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Association analysis among plant morpho-physiological traits related to heat tolerance in upland cotton (*Gossypium hirsutum* L.)

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Abstract
An experiment was carried using 204 upland cotton (*Gossypium hirsutum* L,) diverse genotypes for heat tolerance during summer 2016-17 to study character association by correlation analysis among plant morpho-physiological traits. The results showed that increased canopy temperature due to heat stress can significantly affect plant growth and development, including chlorophyll content as well as leaf area even when the crop was cultivated under irrigated conditions. Since, the cotton cultivars with cooler canopies have higher heat tolerance and as canopy temperature reflects genotype fitness in a stressful environment, it can be used as an indirect selection criterion for genetic improvement of high temperature tolerance in the cultivars.

Keywords: Association, among, plant, morpho-physiological, tolerance, *Gossypium hirsutum* L.

Introduction
The upland cotton (*Gossypium hirsutum* L.) is the important fibre crop in India and in the world. The textile industry in India is basically dependent on cotton and contributes significantly to the economy of the nation (Palanisingh, 2017) [5]. Cotton is grown under both rainfed and irrigated conditions in India but significant area is under rainfed condition. High ambient temperatures occurring during cotton cultivation due to global climate change are considered to be one of the major climatic threats that are going affect seed cotton yield production under. Heat stress affects all the plant phenological stages of cotton and results in reduced production in quantity and quality of cotton fibre (Snider and Oosterhuis, 2012) [6]. Character association by correlation analysis provide an estimate of magnitude and direction of association between the important traits responsible for heat stress tolerance under high temperature regimes. Hence, an attempt was made to assess the nature of association among plant morpho-physiological traits involving diverse genotypes.

Materials and Methods
The present investigation employed a total of 204 genotypes consisting of germplasm, stabilized breeding lines and four regional check varieties. The experiment was carried out in augmented II design during the summer 2016-2017 under irrigated condition at Agricultural Research station (ARS), Dharwad Farm. The canopy temperature among the experimental genotypes gives an indication of heat stress levels undergone by each genotype under high temperature stress. Hence, canopy temperature (CTMP) along with other physiological traits like relative water content (RLWC), specific leaf weight (SPLW), leaf area (LEAF) and SPAD chlorophyll meter reading (SCMR) were recorded at peak flowering stage (90 days after flowering (90DAS)) and the plant morphological traits such as number of dried squares (NDRS), number of monopodia (NMON), number of sympodia (NSYP), number of nodes on main stem (NNMS), plant height (PLHT) and number of fruiting points (NFTP) were recorded at crop senescence stage.
The crop at ARS, Dharwad farm suffered due to heat stress during summer 2016-2017 from 4th week after sowing till the crop senescence and maximum day temperature during the crop. The collected data was subjected for correlation analysis.

Estimation of correlation coefficient: The correlation coefficients were calculated to determine the degree of association of the yield attributes with yield, fibre quality and physiological traits. Across the genotypes, the simple correlation coefficients were calculated

to determine the direction and magnitude of association among various characters and tested against table 'r' values (Fisher and Yates, 1963) [2] at (n-2) degree of freedom, both at 0.05 and 0.01 probability levels for their significance. Simple correlations were calculated by using the formula as given by Weber and Moorthy (1952) [7].

$$r = \frac{Cov\ (x, y)}{\sigma_x\ \sigma_y}$$

Where,

Cov (x, y)	=	covariance x and y
σx	=	Standard deviation of x
σy	=	Standard deviation of y

Results and Discussion

The high temperature tolerance screening at ARS, Dharwad Farm underwent heat stress during summer 2017 with a total of 94 stressful warm days (temperatures ≥ 32 ˚C) during the crop period. The experimental summer crop coincided with the extremely high temperatures at especially at reproductive phase, which resulted in early senescence among most of the genotypes.

Significant associations in negative direction were recorded between canopy temperature with plant morphological traits like number of sympodia, number of nodes on main stem, plant height and number of fruiting points (Table 1), revealing the negative impact temperature during peak flowering affecting negatively on seed cotton yield component traits. Among physiological traits, significant associations in negative direction were estimated between canopy temperature with leaf area and SPAD chlorophyll reading, indicating that the chlorophyll content and leaf area are affected by high temperature stress. Reduction in the leaf area under heat stress condition was also reported by Lu *et al.* (1994) [4] and Khan *et al.* (2014) [3] reported similar associations among the selected cotton cultivars used in their study.

According to the above character association in the present study, increased canopy temperature due to heat stress can restrict plant growth and development, including suppression of photosynthetic activity due to lower chlorophyll and leaf area, even when the crop is grown under irrigated conditions. The canopy temperature is a potent integrative trait that is primarily influenced by ambient temperature, water availability in the root zone and a variety of other physiological parameters. Akram-Ghaderi and Soltani (2007) [1] and Khan *et al.* (2014) [3] suggested that cotton cultivars with cooler canopies have higher heat tolerance. As canopy temperature reflects genotype fitness in a stressful environment, it can be used as an indirect selection criterion for improving genetic gains in the crop yields.

Table 1: Phenotypic correlation coefficients for morpho-physiological traits among, germplasm stabilized breeding lines and check varieties of *G. hirsutum* L. during summer 2016-17 at ARS, Dharwad

	NDRS	NMON	NSYP	NNMS	PLHT	RLWC	SPLW	SPAD	CTMP	LEAF	NFTP
NDRS	1.000	0.193**	0.543**	0.532**	0.397**	-0.069	-0.051	0.049	-0.261**	0.284**	0.971**
NMON		1.000	0.043	0.560**	0.080	0.120	0.081	-0.004	0.019	-0.002	0.220**
NSYP			1.000	0.811**	0.759**	-0.093	-0.100	0.056	-0.210**	0.273**	0.428**
NNMS				1.000	0.622**	-0.009	-0.064	0.026	-0.147*	0.198**	0.452**
PLHT					1.000	0.015	-0.099	0.139*	-0.299**	0.285**	0.316**
RLWC						1.000	-0.100	0.036	-0.135	-0.166**	-0.060
SPLW							1.000	-0.017	-0.010	-0.219**	-0.048
SPAD								1.000	-0.186**	-0.095	0.052
CTMP									1.000	-0.184**	-0.247**
LEAF										1.000	0.284**
NFTP											1.000

*,**: Significance at 5% and 1% probability respectively

NDYS: Number of dried squares	NMON: Number of monopodia	NSYP: Number of sympodia
NNMS: Number of nodes on main stem	NFTP: Number of fruiting points	PLHT: Plant height (cm)
SCMR: SPAD chlorophyll reading SPLW: Specific leaf weight (mg cm^{-2})	CMTP: Canopy temperature (˚C) LEAF: Leaf area $(cm)^2$	RLWC: Relative water content (%)

Conclusion

Character association analysis among germplasm under summer field condition in the present study indicated that the level of heat stress was considerably high and it caused significant changes among morpho-physiological characters and their associations. Despite growing under irrigated conditions, increasing canopy temperature owing to heat stress hindered plant growth and development, including inhibition of photosynthetic activity due to decreased chlorophyll and leaf area. The canopy temperature is a powerful integrative trait which depicts the physiological status of a genotype in the given environment, hence, it can be used as an indirect selection criterion to improve heat tolerance in cotton crop.

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