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Unravelling the Association among Characters through Correlation and Path Analyses in Dual Purpose Oats (*Avena sativa* L.)

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ABSTRACT

Recent rise in urbanization of cultivable lands to compensate increasing human population at the cost of agricultural production threatens the globe. So, the crop breeders got the responsibility to generate potential varieties possessing higher productivity to makeup with the future scarcity. Yield, a complex trait, is dependent on several attributes of the crop plant. Therefore, having clear knowledge on trait correlation and path coefficients assists the researchers to come up with the combination of component traits to breed genotypes those hit the maximum yield objective. In *rabi* 2021-22, 31 genotypes of oats were grown to record data on 12 fodder attributing and 12 grain attributing traits. Two separate trait association analyses were conducted using fodder and grain traits, respectively. Among fodder traits, plant height, number of leaves per plant, leaf length, leaf width, number of tillers per plant, dry matter yield and crop growth rate showed significant positive correlation with green fodder yield. Path analysis suggested that the tall plant with numerous tillers showing higher growth rate could be the indirect selection criteria for green fodder yield. Whereas among grain traits, there was a significant positive correlation of 1000 seed weight, flag leaf length, panicle length, no. of effective tillers per plant and spikelet number per panicle with grain yield per plant. Early flowering genotypes with increased number of effective tillers could be the selection index for grain yield as suggested by path coefficients.

Keywords Oats, Dual purpose, Character association, Correlation, Path coefficient analysis.

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INTRODUCTION

Oats (*Avena sativa* L.), a hexaploid (x=7, AACCDD) cereal species belongs to the family of Poaceae, is the sixth most economically cultivated grain crop in the world scenario (Dubey *et al.* 2018). This underrated cereal crop gained importance among farming community only since its ability to ensure returns even in the unlikely environments such as low fertile soils, cold temperature, was discovered. Oats, a *rabi* fodder crop, despite fed as green by dairy cattle, also gives comparatively higher dry matter that can be transformed into hay or silage for usage during deficit period. At early times, oat grains were only used as livestock feed but it occupied a place in human diet soon after the invention of milling equipment (Boczkowska *et al.* 2014). The recent reports have revealed the nutritional richness of oat grains so that it gained the attention of the human kind. In this way, it becomes an important dual purpose crop that suits well into the platters of both cattle and human. Therefore, after cutting the forage, the stubble part is saved in the field to grow again and bear panicles (Poonia and Phogat 2017).

Increasing human population and reduction in agricultural lands has created the competition for human food and livestock feed today (Sood *et al.* 2016). Thus, there should be the development of new varieties with higher yield potential per unit area. Yield is said to be a complex trait as it is dependent on larger number of component traits. To bring improvement in such complex and confusing quantitative characters, it is very much crucial to have knowledge on interrelationships of various phenotypic traits with the dependent trait i.e. yield. Association among characters could be the result of either of the genetic phenomenon namely linkage and pleiotropy. Traits experiencing association due to linkage can be improved by manipulation through recombination. But if the reason is found to be pleiotropy, the only way to achieve desired improvement in dependent trait is by wise selection of genotypes possessing favorable combination of independent traits (Kumar *et al.* 2016).

Character association is the term which encompasses degree and direction of relationship of given trait with the yield as well as the cause and effect relationship between them. Correlation studies estimate the mutual association between the characters along with directions but lags to provide information on cause and effect relationship. Path analysis, a form standardized partial regression analysis that further allows the breakage of correlation coefficient values into components of direct and indirect effects of independent variables on the dependent one (Dewey and Lu 1959). Looking into the aspects discussed above, this investigation was undertaken to analyze the trait interrelationships through two important biometrical tools: Correlation coefficient analysis and path coefficient analysis.

MATERIALS AND METHODS

A collection includes thirty-one oat genotypes from Golden Jubilee Forage farm, AICRP on Forage crops, Assam Agricultural University, Jorhat were raised during *rabi* 2021-22 in the Experimental Farm (latitude 26°47' N, longitude 94°12' E and altitude 86.6m MSL), Department of Plant Breeding and Genetics, Assam Agricultural University. The experimental design followed here was Randomized Block Design consisted of 3 blocks representing replications. In each block, each genotype was grown in 2 rows of 4 m in length and 30 x 10 cm spacing was followed.

Five plants from each genotype in each block were randomly tagged. Readings on traits namely green fodder yield in kg/m^2 (GFY), dry matter yield in kg/m^2 (DMY), crop growth rate in g/m^2/day (CGR), Normalized Difference Vegetation Index value (NDVI) and fodder crude protein in % (FCP) were recorded on a row basis. Observations on other characters viz., plant height in cm (PH), number of leaves per plant (NOLP), leaf length in cm (LL), leaf width in cm (LW), culm diameter in cm (CD), number of tillers per plant (NOTP) and number of nodes per plant (NON) were noted only from the tagged plants. Handheld GreenSeeker™ (NTech Industries Inc., Ukiah, CA, USA) was used to measure the NDVI value. After the data on fodder attributes got recorded, whole green herbage was cut down leaving 15 cm stubble on 70 DAS. Then, the stubbles left in the field were allowed to rise as ratoon for grains. Again 12 traits attributing grain yield viz., days to 50% flowering (DFF), flag leaf length in cm (FLL), flag leaf width in cm (FLW), number of effective tillers per plant (NOET), panicle length in cm (PL), number of spikelets per panicle (SNPP), days to maturity (DM), grain yield per plant in g/plant (GYPP), 1000 seed weight (TSW), grain length in cm (GL), grain width in cm (GW) and grain crude protein in % (GCP) were observed. CD, GL and GW were measured using vernier calliper. Micro Kjeldahl principle was followed to estimate the crude protein content from both ground leaf and grain samples.

Statistical analysis: To establish the existence of variation for traits among genotypes, analysis of variation for RBD was carried out. As improvement in both fodder and grain yield are expected from the experimental material used, correlation and path analysis were done separately for fodder yield attributes and grain yield attributes. Both of the above said statistical parameters were computed in R studio (version 1.4.1106) using the statistical package "variability" (Popat *et al.* 2020). After analysing, the results were tabulated and the path diagram was drawn using the values computed. The correlation estimates between the investigation traits were classified (strong, moderate and weak) and shaded according to Dospekhov (1984).

RESULTS AND DISCUSSION

Analysis of variation establishing significant differences for trait values among the genotypes investigated denotes the opportunity available for the breeders aiming improvement to implement selection procedure once the interaction of one trait over other got understood clearly. Findings providing information on correlations among variables and on cause effect relationship paves the way for identification of essential trait to incorporate into the ideal plant type and to know about the efficiency of indirect and direct selections (Krishna *et al.* 2014).

Character interrelationship-green fodder yield: Tables 1 - 2 provide the estimates of correlation and path coefficients among traits attributing green fodder yield, respectively. Plant height (r_p=0.601, r_g=0.670), number of leaves per plant (r_p=0.549, r_g=0.640), leaf length (r_p=0.351, r_g=0.476) and leaf width (r_p=0.284, r_g=0.415) showed significant positive phenotypic as well as genotypic correlations with green fodder yield. Dry matter yield noticed to have significant positive phenotypic and genotypic correlations with plant height (r_p=0.511, r_g=0.485), number of leaves per plant (r_p=0.516, r_g=0.571) and leaf width (r_p=0.253, r_g=0.360). Reports of Raj and Lodhi (2009) and Singh *et al.* (2018) support this finding of the current investigation. Krishna *et al.* (2014) also reported the significant positive correlations of plant height and leaf length with green fodder yield. Dry matter yield (r_p=0.807, r_g=0.847) and crop growth rate (r_p=0.743, r_g=0.862) also showed strong significant positive phenotypic correlation with green fodder yield. Sim-

Table 1. Phenotypic (r_p - above diagonal) and genotypic (r_g - below diagonal) correlation coefficients among components traits of fodder yield.

	PH	NOLP	LL	LW	CD	NOTP	NONP	NDVI	DMY	CGR	FCP	GFY
PH		0.360**	0.663**	0.458**	0.087	0.150	0.484**	0.270**	0.511**	0.423**	-0.275**	**0.601****
NOLP	0.426*		0.195	-0.017	-0.295**	0.589**	0.317**	0.515**	0.516**	0.497**	-0.156	**0.549****
LL	0.605**	0.293		0.170	-0.014	-0.049	0.062	0.123	0.279**	0.222*	-0.039	**0.351****
LW	0.759**	0.039	0.571**		0.502**	-0.132	0.482**	0.232*	0.253*	0.160	-0.183	**0.284****
CD	0.546**	-0.300	0.803**	0.612**		-0.190	0.205*	0.123	-0.140	-0.185	0.167	-0.134
NOTP	0.428*	0.937**	0.329	-0.224	-0.518**		0.492**	0.617**	0.313**	0.326**	-0.113	**0.426****
NONP	0.912**	0.571**	0.535**	0.525**	0.035	0.496**		0.524**	0.247*	0.234*	-0.142	**0.403****
NDVI	0.629**	0.856**	0.759**	0.243	-0.050	0.636**	0.501**		0.266*	0.202	0.051	**0.385****
DMY	0.485**	0.571**	0.266	0.360*	0.013	0.487**	0.452*	0.511**		0.922**	-0.341**	**0.807****
CGR	0.432*	0.494**	0.2	0.290	-0.127	0.552**	0.468**	0.462**	0.983**		-0.292**	**0.743****
FCP	-0.213	-0.138	0.301	-0.227	0.132	-0.190	-0.239	0.038	-0.324	-0.303		-0.117
GFY	**0.670****	**0.640****	**0.476****	**0.415***	0.048	**0.629****	**0.636****	**0.598****	**0.847****	**0.862****	-0.073	

*, ** - Significance at 5% and 1% probability levels respectively.

Weak positive   Moderate positive   Strong positive

Weak negative   Moderate negative   Strong negative

Table 2. Estimates of direct (bold) and indirect effects of components traits on fodder yield from path analysis.

	PH	NOLP	LL	LW	CD	NOTP	NONP	NDVI	DMY	CGR	FCP	Total = r(GFY)
PH	**0.281**	0.030	-0.019	0.318	-0.025	0.228	-0.172	-0.173	0.106	0.174	-0.078	0.670**
NOLP	0.120	**0.070**	-0.009	0.016	0.014	0.500	-0.107	-0.235	0.124	0.198	-0.050	0.640**
LL	0.170	0.020	**-0.032**	0.239	-0.037	0.176	-0.101	-0.209	0.058	0.080	0.110	0.476**
LW	0.213	0.002	-0.018	**0.419**	-0.028	-0.120	-0.099	-0.067	0.079	0.116	-0.083	0.415**
CD	0.153	-0.020	-0.025	0.256	**-0.046**	-0.277	-0.007	0.014	0.003	-0.051	0.048	0.048
NOTP	0.120	0.065	-0.010	-0.094	0.024	**0.534**	-0.093	-0.175	0.106	0.222	-0.069	0.629**
NONP	0.256	0.040	-0.017	0.220	-0.002	0.265	**-0.188**	-0.136	0.099	0.188	-0.087	0.636**
NDVI	0.177	0.060	-0.024	0.102	0.002	0.340	-0.094	**-0.275**	0.111	0.186	0.013	0.598**
DMY	0.136	0.040	-0.008	0.151	-0.001	0.260	-0.085	-0.140	**0.218**	0.395	-0.118	0.847**
CGR	0.121	0.035	-0.006	0.121	0.006	0.295	-0.088	-0.127	0.215	**0.402**	-0.111	0.862**
FCP	-0.060	-0.010	-0.010	-0.095	-0.006	-0.101	0.045	-0.010	-0.071	-0.122	**0.366**	-0.073

Residual = 0.0542.
*, ** - Significance at 5% and 1% probability levels respectively.

ilar findings were observed by Poonia *et al.* (2017). Number of tillers per plant had significant positive correlation with dry matter yield (r_p=0.313, r_g=0.487) and green fodder yield (r_p=0.426, r_g=0.629) as in accordance with Wagh *et al*. (2018).

NDVI (r_p=0.385, r_g=0.598) had significant positive phenotypic and genotypic correlation with green fodder yield. The fact that assessment of NDVI value is based on the leaf greenness and crop density supports this result (Huang *et al.* 2014). Increased number of leaves and tillers per plant along with increased leaf length and width increases the crop density. As these traits had significant positive correlations with green fodder yield, NDVI also had the same. The non-significant correlation between fodder crude protein and green fodder yield can be justified with the findings of Poonia *et al*. (2017).

Plant height exhibited significant positive phenotypic and genotypic correlation with the traits number of leaves per plant (r_p=0.360, r_g=0.426), leaf length (r_p=0.663, r_g=0.605), leaf width (r_p=0.458, r_g=0.759), number of nodes per plant (r_p=0.484, r_g=0.912), NDVI (r_p=0.270, r_g=0.629) and crop growth rate (r_p=0.423, r_g=0.432). Such correlations were also reported by Kapoor *et al.* (2011). Significant level of positive phenotypic and genotypic correlations were recorded when interaction of number of leaves per plant analyzed with the characters number of tillers per plant (r_p=0.589, r_g=0.937), number of nodes per plant (r_p=0.317, r_g=0.571), NDVI (r_p=0.515, r_g=0.856) and crop growth rate (r_p=0.497, r_g=0.494). Number of tillers per plant exhibited significant positive correlation with number of nodes per plant (r_p=0.492, r_g=0.496), NDVI (r_p=0.617, r_g=0.636) and crop growth rate (r_p=0.326, r_g=0.552). Number of tiller per plant noticed to have significant negative genotypic correlation with culm diameter (r_g= -0.518). This adds the additional advantage in selection of increased number of tillers as it concurrently selects the genotypes with thin culm which is more preferred by dairy animals.

Results of the path coefficient analysis on 12 fodder crop traits revealed that the traits such as plant height (0.281), leaf width (0.419), number of tillers per plant (0.534), dry matter yield (0.218) and crop growth rate (0.402) exhibited moderate to high direct positive effect on green fodder yield. Also, these characters had significant positive correlations with green fodder yield. Similar effects were also reported by Negi *et al*. (2019). High direct positive effect of dry matter yield on green fodder yield was also reported in the findings of Krishna *et al*. (2014). As crop growth rate is the secondary parameter derived from the dry matter yield, it also showed high direct effect on green fodder yield. As these characters recorded moderate to high direct effects on dependent variable along with significant positive correlation, such traits can be used for construction of selection index to improve the fodder yield in oats.

Although fodder crude protein showed moderate positive direct effect, it had negative indirect effect through all other component traits. Because of this negative indirect effects, fodder crude protein exhibited non-significant negative correlation with green fodder yield. The characters number of nodes per plant (-0.188) and NDVI value (-0.275) showed to have moderate negative direct effect on green fodder yield albeit their correlations with fodder yield was positive. This restricts the reliability on those traits while selecting for fodder yield improvement in oats.

The accessions with reduced culm diameter may yield more green fodder per unit area as culm diameter (-0.046) had negative direct effect on green fodder yield. It is also evident that culm diameter exerted negative indirect effect through almost all other triats. This finding is in concurrence with Krishna *et al*. (2014). It is unlikely that highest negative indirect effect of culm diameter (-0.277) was shown through number of tillers per plant. Figure 1 depicts the path diagram indicating direct effects of component traits on green fodder yield and correlation among them. Residual effect for the path coefficient analysis on fodder attributes was measured to be 0.0542 which informs that the 12 traits chosen for this investigation were responsible for about 94.58% of total variability in green fodder yield.

Character interrelationship - grain yield: Tables 3 - 4 provide the estimates of correlation and path coefficients among traits attributing grain yield per plant, respectively. Traits namely 1000 seed weight (r_p=0.589, r_g=0.602), flag leaf length (r_p=0.477, r_g=0.604), number of effective tillers per plant (r_p=0.631, r_g=0.708) and panicle length (r_p=0.253, r_g=0.360) showed significant positive phenotypic correlation and genotypic correlation with grain yield per plant. Other traits exhibited non-significant correlations with grain yield per plant. Similar findings were reported by Kumar *et al*. (2016) and Negi *et al*. (2019).

The significant positive phenotypic and genotypic correlation between number of effective tillers per plant and grain yield per plant was noticed in the present investigation is in agreement with the findings of Lorencetti *et al*. (2006). Spikelets number per panicle (r_p=0.322) also showed significant positive phenotypic correlation with grain yield. Findings of Surje and De (2014) provide the evidence for positive significant correlation of number of effective tillers per plant, panicle length, and spikelets number per plant with grain yield per plant. Number of effective tillers per plant (r_g=0.769) reported significant positive genotypic correlation with flag leaf

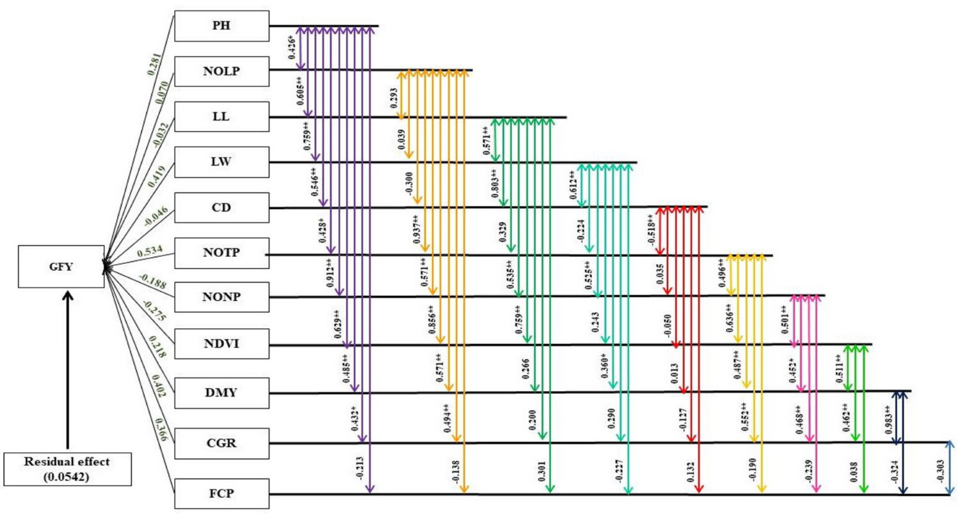

Fig. 1. Path diagram indicating direct effects of fodder attributing traits on green fodder yield and correlation among them.

Table 3. Phenotypic (r_p - above diagonal) and genotypic (r_g - below diagonal) correlation coefficients among components traits of grain yield.

	DFF	FLL	FLW	NOET	PL	SNPP	DM	TSW	GL	GW	GCP	GYPP
DFF		-0.173	-0.079	-0.001	0.122	-0.085	0.332**	0.041	-0.142	0.126	-0.075	-0.064
FLL	-0.256		0.217*	0.337**	0.376**	0.185	-0.115	0.284**	0.270**	0.338**	0.179	**0.477****
FLW	-0.073	-0.286		-0.495**	0.350**	0.619**	0.132	0.194	0.173	0.216*	0.333**	0.055
NOET	-0.027	0.769**	-0.501**		-0.106	-0.287**	-0.241*	0.144	-0.131	-0.022	-0.320**	**0.631****
PL	0.317	-0.043	0.148	0.027		0.389**	-0.004	0.252*	0.356**	0.325**	0.354**	0.253*
SNPP	-0.088	-0.002	0.657**	-0.250	0.499**		0.101	0.178	0.174	0.08	0.354**	**0.322****
DM	0.934**	-0.239	0.192	-0.366*	0.287	0.193		-0.018	-0.063	-0.011	0.023	-0.111
TSW	0.116	0.116	0.061	0.235	0.171	0.123	-0.069		0.192	0.272**	-0.100	**0.589****
GL	-0.174	-0.163	-0.138	-0.026	0.241	-0.034	-0.043	0.004		0.248*	0.446**	0.068
GW	0.412*	-0.426*	-0.497**	0.262	-0.819**	-0.329	0.032	0.195	-0.182		0.180	0.122
GCP	-0.049	-0.339	0.066	-0.279	0.199	0.281	0.035	-0.354	0.262	-0.510**		-0.028
GYPP	-0.051	**0.604****	-0.040	**0.708****	**0.360***	0.313	-0.205	**0.602****	-0.027	0.048	-0.139	

*, ** - Significance at 5% and 1% probability levels respectively.

Weak positive Moderate positive Strong positive

Weak negative Moderate negative Strong negative

length. Also, the traits spikelets number per panicle (r_p=0.389), grain length (r_p=0.356) and grain crude protein (r_p=0.354) found to have significant positive phenotypic correlation with panicle length. Earliness in grain crops is the most preferable character. As the traits, days to 50% flowering and days to maturity had negative but non-significant correlation with grain yield per plant, to some extent, one can assume that the genotypes which flowers and matures earlier may have higher grain yield.

In the current study, it was also witnessed that days to 50% flowering (r_p=0.332, r_g=0.0.934) had strong significant positive correlation with days to maturity. Thus, selecting early flowering accessions indirectly selects the early maturing genotypes. This is in agreement with the reports of Singh *et al*. (2018). Highly significant negative genotypic correlation was observed between grain width (r_g= -0.819) and panicle length which suggested that bold seeded genotypes have shorter panicles.

The findings recorded from the path analysis on 12 grain crop traits informed that highest positive direct effect on grain yield was shown by the trait number of effective tillers per plant (0.633) followed by spikelets number per panicle (0.441), and 1000 seed weight (0.383). Days to 50% flowering (0.212) also showed considerable positive direct effect on grain yield. All such traits aforementioned were observed to have significant positive correlation with the dependent variable grain yield per plant. Therefore, selection for grain yield can be done indirect through early flowering genotypes which have increased number of effective tillers along with larger grains. Kumar *et al*. (2016) also observed the positive direct effect accompanied positive correlations of number of effective tillers per plant, spikelets number per plant and 1000 seed weight on grain yield. Findings of Shankar *et al*. (2002) confirms the positive direct effect of spikelets number per panicle on grain yield per plant. Flag leaf length (0.086) was reported to have low positive direct effect associated positive correlation with grain yield per plant. This finding is in near agreement with reports of Kapoor *et al*. (2011). They also reported the positive direct effects of spikelets number per panicle. Thus, genotypes resembling longer flag leaves along with numerous spikelets per panicle could be selected indirectly to attain higher grain yield.

Days to maturity (-0.211) had moderate negative

Table 4. Estimates of direct (bold) and indirect effects of components traits on grain yield from path analysis.

	DFF	FLL	FLW	NOET	PL	SNPP	DM	TSW	GL	GW	GCP	Total = r(GYPP)
DFF	**0.212**	-0.022	-0.001	-0.017	-0.003	-0.039	-0.197	0.044	-0.004	-0.021	-0.003	-0.051
FLL	-0.05	**0.086**	-0.005	0.487	0.0004	-0.007	0.050	0.045	-0.004	0.022	-0.022	0.604**
FLW	-0.015	-0.024	**0.019**	-0.317	-0.001	0.290	-0.041	0.023	-0.003	0.026	0.004	-0.040
NOET	-0.006	0.066	-0.010	**0.633**	-0.0002	-0.110	0.077	0.090	-0.006	-0.014	-0.018	0.708**
PL	0.067	-0.004	0.003	0.017	**-0.008**	0.220	-0.061	0.066	0.006	0.042	0.013	0.360**
SNPP	-0.017	-0.0001	0.012	-0.158	-0.004	**0.441**	-0.041	0.047	-0.008	0.017	0.018	0.313
DM	0.198	-0.020	0.004	-0.231	-0.002	0.085	**-0.211**	-0.027	-0.001	-0.002	0.002	-0.205
TSW	0.025	0.010	0.001	0.148	-0.001	0.054	0.015	**0.383**	0.0001	-0.010	-0.023	0.602**
GL	-0.037	-0.014	-0.003	-0.016	-0.002	-0.015	0.009	0.002	**0.023**	0.009	0.017	-0.027
GW	0.087	-0.036	-0.009	0.164	0.007	-0.144	-0.007	0.074	-0.004	**-0.052**	-0.032	0.048
GCP	-0.010	-0.029	0.001	-0.177	-0.002	0.124	-0.007	-0.136	0.006	0.026	**0.064**	-0.139

Residual = 0.1150.
*, ** - Significance at 5% and 1% probability levels respectively.

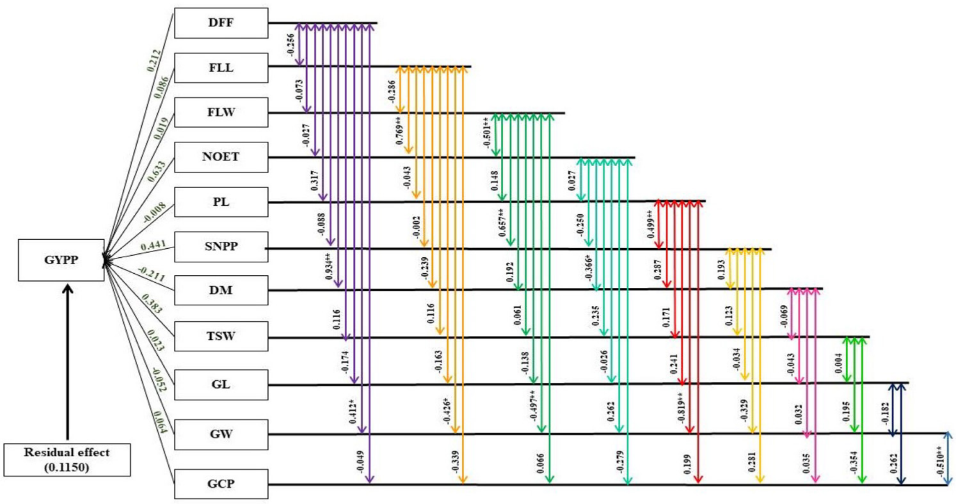

Fig. 2. Path diagram indicating direct effects of grain attributing traits on grain yield per plant and correlation among them.

direct effect on grain yield per plant. Also, the correlation results said there was the negative genotypic correlation found between days to maturity and grain yield. This result suggests that early maturing genotypes might be poor grain yielders. Panicle length (-0.008) also showed negative direct effect on grain yield per plant but which is very much negligible.

Indirect effects of flag leaf length through number of effective tillers per plant (0.487), flag leaf width through spikelets number per panicle (0.290) and panicle length through spikelets number per panicle (0.220) were noticed to be considerable. Furthermore, the correlations among them were found significantly positive. So, indirect selection of such traits might be effective. Figure 2 depicts the path diagram indicating direct effects of component traits on grain yield per plant and correlation among them. Estimate of residual for this path analysis was measured as 0.1150. This explains that the 12 grain attributes chosen for this study contributes about 88.50% of total variability present in grain yield per plant.

CONCLUSION

In light of the results from the current investigation, the traits, that should be given importance for the generation of oat varieties to serve as dual purpose crop are gets unravelled. Careful construction of selection index by combining useful traits highlighted in the findings may show up the best genotype presenting potential economic yield in terms of fodder and grains. Further in future, assessing the character associationship among the significant fodder and grain contributing traits in a single experiment may reveal interesting facts on interrelations to breed more promising dual purpose varieties which could gain maximum returns to the farmers.

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