Developing Heat Tolerant and Climate Resilient Wheat

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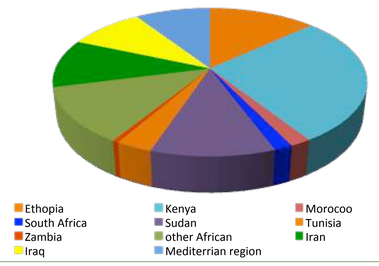
Climate change, particularly the heat stress, poses a serious challenge to the wheat production, which needs to double by 2050 in order to meet the food demand of the growing population. Every 1°C rise in temperature above the optimal results in wheat yield losses of up to 3-4%. By the end of the 21st century, global annual mean temperature, including South Asia, is projected to go up by 4°C, thus adversely affecting the wheat production in most of fertile Indo-Gangetic plains. Therefore, improving wheat heat tolerance is crucial in today's context. As a public-private partnership, 'Feed the Future Innovation Lab' has been setup with the funding from USAID, DBT, ICAR, and BIRAC with a goal to develop climate resilient wheat cultivars by combining all available information, tools, and technologies. Evaluation of heat tolerant material from around the globe both under controlled as well as field conditions showed extensive natural variation for the trait, although, only few lines maintained 'normal' productivity at 40°C. A short period of heat stress during germination had serious and long-term effect on plant development and yield. A ten-day heat stress at germination reduced germination percentage, coleoptile length, and yield. Sugars availability maybe a reason for the effect on germination as external application of sucrose showed significant recovery in germination percentage and coleoptile length. Heat stress during vegetative phase significantly affected tiller number, flowering time, pollen fertility, plant height and yield. During the reproductive stage, heat stress adversely affected photosynthesis and increased membrane disintegration due to decreased chlorophyll index, increased ROS and lipid peroxidase activity. The identified heat tolerant lines will be used to transfer the trait into wheat cultivars by marker assisted background selection combined with simultaneous detection and utilization of QTLs. Various molecular and physiological studies for the trait are underway and initial results are presented.

Goal:

- Develop high yielding, heat tolerant wheat cultivars by combining fast breeding methods with genetic, molecular, physiological, and biochemical approaches to understand heat tolerance trait.
- Training of young scientists in cutting edge research and technology.
- Capacity building to conduct high quality research at the partner institutes.

Germplasm:

- From the Komugi (Wheat Genetic Resource Database, Japan) database 110 lines representing the Fertile Crescent (including Iran and Iraq).
- 192 lines representing the African continent including Ethiopia, Zambia, Tunisia, Sudan, South Africa, Morocco and Kenya were procured from JIC, UK.

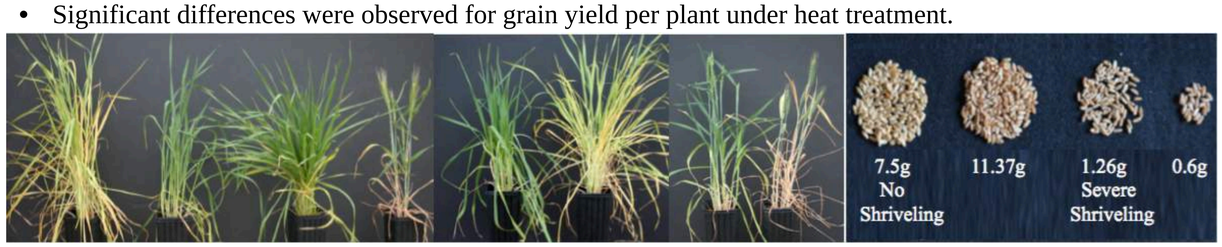


Variation for tolerance to heat stress:

- Collection of 302 genotypes were evaluated under controlled conditions heat screen throughout plant developmental stage after germination.
- Temperature was gradually increased each day to reach maximum of 40ºC for two hours and gradually decreased to 18ºC for night.
- The phenotypic data was recorded on vegetative growth, tiller number, plant height, and plant yield.

Results and conclusion:

- Effect of heat stress on tillering was evident from vegetative stage. Some lines showed profuse tillering in comparison to some lines showing very less tillering.
- Significant differences and variations were observed for the flowering time under heat treatment.
- The ratio of productive/unproductive tillers were highly variable, tolerant lines mostly produced productive tiller.
- Variation in grain filling (healthy vs. shriveled grain) was due to the effect of heat stress on grain filling.
- Significant differences were observed for grain yield per plant under heat treatment.



Effect of heat stress on vegetative growth, flowering time, maturity, grain filling and single plant yield

Effect of heat stress during germination:

- Eight diverse wheat genotypes contrasting with respect to the emergence, root characteristic, tiller number, plant height and coleoptile were selected for the study.
- Twenty seeds for each lines were grown for ten days at different temperatures ranging from 15-40ºC (5ºC increment). After an initial shock of 10 days, the seedling were transplanted in green house under normal wheat growing conditions of 22/18ºC with 16 hrs light and 8 hrs dark till maturity.
- The phenotypic data was recorded on following traits: germination percentage, coleoptile length, tillers per plant, plant height, main spike weight, main spike seed weight, side spikes weight, side spikes seed weight, dry biomass of plant, main spike seed count.

Result and conclusion:

- 20/25ºC is optimum for wheat germination, increase or decrease in temperature leads to effect on speed of germination with 15ºC showing more adverse affect.
- Germination percentage was significantly affected by increasing stress with cv. Indian showing least affect.
- Compared to shoot growth, the effect on root growth was significantly more at 35ºC across all lines.
- Few lines produced better root biomass at higher temperature and some showed increased shoot biomass at 30ºC.
- Effect on shoot biomass correlated with effect on plant yield in most of the lines.
- Plant differentiated its main tiller from side tillers, as effect of stress on side tillers was more in comparison to main tiller, except cv. Perigee.
- Thus suggesting plant remembered the initial exposure to stress. This memory is translated even when the plant return to the normal growing conditions.