Genetic Properties of Drought Resistance Indices

J. Saba¹, M. Moghaddam², K. Ghassemi², and M. R. Nishabouri³

ABSTRACT

Inheritance of several yield-based drought resistance indices was studied by a half-diallel method using seven winter wheat varieties. The parental lines were such chosen as to represent a broad range of drought stress resistance. The experiment was conducted in a split-plot design at the research farm, Faculty of Agriculture, Zanjan University, Iran, in 1998. Irrigated vs. rainfed regimes were considered as the main plots. The F₁ hybrids and parental varieties constituted the subplots. From the grain yield data, some drought resistance indices such as geometric mean productivity (GMP), mean productivity (MP), standard superiority measure (SP), stress susceptibility index (SSI), stress tolerance index (STI), superiority measure (P), and tolerance (TOL) were calculated. Genetic components of variance and heritabilities were estimated using Gardner and Eberhart's Method 3, Model II. Significant differences among parents and F₁s were observed for all indices except for SSI and TOL. Significant general combining abilities (GCA) were obtained for GMP, MP, P, SP, STI, and TOL but not for SSI. Therefore, except for SSI, other indices could be regarded as heritable. The specific combining ability (SCA) effects were also highly significant for GMP, MP, P, SP, and STI. However, additive variances were more important than dominance ones. Narrow-sense heritability estimates were very low for SSI, low for TOL, but moderate for GMP, MP, P, SP, and STI. Thus selection based on the latter indices could be more promising than on SSI and TOL. It seems that SP and STI might be better yield-based drought resistance indices to be employed in plant breeding programs, because of their moderate narrow-sense heritabilities and the inherent ability of selecting high yielding genotypes in either stressed or non-stressed conditions.

Keywords: Combining ability, Diallel, Drought resistance, Genetic properties, Wheat.

INTRODUCTION

In semiarid regions, dry farming is often practiced for wheat production. In these areas, precipitation being low and irregular, water deficit becomes the most important limitation to crop, including wheat production (5) and therefore breeding for drought resistant wheat is an important task and objective in these semiarid regions (2,14). On the other hand, good selection criteria are needed to identify drought resistant genotypes.

Levitt (15) noted that drought resistance can be defined as: the water stress necessary to produce a specific plastic strain. The choice of parameters used to quantify the level of stress and the intensity of strain are somewhat arbitrary. Drought tolerance or resistance in native plant species is often defined as survival, but in crop species it must be defined in terms of productivity (18).

Several indices have been utilized to evaluate genotypes for drought resistance based on grain yield such as geometric mean productivity (7), mean productivity (20),

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standard superiority measure (9), stress susceptibility index (8), stress tolerance index (7), superiority measure (16), and tolerance (20). According to Richards (19), selection for yield automatically integrates all the known and unknown factors that contribute to drought resistance. These indices have been compared by some researchers (7,19), but their genetic properties and consistencies have not been studied. This could be one of the main reasons for the lack of significant progress in developing drought resistant plants.

Heritability of a quantitative trait such as grain yield directly determines the efficiency of selection for that trait. Traits with high heritability are easier to be improved than those with lower heritability. Most cultivars in self-pollinated crops, such as wheat, are pure lines produced by selection methods following hybridization. Thus, selection is mainly based on the presence of additive genetic variance in these methods. Higher genetic advances could be realized when employing characters with higher rather than lower narrow-sense heritability. The objective of this study was, to estimate the genetic parameters and especially the narrow sense heritability of the important yield-based drought resistance indices using diallel method.

MATERIALS AND METHODS

A half-diallel cross of 7 winter wheat lines was made in 1997 at the research farm, Faculty of Agriculture, Zanjan University, Iran (Latitude 36° 41'; Altitude 1620 m). For each cross, more than 600 F1 seeds were produced in order to be able to evaluate F1 hybrids for their agronomic performance. The parents were: (1) P8-5/Kavkaz, (2) 4839 Sarakhs, (3) Ska/Aurifen, (4) Sabalan, (5) Sardari, (6) MV17, and (7) Alamoot. These cultivars represented a broad range of response to drought stress (11).

The experiment, on a silty-loam soil was conducted in October, 1997. A split-plot design, arranged in 3 randomized complete blocks, was used. Irrigated (non-stress) and rainfed (stress) regimes were considered as main plots. Twenty eight genotypes, including 21 F1 hybrids plus 7 parental lines represented the subplots. Each subplot consisted of two 98 cm long, 18 cm apart rows. Seventy kgs of N/ha and 150 kgs of P2O5 /ha were applied to the soil prior to planting. From mid-May 1998 (anthesis) until the end of growing season only the non-stressed plots were irrigated. This was when tensiometers indicated a soil water suction of 50 KPa. At each irrigation, about 30-40 mm of water was applied to the non-stressed plots, totaling to 200mm of irrigation water during the whole period. After harvest the grain yield was recorded for every subplot. The seven drought resistance indices were calculated for every genotype using the corresponding non-stressed and stressed subplots in each block. The resulting data were analyzed as obtained from a randomized complete block design.

The drought tolerance indices were calculated as follows:

1) Stress Susceptibility Index (8):

\[ \text{SSI} = \frac{1 - Y_s / Y_p}{\text{SI}} = 1 - \frac{Y_s}{pY} \]

where: SI = Stress Intensity

2) Mean Productivity (20):

\[ \text{MP} = \frac{Y_s + Y_p}{2} \]

3) Tolerance (20):

\[ \text{TOL} = \frac{Y_p - Y_s}{Y_p} \]

4) Superiority Measure (16):

\[ P = \frac{\sum (X_p - M_p)^2}{2n} \]

5) Standard Superiority Measure (9):

\[ \text{SP} = \text{Similar to P but uses standardized data} \]

6) Geometric Mean Productivity (7):

\[ \text{GMP} = \sqrt{\frac{Y_p}{Y_p}} \]

7) Stress Tolerance Index (7):

\[ \text{STI} = \frac{Y_p}{Y_s} \]

where:

\[ Y_p = \text{yield of a given genotype in a non-stressed environment.} \]

\[ Y_s = \text{yield of a genotype in drought stressed environment.} \]

\[ pY = \text{mean yield in non-stressed environment.} \]
\( \bar{y} \) = mean yield in drought stressed environment.

n = number of environments.

\( X_{ij} \) = grain yield of ith genotype at the jth environment, and

\( M_j \) = grain yield of the genotype with maximum yield at jth environment.

Genetic components of variance and heritabilities were estimated using Gardner and Eberhart’s Method 3, Model II (10). The data were analyzed using a computer package developed by Burow and Coors (3).

**RESULTS AND DISCUSSION**

The growing season rainfall in 1997-1998 was 306 mm, very close to the long term mean (311 mm for a 30 year period), thus it was considered a typical season in the study area. According to Begg and Turner (1) drought resistance could be categorized based on the growth stage in which it occurs, e.g. early season (pre-anthesis), midseason (flowering), late season (grain filling) or intermittent. At the experimental site the drought is mainly of the mid or late season type and usually occurs during flowering and/or grain filling period.

In 1997, there was enough rainfall until mid-May, corresponding to anthesis period, tensiometers indicating no considerable soil moisture deficit. Up to this time, therefore, non-stressed plots did not need to be and were not irrigated. Afterwards no effective rainfall occurred in the area, thus during grain filling period, the non-irrigated plots were under drought stress with an intensity (SI) of 0.45.

Analysis of variance for various yield-based drought tolerance indices for parental lines and their F1 hybrids is shown in Table 1. There were significant differences among parents and F1’s for all indices except for SSI and TOL. Initial studies, have also indicated the existence of variation for drought response among the parents under study (11). F1’s vs. parents’ mean squares were not significant for any of the drought indices indicating no average heterosis for these criteria. Partitioning of F1 sum of squares into general and specific combining abilities (GCA and SCA, respectively) resulted in significant GCA effects for GMP, MP, P, SP, STI, and TOL but not for SSI. Therefore, except for SSI, other indices could be regarded as heritable. The SCA effect was also highly significant for any of the drought indices indicating no average heterosis for these criteria. The additive and dominance genetic variances were estimated by Method 3, Model II of Gardner and Eberhart (10), Table 2. Additive variances were more important than non-additive (dominance) ones for these indices. The ad-

**Table 1.** Pertinent mean squares of seven winter wheat lines and their F1 diallel hybrids for different yield-based drought tolerance indices grown at Zanjan University, research farm, Zanjan, Iran, in 1997-1998.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>DF</th>
<th>GMP</th>
<th>MP</th>
<th>P ( \times 10^{-4} )</th>
<th>SP</th>
<th>SSI ( \times 10^3 )</th>
<th>STI ( \times 10^3 )</th>
<th>TOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reps</td>
<td>2</td>
<td>585</td>
<td>475</td>
<td>598</td>
<td>10.36</td>
<td>1</td>
<td>14</td>
<td>365</td>
</tr>
<tr>
<td>Genotypes</td>
<td>27</td>
<td>1448 **</td>
<td>1554 **</td>
<td>599 **</td>
<td>7.47 **</td>
<td>48</td>
<td>89 **</td>
<td>1080</td>
</tr>
<tr>
<td>Parents</td>
<td>6</td>
<td>1483 **</td>
<td>1462 **</td>
<td>532 **</td>
<td>8.28 **</td>
<td>91</td>
<td>87 **</td>
<td>1107</td>
</tr>
<tr>
<td>F1’s vs Parents</td>
<td>1</td>
<td>347</td>
<td>364</td>
<td>88</td>
<td>1.71</td>
<td>9</td>
<td>23</td>
<td>45</td>
</tr>
<tr>
<td>F1’s</td>
<td>20</td>
<td>1492 **</td>
<td>1641 **</td>
<td>645 **</td>
<td>7.51 **</td>
<td>37</td>
<td>94 **</td>
<td>1123</td>
</tr>
<tr>
<td>Error 1</td>
<td>54</td>
<td>257</td>
<td>238</td>
<td>88</td>
<td>1.11</td>
<td>75</td>
<td>17</td>
<td>652</td>
</tr>
<tr>
<td>GCA</td>
<td>6</td>
<td>3107 *</td>
<td>3439 *</td>
<td>1232 *</td>
<td>14.56 *</td>
<td>45</td>
<td>197 *</td>
<td>2226 *</td>
</tr>
<tr>
<td>SCA</td>
<td>14</td>
<td>800 **</td>
<td>871 **</td>
<td>393 **</td>
<td>4.49 **</td>
<td>34</td>
<td>49 **</td>
<td>650</td>
</tr>
<tr>
<td>Error 2</td>
<td>40</td>
<td>255</td>
<td>224</td>
<td>83</td>
<td>0.98</td>
<td>89</td>
<td>17</td>
<td>705</td>
</tr>
</tbody>
</table>

* and **: Significant at 0.05 and 0.01 probability levels, respectively. GCA : general combining ability. SCA: specific combining ability. GMP: geometric mean productivity. MP: mean productivity. P: superiority measure. SP: standard superiority measure. SSI: stress susceptibility index. STI: stress tolerance index. TOL: tolerance.
Additive variance is the main determinant of the observable genetic properties of the population and its response to selection (6). The conspicuity of additive inheritance indicates the possibility of improving drought tolerance through breeding programs and by using the heritable indices considered in this study.

Broad and narrow-sense heritability estimates are presented in Table 2. Estimates were very low for SSI, low for TOL, and moderate for GMP, MP, P, SP, and STI. Genetic advances are directly related to the magnitude of narrow-sense heritabilities (13). Thus, it seems that selection for drought resistance based on GMP, MP, P, SP, and STI will be more fruitful than based on SSI and TOL.

For a trait or parameter to be useful in the selection of superior genotypes, it must be heritable as well as repeatable across samples of the environments (12). In this experiment SSI exhibited negligible heritability, and TOL was less heritable than GMP, MP, P, SP, and STI, as determined by narrow-sense heritability estimates (Table 2). Also, through a good drought tolerance index one should be able to identify superior genotypes in both drought prone and favorable environments.

Table 3 shows the parent lines, means for grain yield, in stressed (Y_s) and non-stressed (Y_p) environments, and drought resistance indices. The ranks of parents for GMP, MP, P, SP, and STI were identical and almost corresponded to the ranking for Y_s and Y_p. On the other hand, TOL and SSI exhibited rankings different than the other indices. Correlation coefficients, calculated from the data obtained for parental lines, are presented in Table 4. GMP, MP, P, SP, and STI were highly correlated with each other as well as with Y_s and Y_p. Thus, through these indices it is possible to distinguish high yielding genotypes in either condition. However, TOL and SSI were not strongly correlated with the above mentioned indices. The correlation coefficient of SSI with Y_s was high and negative while that of TOL with Y_p was high and positive. The correlation coefficients of TOL with Y_p were negligible. According to Fernandez (7), genotypes can be categorized into four groups based on their performance in stressed and non-stressed environments: genotypes which express uniform superiority in both conditions (Group A); genotypes that perform favorably only in non-stressed environments (Group B); genotypes which yield relatively higher only in stressed environments (Group C); and genotypes that perform poorly in either condition (Group D). Fernandez (7) stated that an optimal selection criterion should be to distinguish Group A from the other three. He compared effectiveness of several stress tolerance criteria (GMP, MP, SSI, STI, TOL) and concluded that MP, SSI and TOL failed to identify

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**Table 2.** Estimates of additive genetic variance ($\sigma_g^2$), non-additive genetic variance ($\sigma_{ga}^2$), phenotypic variance on a plot mean basis ($\sigma_p^2$), broad-sense heritability ($h_b^2$), and narrow-sense heritability ($h_n^2$), for different drought resistance indices from wheat dialled grown at Zanjan University, research farm, Zanjan, Iran, in 1997-1998.

<table>
<thead>
<tr>
<th>Component</th>
<th>GMP</th>
<th>MP</th>
<th>P</th>
<th>SP</th>
<th>SSI</th>
<th>STI</th>
<th>TOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_g^2$</td>
<td>307.5 ± 242.5</td>
<td>342.4 ± 368.3</td>
<td>1118797 ± 968926</td>
<td>1.34 ± 1.14</td>
<td>0.001 ± 0.004</td>
<td>0.020 ± 0.015</td>
<td>210.0 ± 174.4</td>
</tr>
<tr>
<td>$\sigma_{ga}^2$</td>
<td>181.7 ± 102.6</td>
<td>215.5 ± 111.0</td>
<td>1032716 ± 498999</td>
<td>1.17 ± 0.57</td>
<td>0</td>
<td>0.011 ± 0.006</td>
<td>0</td>
</tr>
<tr>
<td>$\sigma_p^2$</td>
<td>744.5 ± 269.5</td>
<td>782.4 ± 294.7</td>
<td>2983357 ± 1105630</td>
<td>3.49 ± 1.30</td>
<td>0.089 ± 0.022</td>
<td>0.048 ± 0.017</td>
<td>915.0 ± 254.5</td>
</tr>
<tr>
<td>$h_b^2$ (%)</td>
<td>66 ± 36</td>
<td>71 ± 38</td>
<td>72 ± 38</td>
<td>72 ± 38</td>
<td>1.6 ± 0.09</td>
<td>64 ± 35</td>
<td>23 ± 28</td>
</tr>
<tr>
<td>$h_n^2$ (%)</td>
<td>41 ± 31</td>
<td>44 ± 33</td>
<td>38 ± 31</td>
<td>38 ± 31</td>
<td>1.6 ± 0.04</td>
<td>41 ± 31</td>
<td>23 ± 25</td>
</tr>
</tbody>
</table>

genotypes with both high yield and stress tolerance potentials, whereas through STI, genotypes with these attributes could be identified. Clark et al. (4) assessed drought tolerance indices, P, SP and SSI using 25 hexaploid and 16 tetraploid wheat genotypes grown under dry Vs. irrigated conditions. They observed year-to-year variation in SSI within genotypes as well as changes in genotype ranking within years. Also, SSI did not differentiate between potentially drought tolerant genotypes and those of low yield potential from other causes, whereas P was correlated with mean yield in both hexaploid and tetraploid groups. However, P was strongly influenced by high yield environments, but standardization of the yield data resolved this problem. Several studies conducted in Iran measuring drought response of improved wheat varieties (11), pure lines derived from winter wheat landraces (21), and spring wheat landraces (17) showed that indices such as SSI and TOL were not efficient to be used in selecting genotypes with high yield capacity in either stressed or non-stressed environments. In contrast, STI and SP were identified as efficient indices. SSI and TOL indices only assess the plasticities of the genotypes under study, whereas a variety may rank first in both environments but still have higher SSI and TOL than other varieties.

In conclusion, based on our studies, it seemed that SSI and TOL were not useful indices to select for drought tolerant genotypes in plant breeding programs, because, SSI exhibited negligible heritability and TOL was less heritable than other indices usually not identifying genotypes with both high yield and drought tolerance characteris-

### Table 3. Means of parental lines under study, for drought resistance indices and grain yield in stressed and non-stressed environments.

<table>
<thead>
<tr>
<th>Parents Codes</th>
<th>GMP</th>
<th>MP</th>
<th>P</th>
<th>SP</th>
<th>SSI</th>
<th>STI</th>
<th>TOL</th>
<th>Ys</th>
<th>Yp</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>360.77</td>
<td>370.19</td>
<td>18221.54</td>
<td>2.4057</td>
<td>0.7961</td>
<td>0.4921</td>
<td>164.35</td>
<td>288.02</td>
<td>452.37</td>
</tr>
<tr>
<td>2</td>
<td>426.72</td>
<td>439.46</td>
<td>8566.49</td>
<td>1.1995</td>
<td>0.8516</td>
<td>0.6926</td>
<td>209.93</td>
<td>334.50</td>
<td>544.43</td>
</tr>
<tr>
<td>3</td>
<td>330.41</td>
<td>348.12</td>
<td>22923.69</td>
<td>3.4809</td>
<td>1.0126</td>
<td>0.4239</td>
<td>211.56</td>
<td>242.34</td>
<td>453.86</td>
</tr>
<tr>
<td>4</td>
<td>402.29</td>
<td>436.68</td>
<td>9619.75</td>
<td>1.7578</td>
<td>1.2360</td>
<td>0.6237</td>
<td>336.90</td>
<td>268.24</td>
<td>605.13</td>
</tr>
<tr>
<td>5</td>
<td>442.25</td>
<td>461.18</td>
<td>5334.28</td>
<td>0.7086</td>
<td>0.9431</td>
<td>0.7440</td>
<td>256.18</td>
<td>333.09</td>
<td>589.27</td>
</tr>
<tr>
<td>6</td>
<td>258.28</td>
<td>283.59</td>
<td>36708.59</td>
<td>5.6836</td>
<td>1.2385</td>
<td>0.2524</td>
<td>228.24</td>
<td>169.47</td>
<td>397.71</td>
</tr>
<tr>
<td>7</td>
<td>354.24</td>
<td>370.23</td>
<td>17195.50</td>
<td>2.4223</td>
<td>0.9457</td>
<td>0.4799</td>
<td>204.99</td>
<td>267.73</td>
<td>472.72</td>
</tr>
</tbody>
</table>

LSD<sub>0.05</sub> 74.41 71.66 12311.50 1.7271 0.4483 0.2134 118.50 86.46 99.06


### Table 4. Correlation coefficients among drought resistance indices and grain yield in stressed and non-stressed environments.

<table>
<thead>
<tr>
<th></th>
<th>GMP</th>
<th>MP</th>
<th>P</th>
<th>SP</th>
<th>SSI</th>
<th>STI</th>
<th>TOL</th>
<th>Ys</th>
<th>Yp</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMP</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP</td>
<td>0.988</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>-0.919</td>
<td>-0.935</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP</td>
<td>-0.944</td>
<td>-0.931</td>
<td>0.963</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSI</td>
<td>-0.350</td>
<td>-0.205</td>
<td>0.214</td>
<td>0.361</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STI</td>
<td>0.988</td>
<td>0.980</td>
<td>-0.898</td>
<td>-0.901</td>
<td>-0.324</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOL</td>
<td>0.280</td>
<td>0.425</td>
<td>-0.407</td>
<td>-0.251</td>
<td>0.786</td>
<td>0.305</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ys</td>
<td>0.930</td>
<td>0.863</td>
<td>-0.801</td>
<td>-0.884</td>
<td>-0.664</td>
<td>0.908</td>
<td>-0.092</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Yp</td>
<td>0.869</td>
<td>0.935</td>
<td>-0.879</td>
<td>-0.814</td>
<td>0.150</td>
<td>0.873</td>
<td>0.718</td>
<td>0.628</td>
<td>1.000</td>
</tr>
</tbody>
</table>

tics. On the other hand indices like SP and STI were moderately heritable and are usually able to select high yielding genotypes in both environments. Therefore, based on the results obtained in this and previous studies (4,7,11,17,21), STI and SP seem to be useful yield-based drought tolerance indices to be employed in plant breeding programs for wheat.

The consistency or repeatability of the heritable indices could not be studied at this stage. To test this, the experiments should be repeated at different locations and years with different drought intensity levels.

REFERENCES

منشأت زنبوری شاخص‌های مقاومت به خشکی

چکیده

نحوه تواریث چندین معیار مقاومت به خشکی مبتنی بر عملکرد بر روی نیمه دیالل با استفاده از هفت واریته گندم پایینه مورد بررسی قرار گرفت. لاین‌هاو الکایی، به طور تصادفی از دامنه وسیعی از مقاومت به شاخص انتخاب شدند. آزمایش در سال زراعی 1379 به صورت اصلی قابل مطالعه و بررسی با طرح پایه بلورکه‌های میل کیکی و به صورت تصادفی در سه گروه اصلی دانشکده کشاورزی دانشگاه شهید چمران شد. زعیم‌های آپارتمان و پنجم‌گی به عنوان دو کریکت اصلی در نظر گرفته شدند. از تولیدهای ولی درکردهای مبتنی بر عملکرد شاخص‌های مقاومت به خشکی واریته‌های F1 و گردانگی به عنوان پایین‌گرد حسابگر و میانگین عملکرد (GMP)، میانگین عملکرد (MP)، (SP) و از تولیدهای کثرت (STI)، شاخص حمل تنش (SSI) و عبور از تولیدهای تولیدهای F1، واریته‌های TOL، نشانه‌های نیز واریته‌های GMP، MP، P، SP، STI و TOL از نظر تحلیل واریانس، با توجه به صفت نیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت نیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت نیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت نیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت نیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت نیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نشانه‌های MP، P، STI و TOL از نظر تحلیل واریانس، با توجه به صفت Nیاز به نش