerne (*Medicago sativa*) become dormant during the winter months. Oats exhibit notable cold tolerance and drought resistance, coupled with a strong ability to regenerate vegetatively for multiple cuts. Under minimum irrigation it gives high fodder yield per unit area and time due to its multi-cut nature it ensures regular supply of fodder over a long period of time. The global area under oats cultivation covers ha with production of 19.4 metric tons (USDA, 2023). India's oats production was 3200 metric tons and productivity was 1684 kg/ha (4th Advance Estimates from Directorate of Economics and Statistics (DES), MoA and FW). Country is facing a deficit of 11.24% in green fodder, 23.4% in dry fodder and 28.9% in concentrated feed ingredients. The total green fodder available is 734.2 MT, while the requirement is 827.19 MT (Roy *et al.*, 2019) [12]. Understanding the correlation between yield and its component traits helps in identifying and eliminating traits of little or no use during selection. However, as the number of variables increases, the association becomes increasingly complex. This complexity can be addressed through path analysis, which focuses on the nature and magnitude of direct and indirect trait contributions. Path analysis helps in selecting appropriate traits to enhance crop yield.

Materials and Methods

The present investigation was conducted at Student Instructional Farm, C. S. Azad University of Agriculture and Technology, Kanpur (U.P.) during *Rabi* 2023-24. The material for investigation comprised of 10 genotypes of Oats (*Avena sativa* L.) viz., JHO-851, UPO 212, RO-19, UPO-94, JHO-822, JHO 99-2, Kent, JHO 2004, JO-1 and NDO1. These genotypes were crossed to develop 45 F₁ hybrids in 10 × 10 half diallel design. 100 treatments (10 parents, 45 F₁s and 45 F₂s) were grown in Randomized Block Design (RBD) with three replications. The data on 15 characters viz., days to 50% flowering, days to maturity, plant height, number of tillers per plant, number of leaves per plant, spike length, leaf length, leaf width, leaf: stem ratio, green fodder yield per plant, dry matter yield, biological yield per plant, harvest index, 1000 seed weight, grain yield per plant for no cut and single cut were recorded. The data thus recorded on these characters were subjected to statistical analysis for correlation analysis (Al-Jibouri *et al.*, 1958)^[1] and path analysis (Dewey and Lu, 1959)^[4].

Result and Discussion

Correlation coefficients

Results on correlation coefficients, computed at phenotypic and genotypic both levels among all the traits.

The phenotypic and genotypic coefficients values of traits under study are given in Table 1 and 2 (no cut) and Table 3 and 4 (Single cut). In the no cut condition for the F₁ generation, grain yield per plant exhibited highly significant and positive genotypic correlation with leaf: stem ratio (1.013), number of tillers per plant (0.912), harvest index (0.618), plant height (0.539), biological yield per plant (0.442), leaf length (0.202) while significant and positive correlation with days to 50% flowering (0.168). In F₂ generation, grain yield per plant showed highly significant and positive genotypic correlation with number of tillers per plant (0.945), leaf: stem ratio (0.695), plant height (0.665), harvest index (0.64), biological yield per plant (0.585), days to maturity (0.24), leaf length (0.22). However, it exhibited a highly significant and negative genotypic correlation with number of leaves per plant (-0.36).

In single cut for F₁ generation, grain yield per plant exhibited highly significant and positive correlation with plant height (0.702), number of tillers per plant (0.856), number of leaves per plant (0.436), spike length (0.812), leaf length (0.283), biological yield per plant (0.409), harvest index (0.469). In F₂ generation, grain yield per plant exhibited highly significant and positive correlation with plant height (1.00), spike length (0.94), number of leaves per plant (0.92), number of tillers per plant (0.89), leaf: stem ratio (0.87), harvest index (0.71), biological yield per plant (0.51). It suggested that these traits may be considered as important yield component for oats. Green fodder yield per plant for F₁ generation exhibited highly significant and positive correlation with dry matter yield (0.266) while highly significant and negative correlation plant height (-0.405), number of leaves per plant (-0.355), leaf width (-0.213), biological yield per plant (-0.252). Green fodder yield per plant showed significant negative correlation with days to 50% flowering (-0.181) and spike length (-0.161). Green fodder yield per plant for F₂ generation exhibited highly significant and positive correlation with dry matter yield (0.20) and leaf: stem ratio (0.18). Similar results were found by Deep *et al.* (2019)^[2], Negi *et al.* (2019)^[8], Shweta *et al.* (2020)^[13], Kumar *et al.* (2022)^[6] and Pankaj *et al.* (2022)^[9].

At phenotypic level all the character showed similar association as genotypic one's direction but lower in magnitude in both F₁ and F₂ generations.

Path coefficient analysis

Genotypic path coefficient

The results of path coefficient analysis at genotypic level are depicted in Table 5 & 6, for no cut and Table 7 and 8 for single cut. In no cut condition for F₁ generation, highest direct effect on grain yield per plant was expressed by harvest index (0.652) followed by biological yield per plant (0.585), leaf: stem ratio (0.252), number of tillers per plant (0.184), leaf length (0.088), number of leaves per plant (0.051) and days to 50% flowering (0.013). In F₂ generation, highest direct effect on grain yield per plant was expressed by harvest index (1.161) followed by biological yield per plant (1.108), leaf length (0.126) and plant height (0.038). In single cut condition for F₁ generation, highest direct effect on grain yield per plant was expressed by plant height (1.069) followed by harvest index (0.414), green fodder yield per plant (0.377), number of leaves per plant (0.312), dry matter yield (0.176), leaf width (0.133), leaf: stem ratio (0.089), leaf length (0.050), biological yield per plant (0.031), 1000 seed weight (0.029). In single cut condition for F₂ generation, highest direct effect on grain yield per plant was expressed by spike length (0.524), leaf: stem ratio (0.195), number of leaves per plant (0.192), plant height (0.128), 1000 seed weight (0.092), harvest index (0.077), biological yield per plant (0.064), days to 50% flowering (0.024) and days to maturity (0.007). These traits can be considered primary selection criteria in breeding programs for improvement of grain yield in oats.

On green fodder yield per plant in F₁ generation, highest direct effect was expressed by number of tillers per plant (0.651) followed by 1000 seed weight (0.504), days to maturity (0.419), biological yield per plant (0.398), leaf length (0.276), harvest index (0.250). In F₂ generation, highest direct effect was expressed by grain yield per plant (0.969), harvest index (0.914), leaf width (0.506), dry matter yield (0.444), leaf length (0.406), biological yield per plant (0.216), days to maturity (0.014).

Phenotypic path coefficient

According to the results of phenotypic path analysis, in the no cut condition for the F₁ generation, highest positive direct effect on grain yield per plant was exerted by harvest index (0.688) followed by biological yield per plant (0.596), leaf: stem ratio (0.236), plant height (0.092), number of tillers per plant (0.061), number of leaves per plant (0.059), 1000 seed weight (0.029), days to maturity (0.020), leaf width (0.008). The characters contributed negative direct effect on grain yield per plant were leaf length (-0.043), days to 50% flowering (-0.027), spike length (-0.008). In F₂ generation highest positive direct effect on grain yield per plant was exerted by harvest index (0.68) followed by biological yield per plant (0.68), number of tillers per plant (0.13), leaf: stem ratio (0.06), number of leaves per plant (0.06), 1000 seed weight (0.06), plant height (0.05), spike length (0.04) and leaf width (0.01).

In single cut for the F₁ generation the highest positive direct effect on grain yield per plant were exerted by number of tillers per plant (0.331) followed by harvest index (0.296), number of leaves per plant (0.229), plant height (0.227), spike length (0.214), green fodder yield per plant (0.142), biological yield per plant (0.137), leaf length (0.117), 1000 seed weight (0.095), leaf width (0.089), leaf: stem ratio

(0.040), dry matter yield (0.034). The characters that contributed negative direct effect on grain yield per plant were days to maturity (-0.134) and days to 50% flowering (-0.063). In F2 generation the highest positive direct effect on grain yield per plant were exerted by harvest index (0.541) followed by biological yield per plant (0.426), number of leaves per plant (0.232), number of tillers per plant (0.117), green fodder yield per plant (0.049), plant height (0.042), leaf: stem ratio (0.038), leaf length (0.37), leaf width (0.035), spike length (0.028) and dry matter yield (0.020).

Similar findings are also reported by Krishna *et al.* (2014)^[5], Poonia *et al.* (2018)^[10], Negi *et al.* (2019)^[8], Kumar *et al.* (2022)^[6], Devi *et al.* (2024)^[3].

On green fodder yield per plant in F1 generation, highest direct effect was expressed by grain yield per plant followed by days to maturity and dry matter yield. In F2 generation highest direct effect was expressed by grain yield per plant followed by days to maturity, plant height, leaf length, leaf width, biological yield per plant, harvest index (Table 9 and 10).

Table 1: Genotypic and Phenotypic correlation coefficients among different traits in no cut condition in F1 hybrids of Oats

Traits		Days to 50% flowering	Days to maturity	Plant height	No. of tillers per plant	No. of leaves per plant	Spike length	Leaf length	Leaf width	Leaf: stem ratio	Biological yield per plant	Harvest Index	1000 seed weight	Grain yield per plant
Days to 50% flowering	G	1.000	0.115	0.342**	0.277**	-0.140	-0.062	-0.123	-0.039	0.237**	0.117	0.056	0.107	0.168*
	P	1.000	0.114	0.244**	0.257**	-0.130	-0.062	-0.045	-0.018	0.177*	0.115	0.048	0.081	0.153*
Days to maturity	G		1.000	-0.054	-0.014	-0.162*	-0.036	-0.028	0.024	-0.125	0.033	-0.129	-0.052	-0.101
	P		1.000	-0.022	-0.023	-0.137	-0.042	-0.005	0.034	-0.090	0.033	-0.132	-0.042	-0.088
Plant height	G			1.000	0.693**	0.067	0.086	-0.047	-0.104	0.664**	0.443**	0.153*	-0.107	0.539**
	P			1.000	0.451**	0.016	0.098	-0.098	-0.039	0.283**	0.339**	0.126	-0.161*	0.467**
No. of tillers per plant	G				1.000	-0.078	-0.046	-0.057	0.029	0.927**	0.535**	0.425**	0.042	0.912**
	P				1.000	-0.091	-0.038	-0.020	0.008	0.747**	0.496**	0.408**	0.048	0.845**
No. of leaves per plant	G					1.000	-0.171*	-0.200*	-0.092	-0.131	0.028	-0.106	-0.165*	-0.061
	P					1.000	-0.237**	-0.129	-0.031	-0.116	0.031	-0.128	-0.112	-0.037
Spike length	G						1.000	0.437**	0.124	0.070	-0.149	0.175*	0.169*	0.016
	P						1.000	0.068	-0.019	0.100	-0.128	0.143	0.047	0.028
Leaf length	G							1.000	0.058	0.159*	-0.030	0.200**	0.262**	0.202**
	P							1.000	-0.118	0.018	0.025	0.108	0.146	0.036
Leaf width	G								1.000	0.092	0.059	-0.123	-0.061	-0.073
	P								1.000	-0.068	0.019	-0.069	-0.062	-0.044
Leaf: stem ratio	G									1.000	0.453**	0.629**	0.100	1.013**
	P									1.000	0.297**	0.455**	0.138	0.785**
Biological yield per plant	G										1.000	-0.457**	0.048	0.442**
	P										1.000	-0.443**	0.018	0.423**
Harvest Index	G											1.000	0.037	0.618**
	P											1.000	-0.010	0.550**
1000 seed weight	G												1.000	0.082
	P												1.000	0.037
Grain yield per plant	G													1.000
	P													1.000

*, ** significant at 5% and 1% level, respectively

Table 2: Genotypic and Phenotypic correlation coefficients among different traits in no cut condition in F2 of Oats

Traits		Days to 50% flowering	Days to maturity	Plant height	No. of tillers per plant	No. of leaves per plant	Spike length	Leaf length	Leaf width	Leaf: stem ratio	Biological yield per plant	Harvest Index	1000 seed weight	Grain yield per plant
Days to 50% flowering	G	1.000	0.089	-0.040	-0.124	-0.126	0.143	0.275**	0.017	-0.201**	-0.287**	0.174*	0.122	-0.100
	P	1.000	0.088	-0.057	-0.114	-0.117	0.118	0.151	-0.019	-0.119	-0.259**	0.161*	0.087	-0.096
Days to maturity	G		1.000	0.156*	0.260**	-0.464**	0.137	-0.121	-0.063	0.146	0.245**	0.095	0.027	0.239**
	P		1.000	0.124	0.235**	-0.402**	0.107	-0.066	-0.033	0.118	0.208**	0.094	-0.004	0.226**
Plant height	G			1.000	0.723**	-0.118	0.063	0.107	-0.042	0.428**	0.490**	0.321**	-0.195*	0.665**
	P			1.000	0.457**	-0.073	0.064	0.008	0.016	0.070	0.399**	0.224**	-0.238**	0.522**
No. of tillers per plant	G				1.000	-0.423**	0.157*	0.241**	0.051	0.608**	0.624**	0.523**	-0.147	0.945**
	P				1.000	-0.416**	0.101	0.154*	0.027	0.485**	0.572**	0.515**	-0.116	0.888**
No. of leaves per plant	G					1.000	-0.044	-0.015	-0.053	-0.258**	-0.493**	0.032	-0.258**	-0.360**
	P					1.000	-0.100	-0.043	-0.014	-0.188*	-0.445**	0.002	-0.171*	-0.320**
Spike length	G						1.000	0.409**	0.050	-0.103	0.090	0.063	-0.024	0.095
	P						1.000	-0.067	0.006	-0.007	0.057	0.048	-0.147	0.115
Leaf length	G							1.000	0.272**	0.022	0.044	0.155*	-0.055	0.221**
	P							1.000	-0.100	-0.050	0.072	0.065	0.002	0.064
Leaf width	G								1.000	-0.110	0.160*	-0.125	0.300**	0.046
	P								1.000	-0.186*	0.079	-0.065	0.194*	0.029
Leaf: stem ratio	G									1.000	0.452**	0.434**	-0.321**	0.695**
	P									1.000	0.306**	0.318**	-0.180*	0.530**
Biological yield per plant	G										1.000	-0.261**	-0.085	0.585**
	P										1.000	-0.276**	-0.091	0.569**
Harvest Index	G											1.000	-0.095	0.640**
	P											1.000	-0.124	0.585**
1000 seed weight	G												1.000	-0.122
	P												1.000	-0.141
Grain yield per plant	G													1.000
	P													1.000

Table 3: Genotypic and Phenotypic correlation coefficients among different traits in single cut condition in F₁ hybrids of Oats

Traits		Days to 50% flowering	Days to maturity	Plant height	No. of tillers per plant	No. of leaves per plant	Spike length	Leaf length	Leaf width	Leaf: stem ratio	Green fodder yield per plant	Dry matter yield	Biological yield per plant	Harvest Index	1000 seed weight	Grain yield per plant
Days to 50% flowering	G	1.000	0.276**	-0.017	-0.083	-0.032	-0.088	-0.142	0.018	0.245**	-0.181*	0.033	0.102	0.102	0.147	-0.117
	P	1.000	0.251**	0.005	-0.071	-0.029	-0.059	-0.067	-0.016	0.175*	-0.128	0.022	0.088	0.092	0.135	-0.106
Days to maturity	G		1.000	0.161*	-0.016	0.200**	-0.046	-0.159*	0.004	0.138	-0.008	-0.152	-0.240**	0.132	0.058	-0.099
	P		1.000	0.113	-0.009	0.167*	-0.039	-0.088	-0.018	0.116	-0.003	-0.103	-0.217**	0.110	0.074	-0.099
Plant height	G			1.000	0.763**	0.268**	0.877**	0.045	0.017	-0.126	-0.405**	-0.295**	0.447**	0.004	0.119	0.702**
	P			1.000	0.519**	0.161*	0.668**	-0.129	0.015	-0.151	-0.191*	-0.144	0.297**	0.069	-0.026	0.570**
No. of tillers per plant	G				1.000	0.372**	0.732**	0.117	0.034	0.026	-0.018	-0.022	0.457**	0.261**	0.062	0.856**
	P				1.000	0.313**	0.522**	0.141	-0.037	0.036	-0.067	0.004	0.420**	0.235**	0.094	0.780**
No. of leaves per plant	G					1.000	0.220**	0.106	-0.207**	0.179*	-0.355**	0.114	0.191*	0.227**	0.035	0.436**
	P					1.000	0.071	0.045	-0.078	0.081	-0.248**	0.052	0.196*	0.205**	0.026	0.423**
Spike length	G						1.000	0.115	0.065	-0.233**	-0.161*	-0.037	0.334**	0.155*	-0.053	0.812**
	P						1.000	-0.094	-0.022	-0.042	-0.246**	0.006	0.168*	0.171*	-0.058	0.583**
Leaf length	G							1.000	-0.029	0.311**	-0.132	0.344**	0.224**	0.198*	-0.072	0.283**
	P							1.000	-0.167*	0.185*	0.004	0.056	0.165*	0.082	0.048	0.188*
Leaf width	G								1.000	-0.106	-0.213**	-0.056	0.136	-0.211**	0.043	-0.110
	P								1.000	-0.220**	-0.057	0.011	0.019	-0.135	-0.046	-0.017
Leaf: stem ratio	G									1.000	-0.035	0.052	-0.039	0.326**	0.079	0.116
	P									1.000	-0.176*	0.082	-0.011	0.214**	0.087	0.050
Green fodder yield per plant	G										1.000	0.266**	-0.252**	0.121	0.071	-0.086
	P										1.000	0.018	-0.173*	0.100	-0.026	-0.032
Dry matter yield	G											1.000	0.065	0.176*	-0.207**	0.142
	P											1.000	-0.018	0.171*	-0.174*	0.074
Biological yield per plant	G												1.000	-0.228**	0.103	0.409**
	P												1.000	-0.257**	0.114	0.379**
Harvest Index	G													1.000	-0.044	0.469**
	P													1.000	-0.086	0.435**
1000 seed weight	G														1.000	0.128
	P														1.000	0.081
Grain yield per plant	G															1.000
	P															1.000

*, ** significant at 5% and 1% level, respectively

Table 4: Genotypic and Phenotypic correlation coefficients among different traits in single cut condition in F₂s of Oats

Traits		Days to 50% flowering	Days to maturity	Plant height	No. of tillers per plant	No. of leaves per plant	Spike length	Leaf length	Leaf width	Leaf: stem ratio	Green fodder yield per plant	Dry matter yield	Biological yield per plant	Harvest Index	1000 seed weight	Grain yield per plant
Days to 50% flowering	G	1.000	0.121	-0.038	-0.103	-0.005	-0.067	0.152	0.001	0.003	0.018	0.200**	-0.284**	0.195*	0.175*	-0.029
	P	1.000	0.110	0.020	-0.087	-0.018	0.014	0.066	0.011	-0.004	-0.055	0.179*	-0.270**	0.187*	0.160*	-0.032
Days to maturity	G		1.000	0.192*	-0.012	0.117	-0.047	-0.197*	0.284**	-0.028	0.082	0.144	-0.112	0.143	0.162*	0.027
	P		1.000	0.117	-0.008	0.110	-0.049	-0.109	0.193*	-0.032	0.071	0.107	-0.110	0.134	0.150	0.023
Plant height	G			1.000	0.913**	1.001**	0.883**	0.294**	-0.084	0.882**	-0.090	-0.278**	0.590**	0.633**	0.055	1.000**
	P			1.000	0.588**	0.666**	0.608**	0.023	-0.046	0.404**	-0.006	-0.093	0.363**	0.513**	-0.066	0.722**
No. of tillers per plant	G				1.000	0.825**	0.822**	0.141	0.060	0.759**	-0.141	-0.365**	0.481**	0.577**	0.001	0.886**
	P				1.000	0.749**	0.568**	0.132	0.009	0.602**	-0.139	-0.250**	0.457**	0.539**	0.044	0.835**
No. of leaves per plant	G					1.000	0.815**	0.156*	-0.014	0.751**	-0.140	-0.122	0.481**	0.636**	-0.021	0.924**
	P					1.000	0.513**	0.074	0.044	0.554**	-0.097	-0.136	0.455**	0.607**	-0.049	0.898**
Spike length	G						1.000	0.222**	0.013	0.814**	0.077	-0.086	0.448**	0.689**	-0.306**	0.938**
	P						1.000	-0.083	-0.047	0.538**	-0.084	-0.051	0.286**	0.505**	-0.166*	0.646**
Leaf length	G							1.000	-0.089	0.195*	-0.048	0.000	0.049	0.061	-0.358**	0.112
	P							1.000	-0.231**	0.097	0.110	-0.113	0.035	0.008	-0.200*	0.089
Leaf width	G								1.000	-0.042	-0.011	-0.102	0.192*	-0.204**	0.336**	-0.044
	P								1.000	-0.178*	-0.065	0.068	0.080	-0.135	0.135	-0.020
Leaf: stem ratio	G									1.000	0.178*	-0.008	0.535**	0.498**	-0.173*	0.869**
	P									1.000	-0.178*	-0.065	0.068	0.080	-0.135	0.135
Green fodder yield per plant	G										1.000	0.198*	-0.066	-0.004	-0.136	-0.015
	P										1.000	-0.046	-0.055	0.023	-0.147	-0.006
Dry matter yield	G											1.000	-0.104	-0.107	-0.209**	-0.202**
	P											1.000	-0.140	-0.102	-0.084	-0.173*
Biological yield per plant	G												1.000	-0.265**	-0.003	0.506**
	P												1.000	-0.263**	-0.029	0.487**
Harvest Index	G													1.000	-0.059	0.705**
	P													1.000	-0.085	0.671**
1000 seed weight	G														1.000	-0.068
	P														1.000	-0.089
Grain yield per plant	G															1.000
	P															1.000

*, ** significant at 5% and 1% level, respectively

Table 5: Genotypic and phenotypic path coefficient of grain yield and it's components in no cut condition (F₁S) of Oats

Traits		Days to 50% flowering	Days to maturity	Plant height	No. of tillers per plant	No. of leaves per plant	Spike length	Leaf length	Leaf width	Leaf: Stem ratio	Biological yield per plant	Harvest Index	1000 seed weight	Grain yield per plant
Days to 50% flowering	G	-0.027	0.002	0.022	0.016	-0.008	0.001	0.002	-0.001	0.042	0.068	0.033	0.002	0.153*
	P	0.014	0.000	-0.043	0.051	-0.007	0.002	-0.011	0.003	0.060	0.068	0.037	-0.004	0.168*
Days to maturity	G	-0.003	0.020	-0.002	-0.001	-0.008	0.001	0.001	0.001	-0.021	0.020	-0.091	-0.001	-0.088
	P	0.002	-0.001	0.007	-0.003	-0.008	0.001	-0.003	-0.002	-0.031	0.020	-0.084	0.002	-0.101
Plant height	G	-0.007	-0.001	0.092	0.028	0.001	-0.001	0.004	-0.001	0.067	0.202	0.087	-0.005	0.467**
	P	0.005	0.001	-0.126	0.127	0.003	-0.002	-0.004	0.007	0.167	0.259	0.100	0.004	0.539**
No. of tillers per plant	G	-0.007	-0.001	0.041	0.061	-0.005	0.001	0.001	0.001	0.176	0.296	0.281	0.001	0.845**
	P	0.004	0.001	-0.088	0.184	-0.004	0.001	-0.005	-0.002	0.234	0.313	0.277	-0.002	0.912**
No. of leaves per plant	G	0.004	-0.003	0.002	-0.006	0.060	0.002	0.006	-0.001	-0.027	0.018	-0.088	-0.003	-0.037
	P	-0.002	0.001	-0.008	-0.014	0.051	0.004	-0.018	0.006	-0.033	0.016	-0.069	0.005	-0.061
Spike length	G	0.002	-0.001	0.009	-0.002	-0.014	-0.009	-0.003	-0.001	0.024	-0.076	0.098	0.001	0.028
	P	-0.001	0.001	-0.011	-0.008	-0.009	-0.024	0.039	-0.008	0.018	-0.087	0.114	-0.006	0.016
Leaf length	G	0.001	-0.001	-0.009	-0.001	-0.008	-0.001	-0.043	-0.001	0.004	0.015	0.074	0.004	0.036
	P	-0.002	0.001	0.006	-0.011	-0.010	-0.012	0.088	-0.004	0.040	-0.017	0.131	-0.009	0.202**
Leaf width	G	0.002	0.001	-0.004	0.001	-0.002	0.001	0.005	0.009	-0.016	0.012	-0.047	-0.002	-0.044
	P	-0.001	0.001	0.013	0.005	-0.005	-0.003	0.005	-0.068	0.023	0.035	-0.080	0.002	-0.073
Leaf: Stem ratio	G	-0.005	-0.002	0.026	0.046	-0.007	-0.001	-0.001	-0.001	0.236	0.177	0.313	0.004	0.785**
	P	0.003	0.001	-0.084	0.170	-0.007	-0.002	0.014	-0.006	0.252	0.265	0.410	-0.003	1.013**
Biological yield per plant	G	-0.003	0.001	0.031	0.030	0.002	0.001	-0.001	0.001	0.070	0.596	-0.305	0.001	0.423**
	P	0.002	0.001	-0.056	0.098	0.001	0.004	-0.003	-0.004	0.114	0.585	-0.298	-0.002	0.442**
Harvest Index	G	-0.001	-0.003	0.012	0.025	-0.008	-0.001	-0.005	-0.001	0.107	-0.264	0.688	-0.001	0.550**
	P	0.001	0.001	-0.019	0.078	-0.005	-0.004	0.018	0.008	0.159	-0.267	0.652	-0.001	0.618**
1000 seed weight	G	-0.002	-0.001	-0.015	0.003	-0.007	-0.001	-0.006	-0.001	0.033	0.011	-0.007	0.029	0.037
	P	0.001	0.001	0.014	0.008	-0.008	-0.004	0.023	0.004	0.025	0.028	0.024	-0.032	0.082

Bold are direct effects; **G**: Genotypic path coefficient; **P**: Phenotypic path coefficient; Residual effects (G): 0.0349; Residual effects (P): 0.0992

*, ** significant at 5% and 1% level, respectively

Traits		Days to 50% flowering	Days to maturity	Plant height	No. of tillers per plant	No. of leaves per plant	Spike length	Leaf length	Leaf width	Leaf: Stem ratio	Biological yield per plant	Harvest Index	1000 seed weight	Grain yield per plant
Days to 50% flowering	G	-0.083	-0.003	-0.002	0.039	0.007	-0.012	0.035	-0.001	0.036	-0.318	0.202	-0.001	-0.100
	P	-0.002	-0.001	-0.003	-0.015	-0.007	0.005	-0.006	-0.001	-0.008	-0.175	0.110	0.005	-0.096
Days to maturity	G	-0.007	-0.033	0.006	-0.082	0.026	-0.012	-0.015	0.001	-0.026	0.271	0.111	-0.001	0.239**
	P	-0.001	-0.006	0.007	0.030	-0.024	0.004	0.003	-0.001	0.007	0.141	0.065	-0.001	0.226**
Plant height	G	0.003	-0.005	0.038	-0.228	0.007	-0.005	0.013	0.001	-0.076	0.543	0.373	0.001	0.665**
	P	0.001	-0.001	0.052	0.059	-0.004	0.003	-0.001	0.001	0.005	0.270	0.153	-0.014	0.522**
No. of tillers per plant	G	0.010	-0.009	0.028	-0.315	0.024	-0.014	0.031	-0.001	-0.108	0.691	0.607	0.001	0.945**
	P	0.001	-0.001	0.024	0.128	-0.024	0.004	-0.006	0.001	0.030	0.387	0.352	-0.007	0.888**
No. of leaves per plant	G	0.011	0.016	-0.005	0.133	-0.056	0.004	-0.002	0.001	0.046	-0.546	0.037	0.002	-0.360**
	P	0.001	0.002	-0.004	-0.053	0.058	-0.004	0.002	-0.001	-0.012	-0.301	0.001	-0.010	-0.320**
Spike length	G	-0.012	-0.005	0.002	-0.050	0.003	-0.086	0.052	-0.001	0.019	0.100	0.073	0.001	0.095
	P	-0.001	-0.001	0.003	0.013	-0.006	0.040	0.003	0.001	-0.001	0.038	0.033	-0.009	0.115
Leaf length	G	-0.023	0.004	0.004	-0.076	0.001	-0.035	0.126	-0.005	-0.004	0.049	0.180	0.001	0.221**
	P	-0.001	0.001	0.001	0.020	-0.003	-0.003	-0.040	-0.001	-0.003	0.049	0.044	0.001	0.064
Leaf width	G	-0.001	0.002	-0.002	-0.016	0.003	-0.004	0.034	-0.020	0.020	0.177	-0.145	-0.002	0.046

	P	0.001	0.001	0.001	0.003	-0.001	0.001	0.004	0.013	-0.012	0.053	-0.045	0.011	0.029
Leaf: Stem ratio	G	0.017	-0.005	0.016	-0.192	0.015	0.009	0.003	0.002	-0.178	0.501	0.504	0.002	0.695**
	P	0.001	-0.001	0.004	0.062	-0.011	0.000	0.002	-0.002	0.063	0.207	0.217	-0.010	0.530**
Biological yield per plant	G	0.024	-0.008	0.019	-0.197	0.028	-0.008	0.006	-0.003	-0.081	1.108	-0.304	0.001	0.585**
	P	0.001	-0.001	0.021	0.073	-0.026	0.002	-0.003	0.001	0.019	0.677	-0.189	-0.005	0.569**
Harvest Index	G	-0.014	-0.003	0.012	-0.165	-0.002	-0.005	0.020	0.002	-0.077	-0.290	1.161	0.001	0.640**
	P	-0.001	-0.001	0.012	0.066	0.001	0.002	-0.003	-0.001	0.020	-0.187	0.684	-0.007	0.585**
1000 seed weight	G	-0.010	-0.001	-0.007	0.046	0.015	0.002	-0.007	-0.006	0.057	-0.094	-0.110	-0.007	-0.122
	P	-0.001	0.001	-0.012	-0.015	-0.010	-0.006	-0.001	0.003	-0.011	-0.062	-0.085	0.058	-0.141

Bold are direct effects; G: Genotypic path coefficient; P: Phenotypic path coefficient; Residual effects (G): 0.0348; Residual effects (P): 0.0660

*, ** significant at 5% and 1% level, respectively

Table 7: Genotypic and phenotypic path coefficient of grain yield and it's components in single cut condition (F₁s) of Oats

Traits		Days to 50% flowering	Days to maturity	Plant height	No. of tillers per plant	No. of leaves per plant	Spike length	Leaf length	Leaf width	Leaf: Stem ratio	Green fodder Yield per plant	Dry matter yield	Biological yield per plant	Harvest Index	1000 seed weight	Grain yield per plant
Days to 50% flowering	G	-0.063	-0.034	0.001	-0.023	-0.007	-0.013	-0.008	-0.002	0.007	-0.018	0.001	0.012	0.027	0.013	-0.106
	P	-0.015	-0.100	-0.018	0.010	-0.010	0.011	-0.007	0.002	0.022	-0.068	0.006	0.003	0.042	0.004	-0.117
Days to maturity	G	-0.016	-0.134	0.026	-0.003	0.038	-0.008	-0.010	-0.002	0.005	-0.001	-0.004	-0.030	0.033	0.007	-0.099
	P	-0.004	-0.361	0.172	0.002	0.062	0.006	-0.008	0.001	0.012	-0.003	-0.027	-0.007	0.055	0.002	-0.099
Plant height	G	-0.001	-0.015	0.227	0.172	0.037	0.143	-0.015	0.001	-0.006	-0.027	-0.005	0.041	0.021	-0.003	0.570**
	P	0.001	-0.058	1.069	-0.089	0.084	-0.111	0.002	0.002	-0.011	-0.153	-0.052	0.014	0.002	0.003	0.702**
No. of tillers per plant	G	0.005	0.001	0.118	0.332	0.072	0.112	0.017	-0.003	0.001	-0.010	0.001	0.058	0.070	0.009	0.780**
	P	0.001	0.006	0.816	-0.116	0.116	-0.092	0.006	0.005	0.002	-0.007	-0.004	0.014	0.108	0.002	0.856**
No. of leaves per plant	G	0.002	-0.022	0.037	0.104	0.230	0.015	0.005	-0.007	0.003	-0.035	0.002	0.027	0.061	0.003	0.423**
	P	0.001	-0.072	0.286	-0.043	0.312	-0.028	0.005	-0.027	0.016	-0.134	0.020	0.006	0.094	0.001	0.436**
Spike length	G	0.004	0.005	0.151	0.173	0.016	0.214	-0.011	-0.002	-0.002	-0.035	0.001	0.023	0.051	-0.006	0.583**
	P	0.001	0.017	0.938	-0.085	0.069	-0.126	0.006	0.009	-0.021	-0.061	-0.007	0.010	0.064	-0.002	0.812**
Leaf length	G	0.004	0.012	-0.029	0.047	0.010	-0.020	0.117	-0.015	0.007	0.001	0.002	0.023	0.024	0.005	0.188*
	P	0.002	0.057	0.048	-0.014	0.033	-0.015	0.050	-0.004	0.028	-0.050	0.061	0.007	0.082	-0.002	0.283**
Leaf width	G	0.001	0.003	0.004	-0.012	-0.018	-0.005	-0.020	0.089	-0.009	-0.008	0.001	0.003	-0.040	-0.004	-0.017
	P	-0.001	-0.001	0.018	-0.004	-0.064	-0.008	-0.002	0.133	-0.009	-0.080	-0.010	0.004	-0.087	0.001	-0.110
Leaf: Stem ratio	G	-0.011	-0.016	-0.034	0.012	0.019	-0.009	0.022	-0.020	0.040	-0.025	0.003	-0.002	0.063	0.008	0.050
	P	-0.004	-0.050	-0.135	-0.003	0.056	0.030	0.016	-0.014	0.089	-0.013	0.009	-0.001	0.135	0.002	0.116
Green fodder Yield per plant	G	0.008	0.000	-0.043	-0.022	-0.057	-0.053	0.001	-0.005	-0.007	0.142	0.001	-0.024	0.030	-0.003	-0.032
	P	0.003	0.003	-0.433	0.002	-0.111	0.021	-0.007	-0.028	-0.003	0.377	0.047	-0.008	0.050	0.002	-0.086
Dry matter yield	G	-0.001	0.014	-0.033	0.002	0.012	0.001	0.007	0.001	0.003	0.003	0.034	-0.003	0.051	-0.017	0.074
	P	-0.001	0.055	-0.315	0.003	0.036	0.005	0.017	-0.008	0.005	0.100	0.176	0.002	0.073	-0.006	0.142
Biological yield per plant	G	-0.006	0.029	0.067	0.140	0.045	0.036	0.019	0.002	-0.001	-0.025	-0.001	0.138	-0.076	0.011	0.379**
	P	-0.002	0.087	0.478	-0.053	0.060	-0.042	0.011	0.018	-0.004	-0.095	0.011	0.031	-0.095	0.003	0.409**
Harvest Index	G	-0.006	-0.015	0.016	0.078	0.047	0.037	0.010	-0.012	0.009	0.014	0.006	-0.035	0.296	-0.008	0.435**
	P	-0.002	-0.047	0.004	-0.030	0.071	-0.020	0.010	-0.028	0.029	0.046	0.031	-0.007	0.414	-0.001	0.469**
1000 seed weight	G	-0.009	-0.010	-0.006	0.031	0.006	-0.012	0.006	-0.004	0.004	-0.004	-0.006	0.016	-0.026	0.096	0.081
	P	-0.002	-0.021	0.127	-0.007	0.011	0.007	-0.004	0.006	0.007	0.027	-0.037	0.003	-0.018	0.029	0.128

Bold are direct effects; G: Genotypic path coefficient; P: Phenotypic path coefficient; Residual effects (G): 0.0654; Residual effects (P): 0.0161

*, ** significant at 5% and 1% level, respectively

Table 8: Genotypic and phenotypic path coefficient of grain yield and it's components in single cut condition (F_{2s}) of Oats

Traits		Days to 50% flowering	Days to maturity	Plant height	No. of tillers per plant	No. of leaves per plant	Spike length	Leaf length	Leaf width	Leaf: Stem ratio	Green fodder Yield per plant	Dry matter yield	Biological yield per plant	Harvest Index	1000 seed weight	Grain yield per plant
Days to 50% flowering	G	0.024	0.001	-0.005	0.006	-0.001	-0.035	-0.013	-0.001	0.001	-0.001	-0.019	-0.018	0.015	0.016	-0.029
	P	-0.005	-0.004	0.001	-0.010	-0.004	0.000	0.002	0.000	-0.001	-0.003	0.004	-0.115	0.101	0.001	-0.032
Days to maturity	G	0.003	0.007	0.025	0.001	0.023	-0.025	0.017	-0.021	-0.005	-0.003	-0.013	-0.007	0.011	0.015	0.027
	P	-0.001	-0.038	0.005	-0.001	0.026	-0.002	-0.004	0.007	-0.001	0.004	0.002	-0.047	0.072	0.001	0.023
Plant height	G	-0.001	0.001	0.128	-0.057	0.193	0.463	-0.025	0.006	0.172	0.003	0.026	0.038	0.049	0.005	1.000**
	P	-0.001	-0.005	0.042	0.069	0.155	0.017	0.001	-0.002	0.015	-0.001	-0.002	0.155	0.277	-0.001	0.722**
No. of tillers per plant	G	-0.003	-0.001	0.117	-0.063	0.159	0.431	-0.012	-0.004	0.148	0.004	0.034	0.031	0.044	0.001	0.886**
	P	0.001	0.001	0.025	0.117	0.174	0.016	0.005	0.001	0.023	-0.007	-0.005	0.195	0.292	0.001	0.835**
No. of leaves per plant	G	-0.001	0.001	0.128	-0.052	0.192	0.427	-0.014	0.001	0.147	0.004	0.011	0.031	0.049	-0.002	0.924**
	P	0.001	-0.004	0.028	0.088	0.232	0.015	0.003	0.002	0.021	-0.005	-0.003	0.194	0.329	-0.001	0.898**
Spike length	G	-0.002	-0.001	0.113	-0.051	0.157	0.524	-0.019	-0.001	0.159	-0.002	0.008	0.029	0.053	-0.028	0.938**
	P	0.000	0.002	0.026	0.067	0.119	0.028	-0.003	-0.002	0.020	-0.004	-0.001	0.122	0.273	-0.001	0.646**
Leaf length	G	0.004	-0.001	0.038	-0.009	0.030	0.116	-0.086	0.007	0.038	0.002	0.001	0.003	0.005	-0.033	0.112
	P	-0.001	0.004	0.001	0.016	0.017	-0.002	0.037	-0.008	0.004	0.005	-0.002	0.015	0.004	-0.001	0.089
Leaf width	G	0.001	0.002	-0.011	-0.004	-0.003	0.007	0.008	-0.073	-0.008	0.001	0.009	0.012	-0.016	0.031	-0.044
	P	-0.001	-0.007	-0.002	0.001	0.010	-0.001	-0.009	0.035	-0.007	-0.003	0.001	0.034	-0.073	0.001	-0.020
Leaf: Stem ratio	G	0.001	-0.001	0.113	-0.047	0.145	0.426	-0.017	0.003	0.195	-0.005	0.001	0.034	0.038	-0.016	0.869**
	P	0.001	0.001	0.017	0.071	0.129	0.015	0.004	-0.006	0.038	-0.001	-0.001	0.191	0.206	-0.001	0.663**
Green fodder yield per plant	G	0.001	0.001	-0.012	0.009	-0.027	0.040	0.004	0.001	0.035	-0.030	-0.018	-0.004	-0.001	-0.013	-0.015
	P	0.001	-0.003	-0.001	-0.016	-0.023	-0.002	0.004	-0.002	-0.001	0.049	-0.001	-0.024	0.013	-0.001	-0.006
Dry matter yield	G	0.005	0.001	-0.036	0.023	-0.023	-0.045	0.001	0.008	-0.002	-0.006	-0.093	-0.007	-0.008	-0.019	-0.202**
	P	-0.001	-0.004	-0.004	-0.029	-0.032	-0.001	-0.004	0.002	-0.002	-0.002	0.020	-0.060	-0.055	-0.001	-0.173*
Biological yield per plant	G	-0.007	-0.001	0.076	-0.030	0.093	0.235	-0.004	-0.014	0.104	0.002	0.009	0.064	-0.020	-0.001	0.506**
	P	0.002	0.004	0.015	0.054	0.106	0.008	0.001	0.003	0.017	-0.003	-0.003	0.426	-0.142	-0.001	0.487**
Harvest Index	G	0.005	0.001	0.081	-0.036	0.122	0.361	-0.005	0.015	0.097	0.002	0.010	-0.017	0.077	-0.005	0.705**
	P	-0.001	-0.005	0.022	0.063	0.141	0.014	0.001	-0.005	0.014	0.001	-0.002	-0.112	0.541	-0.001	0.671**
1000 seed weight	G	0.004	0.001	0.007	0.001	-0.004	-0.161	0.031	-0.025	-0.034	0.004	0.019	-0.001	-0.005	0.092	-0.068
	P	-0.001	-0.006	-0.003	0.005	-0.011	-0.005	-0.007	0.005	-0.004	-0.007	-0.002	-0.013	-0.046	0.005	-0.089

Bold are direct effects; G: Genotypic path coefficient; P: Phenotypic path coefficient; Residual effects (G): 0.00361; Residual effects (P): 0.0521

*, ** significant at 5% and 1% level, respectively

Table 9: Estimates of direct and indirect effects of green fodder yield in F₁ generation of oats

Traits		Days to 50% flowering	Days to maturity	Plant height	No. of tillers per plant	No. of leaves per plant	Spike length	Leaf length	Leaf width	Leaf: Stem ratio	Dry matter yield	Biological yield per plant	Harvest Index	1000 seed weight	Grain yield per plant	Green fodder yield per plant
Days to 50% flowering	G	-0.591	0.392	0.118	-0.304	0.009	-0.578	-0.068	-0.026	-0.050	-0.020	0.143	0.046	0.222	0.526	-0.181*
	P	-0.109	0.031	-0.001	0.001	0.013	0.028	0.008	0.002	-0.011	0.000	-0.012	-0.001	-0.010	-0.067	-0.128
Days to maturity	G	-0.163	0.419	-0.147	-0.058	-0.055	-0.305	-0.076	-0.005	0.033	0.093	-0.336	0.059	0.087	0.446	-0.008
	P	-0.027	0.122	-0.022	0.000	-0.075	0.018	0.011	0.003	0.009	0.000	0.029	-0.001	-0.005	-0.063	-0.003
Plant height	G	0.010	0.229	-0.623	0.287	-0.074	0.277	0.022	-0.524	0.174	0.180	0.125	0.002	0.179	-0.668	-0.405**
	P	-0.001	0.014	-0.194	-0.004	-0.072	-0.310	0.016	-0.002	0.040	0.000	-0.039	-0.001	0.002	0.361	-0.191*
No. of tillers per plant	G	0.049	-0.023	-0.437	0.651	-0.103	0.322	0.056	-0.049	0.010	0.014	0.139	0.117	0.093	-0.859	-0.018
	P	0.008	-0.001	-0.101	-0.008	-0.140	-0.242	-0.017	0.005	0.001	0.001	-0.055	-0.003	-0.007	0.493	-0.067
No. of leaves per plant	G	0.019	0.284	-0.908	0.359	-0.276	0.448	0.051	0.299	-0.016	-0.070	0.267	0.102	0.053	-0.966	-0.355**
	P	0.003	0.020	-0.031	-0.002	-0.449	-0.033	-0.006	0.011	0.001	0.000	-0.026	-0.002	-0.002	0.268	-0.248**
Spike length	G	0.052	-0.066	-0.249	0.174	-0.061	0.085	0.055	-0.095	0.127	0.023	0.467	0.070	-0.080	-0.663	-0.161*
	P	0.007	-0.005	-0.130	-0.004	-0.032	-0.464	0.012	0.003	0.019	0.001	-0.022	-0.002	0.004	0.368	-0.246**
Leaf length	G	0.084	-0.225	-0.322	0.128	-0.029	0.257	0.278	0.043	-0.151	-0.210	0.314	0.089	-0.108	-0.278	-0.132
	P	0.007	-0.011	0.025	-0.001	-0.020	0.043	-0.123	0.023	-0.033	0.000	-0.022	-0.001	-0.003	0.119	0.004
Leaf width	G	-0.011	0.005	-0.320	0.123	0.057	0.030	-0.014	-0.448	0.073	0.034	0.189	-0.095	0.065	0.097	-0.213**
	P	0.002	-0.002	-0.003	0.000	0.035	0.010	0.021	-0.139	0.028	0.001	-0.003	0.002	0.003	-0.011	-0.057
Leaf: Stem ratio	G	-0.066	-0.106	0.795	-0.086	-0.010	-0.291	0.162	0.237	-0.244	-0.128	-0.125	0.134	0.077	-0.173	0.178*
	P	-0.010	-0.009	0.062	0.000	0.005	0.068	-0.032	0.031	-0.126	0.000	0.011	-0.003	-0.004	0.030	0.024
Dry matter yield	G	-0.020	-0.216	0.599	-0.081	-0.032	-0.247	0.164	0.081	-0.093	-0.111	0.590	0.079	-0.312	-0.139	0.266**
	P	-0.002	-0.013	0.028	0.001	-0.023	-0.003	-0.007	-0.002	-0.023	0.002	0.002	-0.002	0.012	0.047	0.018
Biological yield per plant	G	-0.060	-0.341	-0.186	0.670	-0.053	0.200	0.107	-0.196	0.040	-0.040	0.398	-0.103	0.155	-0.843	-0.252**
	P	-0.010	-0.026	-0.058	-0.003	-0.088	-0.078	-0.020	-0.003	0.010	0.001	-0.132	0.003	-0.008	0.240	-0.173*
Harvest Index	G	-0.060	0.187	-0.028	0.152	-0.063	0.024	0.095	0.305	-0.133	-0.107	-0.319	0.250	-0.066	-0.115	0.121
	P	-0.010	0.013	-0.013	-0.002	-0.092	-0.080	-0.010	0.019	-0.030	0.000	0.034	-0.011	0.006	0.275	0.100
1000 seed weight	G	-0.087	0.082	-0.249	0.227	-0.010	-0.349	-0.034	-0.063	-0.023	0.127	0.144	-0.020	0.504	-0.177	0.071
	P	-0.015	0.009	0.005	-0.001	-0.012	0.027	-0.006	0.006	-0.007	0.000	-0.015	0.001	-0.071	0.052	-0.026
Grain yield per plant	G	0.069	-0.140	-0.003	0.124	-0.120	0.148	0.135	0.060	-0.037	-0.087	0.071	0.111	0.193	-0.610	-0.086
	P	0.012	-0.012	-0.111	-0.006	-0.190	-0.270	-0.023	0.002	-0.006	0.000	-0.050	-0.005	-0.006	0.632	-0.032

Bold are direct effects; G: Genotypic path coefficient; P: Phenotypic path coefficient; Residual effects (G): 0.154; Residual effects (P)-0.0715

*, ** significant at 5% and 1% level, respectively

Table 10: Estimates of direct and indirect effects of green fodder yield in F₂ generation of oats

Traits		Days to 50% flowering	Days to maturity	Plant height	No. of tillers per plant	No. of leaves per plant	Spike length	Leaf length	Leaf width	Leaf: Stem ratio	Dry matter yield	Biological yield per plant	Harvest Index	1000 seed weight	Grain yield per plant	Green fodder yield per plant
Days to 50% flowering	G	-0.142	0.002	0.016	0.009	0.011	0.189	0.062	0.001	0.015	0.089	-0.629	0.569	-0.115	-0.056	0.018
	P	-0.081	0.014	0.001	0.039	0.010	-0.002	0.008	0.001	0.001	-0.013	-0.021	0.028	-0.014	-0.026	-0.055
Days to maturity	G	-0.017	0.014	-0.078	0.001	-0.226	0.133	-0.080	0.144	0.012	0.064	-0.249	0.417	-0.106	0.054	0.082
	P	-0.009	0.130	0.004	0.004	-0.065	0.008	-0.013	0.001	0.001	-0.008	-0.008	0.020	-0.013	0.018	0.071
Plant height	G	0.006	0.003	-0.405	-0.076	-0.924	-0.488	0.119	-0.042	-0.243	-0.123	0.307	0.846	-0.036	0.968	-0.090
	P	-0.002	0.015	0.036	-0.261	-0.390	-0.099	0.003	-0.001	-0.007	0.007	0.028	0.077	0.006	0.582	-0.006
No. of tillers per plant	G	0.015	-0.001	-0.370	-0.083	-0.585	-0.316	0.057	0.030	-0.218	-0.162	0.065	0.682	-0.001	0.744	-0.141
	P	0.007	-0.001	0.021	-0.443	-0.438	-0.093	0.016	0.001	-0.010	0.018	0.035	0.081	-0.004	0.673	-0.139
No. of leaves per plant	G	0.001	0.002	-0.406	-0.069	-0.922	-0.296	0.063	-0.007	-0.206	-0.054	0.066	0.854	0.014	0.820	-0.140
	P	0.001	0.014	0.024	-0.332	-0.585	-0.084	0.009	0.000	-0.009	0.010	0.035	0.091	0.004	0.724	-0.097
Spike length	G	0.010	-0.001	-0.358	-0.069	-0.567	-0.816	0.090	0.007	-0.228	-0.038	0.992	0.107	0.201	0.747	0.077
	P	-0.001	-0.006	0.022	-0.252	-0.300	-0.163	-0.010	-0.001	-0.009	0.004	0.022	0.076	0.014	0.520	-0.084
Leaf length	G	-0.022	-0.003	-0.119	-0.012	-0.301	-0.626	0.406	-0.045	-0.069	0.001	0.108	0.178	0.234	0.221	-0.048
	P	-0.005	-0.014	0.001	-0.059	-0.044	0.014	0.119	-0.001	-0.002	0.008	0.003	0.001	0.017	0.072	0.110
Leaf width	G	0.000	0.004	0.034	-0.005	0.027	-0.036	-0.036	0.506	0.016	-0.045	0.425	-0.593	-0.220	-0.087	-0.011
	P	-0.001	0.025	-0.002	-0.004	-0.026	0.008	-0.028	0.005	0.003	-0.005	0.006	-0.020	-0.011	-0.016	-0.065
Leaf: Stem ratio	G	0.007	-0.001	-0.348	-0.064	-0.402	-0.267	0.099	-0.029	-0.283	-0.026	0.212	0.429	0.095	0.715	0.137
	P	0.003	-0.006	0.015	-0.271	-0.323	-0.090	0.014	-0.001	-0.016	0.007	0.035	0.058	0.009	0.547	-0.019
Dry matter yield	G	-0.028	0.002	0.113	0.030	0.234	0.243	0.001	-0.052	0.017	0.444	-0.230	-0.313	0.137	-0.399	0.198*
	P	-0.014	0.014	-0.003	0.111	0.079	0.008	-0.014	0.000	0.002	-0.072	-0.011	-0.015	0.007	-0.139	-0.046
Biological yield per plant	G	0.040	-0.002	-0.239	-0.040	-0.525	-0.261	0.020	0.097	-0.155	-0.046	0.216	-0.171	0.002	0.996	-0.066
	P	0.022	-0.014	0.013	-0.202	-0.266	-0.047	0.004	0.000	-0.007	0.010	0.077	-0.040	0.003	0.393	-0.055
Harvest Index	G	-0.028	0.002	-0.257	-0.048	-0.223	-0.440	0.025	-0.103	-0.139	-0.048	-0.087	0.914	0.038	0.389	-0.004
	P	-0.015	0.018	0.018	-0.239	-0.355	-0.082	0.001	-0.001	-0.006	0.007	-0.020	0.150	0.007	0.541	0.023
1000 seed weight	G	-0.025	0.002	-0.022	0.000	0.040	0.863	-0.145	0.170	0.041	-0.093	-0.007	-0.171	-0.655	-0.135	-0.136
	P	-0.013	0.020	-0.002	-0.020	0.029	0.027	-0.024	0.001	0.002	0.006	-0.002	-0.013	-0.085	-0.072	-0.147
Grain yield per plant	G	0.004	0.000	-0.405	-0.074	-0.276	-0.141	0.046	-0.022	-0.246	-0.090	0.121	0.055	0.045	0.969	-0.015
	P	0.003	0.003	0.026	-0.370	-0.525	-0.105	0.011	-0.001	-0.011	0.012	0.037	0.101	0.008	0.806	-0.006

Bold are direct effects; G: Genotypic path coefficient; P: Phenotypic path coefficient; Residual effects (G): 0.097; Residual effects (P): 0.0813

*, ** significant at 5% and 1% level, respectively

Conclusion

In the present investigation, association analysis revealed that generally, genotypic correlation exhibited a greater magnitude than the phenotypic correlation across all traits, signifying an inherent association among the various traits. It was found that seed yield per plant showed positive correlation with plant height, number of tillers per plant, leaf: stem ratio, biological yield per plant and harvest index in both no cut and single cut. Path coefficient analysis revealed positive direct effects towards grain yield per plant were shown by plant height, number of tillers, leaf length, leaf: stem ratio, biological yield per plant and harvest index under no cut, however under single cut with plant height, number tillers per plant, number of leaves per plant, spike length, biological yield per plant and harvest index. Also, positive direct effects on green fodder yield per plant were observed for days to maturity, dry matter yield, biological yield per plant, grain yield per plant.

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