

Correlation and Path Coefficient Analyses of Grain Yield and Yield Components in Two-Rowed of Barley (*Hordeum vulgare* convar. *distichon*) Varieties

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Abstract

This research sought to determine the correlations between grain yield and yield components and to measure the direct and indirect effects of yield components on grain yield in barley by using correlation coefficient and path analysis methods, respectively. This research was conducted with ten varieties of two-rowed barley under the ecological conditions of the coastal zone of northwest Turkey during the years 2003-2004. Agronomic traits such as grain yield, plant height, spike length, kernel number per spike, kernel weight per spike, spike number per m², harvest index and 1000-kernel weight were determined. The data from two years were combined. Correlation analyses indicated that the grain yield was positively and significantly associated with all the yield components except 1000-kernel weight. The highest correlation coefficients were found between grain yield and kernel number per spike ($r = +0.406$), and between grain yield and harvest index ($r = +0.474$). Results of path analyses indicated that harvest index had the greatest direct effect (+0.7716) on grain yield followed by spike number per m² (+0.3359) and kernel number per spike (+0.2081). Percentages of their direct effect were 71.97%, 48.47% and 28.22%, respectively. On the other hand, most of the indirect effects of yield components on grain yield were found to be significant and positive. Because of the significant effects of the harvest index, spike number per m² and kernel number per spike on grain yield, they may be regarded as criteria for barley improvement and breeding programs.

Keywords: barley, correlation, grain yield, path analysis, yield components

Introduction

Barley (*Hordeum vulgare* L.) is a common cereal used as food and as a feed crop. Barley is grown in nearly all the cultivated areas of the world. In Turkey, it is an important cereal crop, ranked second after wheat both in acreage and in production. For this reason and because of the need for new varieties, many studies aimed at creating improved, new genotypes have recently been conducted. A considerable number of grain production studies on barley include statistical correlations between agronomic and morphological characteristics and grain yield. Although these correlations are helpful in determining the principal components influencing final grain yield, they provide an incomplete representation of the relative importance of direct and indirect influences on the individual factors involved (Garcia del Moral *et al.*, 1991). This generalization applies particularly to cereals. In cereals, yield components appear consecutively during the growing season, and they may compensate for each other's effects. It is known that the grain yield in cereals is determined by certain interrelated yield components. To identify the dimension of the effect of each yield component on grain yield is of importance for use in defining selection criteria for improving new varieties. Path coefficient and correlation analyses are used widely in many crop species by plant breeders to define the nature of complex interrelationships among yield

components and to identify the sources of variation in yield. Knowledge derived in this way can be used to develop selection criteria to improve grain yield in relation to agricultural practices (Board *et al.*, 1997; Finne *et al.*, 2000; Gravois and McNew, 1993; Samonte *et al.*, 1998; Sinebo, 2002).

A number of barley researchers sought to explain the relations of yield-related components by using path coefficient analysis (Dofing and Knight, 1994; Grafius, 1964; Garcia Del Moral *et al.*, 1991; Hamid and Grafius, 1978; Puri *et al.*, 1982). These researchers and others obtained results that included some discrepancies. Some studies reported that grain yield was determined by three yield components, e.g., spike number per m², kernel number per spike and kernel weight per spike (Grafius, 1964). Some studies concluded that spike number per m² was the primary determinant of grain yield in barley (Dofing and Knight, 1994). On the other hand, Singh *et al.* (1987) found that grain yield in barley was significantly correlated with plant height and spike length and that these two components had high positive direct effects on yield.

Materials and methods

This experiment was conducted during 2003-2004 in the coastal zone of northwest Turkey (40°11' North, 29°04' East), at the Agricultural Research and Experiment

Station of the Agriculture Faculty, Uludag University (Turkey). Ten varieties of two-rowed barley were used as genetic materials. The experimental soil was clay loam, nonsaline, poor in lime and organic matter, rich in potassium and had a neutral pH. Average temperature, relative humidity and precipitation of growing seasons were, respectively, 10.5°C, 67.0% and 461.5 mm in 2003, and 11.1°C, 68.1% and 555.7 mm in 2004. The values of temperature, relative humidity and precipitation in 2003 were lower than normal. In 2004, temperature and precipitation had nearly normal values, but relative humidity was lower than normal.

The experiment was carried out using a split-plot design with three replications. The varieties studied were 'Angora', 'Balkan-96', 'Bilgi-91', 'Bornova-92', 'Cumhuriyet-50', 'Çildir-02', 'Kalayci-97', 'Sladoran', 'Süleymanbey-98' and 'Şerifehanım-98'. The second experimental treatment included four levels of nitrogen (0, 50, 100 and 150 kg ha⁻¹). The main plots were allocated to varieties and the sub-plots to nitrogen levels. Sowing was done using a plot sowing machine. The area of sub-plot was 3 x 1.2 m. Eight rows were seeded at each sub-plot with 15 cm spacing. A hand-driven roller was used after sowing to pack down the soil for contact with the seeds. Meanwhile, one-third of each level of nitrogen fertilizer was applied at sowing and two-thirds at the jointing stage of plants. Ammonium nitrate of 26% was the source of nitrogen fertilizer. Measurements and observations for the parameters were accomplished on 15 plants chosen randomly from the mid-row of each plot. The parameters measured were plant height, spike length, kernel number per spike and kernel weight per spike, spike number per m², harvest index, 1000-kernel weight and grain yield. Plant height and spike number per m² were measured before harvest and the other parameters at or after harvest.

Data from both study years were combined. The simple phenotypic coefficients among all the measured components were first calculated by the Tarist statistical program and then separated into direct and indirect effects via path coefficient analysis as suggested by Anlarsal and Gulcan (1989), Sabanci (1996) and Turk and Celik (2006).

Results and discussion

Positive correlations appeared between grain yield and all the yield components except the 1000-kernel weight (Tab. 1). The positive and significant correlation coefficients (r-values) between grain yield and the yield components such as plant height, spike length, kernel number per spike, kernel weight per spike, spike number per m² and harvest index were 0.191**, 0.265**, 0.406**, 0.247**, 0.361**, and 0.474**, respectively. Similar results for grain yield and plant height in barley were reported by other studies (Bhutta *et al.*, 2005; Kisana *et al.*, 1999; Samarrai *et al.*, 1987). Akdeniz *et al.* (2004) observed positive and significant correlations between grain yield and yield compo-

nents such as plant height, spike length and spike number per m² but found negative and nonsignificant correlations between grain yield and kernel number per spike. Positive and significant correlations of grain yield with spike number per m² and 1000-kernel weight were reported by Ataei (2006). In agreement with the results of this study, Bhutta *et al.* (2005) and Ilker (2006) found no significant correlation between grain yield and 1000-kernel weight. Most of the reciprocal relations among yield components were significantly positive. For instance, the correlations of plant height with spike length, kernel number per spike, kernel weight per spike, spike number per m² and harvest index, and the correlations of spike length with kernel number per spike, kernel weight per spike and spike number per m², as well as the correlations of kernel number per spike with kernel weight and spike number per m² were all positive and significant. However, the analysis found some negative but significant correlations among some yield components, especially those involving harvest index. Indeed, the correlations of harvest index with spike length, kernel number per spike, kernel weight per spike and spike number per m² were of this sort. On the other hand, the reciprocal relations of 1000-kernel weight with other yield components were nearly negative and/or nonsignificant, with some exceptions. The important exception was the correlation between 1000-kernel weight and kernel weight per spike, which was positive and significant (Tab. 1).

Path coefficient analysis was conducted by applying the correlation coefficients. This method partitioned the correlation coefficients into direct and indirect effects. The purpose of using path coefficient analysis in this study was to obtain further information about the interrelationships between the yield components studied and about their influence on grain yield.

The direct effects obtained from path coefficient analysis indicated that grain yields of barley cultivars were significantly and positively affected by yield components such as plant height, spike length, kernel number per spike, kernel weight per spike, spike number per m² and harvest index (Tab. 2). These results indicate that an increase in any of these yield components causes some increase in grain yield. Similar results were reported by other researchers who conducted studies on different plant species and determined the direct effects of different yield components on grain yield: Khan *et al.* (1999); Moghaddam *et al.* (1998); Aycicek and Yildirim (2006); Turk *et al.* (2008) for plant height; Ataei (2006); Aycicek and Yildirim (2006); Mohammad *et al.* (2002); Narwal *et al.* (1999) for kernel number per spike; Aycicek and Yildirim (2006) for kernel weight per spike; Dofing and Knight (1994) for spike number per m²; Turk *et al.* (2008); Surek and Beser (2003); Surek *et al.* (1998); Albayrak and Tongel (2006) for harvest index. In terms of the priorities of the effects of yield components, the grain yield of the cultivars depended primarily upon harvest index and secondarily upon spike number per m² in the research reported here.

Tab. 1. Correlation coefficients among characters of varieties in two-rowed barley (averages of two years)

Yield components	1000-kernel weight	Harvest index	Number spike per m ²	Kernel weight per spike	Kernel number per spike	Spike length	Plant height
Grain yield	-0.092 ^{ns}	0.474 ^{**}	0.361 ^{**}	0.247 ^{**}	0.406 ^{**}	0.265 ^{**}	0.191 ^{**}
Plant height	-0.038 ^{ns}	0.549 ^{**}	0.406 ^{**}	0.615 ^{**}	0.629 ^{**}	0.657 ^{**}	-
Spike length	-0.040 ^{ns}	-0.313 ^{**}	0.188 ^{**}	0.736 ^{**}	0.776 ^{**}	-	-
Kernel number per spike	0.055 ^{ns}	-0.211 ^{**}	0.284 ^{**}	0.790 ^{**}	-	-	-
Kernel weight per spike	0.303 ^{**}	-0.284 ^{**}	0.107 ^{ns}	-	-	-	-
Number spike per m ²	-0.150 ^{**}	-0.215 ^{**}	-	-	-	-	-
Harvest index	-0.024 ^{ns}	-	-	-	-	-	-
1000-kernel weight	-	-	-	-	-	-	-

* significant at the 0.05 probability level, ** significant at the 0.01 probability level, ns: non-significant

Tab. 2. Path analyses showing direct and indirect effects of yield components on grain yield (averages of two years)

Yield components	Direct effects	Indirect Effects						
		Plant height	Spike length	Kernel number per spike	Kernel weight per spike	Number spike per m ²	Harvest index	1000-kernel weight
Plant height	0.2640 (25.41%)*	-	0.0271 (2.61%)	0.1310 (12.61%)	0.0546 (5.25%)	0.1366 (13.14%)	-0.4239 (40.80%)	0.0019 (0.18%)
Spike length	0.0413 (5.52%)	0.1734 (23.18%)	-	0.1614 (21.58%)	0.0653 (8.73%)	0.0631 (8.44%)	-0.2414 (32.28%)	0.0020 (0.27%)
Kernel number per spike	0.2081 (28.22%)	0.1662 (22.54%)	0.0320 (4.35%)	-	0.0701 (9.51%)	0.0954 (12.95%)	-0.1626 (22.05%)	-0.0028 (0.38%)
Kernel weight per spike	0.0887 (12.38%)	0.1624 (22.65%)	0.0304 (4.24%)	0.1645 (22.95%)	-	0.0360 (5.03%)	-0.2194 (30.61%)	-0.0153 (2.14%)
Number spike per m ²	0.3359 (48.47%)	0.1073 (15.49%)	0.0078 (1.12%)	0.0591 (8.53%)	0.0095 (1.37%)	-	-0.1659 (23.93%)	0.0076 (1.09%)
Harvest index	0.7716 (71.97%)	-0.1451 (13.53%)	-0.0129 (1.21%)	-0.0439 (4.09%)	-0.0252 (2.35%)	-0.0722 (6.74%)	-	0.0012 (0.11%)
1000-kernel weight	-0.0505 (29.81%)	-0.0100 (5.89%)	-0.0017 (0.98%)	0.0115 (6.78%)	0.0269 (15.90%)	-0.0504 (29.79%)	-0.0184 (10.85%)	-

* Numbers in parentheses refer to the percentages of path coefficients.

The indirect effects of yield components on grain yield on one another were generally positive with some exceptions. The most remarkable instance of the indirect effects of yield components involved the effect of harvest index on grain yield. Indeed, the indirect effects of harvest index on grain yield via yield components such as plant height, spike length, kernel number per spike, kernel weight per spike and spike number per m² were significantly negative, indicating that an increase in one component caused a similar decrease in the other. Only a small positive indirect effect of harvest index on grain yield occurred. The effect was associated with an intercorrelation with 1000-kernel weight (Tab. 2).

This study has demonstrated that the grain yield of barley has significant and positive correlations with plant height, spike length, kernel number per spike, kernel weight per spike, spike number per m² and harvest index. These relations mean that any increase in any one of the yield components causes some increase in grain yield. However, yield components have different effects on grain yield. These positive correlations between grain yield and yield components may be arranged, from higher to lower,

as follows: 0.474 for harvest index, 0.406 for kernel number per spike, 0.361 for spike number per m², 0.265 for spike length, 0.247 for kernel weight per spike and 0.191 for plant height. Finally, it is seen that harvest index, kernel number per spike and spike number per m² have stronger effects on grain yield than do the other components. The direct effects of harvest index, spike number per m² and kernel number per spike on grain yields of barley cultivars were more important than those of other yield components as indicated by path analysis. Their ranked percentages of direct effect were 71.97, 48.47 and 28.22%, respectively. The results of this study indicate that harvest index, spike number per m² and kernel number per spike may be used as selection criteria for new cultivars of two-rowed barley with higher grain yield.

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