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EVALUATION OF DROUGHT TOLERANCE IN NEW COTTON CULTIVARS USING STRESS TOLERANCE INDICES

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ABSTRACT

Drought is a wide-spread problem seriously influencing production and quality of cotton (*Gossypium hirsutum* L.), but development of resistant cultivars is hampered by the lack of effective selection criteria. The objective of this study was to evaluate the ability of several selection indices to identify drought tolerant cultivars under different environmental conditions. Thirteen cotton cultivars were evaluated under both moisture stress (2016) and non-stress (2013) field environments using a randomized complete block design for each environment. Six drought tolerance indices including stress susceptibility index (SSI), stress tolerance index (STI), tolerance index (TOL), mean productivity (MP), geometric mean productivity (GMP) and mean harmonic productivity (HMP) were used. The significant and positive correlation of yield of genotype under non-stress condition (Yp) and MP, GMP and STI showed that these indices were more effective in identifying high yielding cultivars under different moisture conditions. The results of calculated gain from indirect selection in moisture stress environment would improve yield better than selection from non moisture stress environment. Coton breeders should, therefore, take into account the stress severity of the environment in choosing an index. The varieties Viki and Avangard-264 had the highest yields under non-stress conditions. Vega and Chirpan-539 varieties had a low yield potential and showed a high stress tolerance to drought.

Keywords: *cotton, drought tolerance index, moisture stress.*

INTRODUCTION

Cotton (*G. hirsutum L.*) is one of the most important fiber crops, which is of great economic and social importance. Despite the fact that it is a relatively drought-resistant crop and shows high tolerance to drought, insufficient soil moisture adversely affects the normal seed emergence, plant growth, development, yield and fiber quality (Hearn, 1979). The water balance deficit during the flowering-ballformation period is critical for cotton. In experiments with cotton grown under optimal and hydropower conditions, Karademir et al. (2011) found that water stress caused a decrease in fiber yield by 49.4%. The technological fiber properties were negatively affected, too.

Climatically, Bulgaria falls into the zone of unsustainable humidification (Sabeva, 1968). Cotton-producing areas are characterized by well-expressed drought in July-August, because of which the yields are below the genetic potential. Changes in the global climate, with an increase in the average air temperature and a decrease in rainfall (Aleksandrov, 2002), are also found in Bulgaria. The moisture losses from evapotranspiration has been steadily increasing and this trend will continue in the coming decades of this century (Aleksandrov, 2002), which is a prerequisite for efforts to adapt the agricultural production to the conditions of the constantly-changing climate.

The creation of high-yielding varieties to realize their yield potential, esspecially in drought conditions is an extremely difficult task for breeders (Mustatea et al., 2003; Richards et al., 2002). Susceptibility of plant to drought is often measured as a function of yield reduction in water stress (Blum, 1988), referred to yield potential values (Ramirez & Kelly, 1998). Drought indices, based on plant production losses under dry and normal conditions, are used for the screening of drought resistant genotypes (Mitra, 2001). Separate selection criteria evaluate genotypes, based on the results obtained under stress and non-stress conditions. Rosielle & Hamblin (1981) defined the stress tolerance index (TOL) as a difference in yield under irrigated and non-irrigated conditions and average productivity (MP), as the mean value of yield in stress and non-stress conditions.

Geometric mean productivity (GMP) is often used by breeders who are interested in relative productivity, as water stress varies in field conditions over the years (Fernandez, 1992). Fisher and Maurer (1978) recommend the stress susceptibility index (SSI) to measure yield stability, and this index captures changes in potential and real yield in a variable environment. The stress tolerance index (STI) is a useful tool for identifying high yielding genotypes that also have a high stress-tolerance potential (Fernandez, 1992).

MATERIAL AND METHODS

In this research 13 cotton varieties – Chirpan-539, Avangard-264, Perla, Natalia, Darmi, Colorit, Vega, Dorina, Nelina, Rumi, Helius, Boyana and Viki, created in the Field Crops Institute – Chirpan, Bulgaria were included. The trial was carried out in 2013 and 2016, in the experimental field of the Institute, on pellic vertisols (FAO), set up by randomized block design in four replications and harvesting plot of 20 m^2. Drought resistance indices were calculated using the following relationships:

Mean productivity	$MP = (Ys+Yp)/2$	(Rosielle and Hamblin, 1981)
Geometric mean productivity	$GMP = \sqrt{(Ys \times Yp)}$	(Fernandez, 1992)
Tolerance index	$TOL = Yp - Ys$	(Rosielle and Hamblin, 1981)
Stress susceptibility index	$SSI = \dfrac{1-\left(Ys/Yp\right)}{1-\left(\bar{Y}s/\bar{Y}p\right)}$	(Fischer and Maurer, 1978)
Stress tolerance index	$STI = \dfrac{Ys \times Yp}{\bar{Y}p^2}$	(Fernandez, 1992)
Harmonic mean productivity	$HMP = \dfrac{2(Ys)(Yp)}{(Ys+Yp)}$	(Kristin et al., 1997)

Where:
Yp – yield of genotype under non-stress condition;
Ys – yield of genotype under stress conditions;
$\bar{Y}$p – potential yield of all genotypes in non-stress conditions;
$\bar{Y}$s – potential yield of all genotypes in stress conditions;

RESULTS AND DISCUSSION

The years of the investigation as regards weather conditions, were characterized as follows: 2013 was considered agro-meteorologically favorable for the growth and development of cotton; in 2016 the amount of rainfall in June and July was by 77% and 92%, respectively lower than the average of many year values, while the temperature sum was higher by 9-10% (Fig. 1).

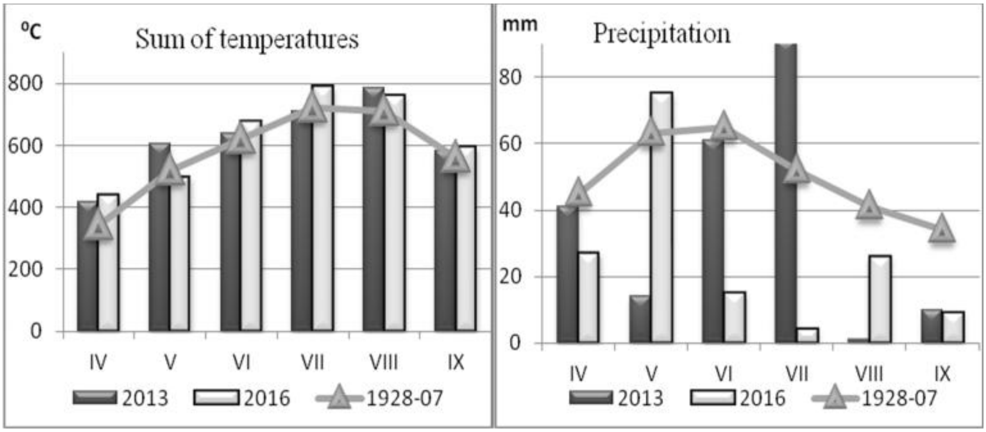

Figure 1. Meteorological conditions during the cotton growing season in 2013 and 2016 and average for the period 1928-2007

To calculate drought indexes we used the data for the total seed cotton yield obtained in 2013 and 2016 (Table 1), taking the yield reported in 2013 for potential yield - Yp, and the yield reported in 2016 marked as Ys - yield under stress conditions. The highest potential yield was recorded for Viki and Avangard-264 varieties, respectively 239.6 kg/da and 236.0 kg/da (10 da = 1 ha). The lowest potential yield was observed for Vega (176.2 kg/da) and Chirpan-539 (187.6 kg/da), which were defined as genotypes with low potential yield. In the dry 2016, the average seed cotton yield for all varieties was by 36% lower than the average potential yield. Highest yield under stress conditions (Ys) was achieved with Vega and Nelina varieties (155.0 kg/da and 148.7 kg/da). The Colorit and Dorina varieties had the lowest yields under stress conditions - 117.5 kg/da and 106.3 kg/da, respectively. The highest mean productivity (MP) values were calculated for Avangard-264 and Viki varieties. Generally, higher values of mean productivity are indicator for genotypes with high yield potential. MP shows a preference for higher yield potential and lower resistance to stress (Zangi, 2005). The lowest MP values were found for Colorit and Dorina varieties.

Geometric mean productivity (GMP) is less sensitive to larger differences between potential yield values and those of yield under stress conditions. Highest GMP values were recorded for Nelina and Avangard-264 varieties. The lowest values for GMP were found for Colorit and Dorina varieties, which again appeared to be the most sensitive to water stress. Varieties with hight HMP values were preferred under stress conditions (Farshadfar and Javadinia, 2011). The highest harmonic mean values were calculated for Nelina and Avangard-264 varieties, and the lowest - for Colorit and Dorina. Varieties having high values of the stress tolerance index (STI) possessed significant yield potential and substantial stress tolerance (Rosielle and Hamblin, 1981; Rajmani, A.1994). The highest values for STI were calculated for Nelina, Perla and Avangard-264 varieties. The variety Dorina was the most sensitive to this indicator. Stress tolerance (TOL) was calculated as a difference in yield under non-stress (Yp) and stress (Ys) conditions. Higher TOL values showed greater stress sensitivity and that’s why genotypes with low values of this indicator were preferred (Zangi, 2005). The lowest TOL indexes were found for Vega and Chirpan-539 varieties. According to Zangi (2005), genotypes selected on the base of TOL will have a low yield potential and will realize high yields under stress conditions. Higher TOL values suggested greater losses under unfavorable conditions and a higher sensitivity to drought. In our investigation Viki and Dorina varieties had the highest values for this index.

Low values of the stress sensitivity index (SSI) were a prerequisite for higher stress tolerance (Zangi, 2005). According to a number of authors, when SSI values are less than 1, these varieties can be defined as drought-resistant (Ramirez and Kelly, 1998). The varieties with the lowest SSI values, i.e. having high stress tolerance were Vega and Chirpan-539. It should be noted that for Natalia, Darmi, Nelina, Rumi and Boyana varieties the SSI values were smaller than one, too. The highest values of the stress sensitivity index were recorded for Dorina and Viky varieties. By this indicator these varieties exhibited the highest sensitivity.

Table 1. Indices for assessing of drought tolerance of 13 cotton varieties on the basis of yield (2016) under stress and non-stress (2013) conditions.

	Cultivar	Yp	Ys	MP	GMP	HMP	STI	TOL	SSI
1	Chirpan-539	187,6	142,4	165,0	163,4	161,9	1,5	**45,2**	**0,662**
2	Avangard-264	**236,0**	136,2	**186,1**	**179,3**	**172,7**	**1,8**	99,8	1,161
3	Perla	231,1	137,4	184,3	178,2	172,4	**1,8**	93,7	1,113
4	Natalia	198,8	138,8	168,8	166,1	163,5	1,5	60,0	0,829
5	Darmi	206,3	132,4	169,4	165,3	161,3	1,5	73,9	0,984
6	Colorit	211,1	117,5	164,3	157,5	150,9	1,4	93,7	1,218
7	Vega	176,2	**155,0**	165,6	165,3	164,9	1,5	**21,2**	**0,330**
8	Dorina	208,5	106,3	157,4	148,8	140,8	1,2	102,3	1,347
9	Nelina	217,1	**148,7**	182,9	**179,7**	**176,5**	**1,8**	68,4	0,866
10	Rumi	213,6	144,0	178,8	175,4	172,0	1,7	69,7	0,896
11	Helius	224,8	129,8	177,3	170,8	164,6	1,6	95,0	1,161
12	Boyana	198,8	130,1	164,4	160,8	157,2	1,4	68,7	0,950
13	Viki	**239,6**	130,2	**184,9**	176,6	168,7	1,7	109,4	1,254

Table 2. Correlations between seed cotton yield and drought tolerance indices

	Yp	**Ys**	**MP**	**GMP**	**HMP**	**STI**	**TOL**	**SSI**
Yp	1,00							
Ys	-0,28	1,00						
MP	0,78***	0,39***	1,00***					
GMP	0,58***	0,62***	0,96***	1,00***				
HMP	0,37***	0,79***	0,87***	0,97***	1,00***			
STI	0,60***	0,60***	0,97***	1,00***	0,96***	1,00		
TOL	0,88***	-0,71***	0,37***	0,12***	-0,13***	0,14	1,00***	
SSI	0,78***	-0,82***	0,21***	-0,05***	-0,29***	-0,03	0,98***	1,00

* = 0.05, **= 0.01, ***= 0.001

Based on the performed correlation analysis, it was found that the relation between Yp and Ys was negative (Table 2) i.e. if the selection of genotypes is performed under optimum conditions, high yields would only be achieved under non-stress conditions. Tolerance to stress and stress sensitivity index were in a positive correlation and significant on a very high probability level.

Positive and significant correlation was found between SSI and Yp, while between SSI and Ys it was negative. This gives us reason to believe that varieties selected under this criterion will have a high stress tolerance and will produce high yields under unfavorable conditions, but under low stress conditions will have a low yield potential.

CONCLUSIONS

The varieties Viki and Avangard-264 produced the highest yields under non-stress conditions. The varieties Vega and Chirpan-539 had low potential yields and showed a high stress tolerance to drought. On the GMP, HMP, STI the varieties Nelina and Avangard-264 had the best performance, while the varieties Colorit and Dorina showed the highest sensitivity.

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