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Multivariate analysis in durum wheat [*Triticum turgidum* L. subsp. *durum* (Desf.)]

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Abstract
The study was conducted with Randomized Block Design with three replications and fourty genotypes of durum wheat at Junagadh Agricultural University, during the *rabi* 2020-21 growing season. The analysis is done using the indo-stat software. Correlation studies of the characters, grain yield per plant was found to be significantly and positively correlated with plant height followed by number of productive tillers per plant, biological yield per plant and harvest index at both the genotypic and phenotypic levels. The path analysis revealed that biological yield per plant and harvest index exhibited high and positive direct effect on grain yield per plant and was found to be the most important yield components. The characters, days to maturity had moderate and positive direct effect on grain yield per plant. While days to 50% flowering and grain filling period had low and negative direct effect on grain yield per plant. Thus, these characters were the most important traits and may contribute considerably towards higher grain yield.

Keywords: Durum wheat, multivariate, correlation coefficient, path coefficient analysis

Introduction
Wheat belongs to the genus *Triticum* of Poaceae family and believed to be originated from South West Asia (Lupton, 1987) [10]. The bread wheat, a hexaploid with chromosome number 2n=42 is cultivated in all the wheat growing areas of the country. The macaroni or *durum* wheat (tetraploid, 2n=28) is considered very old and is grown from Punjab in North India to Karnataka in South and from Gujarat in West to Bengal in East, while the emmer wheat (tetraploid 2n=28) is confined to the Southern states (mainly Karnataka) and some parts of Gujarat.The primary objective of any crop improvement programme is to increase crop yield. Correlation provides information about the relative contribution of various component traits towards economic yield. Genotypic correlations provide a measure of genetic association between characters and are generally used in selecting for one character as means for improving another. Path analysis splits the correlation coefficient into the measures of direct and indirect effects and determines the direct and indirect contribution of various characters towards yields. Grain yield, a polygenic trait, is influenced by its various components directly as well as indirectly *via* other traits, which create a complex situation for a breeder for making selection. When two or more variables are included in the correlation studies, it becomes difficult to determine which characters enhance the yield. The technique of path coefficient analysis overcomes this situation which partitions the forces of association and examines the relative contribution of direct and indirect effects of the independent variables on the dependent variables.

Material and Methods
The study was carried with aim to assess the correlation coefficient and path analysis in durum wheat during *rabi* 2020-21, the research was conducted at the Wheat Research Station, Department of Genetics and Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh. The experimental material consisted of 40 diverse genotypes of durum wheat. Each genotype was sown in a single row plot of 2.0 m lengths with a spacing of 22.5 cm × 10 cm. The observation was recorded for grain yield and its contributing traits *viz*., days to 50% flowering, days to maturity, grain filling period (days), plant height (cm), number of productive tillers per plant, spike length (cm), number of grains per main spike, grain weight per main spike (g), grain yield per plant (g), biological yield per plant (g), harvest index, 1000 - grain weight (g). The phenotypic and genotypic correlation coefficients of all the pairs of characters were worked out as per Al-Jibouri *et al*. (1958) [4]. The path coefficient analysis was carried out as per the method suggested by Dewey and Lu (1959) [5]

Results and discussion

The analysis of variance revealed that mean square due to genotypes was highly significant for all the 20 characters indicating the presence of sufficient amount of variability in the experimental material used.

Correlation coefficients

The correlation coefficients were worked out among 20 characters to find out the association of grain yield per plant with its components at genotypic (r_g) and phenotypic (r_p) levels. The data given in Table 1 revealed that, in general, the genotypic correlation coefficients were relatively higher than their corresponding phenotypic correlation coefficients.

In the present study, grain yield per plant was found to be significantly and positively correlated with plant height, number of productive tillers per plant, biological yield per plant and harvest index at both the genotypic and phenotypic levels. Such positive interrelationship between grain yield per plant and these attributes has also been reported in durum wheat by several researchers. The positive genotypic and phenotypic association has been reported for plant height, number of productive tillers per plant, biological yield per plant and harvest index with grain yield per plant by Talebi *et al*. (2010) [18], Abinasa *et al*. (2011) [1], Tsegaye *et al*. (2012) [21], Siabidi *et al*. (2013), Zeeshan *et al*. (2014) [23], Singh (2016) [17], Tegenu *et al*. (2019) [20] and Alemu *et al*. (2020) [3] for harvest index; Siabidi *et al*. (2013), Malav (2015) [12], Singh (2016) [17], Tegenu *et al*. (2019) [20] and Alemu *et al*. (2020) [3] for biological yield per plant; Shimelis (2006) [15], Khan *et al*. (2013) [8], Tegenu *et al*. (2019) [20] and Alemu *et al*. (2020) [3] for plant height; Monpara (2009) [14], Khan and Dar (2010) [9], Tsegaye *et al*. (2012) [21], Tambe *et al*. (2013) [19], Zeeshan *et al*. (2014) [23] and Singh (2016) [17] for number of productive tillers per plant.

Days to 50% flowering possessed highly significant and positive genotypic and phenotypic correlation with days to maturity, number of productive tillers per plant, biological yield per plant at genotypic level. Similar results were reported by Singh (2016) [17] for days to maturity; Gashaw *et al*. (2010) [7] and Abinasa *et al*. (2011) [1] for biological yield per plant. Days to maturity possessed highly significant and positive genotypic and phenotypic correlation with number of productive tillers per plant and biological yield per plant. Similar results were reported by Siahbidi *et al*. (2013) [16].

Grain filling period possessed highly significant and positive genotypic and phenotypic correlation with grain weight per main spike. It had significant and positive correlation with plant height and 1000 - grain weight. Similar results were reported by Siahbidi *et al*. (2013) [16] for plant height and Tambe *et al*. (2013) [19] for 1000 - grain weight.

Plant height possessed significant and positive genotypic and phenotypic correlation with biological yield per plant and grain weight per main spike at genotypic level. Similar results were reported by Dogan *et al*. (2009) [6], Yagdi and Sozen (2009) [22], Talebi *et al*. (2010) [18], Tegenu *et al*. (2019) [20] and Alemu *et al*. (2020) [3]. Number of productive tillers per plant possessed highly significant and positive genotypic and phenotypic correlation with biological yield per plant. Similar results were observed by Yagdi and Sozen (2009) [22], Gashaw *et al*. (2010) [7] and Tsegaye *et al*. (2012) [21] for biological yield per plant.

Number of grains per main spike possesses highly significant and positive genotypic and phenotypic correlation with grain weight per main spike. Similar results were observed by Abinasa *et al*. (2011) [1] and Singh (2016) [17]. Grain weight per main spike possessed highly significant and positive genotypic correlation with 1000 - grain weight. It had a significant and positive phenotypic correlation with 1000 - grain weight. Similar results were observed by Yagdi and Sozen (2009) [22]. Harvest index possessed highly significant and positive genotypic and phenotypic correlation with 1000 - grain weight. Similar results were observed reported by Gashaw *et al*. (2010) [7], Abinasa *et al*. (2011) [1], Tsegaye *et al*. (2012) [21], Siahbidi *et al*. (2013) [16] and Alemu *et al*. (2020) [3].

The present results on correlation coefficients revealed that plant height, number of productive tillers per plant, biological yield per plant and harvest index were the most important attributes and may contribute considerably towards higher grain yield. The interrelationship among yield components would help in increasing the yield levels and therefore, more emphasis should be given to these components while selecting better types in durum wheat.

Path coefficient analysis

The path coefficient analysis revealed that the biological yield per plant and harvest index exhibited high and positive direct effects on grain yield per plant as shown in table 2. Similar result has been reported by Majumder *et al*. (2008) [11], Abinasa *et al*. (2011) [1], Ahmadizadeh *et al*. (2011) [2], Tsegaye *et al*. (2012) [21], Singh (2016) [17], Mecha *et al*. (2017) [13] and Tegenu *et al*. (2019) [20].

Days to maturity exhibited moderate and positive direct effect on grain yield per plant. Number of productive tillers per plant, length of main spike, grain weight per main spike and 1000 - grain weight exhibited very low and positive direct effect on grain yield per plant. Thus, these characters turned-out to be minor components.

Days to 50% flowering and grain filling period exhibited low and negative direct effect on grain yield per plant. Plant height and number of grains per main spike exhibited low and negative direct effect on grain yield per plant.

In path coefficient analysis number of productive tillers per plant, days to 50% flowering and days to maturity exhibited high and positive indirect effects *via* biological yield per plant. Plant height exhibited moderate and positive indirect effect *via* biological yield per plant. 1000 - grain weight exhibited moderate and positive indirect effect *via* harvest index. Grain filling period exhibited low and positive indirect effect *via* harvest index.

The residual effect of the present study in path analysis was 0.154 indicating that the characters studied contributed 84.60 per cent of the yield. It is suggested that maximum emphasis should be given to all the characters studied in selecting wheat with higher yield.

Table 1: Genotypic (r_g) & phenotypic (r_p) correlation coefficient among twenty traits in fourty genotypes of durum wheat.

Traits		DFF	DM	GFP	PH	NPTP	LMS	NGMS	GWMS	BYP	HI	1000-GW
GYP	r_g	0.2550	0.3354*	0.0464	0.4563**	0.5222**	-0.0441	-0.1239	0.1041	0.6552**	0.5210**	-0.0845
	r_p	0.2297	0.2926	0.0548	0.3978**	0.4763**	-0.0313	-0.1095	0.0882	0.6260**	0.5419**	-0.0635
DFF	r_g		0.8775**	-0.4431**	0.0511	0.7014**	-0.4185**	-0.0155	-0.4126**	0.5895**	-0.3775*	-0.4843 **
	r_p		0.8119**	-0.4182**	0.0603	0.6262**	-0.3499*	0.0177	-0.2939	0.5655**	-0.3698*	-0.4072 **
DM	r_g			0.1443	0.2892	0.6594**	-0.4128**	-0.1064	-0.0621	0.6127**	-0.3415*	-0.2791
	r_p			0.1566	0.2710	0.5666**	-0.3515*	-0.0559	-0.0305	0.5576**	-0.3162*	-0.2184
GFP	r_g				0.3892*	-0.2239	0.0532	-0.0067	0.6471**	-0.0790	0.1072	0.3501*
	r_p				0.3532*	-0.1874	0.0192	-0.0431	0.4557**	-0.0825	0.1256	0.2830
PH	r_g					0.2958	0.2342	0.0755	0.3526*	0.3668*	0.1271	0.2002
	r_p					0.2715	0.1978	0.0737	0.2916	0.3451*	0.0978	0.1812
NPTP	r_g						-0.2469	0.0646	-0.3416*	0.9183**	-0.3670*	-0.7599 **
	r_p						-0.1615	0.0872	-0.2000	0.8631**	-0.3340*	-0.5930 **
LMS	r_g							0.0929	0.2256	-0.1293	0.0512	0.2624
	r_p							0.1378	0.2757	-0.0798	0.0126	0.2462
NGMS	r_g								0.4940**	0.0702	-0.2184	-0.3847*
	r_p								0.4509**	0.0673	-0.2092	-0.3231*
GWMS	r_g									-0.0203	0.1441	0.4659 **
	r_p									0.0156	0.0775	0.3662*
BYP	r_g										-0.2829	-0.5098 **
	r_p										-0.2870	-0.4142 **
HI	r_g											0.3970 **
	r_p											0.3234*

*, ** Significant at 5% & 1% levels, respectively

Table 2: Phenotypic path coefficient analysis showing direct (diagonal and bold) and indirect effects of different characters on grain yield per plant in fourty genotypes of durum wheat

Traits	DFF	DM	GFP	PH	NPTP	LMS	NGMS	GWMS	BYP	HI	1000-GW
DFF	-0.1013	0.1691	0.0422	-0.0017	0.0374	-0.0062	-0.0002	-0.0124	0.4506	-0.2984	-0.0202
DM	-0.0822	0.2083	-0.0158	-0.0078	0.0339	-0.0062	0.0006	-0.0013	0.4444	-0.2551	-0.0108
GFP	0.0424	0.0326	-0.1008	-0.0101	-0.0112	0.0003	0.0005	0.0193	-0.0658	0.1013	0.0140
PH	-0.0061	0.0564	-0.0356	-0.0287	0.0162	0.0035	-0.0008	0.0124	0.2750	0.0789	0.0090
NPTP	-0.0634	0.1180	0.0189	-0.0078	0.0598	-0.0028	-0.0010	-0.0085	0.6878	-0.2695	-0.0294
LMS	0.0354	-0.0732	-0.0019	-0.0057	-0.0097	0.0176	-0.0016	0.0117	-0.0636	0.0102	0.0122
NGMS	-0.0018	-0.0116	0.0043	-0.0021	0.0052	0.0024	-0.0115	0.0191	0.0536	-0.1688	-0.0160
GWMS	0.0298	-0.0063	-0.0459	-0.0084	-0.0120	0.0048	-0.0052	0.0424	0.0125	0.0626	0.0181
BYP	-0.0573	0.1161	0.0083	-0.0099	0.0516	-0.0014	-0.0008	0.0007	0.7969	-0.2316	-0.0205
HI	0.0375	-0.0658	-0.0127	-0.0028	-0.0200	0.0002	0.0024	0.0033	-0.2288	0.8067	0.0160
1000-GW	0.0412	-0.0455	-0.0285	-0.0052	-0.0355	0.0043	0.0037	0.0155	-0.3301	0.2609	0.0495

*, ** Significant at 5% & 1% levels, respectively (Residual effect, R = 0.154**)**

Abbreviations

DFF = Days to 50% flowering	DM = Days to maturity
GFP = Grain filling period	PH = Plant height
NPTP = No. of productive tillers / plant	LMS = Length of main spike
NGMS = No. of grains per main spike	GWMS = Grain weight per main spike
GYP = Grain yield per plant	BYP = Biological yield per plant
HI = Harvest index	1000-GW = 1000 - Grain weight

Conclusions

The present results on correlation coefficients revealed that plant height, number of productive tillers per plant, biological yield per plant and harvest index were the most important traits and may contribute considerably towards higher grain yield. The interrelationship among grain yield components would help in increasing the grain yield levels. The path coefficient analysis revealed that biological yield per plant and harvest index exhibited high and positive direct effect on grain yield per plant and that was found to be the most important yield components. The characters Days to maturity exhibited moderate and positive direct effect on grain yield per plant. Number of productive tillers per plant, length of main spike, grain weight per main spike and 1000 - grain weight exhibited very low and positive direct effect on grain yield per plant. While days to 50% flowering and grain filling period had low and negative direct effect on grain yield per plant. Thus, these characters turned-out to be minor components of grain yield.

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