Susceptibility index to study genotypic variation in cotton heat tolerance

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ABSTRACT

The susceptibility index developed by Fisher and Maurer (1978) was used to determine the heat resistance of thirty-six upland cotton genotypes. A field experiment with two treatments (heat stress and no stress) was conducted at Alcalá del Río (Seville, Spain). The heat stress treatment was provided by using a plastic shelter covering the rows. The experimental design was a split plot with three replications. The heat stress treatment was the main factor and genotypes were sub plots. A significant genotypic variation in heat susceptibility index was found. The biplot of the susceptibility index and seed cotton yield showed the differential performance of the genotypes. Some genotypes had a low susceptibility index (showed heat resistance) but differed in yield potential. A positive correlation between heat susceptibility index and yield potential was found. The consequences for the selection of heat tolerant cotton genotypes are discussed.

Introduction

Air temperature is a main factor controlling the growth rate and reproductive events of cotton plants. In Andalusia (South of Spain) a higher yield might be expected on the basis of the cumulative days-degree in the absence of other limiting factors. A possible yield limiting factor might be high temperatures which have been negatively associated to seed cotton yield and some fiber traits (length, uniformity) (López *et al.*, 2002). High temperatures are frequently recorded during the summer in the main cotton production area of Spain (Guadalquivir River Valley), which supports the search for heat tolerant genotypes.

Breeding programs are normally undertaken in optimum conditions, as it is considered easier to achieve greater progress in productivity under such conditions (Rosielle and Hamblin, 1981). Heat tolerance results from complex plant-environment interactions and it is not clear which adaptive mechanisms and which traits are better related to greater yield under heat stress conditions. When breeding for improving productivity under stress, two different points of view are considered: selection for high potential yield, accepting the hypothesis that if the yield of a genotype is increased in optimum conditions it will also be increased in non-optimum conditions, or selection for high yield under stress conditions (Blum, 1979).

To study genotypic variation under heat stress, the simplest way might be the placement of cultivars under both optimum and stress conditions. Fisher and Maurer (1978) proposed a susceptibility index to express the decrease in yield of a cultivar under stress with respect to the mean reduction of all the cultivars under consideration. In cotton, a modification of this index was used by other authors to study the behavior of several upland cultivars under drought conditions (Cook, 1989; López, 1998; Gutiérrez *et al.*, 2000). The susceptibility index has been used to evaluate heat tolerance in wheat (Sangam *et al.*, 1998; Chen *et al.*, 2000; Sarkar *et al.*, 2001; Yang *et al.*, 2002). In this work, we present preliminary results of a year study of applying heat stress to upland cotton cultivars, the analysis of selection criteria like a heat susceptibility index and its relationship with yield, yield components and fiber properties. Data from Lopez *et al.* (2003) were used.

Experimental procedure

Thirty-six Upland cotton genotypes (Table 1) were planted in Alcalá del Río (Sevilla, Spain) and heat-stressed as indicated previously (López *et al.*, 2003). A Heat Susceptibility Index (HSI) was calculated modifying original Fisher and Maurer (1978) equation: $HSI = [1-(Yh/Yp)]/D$; where Yh = seed cotton yield under heat stress; Yp = seed cotton yield without stress (potential yield) and D = Heat Intensity = 1- (general mean of all genotypes under stress / general mean of all genotypes without stress). The statistical design was a complete randomized block design with three replications. At harvest, 15 plants were selected from each replicate and plant height, number of nodes, number of fruiting sites and bolls were recorded. The bolls and seed cotton were weighed and fiber properties were determined by HVI after ginning. Seed index was determined as the weight of 100 seeds. Earliness was calculated as the ratio between the final yield and yield recorded at first picking.

Results and Discussion

Significant differences in the heat susceptibility index (HSI) were recorded among genotypes (Table 2). The relationship between HSI and the production under favorable conditions is presented in Figure 1. Heat stress tolerant genotypes were those with HSI values lower than the unit, while susceptible ones were those with HSI values greater than the unit. Most genotypes could be enclosed in quadrant I (Figure 1) because of their high potential yield and HSI values or in quadrant III, characterized by low productivity and low HSI. Genotypes 25, 29 and 30 combined good heat tolerance with yield potential.

Plant height, number of nodes, boll weight and yield of cotton genotypes grown in the absence of heat stress were positively correlated to HSI ($r=0.407$, $P<0.01$; $r=0.370$, $P<0.05$; $r=0.391$, $P<0.01$; $r=0.410$, $P<0.01$, respectively). These results clearly suggest that selecting by high yield under optimum conditions might have a negative effect on productivity under heat stress. The number of bolls per plant when cotton was grown under stress showed a negative association with HSI ($r=-0.512$, $P<0.001$) indicating that the number of bolls might have been the main determinant of lower susceptibility to heat stress.

These results point out a negative relationship between yield under favorable conditions and tolerance to heat stress, determined as HSI, underline the importance of selecting genotypes under stress conditions. Similar conclusions were found when evaluating heat stress tolerance in wheat genotypes (Chen *et al.*, 2000). As it was reported previously (López *et al.*, 2003), working in favorable environments may involve the risk of selecting good performing genotypes with of high sensitivity and low productivity under heat stress conditions. The use of the heat stress index has been useful to confirm the need of performing genotype evaluation under stress when breeding for heat tolerance.

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Table 1. *List of cotton genotypes studied with reference to their origin.*

Genotypes	Code	Origin	Genotypes	Code	Origin
Virgen de Gracia	1	Spain	Carmen	19	Australia
Sor Angela	2	id	Corona	20	USA
Marismas	3	id	Crema 111	21	USA
Carlota	4	id	Anita	22	USA
Conchita	5	id	Bravada	23	USA
Max 9	6	USA	María del Mar	24	Spain
Celia	7	Australia	La Chata	25	Spain
Sonia	8	Australia	Avangard 264	26	
Delta Opalo	9	Australia	GC 510	27	USA
Atina	10	USA	Rosita	28	Spain
Tauro	11	USA	Guadalquivir	29	Spain
Theka	12	Spain	Cristi	30	Spain
Coketa	13	Spain	Acala 1517/77/BR	31	USA
Tashkent 6	14	Russia	DP 90	32	USA
Nata	15	USA	Precoce 1	33	Brazil
Flora	16	Australia	Acala Prema	34	USA
Montana	17	USA	CNPA 3H	35	Brazil
Fotini	18	Australia	Koralle	36	USA

Table 2. Analysis of variance for Heat Stress Index calculated for thirty-six cotton genotypes.

Source of variation	df	MSQ
Genotypes	35	1.01580***
Replications	2	0.14106 ns
Error	70	0.11713

*** Significant at the 0.001 probability level.

ns = not significant.

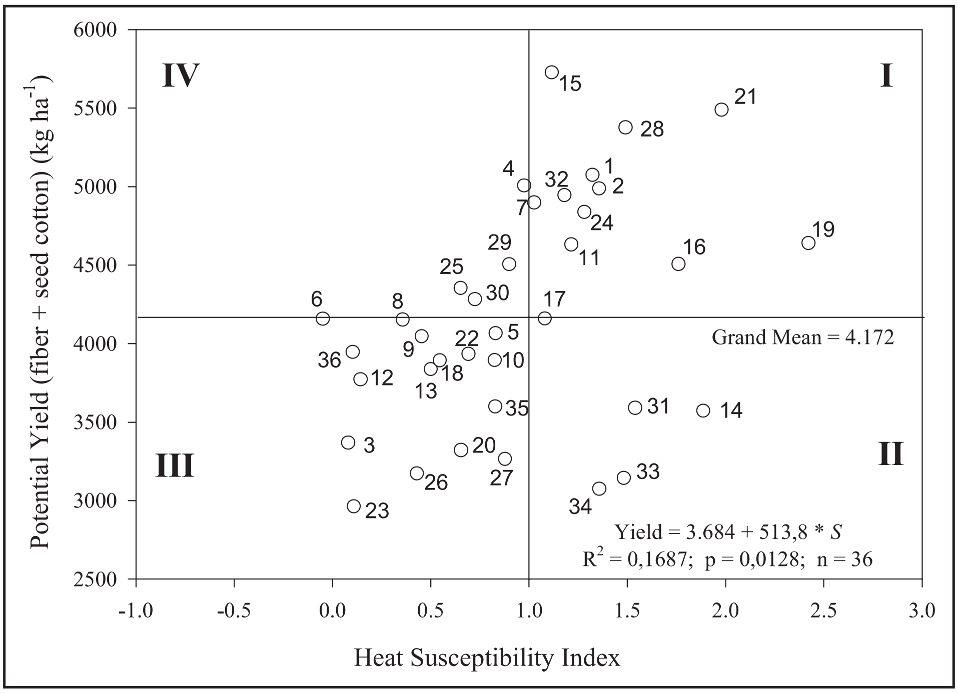

Figure 1. Biplot between cotton yield recorded under optimum conditions and the heat susceptibility index calculated after heat stress treatment imposed on thirty-six upland cotton genotypes.