Transitioning Cereal Systems to Adapt to Climate Change

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Breeding for tolerance to heat and other climatic stresses for lower latitudes worldwide

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Feed the Future Innovation lab: Improved Wheat for Heat Tolerance and Climate Resilience

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Project Goal

Develop high-yielding, heat-tolerant wheat cultivars for the Indo-Gangatic Plains

CRW: Climate Resilient Wheat

Project partners

- **Washington State**
- DWR, Karnal
- Kansas State
- Metahelix
- Dupont-Pioneer
- RAU, Pusa

CCSU, Meerut

GBPU, Pantnagar

JK Seeds

NBPGR

PAU, Ludhiana

IARI, Delhi & Wellington

CRW: Climate Resilient Wheat

Washington State University

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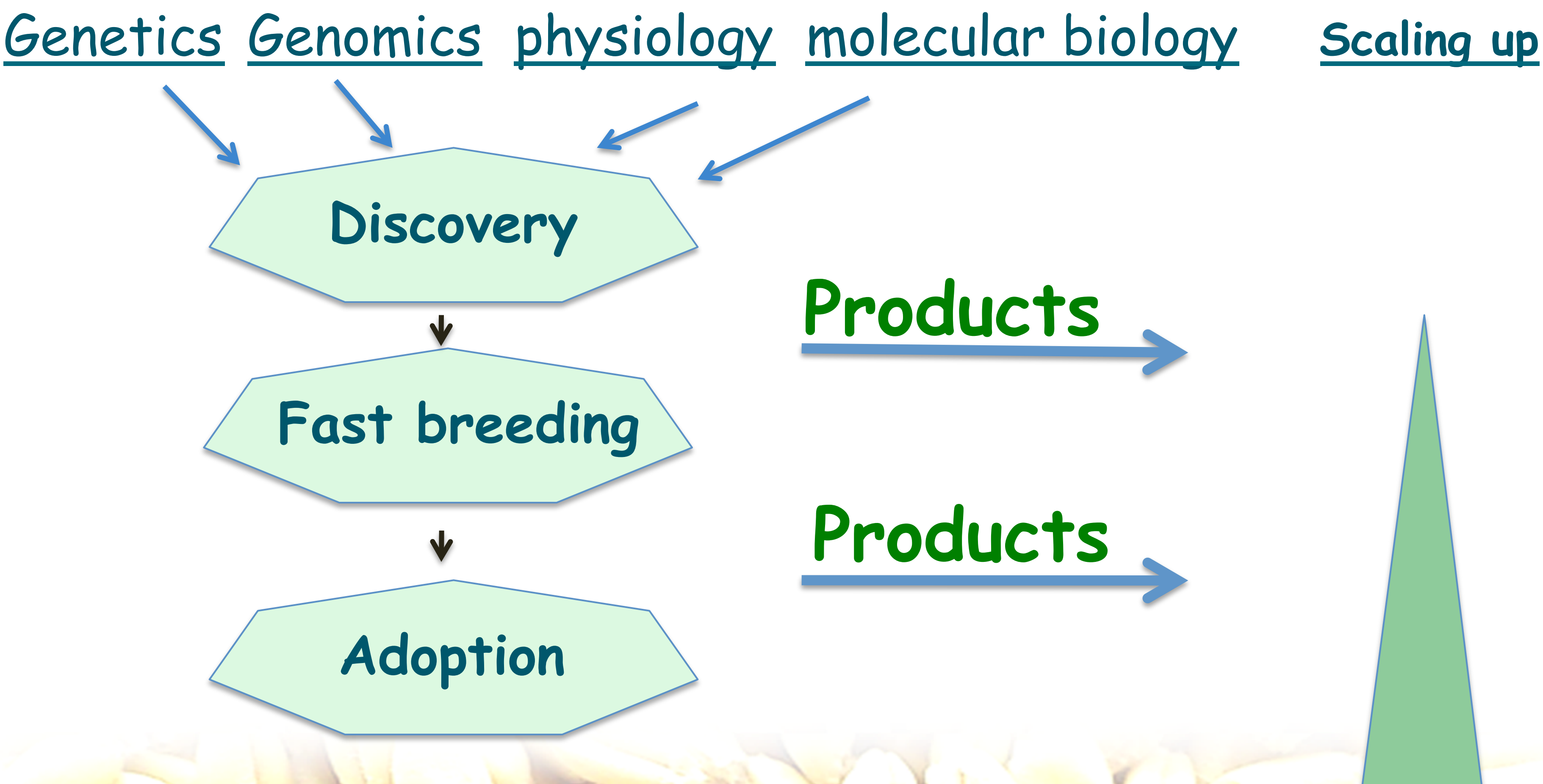
DWR ICAR DBT



CRW: Climate Resilient Wheat

Specific Objectives

1. **Develop heat tolerant varieties using marker assisted background selection and forward breeding approaches**: Acurate phenotyping, QTLs, enzymatic markers, fast breeding methods
2. **User-friendly markers for heat tolerance**: QTLs, physiological markers, biochemical markers
3. **Pyramid genes with complementary mechanisms of heat tolerance**: Doubled-haploid approach, Objective 4 critical for this objective
4. **Understand physiological mechanisms of heat tolerance**: Study genetic, physiological, biochemical, and epigenetic mechanisms controlling heat tolerance
5. **Scientist training and exchange**: Exchange and collaboration (senior scientists), training (younger scientists), and PhD student training.. Younger scientists are a major focus of the project.

SCALING UP AND LINKAGES WITH OTHER INNOVATION LABS

- Heat Screening Methods
- Heat tolerant germplasm
- Heat tolerant varieties
- Markers/Enzymatic assays/other screening tools

- Relationship between heat and drought tolerance
- Effect of terminal heat on grain quality
- Novel breeding and genotyping approaches
- Heat tolerance vs disease severity
- Others?

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Breeding strategy to develop heat tolerant varieties

1. Evaluate cultivated wheat germplasm to select 10 donor lines
2. Select a recurrent parent with highest yield potential and wide adaptation
3. Simultaneous detection and utilization of QTL
4. Forward breeding to increase yield over the recurrent parent
5. Gene pyramiding to combine genes with complementary gene action

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Donor Selection

- Select known heat tolerant material from around the world: Selected 75 lines
- Evaluate by multi-location field, as well as controlled condition screening for heat tolerance
- Enzyme thermal stability tests on the donor and recurrent parents
- Select 10 most heat tolerant lines with complementary heat tolerance mechanisms

CRW: Climate Resilient Wheat

Commonly used physiological Traits

- Canopy Temperature Depression (CTD)
- Stomatal conductance
- Grain filling duration (GFD)
- Membrane thermo-stability (MT)
- Chlorophyll content and fluorescence
- Stem reserve mobilization

Reliability and reproducibility issues

CRW: Climate Resilient Wheat

Heat tolerance mechanisms in wheat

Sugar → Starch

Sugar transport ↑

Photosynthesis

Enzymes/protein Selected for physiological and molecular studies

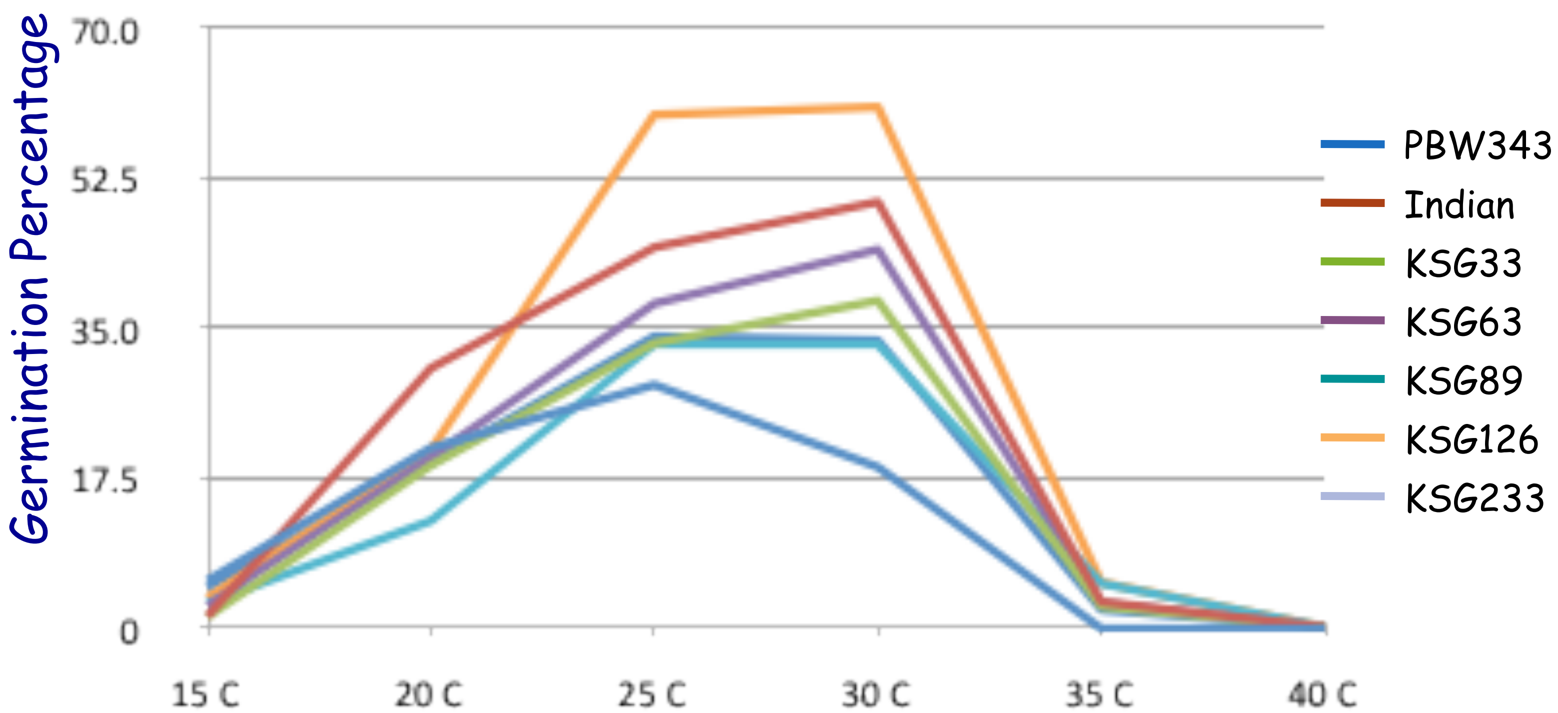
1. AGPase- **Meerut**
2. Sucrose synthase (Sus) -- Pantnagar
3. Starch synthase and branching (SBE) – RAU
4. Alpha amylase – PAU
5. Phosphoglucomutase (PGM) – IARI
6. Phosphglucoisomerase (PGI) – NBPGR
7. Rubisco activase – WSU
8. Sucrose phosphate synthase (SPS)– DWR
9. HSP101 - WSU
10. Heat shock factors
11. Catalase and superoxide dismutase (SOD)
12. Glutathione-S-reductase
13. Glutamate decarboxylase - makes GABA, a signaling molecule and a metabolite in stress tolerance.

Special thanks to Kanwarpal and Raj

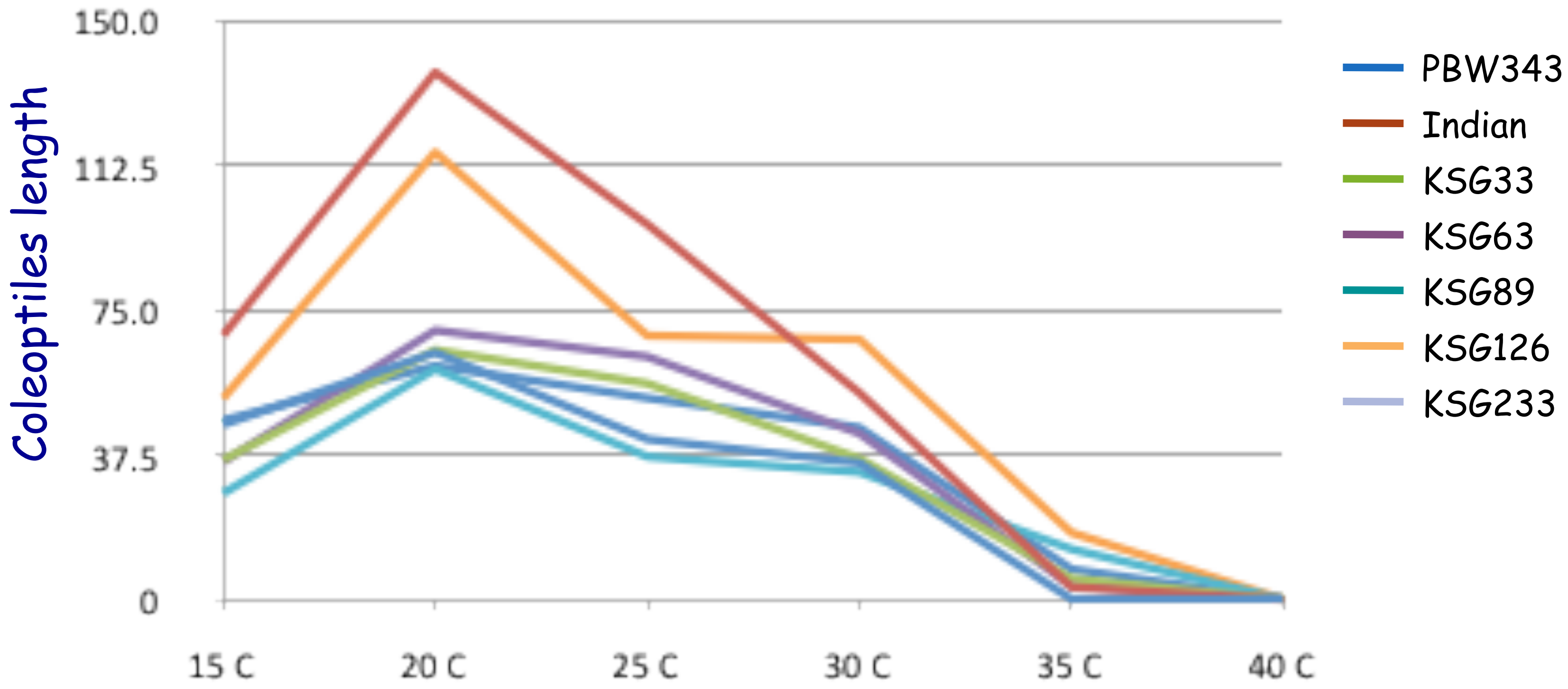
Variation for Root length in the AM population

Parameters	Range	Genotypes	LSD
Root depth (cm)	45 -187	KSG 158, KSG 206	68
Total root length (cm)	720 - 7112	KSG 183, KSG 233	3066
Total surface area of roots (cm2)	85 - 1126	KSG 183, KSG 233	552
Total root volume (cm3)	0.8 - 15	KSG 183, KSG 241	8.7
Root dry weight (g)	0.10- 4.9	KSG 25, KSG 273	0.71
Shoot dry weight (g)	0.10 – 4.3	KSG 89, KSG 184	2.6
Root-shoot ratio	0.01 – 7.8	KSG 78, KSG 195	1.7
Plant height (cm)	7.5 - 60	KSG 160, KSG 19	16

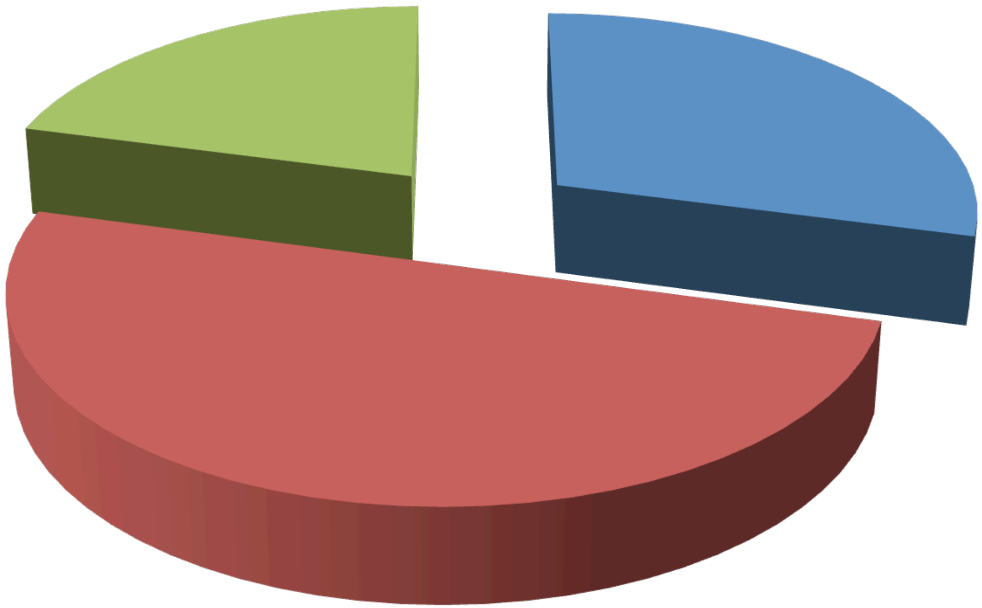
Effect of temperature on germination



Effect of temperature on coleoptiles length



Results summary of initial screening of heat tolerance donors

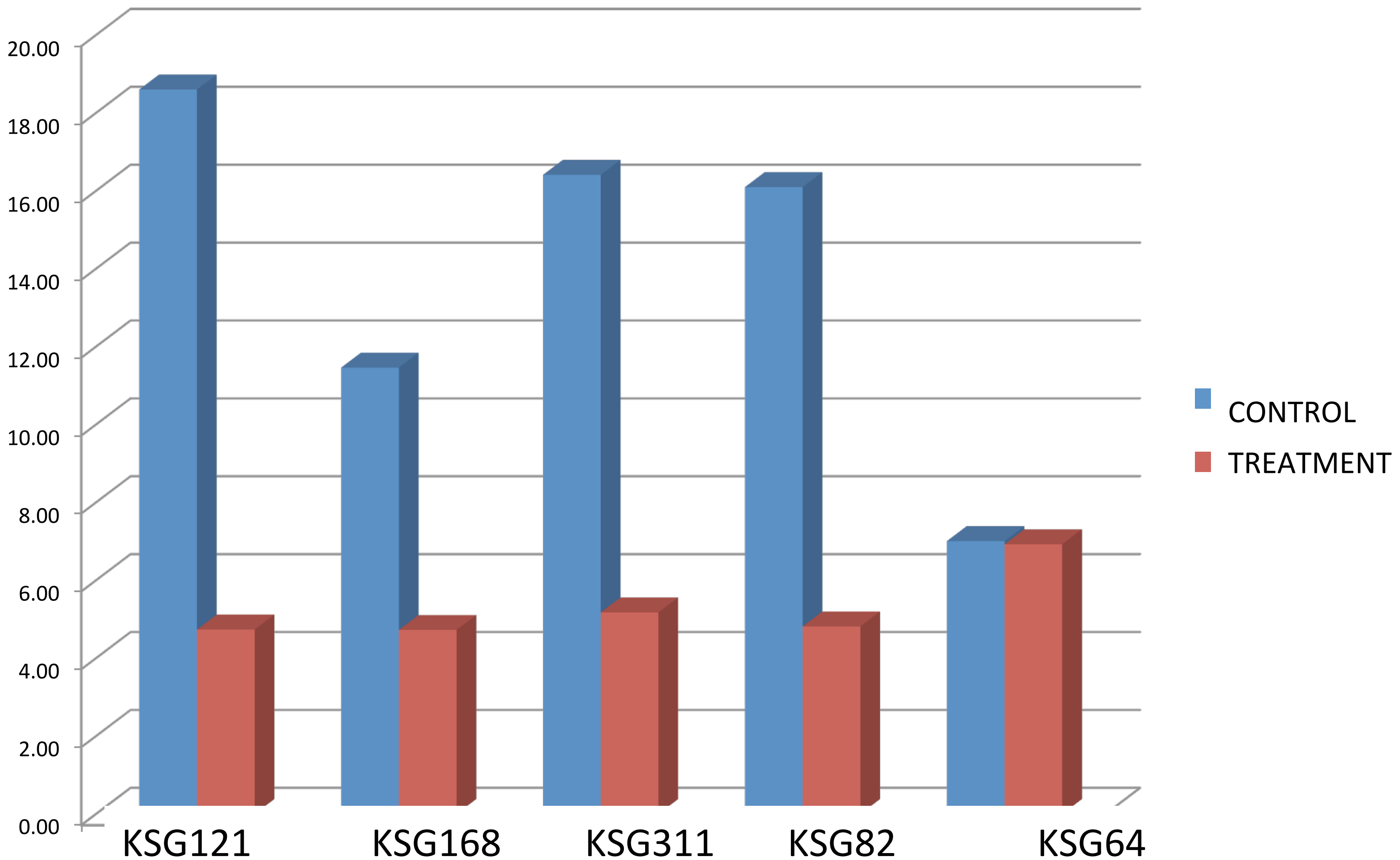


BLUE – HIGHLY Susceptible, no seed set

RED - Susceptible, 0.1 to 0.49

GREEN – Tolerant, 0.67 to 0.88

Spike Weight



Photosynthesis Studies

- Wheat a C_3 species, has no mechanism to concentrate CO_2 to chloroplast
- Converting light energy into biomass at 4.3% efficiency
  - Light energy can become:
    1. Emitted (energy quenched)
    2. Dissipate as heat (non-photochemical quenching [NPQ])
    3. Chlorophyll fluorescence
- Net photosynthetic rate 15-40 (CO_2 assimilated per unit leaf area)
- Optimal temperatures 15-25°C

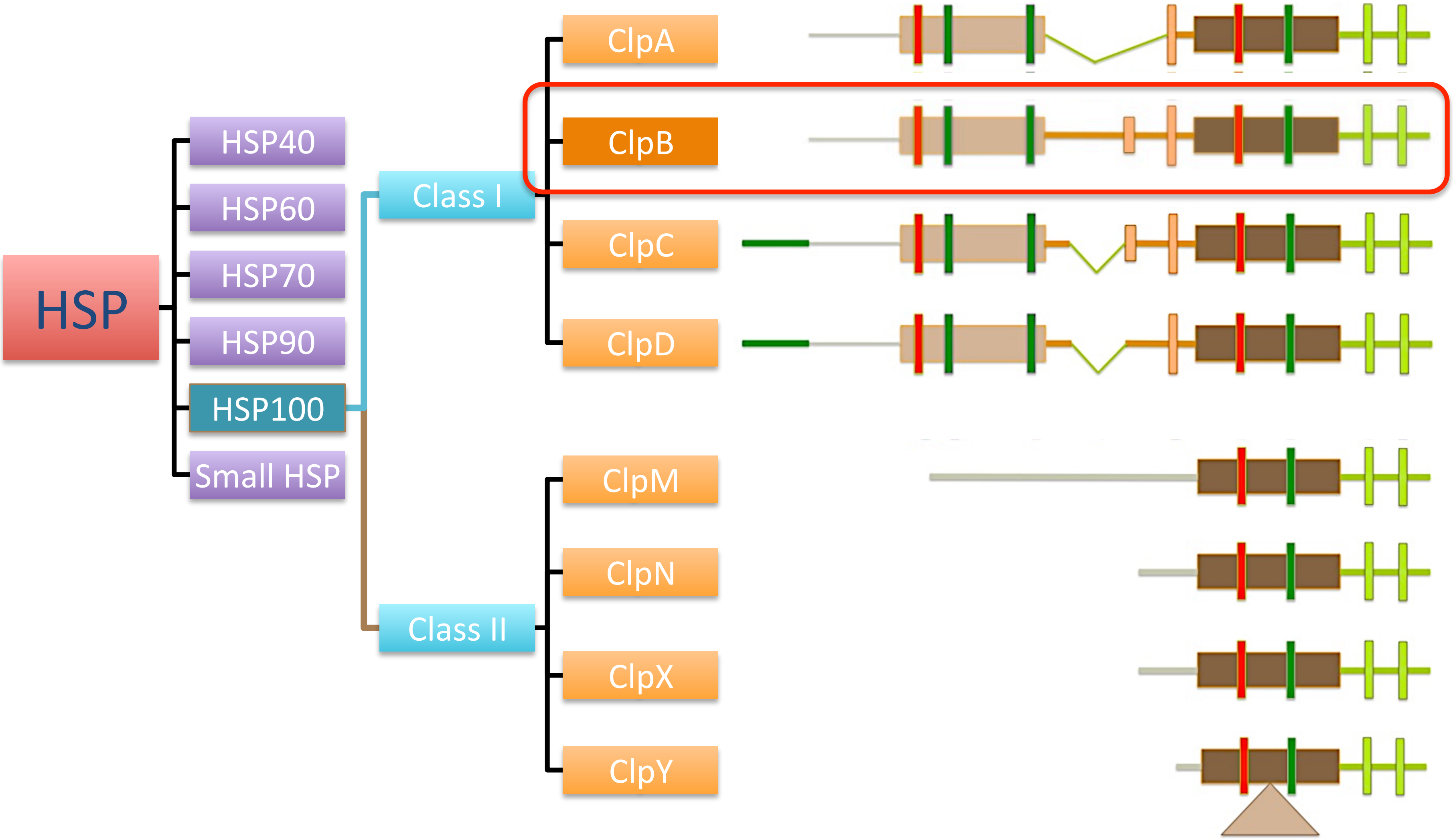
Effect of heat on photosynthesis

- Instability of the 70s chloroplastic ribosomes
- RUBISCO
  - Decreased solubility of CO_2
  - RUBISCO affinity for CO_2 decreases
  - Photorespiration increases
  - RUBISCO inactivation
    - RuBP pool decreases
- ATP synthesis (uncoupling), ATP/e^- decreases
  - Disruption of e^- transfer of water to reaction center
- PSII
  - Heat inactivation
  - Disturbance of lateral distribution of pigments in photosystems
  - Irreversible blockage of reaction (basal fluorescence [F_o] rises)

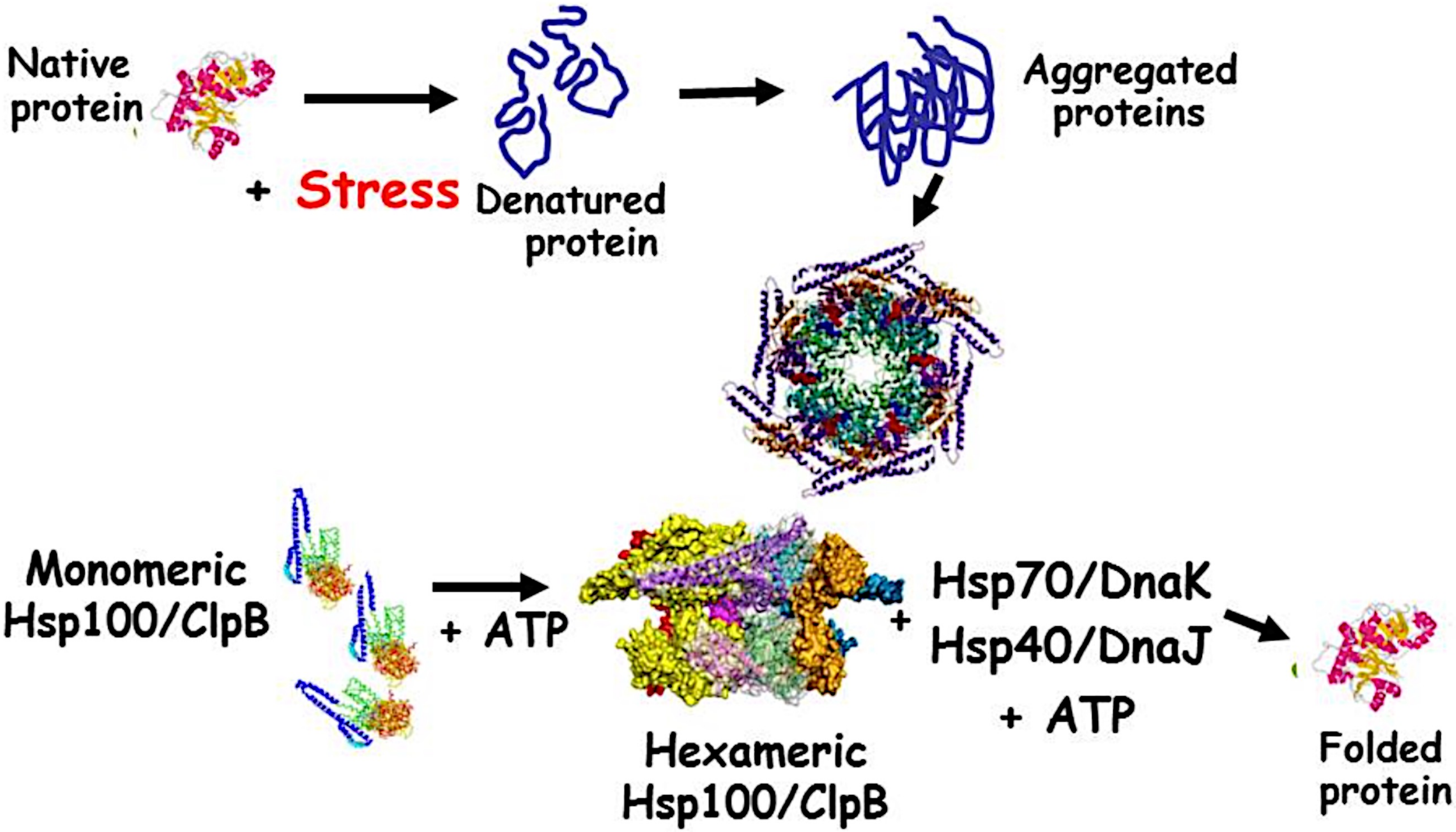
Enzymes/protein targeted for heat tolerance

- Rubisco Activase
- HSP101

The Heat Shock Proteins



Model of HSP101 chaperone activity



http://people.biochem.umass.edu

Wheat HSP101/ClpB

- Three isoforms in hexaploid wheat
  - 101-A, 101-B, 101-C
  - Transcript/protein data
  - Not mapped
- Four isoforms in tetraploid wheat
  - 101B-A, 101B-B, 101C-A, 101C-B
  - Transcript/protein data
  - Mapped in chromosome 1 and 3

Rubisco Activase (RCA)

- Encoded in nucleus
- Translated in cytoplasm
- Functions at chloroplast
- 41-47 kDa
- Sensitive to Heat
- Regulated by Light and ATP/ADP
- Relatively abundant

Transitioning Cereal Systems to Adapt to Climate Change

REACCH
Regional Approaches to Climate Change –
PACIFIC NORTHWEST AGRICULTURE

Thank you!

University of Idaho

Washington State University

USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

Oregon State University OSU

CHS

Pacific Northwest Farmers Cooperative

Monsanto