Genetic variations in post-anthesis heat stress tolerance in US soft wheat germplasm

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Background

- Global demand for cereal is expected to grow by 56% in 2050, and 26% of this yield increase is expected for wheat alone (Godfray, et al., 2010)
- Recently, crop model study have indicated that high yielding wheat growing areas might face hot and humid temperature stress incurring approximately 6% of yield loss with every 1°C increase in temperature (Asseng, et al., 2011)
- Post-anthesis heat stress is a common yield-limiting factor in US wheat growing areas.
- Simulations by Barkley et al. (2014) demonstrated that a 1°C increase in projected mean temperature was associated with a decrease in wheat yields of 715 kg ha^{-1} in USA
- The annual occurrence of moderate heat stress, accompanied by periodic extreme heat stress events, prevents wheat from reaching its full potential yield in the USA
- Heat accelerates premature senescence, causes floret abortion, and reduces the overall grain weight, size and yield
- To achieve global food demand in 2050, wheat breeders must develop varieties that can withstand increasing temperature impacts
- Genetic improvement is the most effective and sustainable method to achieve this goal
- Modern cultivars were reported to be sink limited and sink capacity has to be improved for full exploitation of increased biomass and radiation use efficiency
- Our objective is to improve sink strength by validating essential trait (spike fertility) to increase grain number (Slafer et al., 2014).

Materials and Methods

Field conditions and agronomic practices

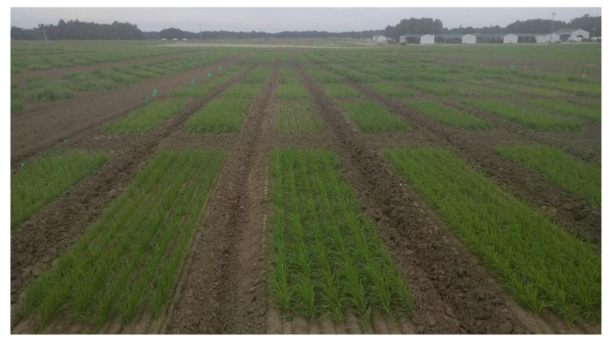

Figure 1 : Plant Science Research & Education Unit - UF/IFAS, Citra, FL.

- Plant Material: 246 soft wheat panel
- Location: Quincy and Citra, Florida
- Experimental design: Non-replicated modified augmented design with 2 repeated checks
- Plot: Six rows, 3.3 by 1.51 m^2
- Sowing date: Dec 16, 2015 (Citra) and Dec 21, 2015 (Quincy)
- Harvesting date: May 19, 2016 (Citra) and May 25, 2016 (Quincy)

Spike Fertility and Other Yield Contributing Traits

- Spike fertility: It is a major potential component of grain number per m² and is calculated as ratio of grain number to spike chaff dry weight.
- Other yield traits: spike density, spikelet/spike, thousand grain weight, yield, grains/ m², grains/spike, grains/spikelet, grain filing rate
- All measurements were taken at the time of maturity

Future Plans

- Determine correlations between spike fertility and grain number and yield in different environments.
- Estimate broad-sense heritability to better understand of repeatability of spike fertility over years and environments, and therefore, evaluate and understand genotype-by-year and genotype-by-environment interaction structure.
- Identify novel alleles and QTLs associated with spike fertility and associated traits through genome-wide association analyses under post anthesis high temperature stress conditions to understand underlying complex genetic mechanism associated with yield and sink strength.
- Based on the findings, we will develop genomic selection models for SF for genetic improvement of yield.

Results

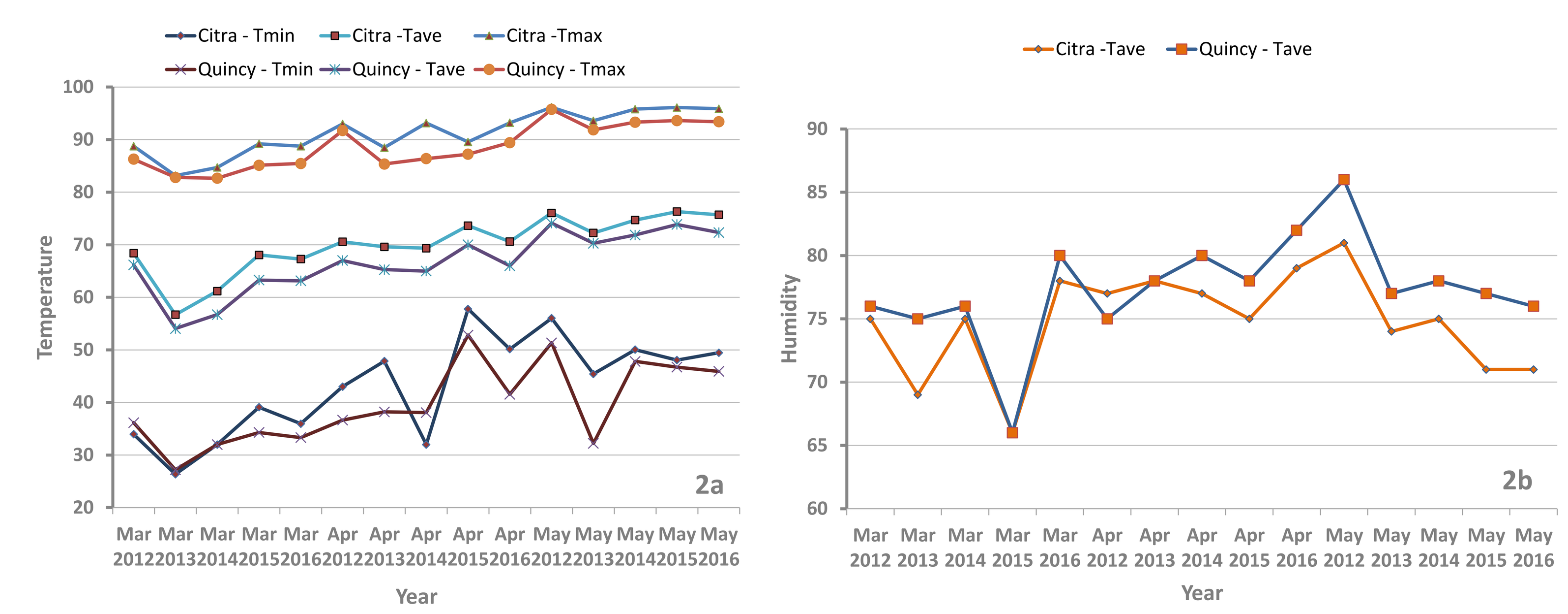

Figure 2a represents monthly average, minimum and maximum temperatures from heading to maturity (March to May) in five year period from 2012 to 2016 in two heat stressed locations of Florida; Citra (green) and Quincy (red). High temperatures during grain filling stages accelerate maturity, causes floret abortion, and reduces the overall grain weight, size and yield and quality. Figure 2b represents monthly average humidity from heading to maturity (March to May) in five year period from 2012 to 2016 in two heat stressed locations of Florida; Citra (green) and Quincy (red). High humidity is negatively correlated with grain yield and quality of wheat mostly due to increase in heat load.

	Anthesis days	Maturity days	Grain filling duration	Yield (kg h^{-1})	1000 grain weight (g)	Grains $spike^{-1}$	Spike m^{-2}	Grain filling rate (kg $day^{-1}h^{-1}$)	Grains m^{-2}	Spike HI	Spike Fertility (grains g^{-1})
Min	101	118	13	1240	15.3	14	198	36.5	4595	61	12
Max	134	161	42	5593	38.8	90	450	304	26237	87	90
Avg	113	139	26	3379	28	40	312	132	12348	76	38

Table 1: Minimum, maximum, and average values of spike fertility, yield and other traits of the selected 248 genotypes under heat stress conditions grown in 2015-2016 at PSREU, Citra, FL. Our preliminary data showed that US soft wheat has significant genetic variations for spike fertility and all other phenotypic traits including spike harvest index, flowering and maturity days, grain filling duration, grains m^{-2}, spike m^{-2}, grains $spike^{-1}$, 1000-grain weight, and yield.

Grains m^{-2}	Chaff wt m^{-2}	Grains $Spike^{-1}$	Spike Harvest Index	Grain filling rate (kg $ha^{-1}day^{-1}$)	Grain Yield (kg ha^{-1})
0.734***	-0.580***	0.758***	0.611***	0.371***	0.566***

Table 2: Correlation between spike fertility and other phenotypic traits in association panel grown at Plant Science Research and Education Unit, Citra, FL under heat stress conditions. Spike fertility showed very strong and significant, correlations with grains m^{-2}, grains $spike^{-1}$, yield, spike harvest index, grain filling duration, and chaff weight m^{-2}. Positive significant correlations between SF with grains m^{-2}, grains $spike^{-1}$ and yield indicate that grain numbers could effectively increase in wheat by using SF as an indirect selection criterion. Moreover, a negative correlation with chaff weight m^{-2} indicates that if we can increase partitioning of spike, we might effectively increase grain number and thus, higher harvest index and effective genetic gain in yield improvement.

Genotype	Yield (kg ha^{-1})	Grains m^{-2}	Grain $Spike^{-1}$	Spike fertility (grains/g)
AR01156-2-1	5047	26237	92.4	89.7
AR06050-7-2	3686	18309	68.8	66.6
LA821	4220	17679	68.3	66.2
GA011124-1-42-13	4457	20752	67.4	65.8
TX12D4625	4746	15705	67.1	64.3
ARS07-1208	2533	8369	21.1	18.1
LA09224C-28	2558	8284	18.7	15.8
McNair_701	2307	6716	18.0	15.7
LA02024E12	1766	5660	19.0	15.4
GA222-22-5	1240	4595	14.4	12.2

Table 3: Spike fertility and related traits in ten South and Southeastern US commercial soft wheat varieties (5 highest spike fertility and 5 lowest spike fertility lines grown under heat stress conditions in PSREU, Citra, FL. Lines with highest spike fertility are showing clear difference for grains m^{-2}, grains $spike^{-1}$ and yield over lines with lowest SF values.

Main idea

- The southeastern US soft red is exposed to high day-time and high night-time temperatures during the growing season
- We have very minimum knowledge about spike fertility and yield related traits of US Soft wheat germplasm
- Genetic basis of yield improvement in wheat is not well established but the progress in yield improvement is mainly attributed to better partitioning of photosynthetic products
- Thus, a clear relationship between yield improvement and grain number was frequently reported including for stress environments
- Wheat yield in modern wheat varieties appears to be more limited to sink strength despite the increase of biomass
- The balanced ratio of source-sink could be achieved by increasing the partitioning of assimilates during spike development, so that grain number is increased, thus improving harvest
- An appropriate avenue to improve yield in wheat is by developing genotypes with higher spike fertility and grain number, or increased sink strength
- This project is aimed toward finding genes associated with spike fertility in US Southeastern soft wheat under heat stress conditions.
- The results will provide clarity and direction for breeders and clear-cut and easy-to-use products to breed new high yielding wheat cultivars under heat stressed conditions

References

- Asseng, S., et al. 2011. The impact of temperature variability on wheat yields. Global Change Biol. 17: 997-1012.
- Barkley A., Track J., Nalley L., Bertold J., Bowden R., Fritz A. (2014) Weather, Disease, and Wheat Breeding Effects on Kansas Wheat Varietal Yields, 1985 to 2011. Agronomy J. 106: 1: 227-235.
- Godfray, H.C.J., et al. 2010. Food security: the challenge of feeding 9 billion people. science 327: 812-818.
- Hubert, B., et al. 2010. The future of food: scenarios for 2050.
- Slafer, G.A., R. Savin and V.O. Sadras. 2014. Coarse and fine regulation of wheat yield components in response to genotype and environment. Field Crops Res. 157: 71-83.

Acknowledgement

This study was funded by University of Florida

For further information

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