Evaluating resistance to drought stress in flue-cured tobacco varieties via stress susceptibility indexes in dry farming condition

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ABSTRACT: The evaluate of resistance indices to post anthesis water deficit can help to identify strategies for selection of resistant cultivars of Tobacco (Nicotiana tabacum L.) and increased crop yield production. an experiment was conducted in a factorial experimental on the basis of randomized complete block design under two irrigated conditions during 2010-2011 cropping season. Five drought tolerance/resistance indices including stress tolerance index (STI), stress susceptibility index (SSI), tolerance index (TOL), geometric mean production (GMP), mean production (MP) were calculated based on leaf weight yield under drought and irrigated conditions. The leaf weight yield in stress and non-stress conditions were significantly and positively correlated with STI, TOL, GMP, MP, and negatively correlated with SSI. Screening drought tolerant cultivars using ranking method, three dimensional plots discriminated cultivars ‘K 394’, N.C 95, Previ stamm 9’ and Tirtash 30 as the most drought tolerant. Cluster analysis classified the cultivars into three groups i.e., tolerant, susceptible and semi-susceptible to drought conditions. In general, Results of this study showed that among drought tolerance indices STI can be used as the most suitable indicators for screening drought tolerant cultivars and ‘K 394’, N.C 95, Previ stamm 9, and Tirtash 30 had the highest tolerance to drought in our studies condition.

Keywords: tobacco, drought stress, cultivars, selection indices

INTRODUCTION

Tobacco (Nicotiana tabacum L.) is a plant within the genus Nicotiana of the Solanaceae (nightshade) family. There are more than 70 species of tobacco. Products manufactured from dried tobacco leaves include cigars, cigarettes, snuff, pipe tobacco, chewing tobacco and flavored shisha tobacco. Other uses of tobacco include plant bioengineering and ornamentals, while chemical components of tobacco are used in some pesticides and medications (Robert, 2012).

The chief commercial species, N. tabacum, is believed to have been native to tropical America, like most nicotiana plants, but has been so long cultivated that it is no longer known in the wild. N. rustica, a species producing fast-burning leaves, was the tobacco originally raised in Virginia, but it is now grown chiefly in Turkey, India, and Russia. The addictive alkaloid nicotine is popularly known as the most characteristic constituent of tobacco, but harmful effects of tobacco consumption can derive from the thousands of different chemicals in the smoke, including polycyclic aromatic hydrocarbons (such as benzopyrene), formaldehyde, cadmium, nickel, arsenic, tobacco-specific nitrosamines (TSNAs), phenols, and many others (Brevedan and Egli, 2003). Tobacco also contains beta-carboline alkaloids which inhibit monoamine oxidase (Alizadeh, 2002). Plant Breeders and physiologists that studied drought tolerance in plants for years are argued that crop yield affected by environmental
conditions, genetic structure and their interactions. Among the various forms of environmental stresses, drought stress is the most important factor that limiting growth and economic yield production of crops such as Tobacco via reducing leaf growth (Ephrath and Heskeht, 1991), chlorophyll concentration, soluble protein concentration, stomatal conductants, accelerating senescence of leaves and reducing the rate of photosynthesis. Of course amount of damage to the plant production depends on the severity and duration of stress application, plant resistance and plant growth stage (Thomas Robertson, 2004).

Several selection criteria have been proposed to select genotypes based on their performance in stress and non-stress environments. Rosielle and Hamblin (1981) demonstrated that lower stress tolerance index (STI), hybrid yield in normal irrigation and drought condition is close to each other or plant is resistant to drought. Stress Tolerance Index (STI) was defined as a useful tool for determining high yield and stress tolerance potential of genotypes (Clarke, 2002). So, Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between stress and irrigated environments and mean productivity (MP) as the average yield of genotypes under stress and non-stress conditions. The geometric mean productivity (GMP) is often used by breeders interested in relative performance, since drought stress can vary in severity in field environments over years (Clarke, 2002). Fischer and Maurer (1978) suggested the stress susceptibility index (SSI) for measurement of yield stability that apprehended the changes in both potential and actual yields in variable environments. Clarke, (2002) used SSI to evaluate drought tolerance in wheat genotypes and found year-to-year variation in SSI for genotypes and could rank their pattern. In spring wheat cultivars, Guttieri, (2001) using SSI, suggested that an SSI > 1 indicated above-average susceptibility to drought stress. Stress Tolerance Index (STI) was defined as a useful tool for determining high yield and stress tolerance potential of genotypes (Clarke, 2002).

This study was carried out in order to evaluate tobacco cultivars reaction to drought stress and determine the best measures for increase and improvement of cultivars yield in stress and non-stress condition. Also, this study was undertaken to assess the selection criteria for identifying drought tolerance in tobacco cultivars, so that suitable cultivars can be recommended for cultivation in drought prone areas of Iran and it similar areas.

MATERIALS AND METHODS

This experiment was conducted on the basis of factorial experimental with completely randomized block design in 3 replications in 2010-2011, at Tirtash Research and Education Center, Iran. Evaluated treatments were included that moisture regimes and different improved Tobacco (Nicotiana tabacum L.) cultivars. Two levels of moisture regimes (includes: Irrigation in all stages of plant growth normally and post-anthesis water deficiency with withholding of irrigation) as the main-plot and different improved cultivars (includes: K 394, N.C 95, Previ stamm 9 Tirtash 30, Bel61-11, Bel61-9, Bel B, BEL61-12) as sub-plot were considered.

Five drought tolerance indices including leaf weight were calculated using the following relationships (Bouslama and Schapaugh, 1984; Clarke, 2002; Fernandez, 1992; Blum A, 1988; Farshadfar, 2014):

$$SSI = \frac{(1-(\bar{Y}_s/\bar{Y}_p))}{(1-(\bar{Y}_s/\bar{Y}_p))} \quad Eq. 1$$
$$STI = (\bar{Y}_s \times \bar{Y}_p)/(\bar{Y}_s \times \bar{Y}_p) \quad Eq. 2$$
$$GMP = \sqrt{\bar{Y}_s \times \bar{Y}_p} \quad Eq. 3$$
$$TOL = \bar{Y}_s - \bar{Y}_p \quad Eq. 4$$
$$MP = (\bar{Y}_s + \bar{Y}_p)/2 \quad Eq. 5$$

In the above formulas $\bar{Y}_s$ and $\bar{Y}_p$ represent leaf weight yield under stress, leaf weight yield non-stress for each cultivar, leaf weight yield mean in stress and non-stress conditions for all cultivars, respectively.

Statistical analyses were performed using SAS software. Mean comparisons were also performed using LSD at 5% level.

RESULTS AND DISCUSSION

To investigate suitable stress resistance indices for screening of cultivars under drought condition, leaf weight yield of cultivars under both non-stress and stress conditions were measured for calculating different sensitivity and tolerance indices (Table. 1). Based on the stress tolerance index (STI), MP, GMP, and leaf weight yield in two conditions, ‘K 394’, N.C 95, Previ stamm 9’ and Tirtash 30 were found drought tolerance with highest STI and leaf weight yield under irrigation (non-stressed) condition, while Bel61-11, Bel61-9, Bel B, BEL61-12 displayed the lowest amount of for this indices under irrigation condition (Table 1). Also, according to SSI and TOL indices selected the ‘K 394’, N.C 95, Previ stamm 9’ as the most relatively tolerant cultivars while for this indices the cultivars Bel61-11, Bel61-9, Bel B were the least relative tolerant. So, according to SSI and TOL indices selected
the ‘K 394’, N.C 95, Previ stamm 9 and Tirtash 30 as the most relatively tolerant cultivars while for SSI the cultivars Bel61-9, Bel B, BEL61-12 and for TOL the cultivars BEL61-12 were the least relative tolerant. Tolerant indices another showed different amount for cultivars. Farshadfar (2012) used the tolerance indices such as, RDI, STI, YSI, SSPI, and MSTI for screening tolerance bread wheat landraces.

To determine the most desirable drought tolerant criteria, the correlation coefficients between Yp, Ys, and other quantitative indices of drought tolerance were calculated. In other words, correlation analysis between leaf weight yield and drought tolerance indices can be a good criterion for screening the best cultivars and indices used (Table 2). A suitable index must have a significant correlation with leaf weight yield under both the conditions (Ehdaie and Shakiba, 1996). The highest positive correlation was observed between MP and Yp and between GMP and Ys, while highest negative correlation was recorded between SSI and yield in drought condition. Ehdaie and Shakiba (1996) in wheat found that there was no correlation between stress susceptibility and yield under optimum condition. Yield in stress condition (Ys) was significantly and positively corrected with TOL, MP, GMP, STI. Also, yield in non-stress condition (Yp) was significant and positively correlated with TOL, MP, GMP, STI, indicating that these criteria were more effective in identifying high yielding cultivars under different water conditions. The results of this study indicated positive and significant correlation between MP and Yp and between STI and Ys.

However, significantly and negatively correlation was recorded between SSI and yield in drought condition. Toorchi, (2012) showed that correlation between MP, GMP, Ys, and Yp was positive. Khalili, (2012) reported that GMP, MP, and STI were significantly and positively correlated with stress yield. The observed relations were consistent with those reported by Farshadfar, (2012) in landrace wheat and Golabadi et al (2006) in durum wheat. Mehrabi, (2011) suggested corn hybrids with high yield may be obtained based on GMP and STI indices. Also, İlker, (2011) concluded that MP, GMP and STI values are convenient parameters to select high yielding wheat genotypes in both stress and non-stress conditions whereas relative decrease in yield. Jafari, (2009) found that STI, GMP indices which showed the highest correlation with leaf weight yield under both optimal and stress conditions, can be used as the best indices for maize breeding programs to introduce drought tolerant hybrids. Consequently, they indicated that Stress Tolerant Index (STI) was more useful in order to select favorable corn cultivars under stress and non-stress conditions. Results showed that among drought tolerance indices, MP, GMP, STI, can be used as the most suitable indicators for screening drought tolerant cultivars because had highest correlation with Yp and Ys and this tolerant correlation had positive correlation together. In the study conducted by Farshadfar and Elyasi (2012) and Farshadfar, (2012a,b) yield in the stress and non-stress conditions were positively correlated with MSTI. Also, our results showed significantly and positively correlation between SSPI with Yp and Ys, thus this index may be able to use as the index for screening tolerant cultivars. Farshadfar, (2001) believe that the most suitable indices for selection of drought tolerant cultivars are indicators which show a relatively high correlation with grain yield in both stress and non-stress conditions.

CONCLUSIONS

Among different resistance and tolerance indices were evaluated all indices expect STI and GMP have high correlation with leaf weight yield under stress and non-stress condition indicating more suitability of these indices for selection of resistant genotype. Screening drought tolerant cultivars using ranking method and Cluster analysis discriminated cultivars ‘K 394’, N.C 95, Previ stamm 9 and Tirtash 30 as the most drought tolerant.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Yp_SSI</th>
<th>Ys_SSI</th>
<th>SSI</th>
<th>STI</th>
<th>GMP</th>
<th>TOL</th>
<th>MP</th>
</tr>
</thead>
<tbody>
<tr>
<td>K 394</td>
<td>9680 a</td>
<td>3780 a</td>
<td>1.018a</td>
<td>1.06a</td>
<td>4968a</td>
<td>2753a</td>
<td>5156a</td>
</tr>
<tr>
<td>N.C 95</td>
<td>5342ab</td>
<td>3133ab</td>
<td>0.971a</td>
<td>0.98a</td>
<td>4709a</td>
<td>2528a</td>
<td>4897a</td>
</tr>
<tr>
<td>Previ stamm 9</td>
<td>9245a</td>
<td>3682a</td>
<td>0.784ab</td>
<td>0.91a</td>
<td>4552a</td>
<td>2009a</td>
<td>4857a</td>
</tr>
<tr>
<td>Tirtash 30</td>
<td>5670ab</td>
<td>3125ab</td>
<td>1.181a</td>
<td>0.82a</td>
<td>4315a</td>
<td>4315a</td>
<td>4558a</td>
</tr>
<tr>
<td>Bel61-9</td>
<td>5953b</td>
<td>1804b</td>
<td>0.93b</td>
<td>0.23b</td>
<td>2245b</td>
<td>1021b</td>
<td>2327b</td>
</tr>
<tr>
<td>Bel61-11</td>
<td>5789b</td>
<td>1453b</td>
<td>0.95b</td>
<td>0.13b</td>
<td>1666b</td>
<td>1283b</td>
<td>1945b</td>
</tr>
<tr>
<td>Bel B</td>
<td>6849ab</td>
<td>2491ab</td>
<td>0.66b</td>
<td>0.30b</td>
<td>2991b</td>
<td>1186b</td>
<td>3021b</td>
</tr>
<tr>
<td>BEL61-12</td>
<td>5423b</td>
<td>1883b</td>
<td>0.83b</td>
<td>0.21b</td>
<td>2314b</td>
<td>946b</td>
<td>2132b</td>
</tr>
</tbody>
</table>

Means with similar letter are not significant at the 5% probability level.
Table 2. Correlation coefficient between Yp, Ys and resistance/tolerance indices

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Yp(kg)</th>
<th>Ys(kg)</th>
<th>TOL</th>
<th>STI</th>
<th>GMP</th>
<th>SSI</th>
<th>MP</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>Yp(kg)</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ys(kg)</td>
<td>0.84**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOL</td>
<td>0.71**</td>
<td>0.8**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STI</td>
<td>0.88**</td>
<td>0.5**</td>
<td>0.37**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GMP</td>
<td>0.5**</td>
<td>0.98</td>
<td>0.9**</td>
<td>0.38**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSI</td>
<td>-0.4*</td>
<td>-0.68**</td>
<td>0.18</td>
<td>0.8**</td>
<td>-0.54**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>MP</td>
<td>0.94</td>
<td>0.78</td>
<td>0.51</td>
<td>0.86</td>
<td>0.78**</td>
<td>0.62**</td>
<td>1</td>
</tr>
</tbody>
</table>

* and ** Significant at the 5% and 1% levels of probability, respectively

REFERENCES