COMPARATIVE PERFORMANCE OF TRITICALE AND WHEAT GRAINS BY USING PATH ANALYSIS

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Abstract


The objectives of this study were to compare released triticale cultivars in terms of grain yield, plant height, protein and spike characters with bread and durum wheat and to evaluate the usefulness of path coefficient analysis for interrelationships among characters determining grain yield in triticale, bread and durum wheat in two locations. It was found that grain yield of triticale was statistically significant higher than that of durum wheat; however, triticale and bread wheat nearly had the same yield. Path coefficient analysis revealed that grain yield of triticale depended on the effect of four yield components (plant height, grain number per spike and thousand grain weight was positive and protein was negative) whereas grain yield of bread and durum wheat was due mainly to plant height, length of spike, protein, in addition to these, spike weight for durum wheat. Even though the effect of spike weight was positive, plant height and protein had a negative effect on the grain yield of durum wheat.

Key words: triticale, wheat, path coefficient analysis, grain yield, spike characters

Introduction

Grain yield in cereals is defined by the number of grains per unit land area and by the individual weight of these grains. In general, grain yield is closely the number of grains per spike and per spike let (Perry and D’Antuono, 1989; Sayre et al., 1997). The studies dealing with comparison for triticale’s grain yield, thousand grain weight, plant height and spike characters were found more out yielded than that of wheat (Barriga et al., 1979; Lehman et al., 1983; Varughese et al., 1987; Gill et al., 1990 and Kukukakca, 1995). Moreover, some comparisons made about protein content between triticale and wheat by researchers indicated that the protein content of triticale commonly varies between 10 and 16% and this value was close to that of bread wheat (Angelova and Kosturki, 1983; Cakmak and Turker, 1987).

A considerable number of studies in small grain cereals include correlations between grain yield and...
its related characters. Simple correlations may not provide the importance of each component in determining grain yield. Researchers observed positive or negative correlations of grain yield with plant height, thousand grain weight, spike length and protein for wheat (Depauw et al., 1998; Simmonds, 1995; Feil, 1998; Feil and Banziger, 1999; Chowdhry et al., 2000; Tamman et al., 2000; Rharrabti et al., 2001). However, some researchers showed that it was possible the determination of effect of yield components on grain yield by using path analysis (Parado et al., 1970; Yagbasanlar and Ozkan, 1995; Garcia del Moral et al., 2003; Okuyama et al., 2004; Garcia del Moral et al., 2005; Ataei, 2006). Path coefficient analysis divides the correlation coefficients into direct and indirect effects (Garcia Del Moral et al., 2003).

Little information is found on the use of path coefficient analysis to compare yield formation of cereals and none exists for comparing triticale with wheat.

Thus, the objectives of this study were (i) to compare two released triticale cultivars in terms of grain yield, plant height, protein and spike characters with two bread and durum wheat at two locations and (ii) to evaluate the usefulness of path coefficient analysis for interrelationships among characters determining grain yield in triticale, bread and durum wheat.

**Materials and Methods**

Two released triticale cultivars (Tatlicak-97 and Karma-2000), two bread wheat (Konya-2002 and Ekiz) and two durum wheat (Meram-2002 and Selcuklu-97) were planted at two locations; Eskisehir (Eskisehir Osmangazi University) and Konya (Bahri Dagdas International Agricultural Research Institute) in semi-arid Central Anatolia Region of Turkey. The field experiments were conducted during two growing seasons (2004/2005 and 2005/2006), planted in

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Locations and agronomical details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Eskisehir</td>
</tr>
<tr>
<td>Coordinates</td>
<td>39°48’ N; 30°31’ E</td>
</tr>
<tr>
<td>Altitude, m</td>
<td>789</td>
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<td>Soil characteristics:</td>
<td></td>
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<tr>
<td>Texture</td>
<td>Silty-loam</td>
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<tr>
<td>pH</td>
<td>7.6</td>
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<tr>
<td>Organic matter, %</td>
<td>1.04</td>
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<tr>
<td>CaCO₃, %</td>
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</tr>
<tr>
<td>Fertilizers, kg ha⁻¹</td>
<td></td>
</tr>
<tr>
<td>N (seed bed+top dressing)</td>
<td>40+30</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>60</td>
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<tr>
<td>Weather data</td>
<td></td>
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<td>Seasonal Precipitation*, mm</td>
<td>Long term 2004/05 2005/06</td>
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<td>Average temperatures, °C</td>
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<td>Temperature-max</td>
<td>35.3</td>
</tr>
<tr>
<td>Temperature-mean</td>
<td>16.3</td>
</tr>
<tr>
<td>Temperature-min</td>
<td>-7.1</td>
</tr>
</tbody>
</table>

*; from sowing to harvesting.

*; grain filling period
October and harvested in July. The experiment was set up as a completely randomized block design with four replications and a plot size of six rows 7 m long and with a distance of 25 cm between the rows.

Climatic data, soil properties and management practices related to the research locations are shown in Table 1. The Central Anatolia region has an annual precipitation varying between 250 and 450 mm and the long term, first and second experimental year of total precipitation from October to June were 295 mm, 170 mm and 262 mm in Konya and 347 mm, 236 mm and 300 mm in Eskisehir, respectively. In this study, precipitation was generally below the long term average in both years. In growing seasons, more precipitation was received in Eskisehir (236 and 300 mm) than in Konya (170 and 262 mm). Temperatures during the grain filling period were much higher in Konya than in Eskisehir. Thus, the plants were irrigated by sprinkling water ones at tillering stage in Konya. The soils at the site of the experiments were silty-loam in Eskisehir and clay in Konya. The soils at both of these locations had a chemical characteristic that was low in organic matter and high in CaCO3. At planting time, phosphorus (P2O5) and nitrogen (N) fertilizers were applied at a standard rate of 60 kg ha\(^{-1}\) P2O5 and 40 kg ha\(^{-1}\) N. Nitrogen topdressing treatments were applied at the tillering stage in March to a total of 70 kg N ha\(^{-1}\).

Grain protein content and total N content were determined by near infrared reflectance spectroscopy (NIR). The number of grain per spike, spike weight and thousand grain weights, plant height, length of spike, spikelet number per spike, grain number per spike, spike weight, thousand grain weight and total protein was determined on randomly selected plants from each plot. Grain yield was also determined for each plot.

The experimental data were analyzed by ANOVA and differences were compared by Least Significant Difference Test (LSD) at P<0.05. In order to identify, the relationship between the causal and effect components, the correlation coefficients were calculated (Asher, 1983). Stepwise regression was used for finding the relationship between the causal and effect components. After these analyses we aim to determine via Path analysis (Shipley, 2004) the components that have an affect on grain yield for triticale, bread and durum wheat, and the amount of direct and indirect effect of the causal components (plant height, length of spike, spikelet number per spike, grain number per spike, spike weight, thousand grain weight and total protein) on the effect component (grain yield) at two location during a period of two years.

**Results and Discussion**

Triticale cultivars were compared in terms of grain yield, plant height and spike characters with bread and durum wheat at two locations in two years and Table 2 contains summary statistics of the mean of these two years, i.e., analysis variance of the effects of year, location, cereal species and cereal varieties on grain yield, plant height, length of spike, spikelet number per spike, grain number per spike, spike weight, thousand grain weight and total protein. Generally, year, location and cereal species were significant; however, interaction of year, location, species and variety had not significant affect on all characters of triticale and wheat cultivars (P<0.05 and 0.01).

Various yielding and average values of yield components were observed for the cereal varieties. For grain yield significant differences between the two locations were found. Grain yield means were found to be 5176, 5134 and 4226 kg ha\(^{-1}\) for triticale, bread wheat and durum wheat, respectively (Table 3). While grain yield of triticale was significantly higher than in durum wheat, triticale and bread wheat were statistically in the same group giving nearly the same yield. Regarding different locations, grain yield of triticale (5833 kg ha\(^{-1}\)) and bread wheat (5483 kg ha\(^{-1}\)) was higher in Konya due to irrigation than that of Eskisehir. However, grain yield of durum wheat (4809 kg ha\(^{-1}\)) in Eskisehir was higher than that of Eskisehir. It was also determined by some researcher (Barriga et al., 1979; Lehman et al., 1983 and Kukukakca 1995) that grain yield of triticale in sufficient water content of soil was higher than that of wheat.

Plant height results were determined to have a statistically significant importance (Table 2). Triticale genotypes were in the first group (116.43 cm), bread
wheat (89.19 cm) and durum wheat (83.66 cm) genotypes followed it. When Table 3 is examined, it appears that plant height of all cereals was taller in Konya in comparison to Eskisehir due to the irrigation of plants in Konya. Varughese et al. (1987) and Gill et al. (1990) determined that triticale varieties taller than wheat varieties.

Location and species of cereals had a significant effect (P<0.01) on all spike characteristics (spike length, spikelet number per spike, grain number per spike and spike weight) (Table 2).

The spike characters of triticale were shown to be significantly superior to bread and durum wheat genotypes (Table 3). This superiority of spike characters is typical for triticale when compared with wheat. Triticale varieties; length of spike (10.66 cm), spikelet number per spike (27.71), grain number per spike (53.47) and spike weight (1.87 g) were all found to be statistically important in comparison to other wheat varieties (Table 3). The spike characters of cereals were arranged in the order of triticale, bread and durum wheat. On account of spike characters of triticale genotypes, the results showed similarities with the results of various researchers (Panwar et al., 1986; Gill et al., 1990 and Kucukakca, 1995) who determined all spike characters of triticale to be higher than those of wheat.

Thousand grain weight and total protein were quality degrees for cereals. Year, location, cereal species and variety significantly affected both quality characters (Table 2). Thousand grain weight and total protein of wheat varieties were determined to be higher than those of triticale (Table 3). Thousand grain weight of bread wheat (36.0 g) was higher than that of durum wheat (34.46 g) and triticale (32.77 g). Comparison studies of triticale with wheat varieties showed that while some researchers found thousand grain weight of triticale genotypes to be equal to or a little higher than that of wheat (Graham et al., 1983 and Kucukakca, 1995).
Table 3
Grain yield, plant height, spike characters, thousand grain weight and total protein means of triticale, bread wheat and durum wheat varieties in two years at two locations (E: Eskisehir; K: Konya)

<table>
<thead>
<tr>
<th>Year</th>
<th>Loc</th>
<th>Species/Variety</th>
<th>Grain yield, kg ha⁻¹</th>
<th>Plant height, cm</th>
<th>Length of spike, cm</th>
<th>Spikelet number per spike</th>
<th>Grain number per spike</th>
<th>Spike weight, g</th>
<th>1000 grain weight, g</th>
<th>Total protein, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004/05 E</td>
<td>Triticale</td>
<td>Tatlicak-97</td>
<td>5202</td>
<td>123</td>
<td>11.0</td>
<td>28.2</td>
<td>49.7</td>
<td>1.71</td>
<td>27.5</td>
<td>10.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Karma 2000</td>
<td>4892</td>
<td>110</td>
<td>11.7</td>
<td>31.1</td>
<td>65.3</td>
<td>2.18</td>
<td>27.1</td>
<td>9.96</td>
</tr>
<tr>
<td></td>
<td>Bread wheat</td>
<td>Konya-2002</td>
<td>5537</td>
<td>87</td>
<td>10.5</td>
<td>19.4</td>
<td>44.2</td>
<td>1.73</td>
<td>33.8</td>
<td>11.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ekiz</td>
<td>4737</td>
<td>92</td>
<td>9.92</td>
<td>20.3</td>
<td>46.2</td>
<td>1.65</td>
<td>29.0</td>
<td>9.77</td>
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<td>Durum wheat</td>
<td>Meram-2002</td>
<td>5227</td>
<td>95</td>
<td>9.5</td>
<td>19.5</td>
<td>45.9</td>
<td>1.81</td>
<td>32.4</td>
<td>11.6</td>
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<td>Selcuklu-97</td>
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<td>87</td>
<td>7.48</td>
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<td>45.1</td>
<td>1.56</td>
<td>30.9</td>
<td>10.8</td>
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<td></td>
<td>K</td>
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<td>114</td>
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<td>45</td>
<td>1.18</td>
<td>38.3</td>
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<td>115</td>
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<td>58.3</td>
<td>2.11</td>
<td>39.6</td>
<td>11.9</td>
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<td></td>
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<td>Konya-2002</td>
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<td>91</td>
<td>9.82</td>
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<td>41</td>
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<tr>
<td></td>
<td></td>
<td>Ekiz</td>
<td>5469</td>
<td>87</td>
<td>9.83</td>
<td>17.6</td>
<td>39.7</td>
<td>1.48</td>
<td>38.1</td>
<td>13.5</td>
</tr>
<tr>
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<td>Meram-2002</td>
<td>3714</td>
<td>94</td>
<td>7.85</td>
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<td>38.3</td>
<td>1.38</td>
<td>41.6</td>
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<td>80</td>
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<td>38.6</td>
<td>1.22</td>
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<td>Triticale</td>
<td>Tatlicak-97</td>
<td>4232</td>
<td>112</td>
<td>10.7</td>
<td>29.7</td>
<td>52.8</td>
<td>2.14</td>
<td>33.9</td>
<td>11.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Karma 2000</td>
<td>3754</td>
<td>104</td>
<td>10.5</td>
<td>27.9</td>
<td>54.2</td>
<td>1.81</td>
<td>34.4</td>
<td>12.4</td>
</tr>
<tr>
<td></td>
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<td>4482</td>
<td>81</td>
<td>10.1</td>
<td>18.8</td>
<td>44</td>
<td>1.91</td>
<td>40.2</td>
<td>11.9</td>
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<tr>
<td></td>
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<td>Ekiz</td>
<td>4384</td>
<td>77</td>
<td>9.52</td>
<td>18.2</td>
<td>41.9</td>
<td>1.7</td>
<td>35.2</td>
<td>12.8</td>
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<td>36.7</td>
<td>1.6</td>
<td>40.6</td>
<td>13.2</td>
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<tr>
<td></td>
<td></td>
<td>Selcuklu-97</td>
<td>5213</td>
<td>70</td>
<td>6.97</td>
<td>19.8</td>
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<td>36.6</td>
<td>15.0</td>
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<td>5961</td>
<td>127</td>
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<td>45.2</td>
<td>1.71</td>
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<td>2.1</td>
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<td>99</td>
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<td>1.91</td>
<td>36.8</td>
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<td>8.95</td>
<td>16.2</td>
<td>39.4</td>
<td>1.45</td>
<td>29.2</td>
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<tr>
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<td>90</td>
<td>7.67</td>
<td>18.7</td>
<td>37.1</td>
<td>1.64</td>
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<tr>
<td></td>
<td></td>
<td>Selcuklu-97</td>
<td>3427</td>
<td>74</td>
<td>6.45</td>
<td>18.5</td>
<td>36.5</td>
<td>1.18</td>
<td>26.6</td>
<td>19.0</td>
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</table>
Total protein mean of durum wheat in Konya was 17.18% while in Eskisehir it was determined to be 12.71% and also, triticale (11.72%) had the least protein content among cereals. Even though total protein mean of durum wheat was 14.94%, higher local differences drew attention. Protein results of this study were in parallel with Angelova and Kosturk (1983), Graham et al. (1983) and Çakmak and Türker (1987), who indicated that protein content of triticale was close to that of bread wheat.

Correlation coefficients calculated among examined characters (grain yield, plant height, length of spike, spikelet number per spike, grain number per spike, spike weight, thousand grain weight and total protein) are shown in Table 4. Positive and statistical significant relationships for triticale were found between grain yield and plant height ($P<0.05$) and thousand grain weight ($P<0.05$). Grain yield of bread wheat was positively related to plant height ($P<0.01$) and protein ($P<0.01$). However, while there was a significant positive correlation between grain yield and length of spike ($P<0.05$), a significant negative relation was found between grain yield and protein ($P<0.01$) for durum wheat. Chowdhry et al. (2000) observed positive correlation of grain yield with plant height, thousand grain weight and spike length and Tamman et al. (2000) reported that grain yield per plant had a positive correlation with thousand grain weight for bread wheat. The result about protein content in triticale showed parallelism to that reported by Feil (1998) and Feil and Banziger (1999) about negative relations between total protein ratio and grain yield; however, Rharrabti et al. (2001) and Depauw et al. (1992) along with Simmonds (1995) determined a strong positive relation between grain yield and protein yield for cereals.

Path analysis is performed in order to determine the differences of the cereal species using the effect of yield characters (length of spike, spikelet number per spike, grain number per spike, spike weight, and thousand grain weights) effect on grain yield. The effects of the five components (length of spike, spikelet number per spike, grain number per spike, spike weight, and thousand grain weights) among the significant causal components on grain yield were determined for each cereal. In order to do this, stepwise regression analysis is applied and significant components are found. Hence the path diagrams based on the causal relations among those components are given in Figures 1, 2 and 3.

Direct effects obtained in path analysis showed that plant height, grain number per spike and thousand grain weights had a significant and positive influence; however, protein had a significant and negative influence on grain yield of triticale ($P<0.05$) and thousand grain weight ($P<0.05$). Grain yield of bread wheat was positively related to plant height ($P<0.01$) and protein ($P<0.01$). However, while there was a significant positive correlation between grain yield and length of spike ($P<0.05$), a significant negative relation was found between grain yield and protein ($P<0.01$) for durum wheat. Chowdhry et al. (2000) observed positive correlation of grain yield with plant height, thousand grain weight and spike length and Tamman et al. (2000) reported that grain yield per plant had a positive correlation with thousand grain weight for bread wheat. The result about protein content in triticale showed parallelism to that reported by Feil (1998) and Feil and Banziger (1999) about negative relations between total protein ratio and grain yield; however, Rharrabti et al. (2001) and Depauw et al. (1992) along with Simmonds (1995) determined a strong positive relation between grain yield and protein yield for cereals.
such as plant height, length of spike and protein on grain yield of bread wheat were positive and significant. These components had a negative influence indirectly on grain yield of bread wheat. Plant height (0.5953) and length of spike (0.5045) had the highest influence on grain yield of bread wheat. The direct effects and simple correlation coefficients of plant height, length of spike and protein on grain yield of bread wheat were shown in Figure 2. Only protein (-0.3203) had a significant direct effect on grain yield of durum wheat (Table 5) while plant height and spike weight did not exercise a direct significant influence.

Table 4
Relations between grain yield and plant height, length of spike, spikelet number per spike, grain number per spike, spike weight, thousand grain weight and total protein

<table>
<thead>
<tr>
<th></th>
<th>Plant height</th>
<th>Length of spike</th>
<th>Spikelet number per spike</th>
<th>Grain number per spike</th>
<th>Spike weight</th>
<th>1000 grain weight</th>
<th>Total protein</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Triticale</td>
<td>0.398*</td>
<td>-0.134</td>
<td>-0.197</td>
<td>-0.068</td>
<td>-0.1</td>
<td>0.361*</td>
<td>-0.011</td>
</tr>
<tr>
<td>Bread</td>
<td>0.560**</td>
<td>0.11</td>
<td>0.01</td>
<td>0.27</td>
<td>0.19</td>
<td>0.05</td>
<td>0.320**</td>
</tr>
<tr>
<td>Durum</td>
<td>0.159</td>
<td>0.408*</td>
<td>0.302</td>
<td>0.324</td>
<td>0.329</td>
<td>-0.0004</td>
<td>-0.463**</td>
</tr>
<tr>
<td>Plant height</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Triticale</td>
<td>-0.188</td>
<td>-0.295</td>
<td>-0.246</td>
<td>-0.044</td>
<td>-0.289</td>
<td>0.313</td>
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</tr>
<tr>
<td>Bread</td>
<td>-0.31</td>
<td>-0.18</td>
<td>0.01</td>
<td>-0.02</td>
<td>-0.18</td>
<td>0.3</td>
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</tr>
<tr>
<td>Durum</td>
<td>0.589**</td>
<td>-0.011</td>
<td>0.341</td>
<td>0.301</td>
<td>0.051</td>
<td>-0.294</td>
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<tr>
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<td>0.303</td>
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* and **. significant at P<0.05 and 0.01. respectively.
Fig. 1. Path coefficient diagram of the grain yield in triticale showing the interrelationships among plant height, grain number per spike, thousand grain weight and protein. The single headed arrows indicate path coefficients and double arrows indicate simple correlation coefficients.

Fig. 2. Path coefficient diagram of the grain yield in bread wheat showing the interrelationships among plant height, length of spike and protein. The single headed arrows indicate path coefficients and double arrows indicate simple correlation coefficients.

Table 5
The effects on the grain yield for triticale, bread and durum wheat of some causal components

<table>
<thead>
<tr>
<th>Cereal Species</th>
<th>Component</th>
<th>Direct effect</th>
<th>Indirect effect</th>
<th>Total effect</th>
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<tr>
<td>Triticale</td>
<td>Plant height</td>
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<td>Grain number per spike</td>
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<td>Protein</td>
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<td>Residual</td>
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<td>Plant height</td>
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<td>-0.0353</td>
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<td>Residual</td>
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*, **, *** significant at P<0.10, 0.05 and 0.01, respectively.
Length of spike depended on plant height and spike weight whereas these characters had negative influence on the length of spike (Figure 3). This was an indication that length of spike had a small effect on grain yield.

A more detailed study of the relationships obtained by path analysis showed that the relation between grain yield and its components was somewhat different from that presented in the simple correlation analysis. In the correlation study, plant height, thousand grain weight and protein for triticale, plant height and protein for bread wheat, length of spike and protein for durum wheat were the main components related to grain yield increase, whereas in the path analysis the other components had a significant effect on grain yield of cereals. Yagbasanlar and Ozkan (1995) found that simple correlation and path coefficient analysis suggested weight of grains per spike to be the most important component of grain yield of triticale and also Parado et al. (1974) obtained a similar result. In accordance with previous studies (Garcia del Moral et al., 2003; Okuyama et al., 2004; Garcia del Moral et al., 2005; Ataei 2006), the effect of yield components on grain yield showed some differences in path analysis when compared with simple correlation. Plant height, grain number per spike, thousand grain weight and protein for triticale; plant height, length of spike and protein for bread wheat; plant height, spike weight and protein for durum wheat had a direct influence on their grain yield. Plant height had a statistical significant and positive effect on grain yield of triticale and bread wheat. Protein had a negative affect on grain yield of triticale and durum wheat whereas bread wheat was positively influenced by protein probably due to environmental conditions.

The results showed that in terms of plant height the effect on grain yield of triticale was similar to that of bread wheat while in terms of protein influence on grain yield of triticale it has similarities with durum wheat. Triticale yield differed depending on the year, locations, and it was determined to be close to grain yield of bread wheat. Stability of agronomy and quality characters over locations and years are especially important for the breeding. For this reason, the understanding of genetic and environmental influences for variation in agronomy parameters is important for the production and to obtain a high quality product. Results obtained in the present study could give good information and suggestions for this objective. Further work will aim to analyze a greater number of cultivars grown in a greater number of different environments to confirm our data and to provide useful information for suitable cereal breeding programs.

References


Received September, 10, 2009; accepted for printing May, 3, 2010.