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Determination of the best indirect selection criteria to improve grain yield and seed weight in oat (Avena sativa L.) genotypes

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ABSTRACT: This research was carried out in 2011-2012 years in Kermanshah province located in west Region of Iran. The experimental design was randomized complete block design with three replications. The aim of research was to determine correlation coefficients of 21 oat genotypes among grain yield (GY) and days to flowering (DF), grain number panicle^{-1} (GNP^{-1}), 1000 grain weight (1000-GW), grain filling period (GFP), panicle number m^{-2} (PN m^{-2}). Determined direct and indirect effects of yield components on GY through path analysis were also determined. Based on results of correlation coefficients, GY had non-significant relationship with other traits while 1000-GW showed negative and highly significant correlation with DF and GNP. PN m^{-2} had positive and significant relation with 1000-GW. Path coefficient analysis indicated that PN m^{-2} and GNP had positive direct effects on GY while DF had positive and direct effect on GNP. However, when the positive direct and indirect effects were added to the negative direct and indirect effects for traits, the sum of direct and indirect effects of GFP and PN m^{-2} on GY were positive. Also, the direct effect of panicle number m^{-2} on 1000-GW was positive. The effects of these traits were higher than those of 1000-GW and GNP^{-1}. In conclusion PN m^{-2} and GNP could have priorities in breeding programs to improve genetically grain yield via indirect selection especially in early generations. Over all, in order to improve the trait 1000-GW selection for higher amounts of PN m^{-2} should be done in preliminary testing.

***Keywords*:** Oat, correlation, path analysis, grain filling period, days to flowering, grain

INTRODUCTION

Oat (Avena sativa L.) is a cereal crop that is used worldwide for human food and animal feed. Compared to other cereal crops, oat is reputed to be better suited for production under marginal environments, including cool- wet climates and soils with low fertility (Lorencetti et al., 2006). However, oat yield cannot compete with wheat and barley grain yields, in the other production areas. It needs improved grain yield for most of the production areas. Grain yield is the result of a number of complex morphological and physiological processes affecting each other and occurring in different growing stages (Dokuyucu and Akkaya, 1999; Akhtar et al., 2011). In general, oat breeders select varieties based on grain yield and desirable traits, observed from heading to maturity. Beside grain yield, these traits are panicle number per square meter, plant height, number of grains per panicle, grain weight per panicle, 1000-grain weight, days to maturity and grain filling period.

The advantage of path analysis is that it permits the partitioning of the correlation coefficient into its components (Dewey and Lu, 1959). In agriculture, path analyses have been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield (Dewey and Lu, 1959; Milligan et al., 1990). This technique is useful in determining the direct influence of one variable on another, and also separates the correlation coefficient into its components (Rodriguez et al., 2001). Path analysis is a tool that is available to the breeder for better understanding the causes involved in the associations between traits and to partition the existing correlation into direct and indirect effects, through a main variable (Lorencetti et al., 2006).

There is rather agreement among plant breeders that associations among oat (Avena sativa L.) agronomic traits are very important to increase the use of indirect selection to improve grain yield (Benin et al., 2003). (Benin et al., 2003) reported that direct and indirect effect of panicle weight, panicle number per plant and average grain weight could help to identify oat plants with large grain production and improving genetic gain efficiency. The number of panicles per plant showed to be the most correlated trait with GY of individual oat plants by means of simple correlations as via direct effects on grain yield (Lorencetti et al., 2006). (Moradi et al., 2005) also determined that PN m-2 and GNP showed the highest direct effect on GY of oat. Meanwhile, there are too limited researches related with path analyses on oat genotypes in the literature, especially for East-Mediterranean environments.

However, for other cereal plants, grain yield has been reported to be influenced by high direct effects of total tillers and days to flowering (Amirthadevarathinam, 1983), the number of panicles per plant, the number of filled grains per panicle and 1000-grain weight (Yang, 1986), the number of filled grains per panicle and plant height (Ruben and Katuli, 1989), productive tillers, panicle length and flowering time (İbrahim et al., 1990), plant height and tiller number (Kumar, 1992), panicle number plant-1 and spikelet number panicle-1 , the number of effective tillers plant-1, grains panicle-1 and 1000 grain weight, grains panicle-1 and productive tillers, the number of filled grains panicle-1 and 1000 grain weight and biological yield, harvest index and 1000-grain weight (Sürek et al., 1998).

The aims of this study were; i) to estimate Pearson correlation coefficients between grain yield and yield components for oat genotypes, and ii) to investigate direct and indirect effects of yield components on oat grain yield and 1000-seed weight.

MATERIALS AND METHODS

Twenty one oat (Avena sativa L.) genotypes used in this study were entitled; Ozark, Ugf775456, Wallaroo, Euro, Wintaroo, GA Mitchell, Potoroo, 13Zop95, Mortlock, OH1022, IA91098-2(High oil –β glucan), 42Zop95, Swan, Kaloptt, Tarahumara, C1/130, Ufrgs948886, Nasta, Brusher, Arnold and Quall.

Field experiments were carried out during 2011-2012. The experimental design was a randomized complete block with three replications. The oat was drill- seeded @ 450 seeds m-2 on November 2011. Each plot consisted of five rows 2 m long and 0.2 m space between rows. Fertilizer was applied in sufficient amount. The whole path diagram can be described as composed of component paths, with each component path having its respective response variable-grain yield, days to flowering (DF), grain number per panicle (GNP), 1000 grain weight (1000-GW), grain filling period (GFP) and panicle number m-2 (PN m-2).

Herbicide (Tribenuron-Methyl 75%) was used for weed control. Traits included in the correlation and path analysis were days to flowering (DF), grain number per panicle (GNP), 1000 grain weight (1000-GW), grain filling period (GFP) and panicle number m-2 (PN m-2) and grain yield (GY). Data for these traits was obtained from inner 3 rows of each plot. Before harvest, the number of panicle number m-2 was counted in the harvest area. Plant height was measured as cm from the base of the lowest culms of oat plant to tip of the furthest panicle on main stem, then 10- panicle sub-samples were randomly harvested before grain yield harvest from these 3 rows, to determine grain number and 1000-grain weight.

The number of days from emergence to flowering was also counted. Grain yield (kg/ha) was determined by weighed of grains obtained after the harvest of rest area in each plot. Correlation coefficients between all pairs of variables were computed based on Pearson's method. The yield-related traits were arranged into first- and second-order variables in the initial path diagram on the basis of previous path and Pearson correlations and path coefficients among yield and yield components were determined using SAS9.02 and PATH2 statistical softwares.

RESULTS AND DISCUSSION

Correlation coefficients between all pairs of variables used in this experiment are shown in Table 1. According to the correlation coefficients, there was non-significant correlation among seed yield and the other traits that were measured on oat genotypes. In previous works, (Buerstmayr et al., 2007) determined significant and negative correlations between yield components and grain yield in oat plants and reported that plant height, panicle number per plant and grain number per panicle were also positively correlated with seed yield. (Rocquigny et al., 2004) also reported that the semi dwarf character in cereals was associated with increased yield. These results are in consistent with our findings.

Table 1. Correlation coefficients among the measured traits based on Pearson's method

	SY	1000-SW	GNP^{-1}	GFP	PNm^{-2}
Days to Flowering	-0.146	-0.670**	0.720**	-0.846**	-0.402
Panicle Number per m2	0.391	0.518**	-0.515*	0.398	
Grain Filling Period	0.278	0.431	-0.664**		
Grain Number per Panicle	-0.381	-0.626**			
1000 Grain Weight	0.197				

*and **: significant at 5 and 1% probability levels, respectively

Correlation coefficients were not enough to determine traits as selection criteria in our study. In agriculture, path analyses have been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield (Dewey and Lu, 1959; Milligan et al., 1990). Path analysis was conducted to determine direct and indirect effect of traits on oat yield, and the results from path analysis are given in tables 2 and 3.

Path analysis for grain yield in oat genotypes showed that traits PNm-2 and GNP-1 had the highest direct effect on this important trait (Table 2). However, these direct effects are positive and negative, respectively. Because of that these traits were determined as the best indirect selection criteria to improve grain yield.

(Ruben and Katuli ,1989; Kumar, 1992) reported direct effect of PH on GY for wheat and barley plants, respectively. (Bhutta et al., 2005) also reported negative direct effect of PH on grain yield for six-rowed barley genotypes. Our findings are in agreement with these results mentioned above.(Moradi et al., 2005) also found that GNP showed the highest direct effect on GY of oat genotypes. Our findings are partly in agreement with these results mentioned above.

It was reported that selection for plants with fewer days from emergence to flowering and longer period between flowering and maturation would provide higher grain yielding genotypes (Lorencetti et al., 2006). This findings isn't in agreement with results given from present study.

Table 2. Path analysis for grain yield as dependent variable

	PNm^{-2}	GNP^{-1}	1000-SW	Sum of effects
PNm^{-2}	<u>0.31</u>	0.17	-0.90	0.39
GNP^{-1}	-0.16	<u>-0.33</u>	0.11	-0.38
1000-SW	0.16	0.20	<u>-0.17</u>	0.19
Residual	0.12			

(Moradi et al., 2005) reported that PN m-2 and GNP had the highest direct effect on GY. (Lorencetti et al., 2006) also reported higher direct effect of PN m-2 on GY and its great importance in determining GY of a genotype.

The results given by path analysis for 1000-seed weight (Table 3) dictated on importance of GNP-1 as the proper indirect selection criteria for improvement of 1000-seed weight. (Dumlupinar et al., 2012) reported similar results. For 1000-seed weight. (Although, Sürek et al., 1998) find that traits PNm-2 and GNP^{-1} had negative effect on 1000-seed weight and introduced these traits as the best selection criteria.

Grain filling period (GFP) had positive direct effect on 1000-seed weight but this effect was very low (Table 3). Because of that this trait isn't suitable to determine as the selection criteria. (Buerstmayr et al., 2007) pointed out that earliness was a breeding goal in many oat breeding programs. (Lorencetti et al., 2006) also reported that selection for plants with longer period between flowering and maturation. Our findings are in agreement with the results obtained from previous works.

Table 3. Path analysis for 1000-seed weight as dependent variable

	GNP^{-1}	PNm^{-2}	GFP	Sum of effects
GNP^{-1}	<u>-0.29</u>	-0.14	-0.001	-0.626
PNm^{-2}	0.15	<u>0.26</u>	0.001	0.518
GFP	0.19	0.11	<u>0.002</u>	0.431
Residual	0.17			

In conclusion, according to the correlation coefficients, grain yield had non-significant relationship with other traits studied. Path analysis revealed that traits panicle number per square meter and grain number per panicle were had the highest positive and negative direct effects on grain yield, respectively. Therefore, these traits were determined as the best selection criteria to improve grain yield via indirect selection. On the other hand, traits panicle number per square meter and grain number per panicle showed positive and negative effects on 1000-seed weight. Because of that, these traits also introduced as the most important criteria to improve 1000-seed weight. Over all, panicle number per square meter and grain number per panicle have sufficient potential for breeding of grain yield and seed weight thought indirect selection programs.

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