Climate Change and Climate Variability: El Salvador – Impacts on Productivity of Grain Crops and Opportunities for Management and Improvement

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Outline

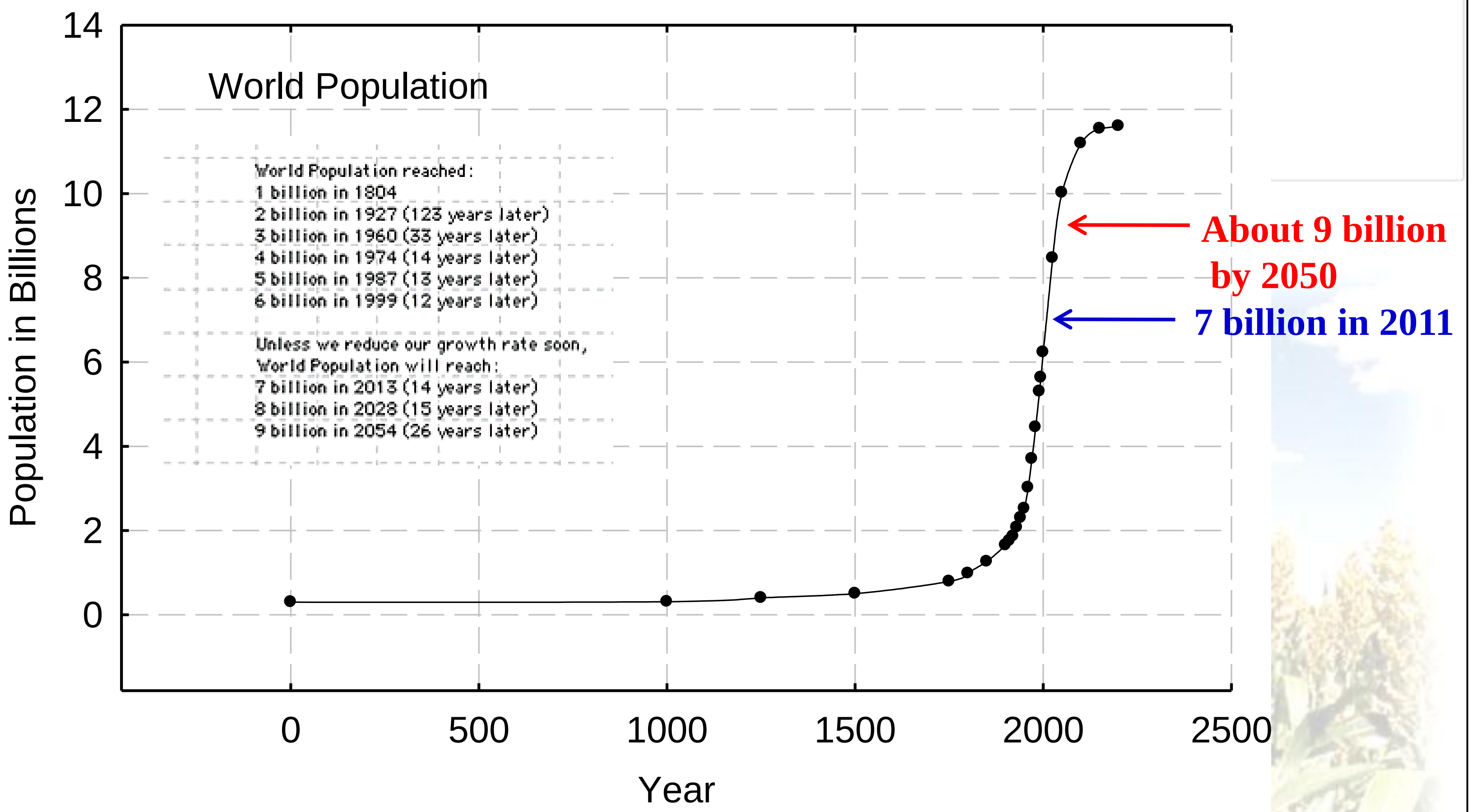
1. Climate change and climate variability (past and future).
2. Climate change and variability in El Salvador (climate models).
3. Impact of temperature on grain yield of dry bean, maize and sorghum in El Salvador (crop simulation models).
4. Effects of temperature, drought and/or carbon dioxide: experimental evidence (response of grain sorghum, maize and dry bean).
5. Opportunities for crop management and genetic improvement.
6. Concluding remarks.

Part I: Climate Change and Climate Variability



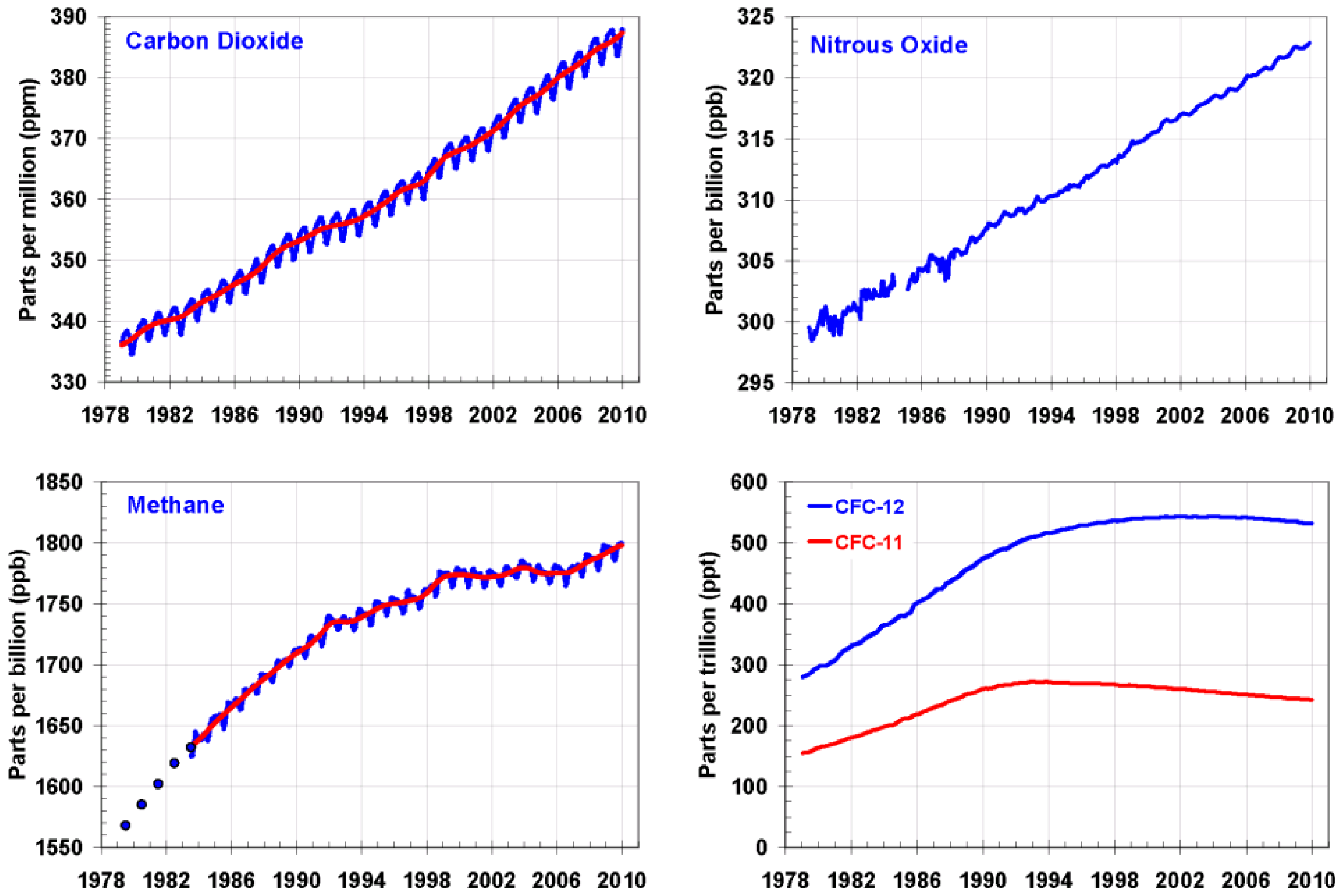
Past, Current and Future Population

World: Current Population (December 2011): 7,006,382,000
El Salvador: Current Population (July 2011 est.): 6,071,774



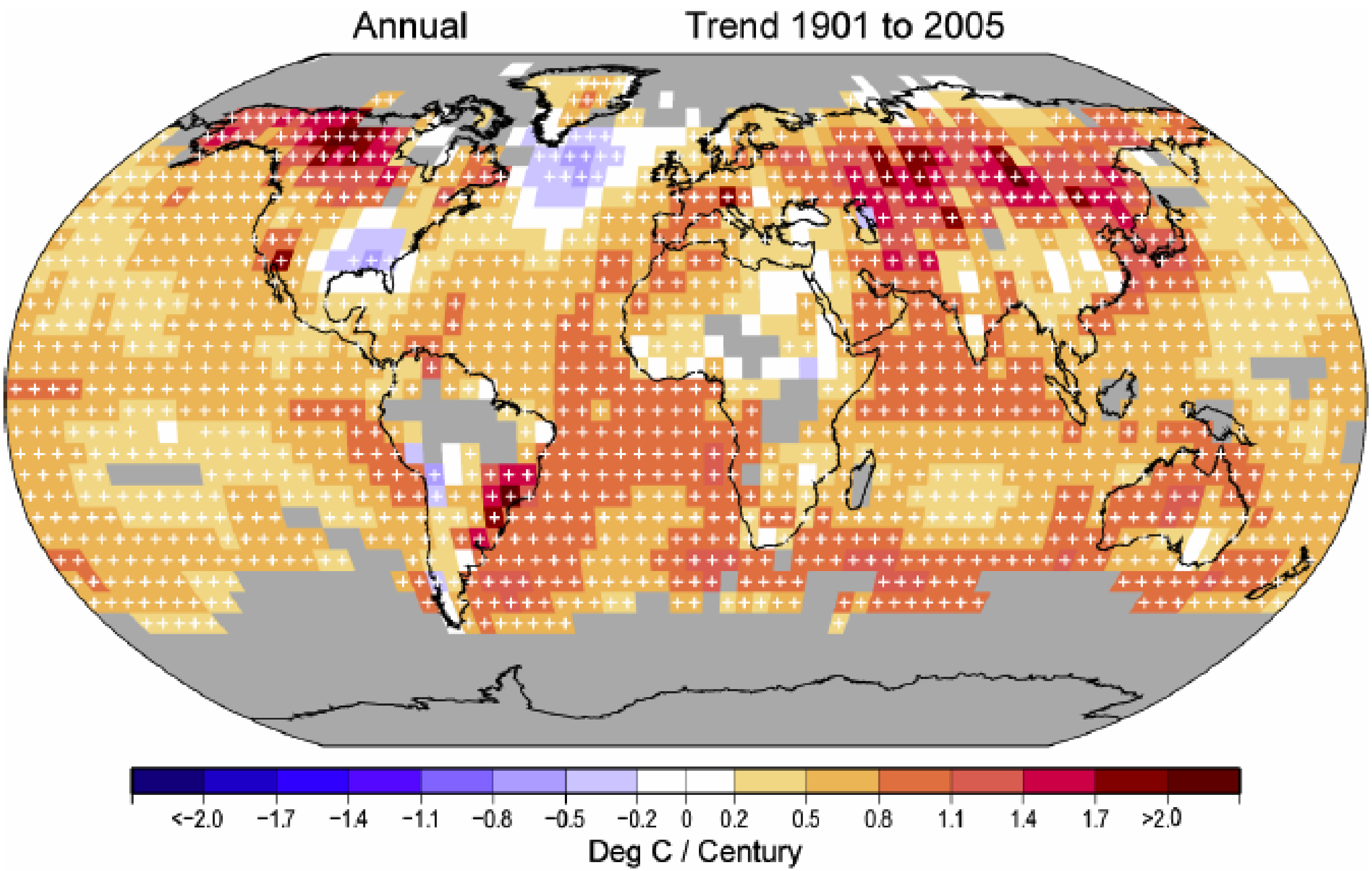
World population is continuing to increase dramatically.

Greenhouse Gases (Recent Changes)



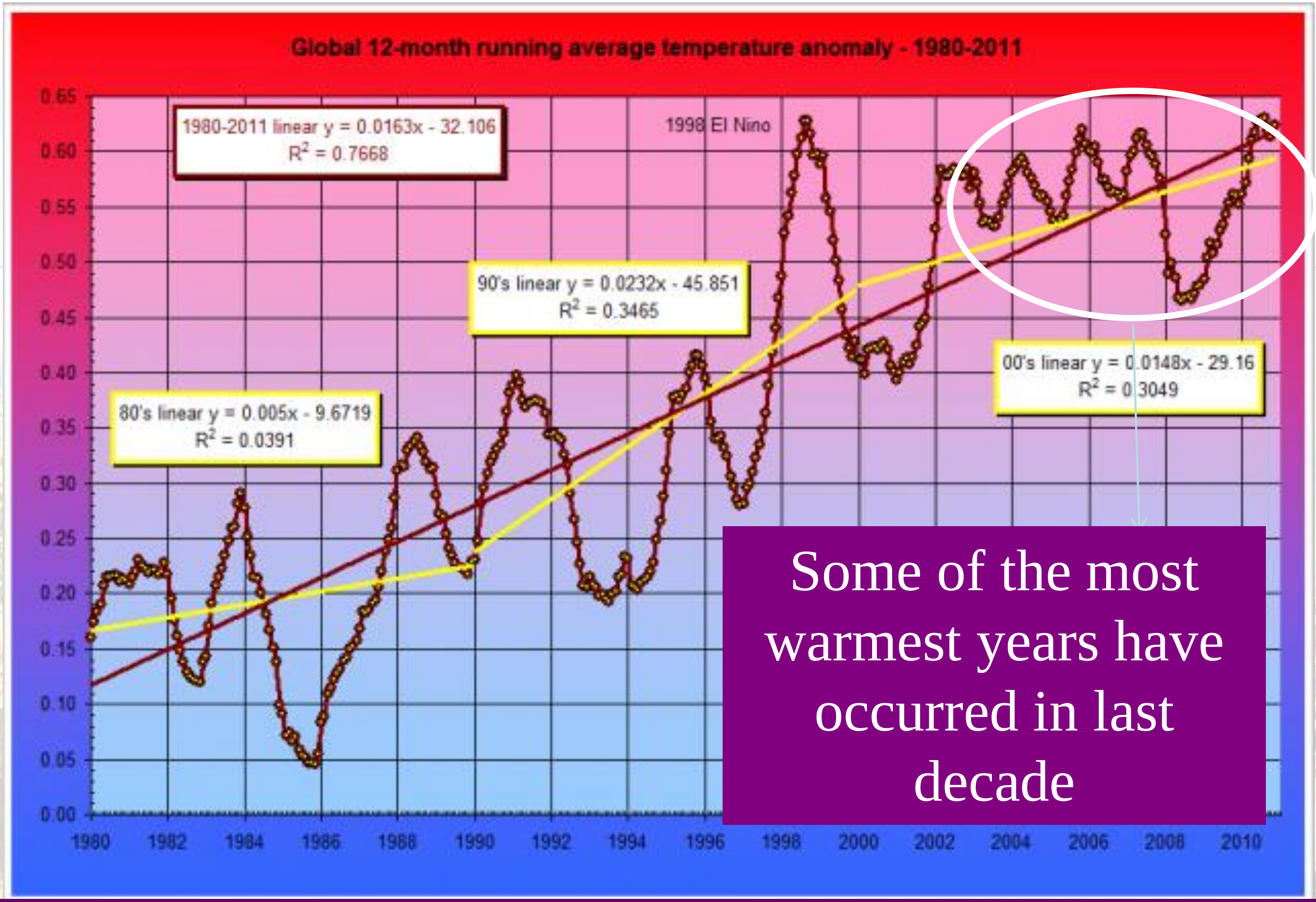
Concentrations of CO_2, CH_4, N_2O and Chlorofluoro Carbons have dramatically increased in the recent years since 1970's.

Annual Temperature Trends (1901-2005)



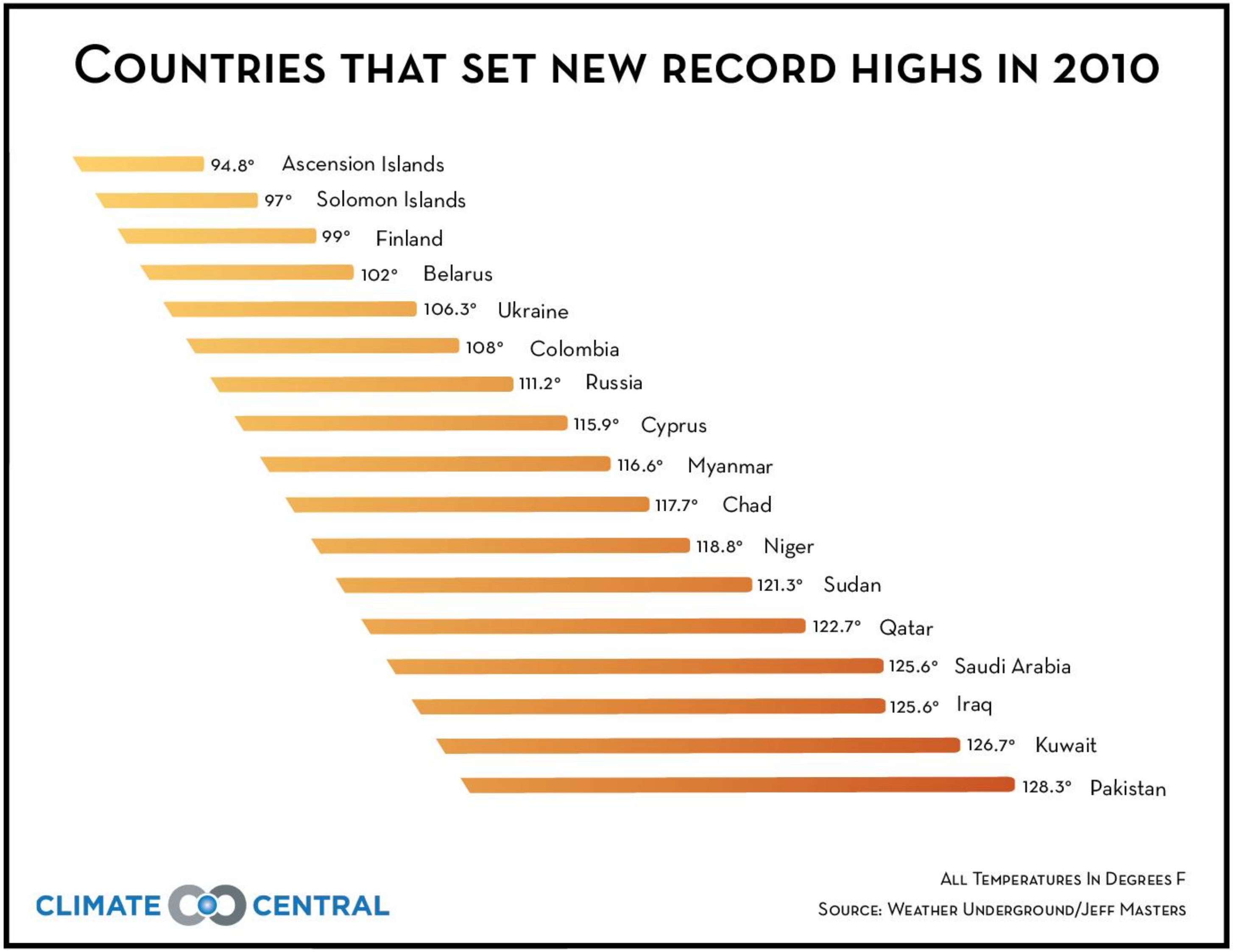
Global surface air temperatures increased on average by 0.8ºC. The world has warmed up !

Frequency of Warm Years has Increased



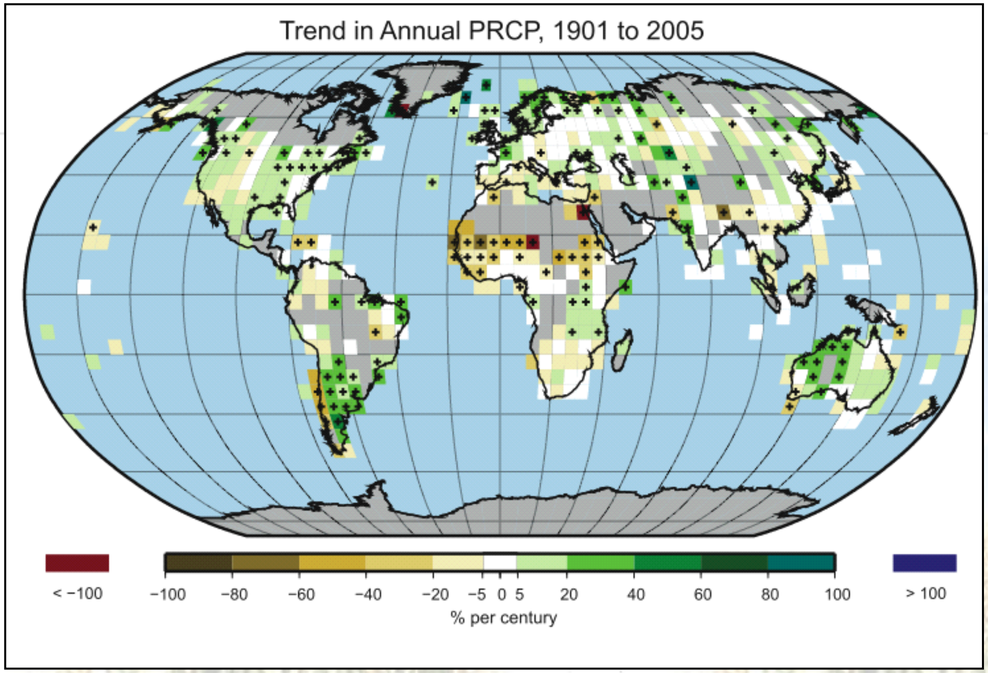
Annual temperatures have changed more rapidly in recent years.

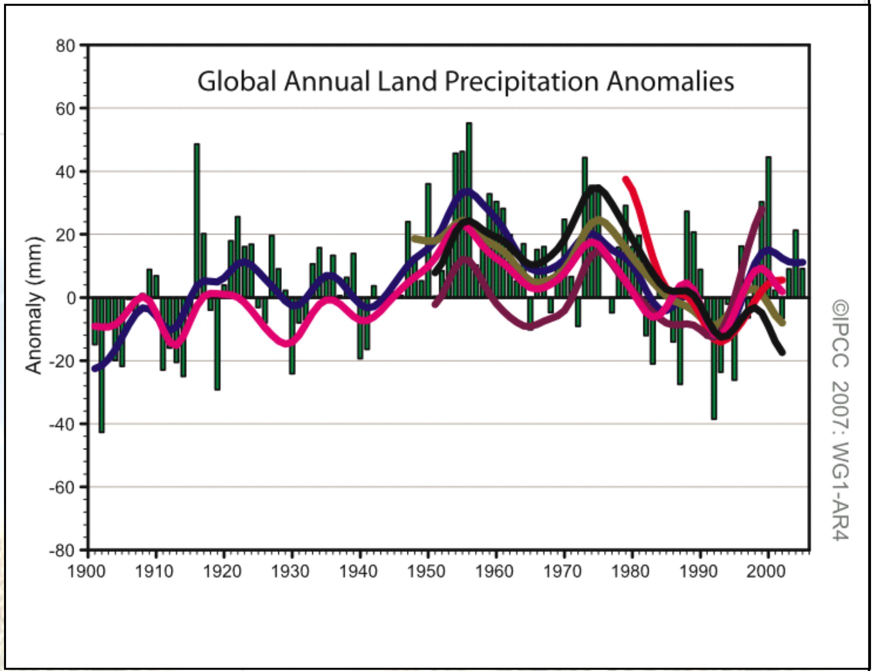
New Record High Temperatures



17 countries around the globe have set new record highs in 2010

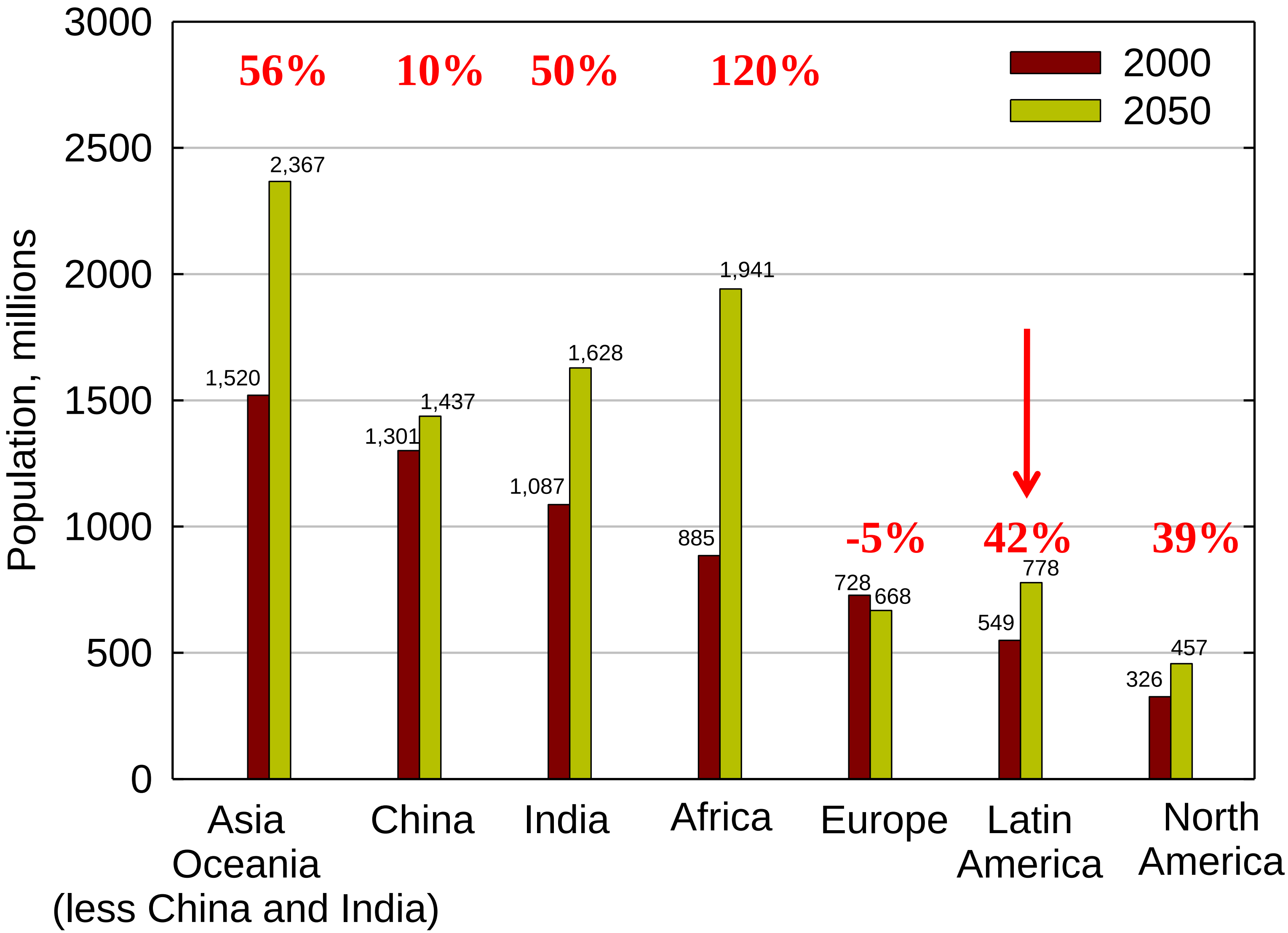
Annual Precipitation Trends (1901-2005)





Annual precipitation slightly changed and has become variable.

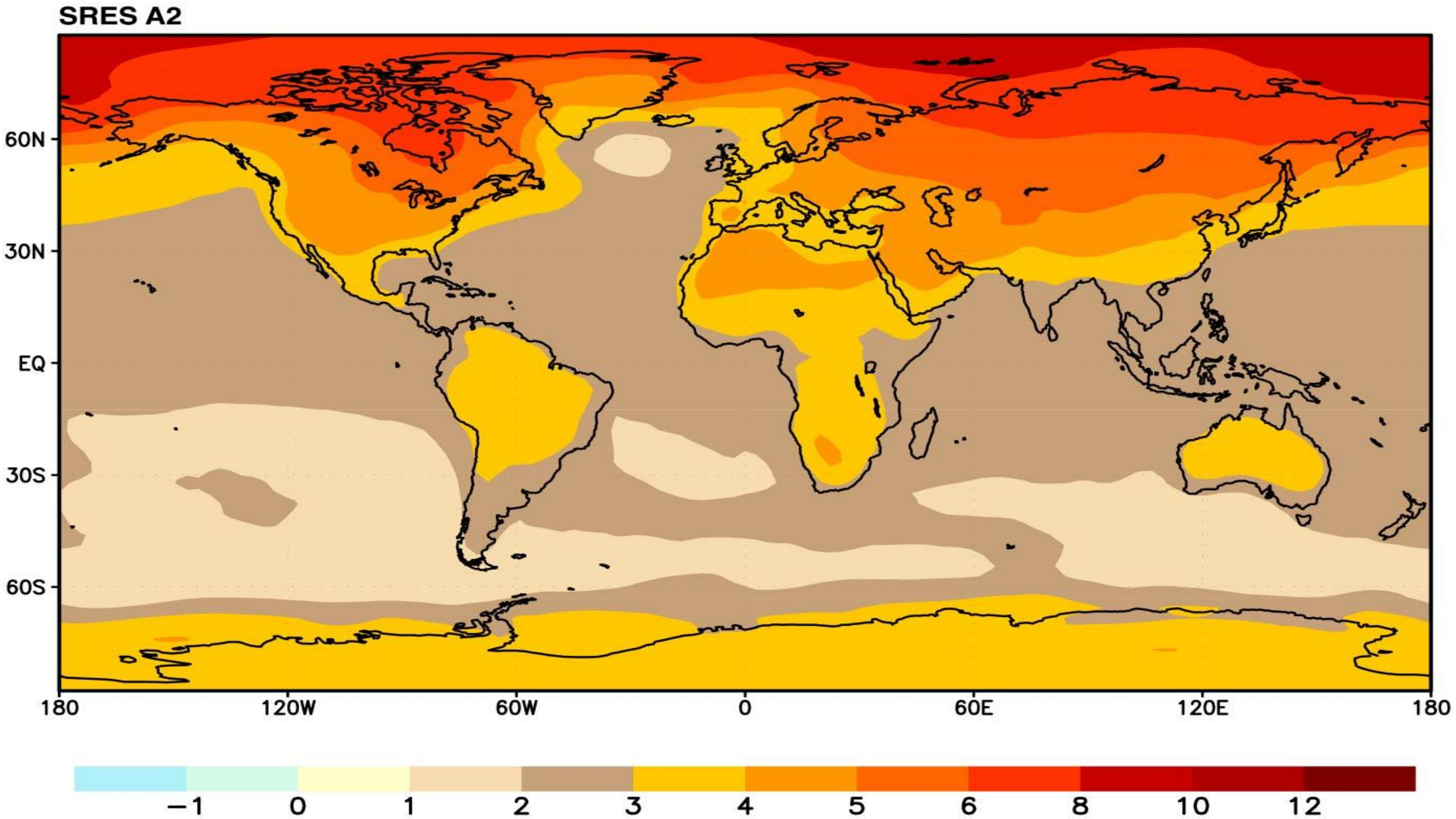
Future Population Growth: Major Countries



El Salvador's population may increase by about 30% by 2050.

Future Changes in Mean Temperature (2100)

IPCC 2007

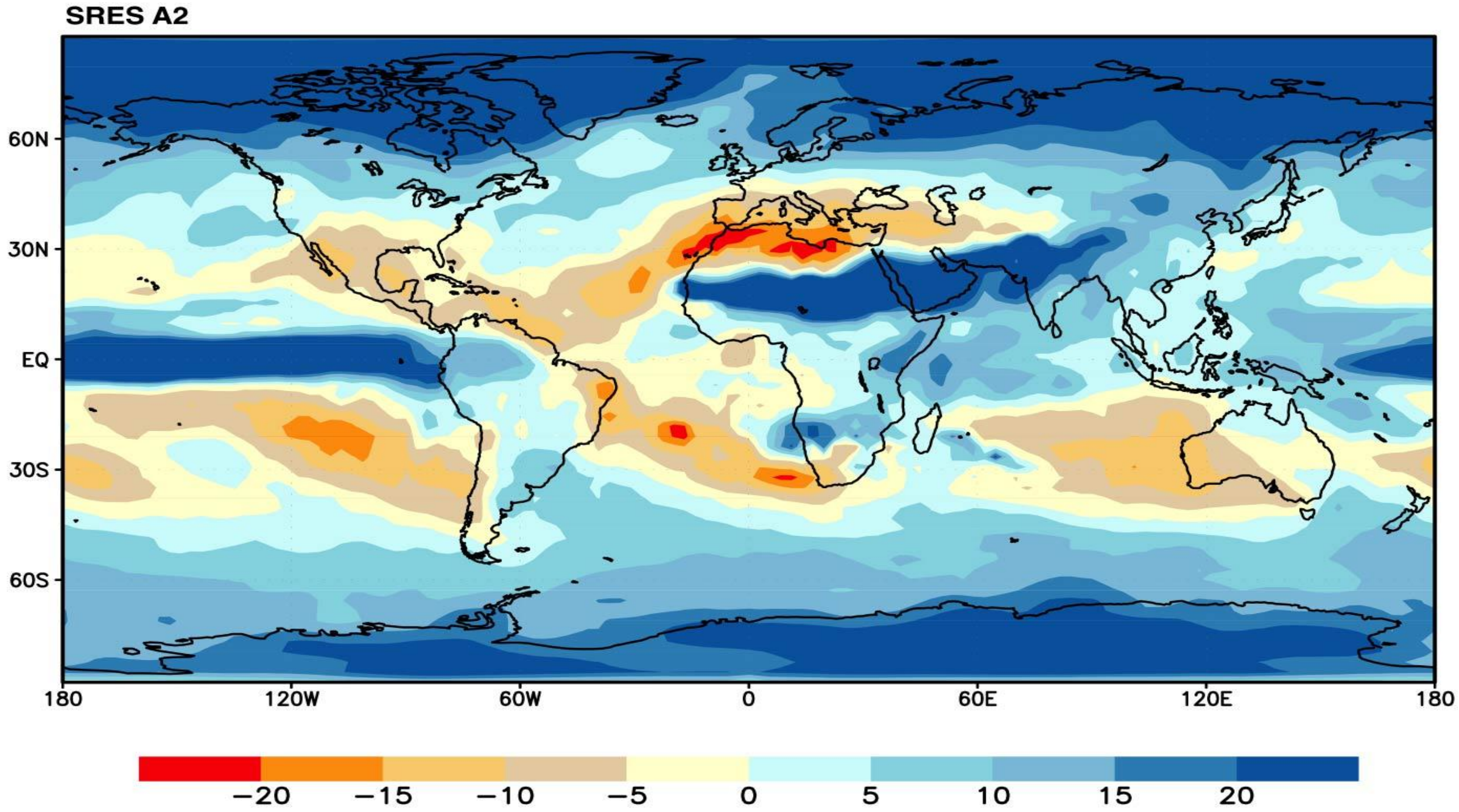


Models predict air temperatures to increase by 1.4 to 5.8°C.

Global average in 2085 relative to 1990 = 3.1°C

Future Changes in Annual Precipitation (2100)

IPCC 2007



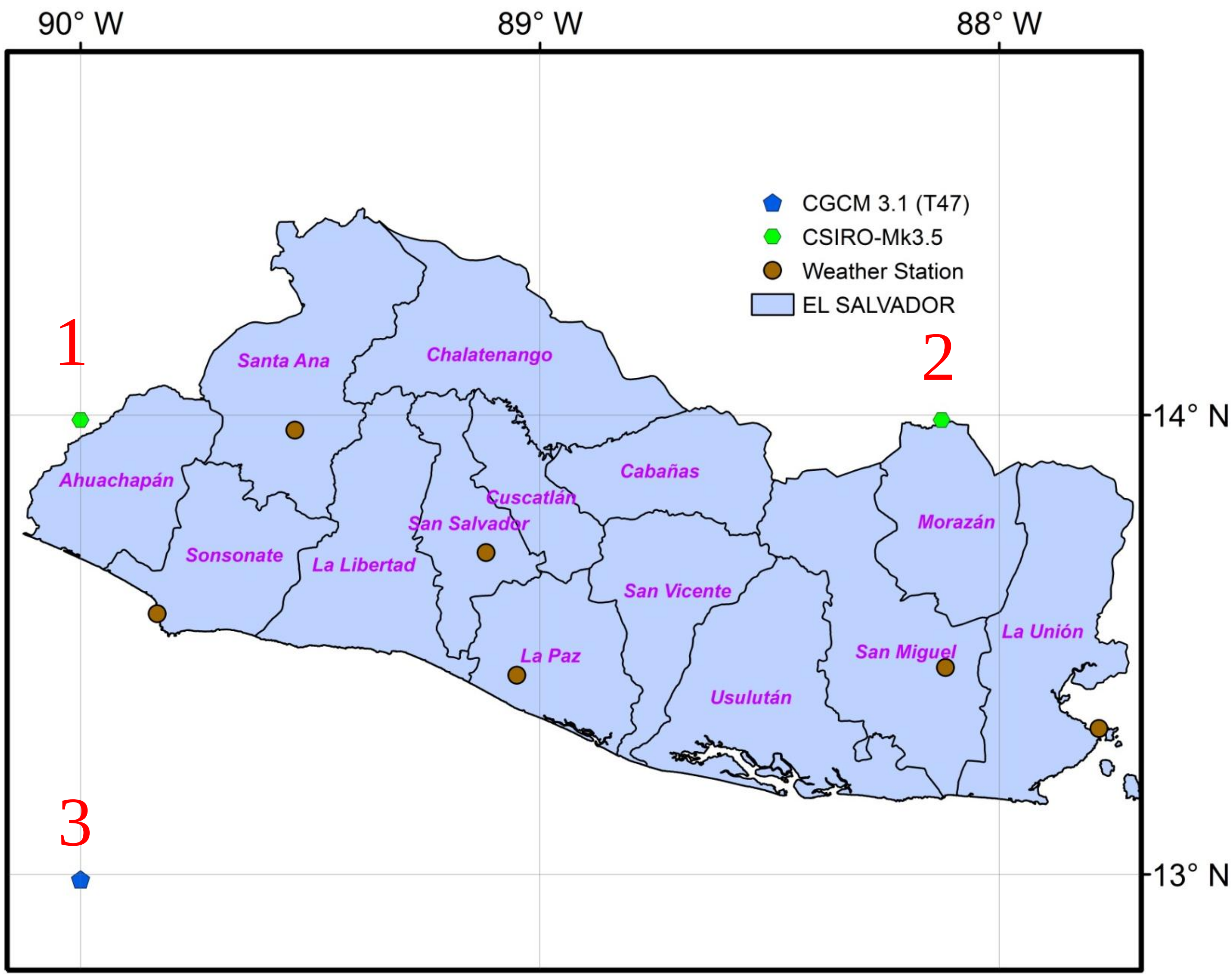
Models predict annual precipitation increase, but more dry spells.

Annual mean precipitation in relative to 1990.

Part II: Climate Change and Variability in El Salvador (General Circulation Models and Emission Scenarios)



El Salvador: General Circulation Models



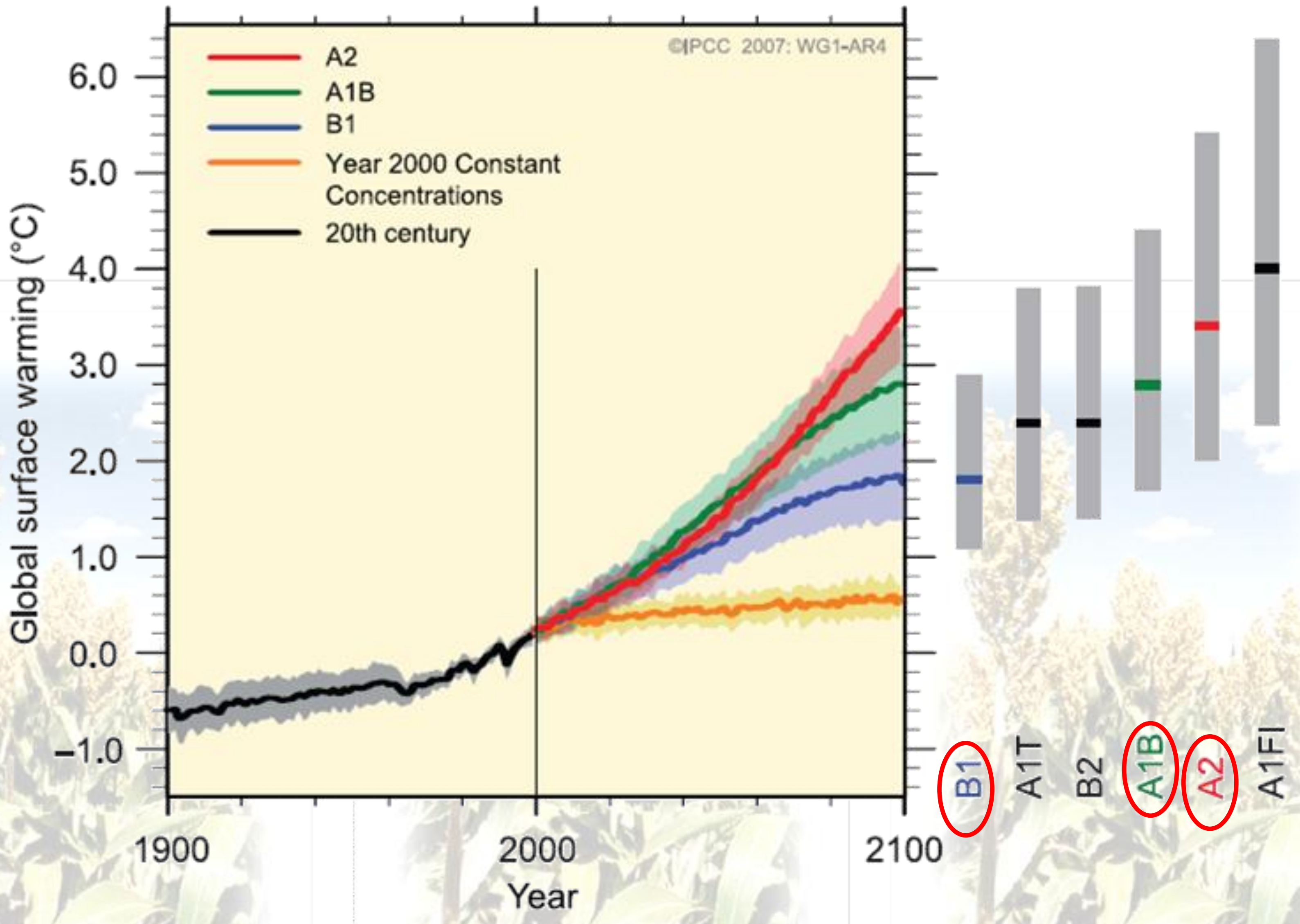
There are two (Australian and Canadian) General Circulation Models at 3 sites) for El Salvador

Methods: Climate and Crop Simulation Models

- Two Global Climate Models (GCM) used in this study were Canadian GCM (CGCM3.1 T47) and Australian GCM (CSIRO-Mk3.5).
- Three IPCC-SRES climate scenario (A1B, A2 and B1) data for historic period (1971-2000) and future (2041-2070) were acquired from World Climate Research Program for Climate Model Diagnosis and Intercomparison (PCMDI).

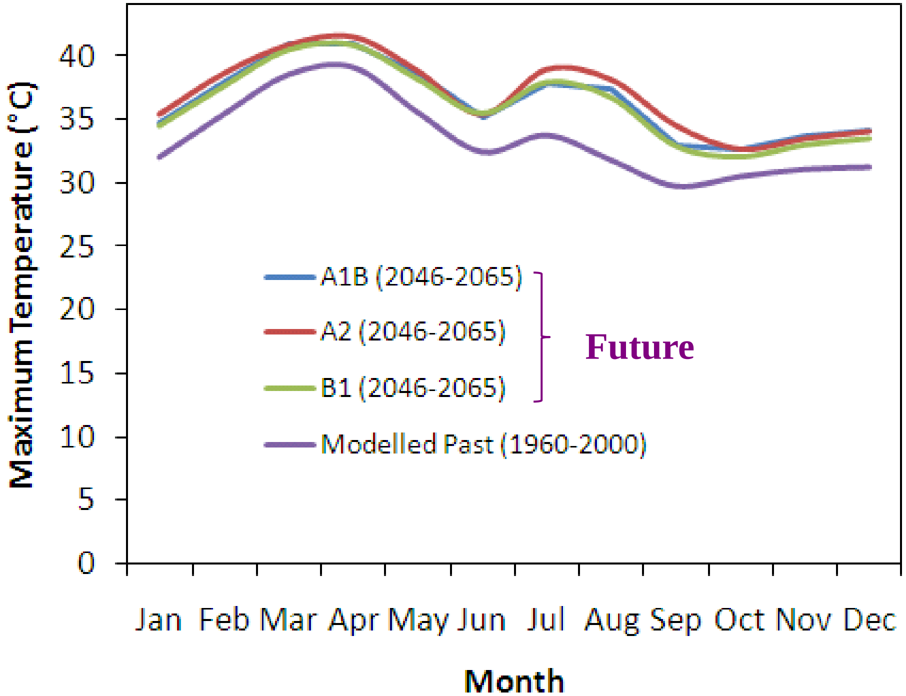
- Crop modeling was performed in DSSAT (Decision Support System for Agrotechnology Transfer) software suite.
- CERES-Sorghum, CERES-Maize and CROPGRO-Dry bean were used to simulate growth duration and grain yield.

IPCC Scenarios Used for Simulations for El Salvador

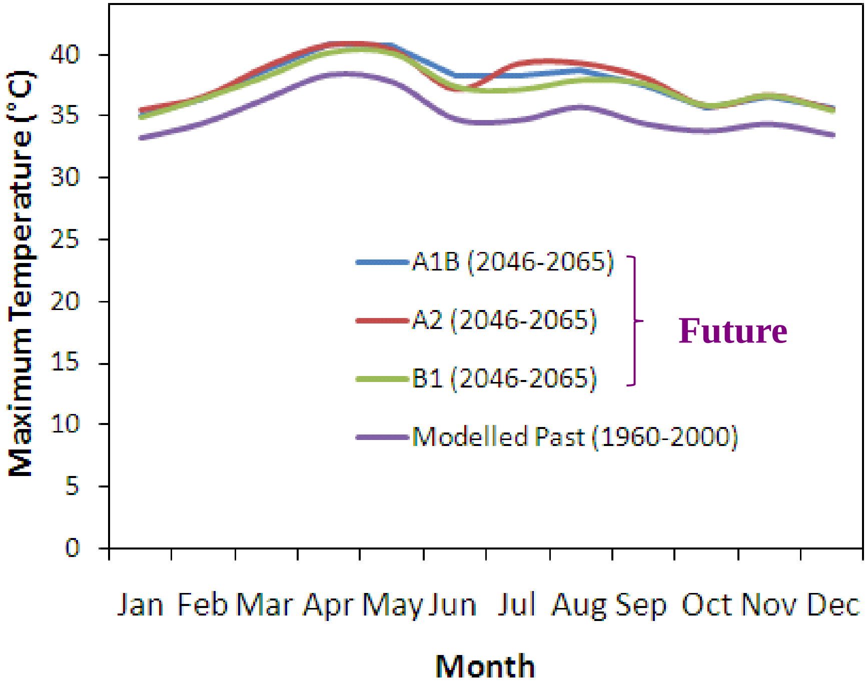


Three scenarios (A1B, A2 and B1) were used for simulations.

El Salvador: Uncertainties in Emission Scenarios: Future: Maximum Temperature



CGCM3.1 (T47)

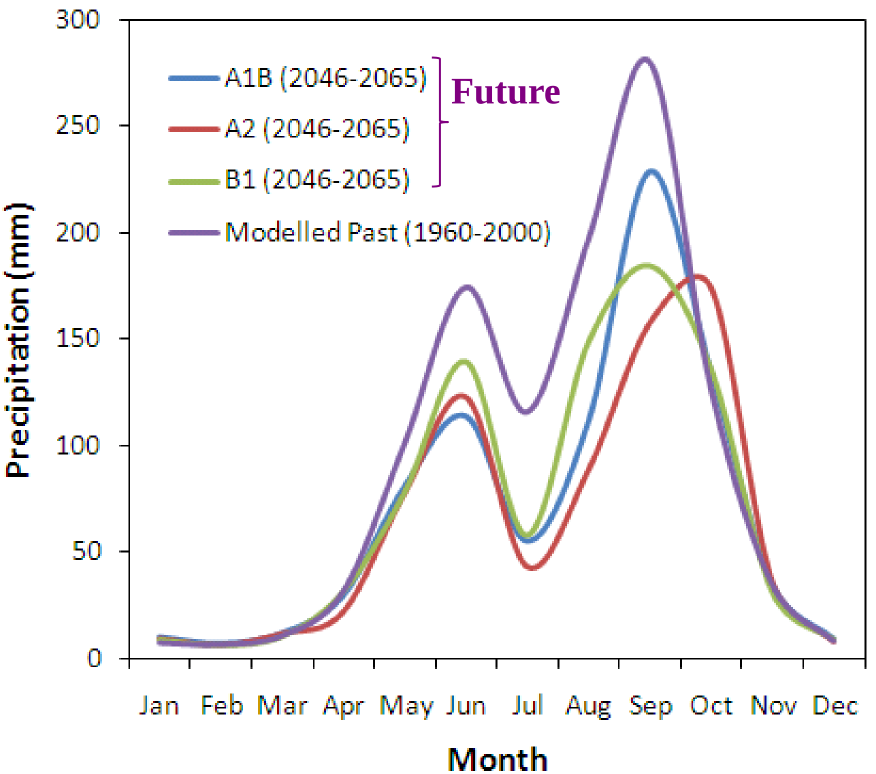


CSIRO-Mk3.5

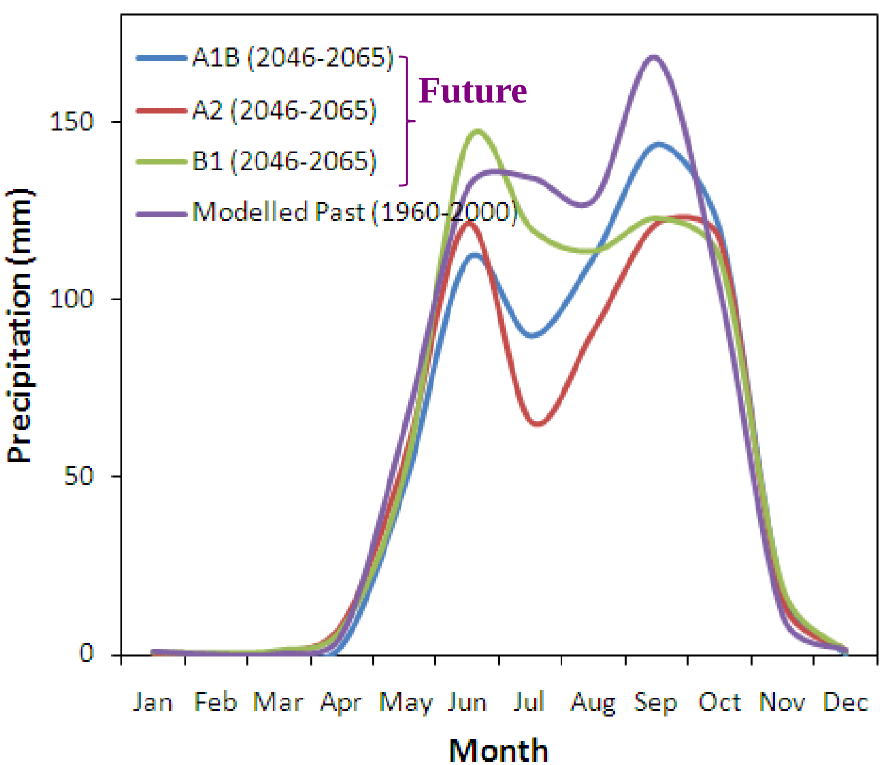
There are uncertainties in emission scenarios and model predictions.

<u>All three models predict increases in maximum temperatures in the range of about 3 - 5 °C in future .</u>

El Salvador: Uncertainties in Emission Scenarios: Future: Precipitation



CGCM3.1 (T47)



CSIRO-Mk3.5

There are uncertainties in emission scenarios and model predictions.

<u>Future climates will be more drier (June, July, Aug, and Sep.).</u>

Part III: El Salvador: Impact of Climate Change (High Temperatures) on Crop Yields

(Crop Simulations Models)

Three Crops: Dry Bean, Maize and Grain Sorghum



El Salvador: Dry Bean Model

Dry Bean (DSSAT Suite)

Soil – Luvic Phaeozem

Cultivar – Landrace cultivar (Rabia de Gato) – indeterminate, prostrate, early maturing type III

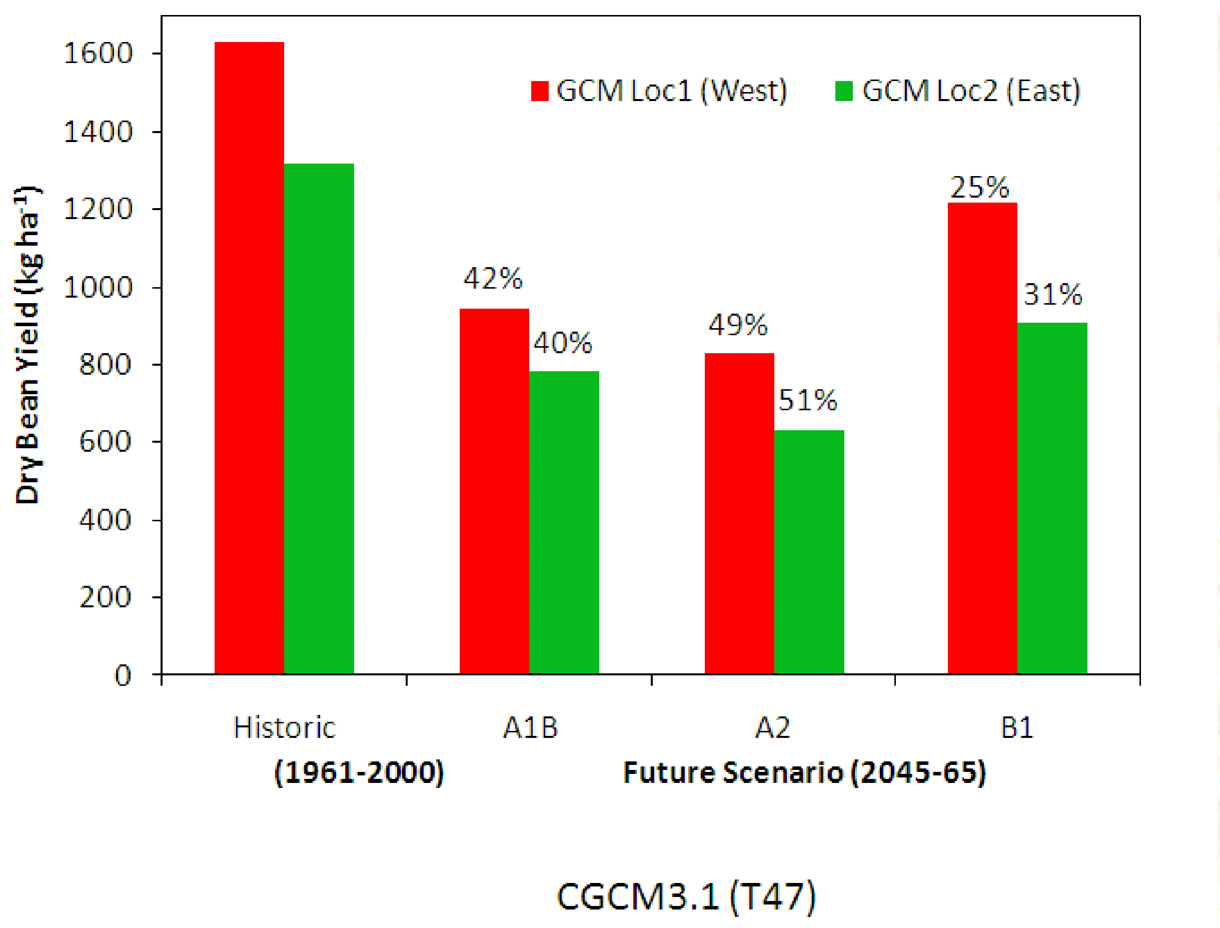
Plant Population – 300,000 plants/ha

Planting Date – August 20

Country was divided into Eastern and Western region

El Salvador:
Impact of Climate Change on Dry Bean Yield

El Salvador was Divided into Two Regions (East and West)



Models predict yield losses of about 25 – 50%, in eastern and western regions.

El Salvador: Maize Model

Maize Model (DSSAT Suite)

Soil – Luvic Phaeozem

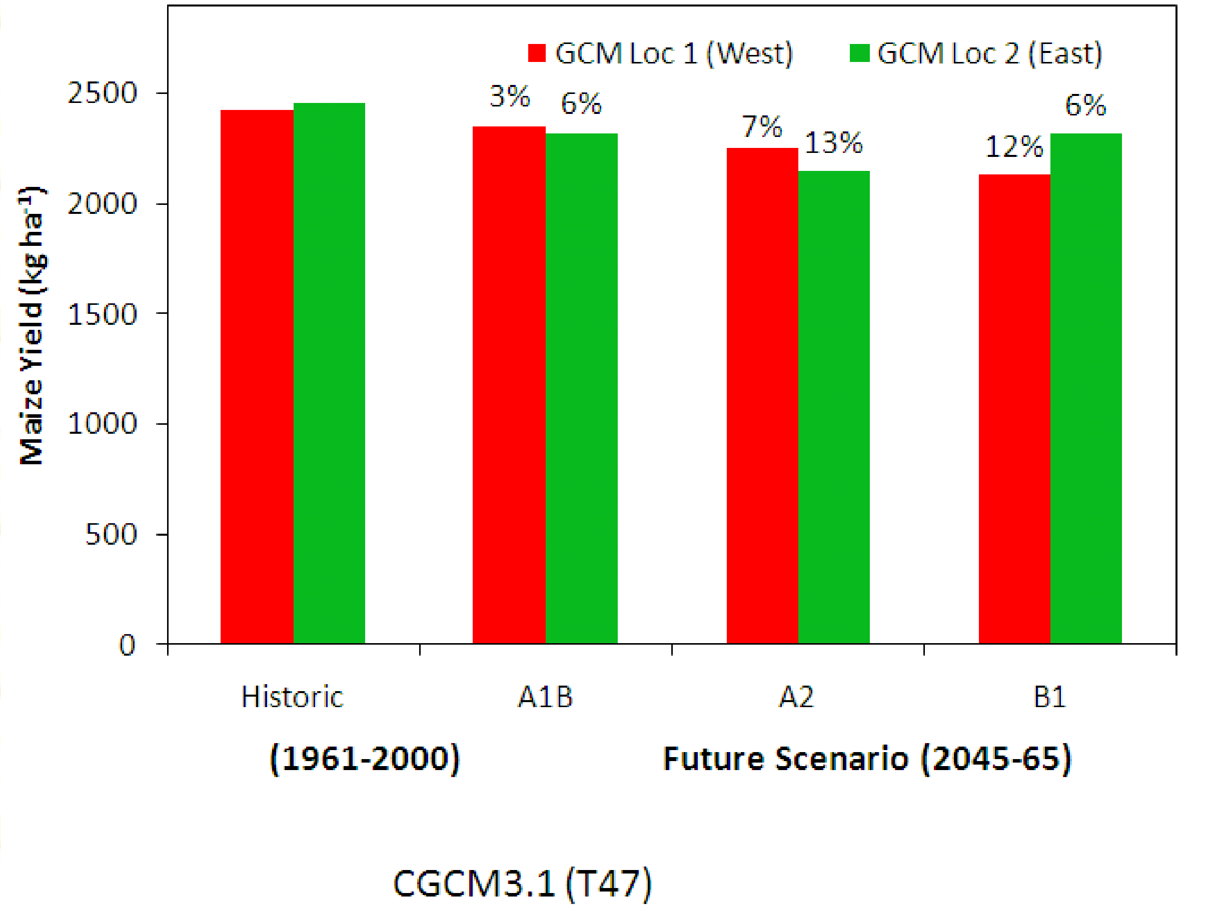
Cultivar – Medium Season Local Cultivar

Plant Population – 150,000 plants/ha

Planting Date – May 15

El Salvador: Impact of Climate Change on Maize Yield

El Salvador was Divided into Two Regions (East and West)



Models predict yield losses of 3 – 13%, in eastern and western regions.

El Salvador: Grain Sorghum Model

Grain Sorghum Model (DSSAT Suite)

Soil – Luvic Phaeozem

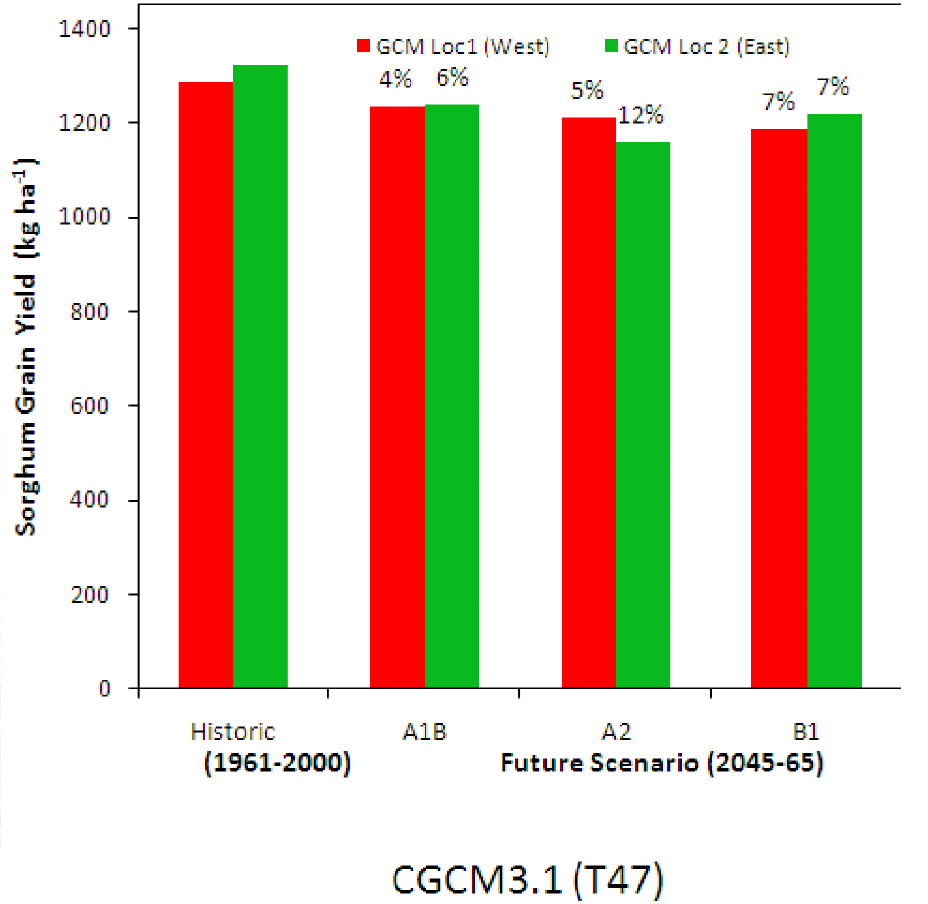
Cultivar – Local Cultivar

Plant Population – 150,000 plants/ha

Planting Date – May 15

El Salvador:
Impact of Climate Change in Grain Sorghum Yield

El was Salvador Divided into Two Regions (East and West)



Models predict yield losses of 4 – 12%, in eastern and western regions.

Part IV: Impact of Climate Change – Temperature, Drought and/or Carbon Dioxide Dry Bean, Maize and Grain Sorghum (Experimental Evidence – Global Literature)

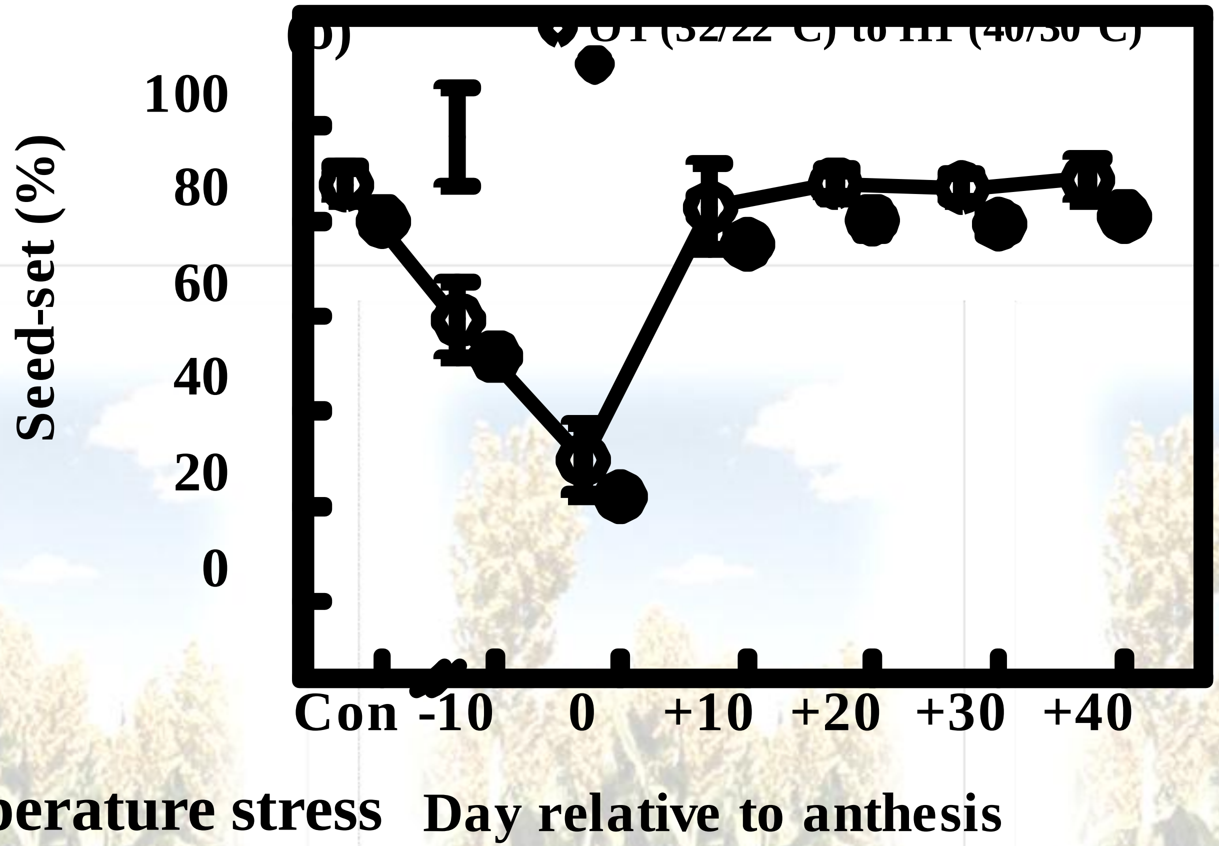


Experimental Evidence: Grain Sorghum and Maize

Sorghum: Short Periods of High Temperature Stress – Seed-set

High temperatures (38 C) for (10 days) just before flowering decreased seed-set and seed yield.

Grain Sorghum – Most Sensitive Stage to Temperature



Prasad et al., 2008. Crop Sci. 48: 1911-1917.

High temperatures stress at 10 d prior to flowering and at flowering decreased seed-set.

Most sensitive stage was at flowering

Short Periods of High Temperature Stress – Summary

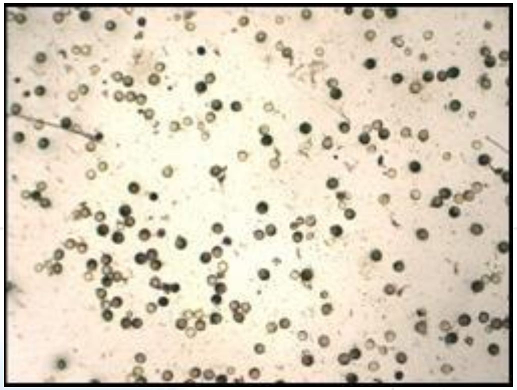
Prasad et al., 2008. Crop Sci. 48: 1911-1917.

High temperature stress decreased plant height, delayed panicle emergence, percent seed-set, and seed yield.

Sorghum: Short Periods of High Temperature Stress – Pollen

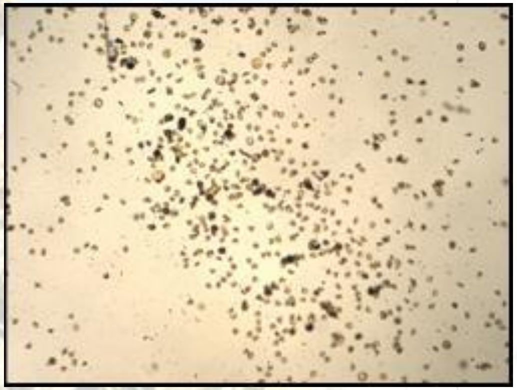
Control = 32/22 C

36/26 C

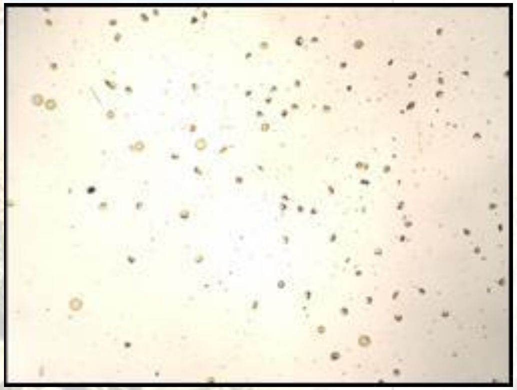


Duration = 10 days
Stage = 10 d before panicle emergence

40/30 C

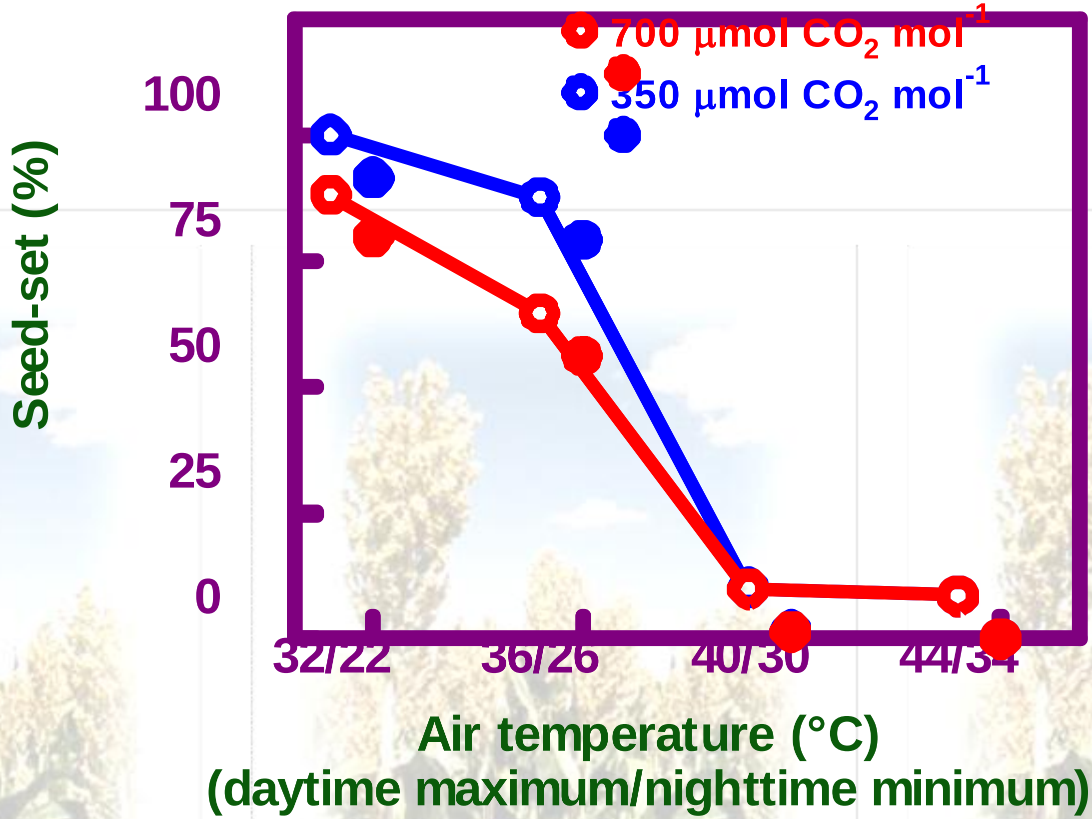


44/34 C



High temperature stress for 10 d at 10 d before panicle emergence decreased pollen starch content and pollen viability.

Grain Sorghum: Seed-Set

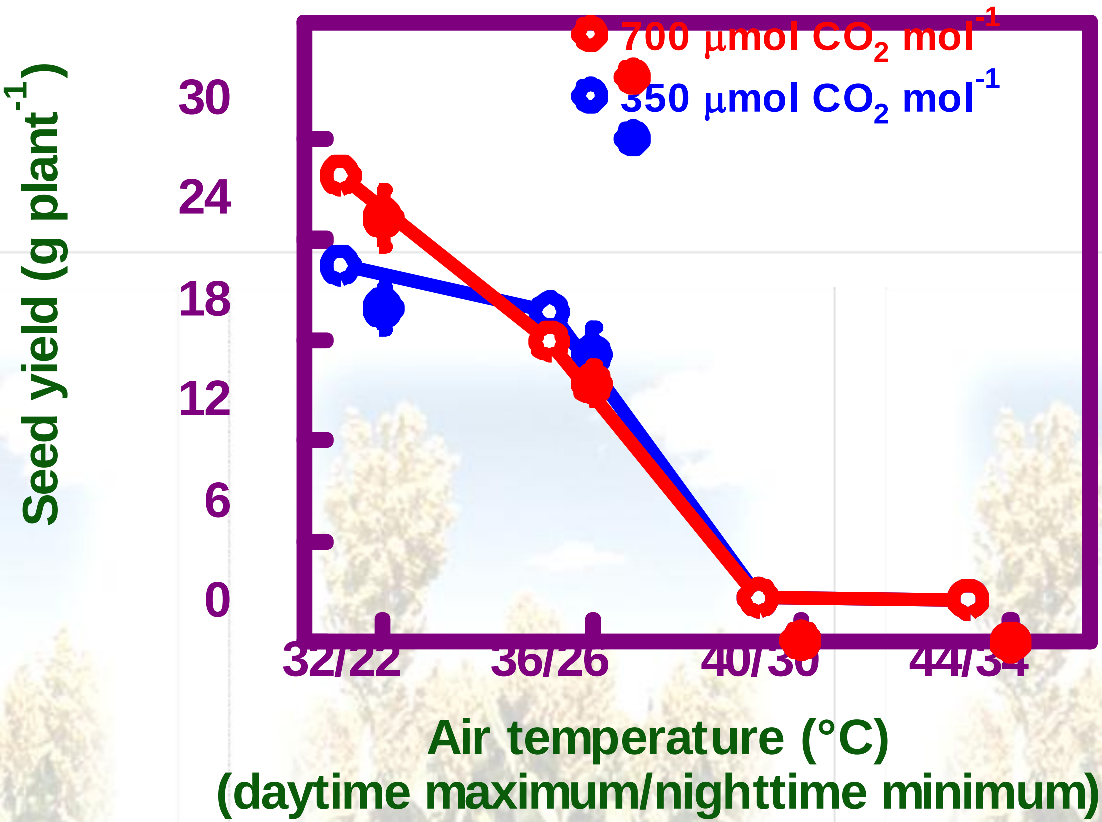


Prasad et al., 2006. Agric. For. Meterol. 139: 237-251.

High temperatures decreased % seed-set.

Elevated CO_2 decreased seed-set.

Grain Sorghum: Seed Yield



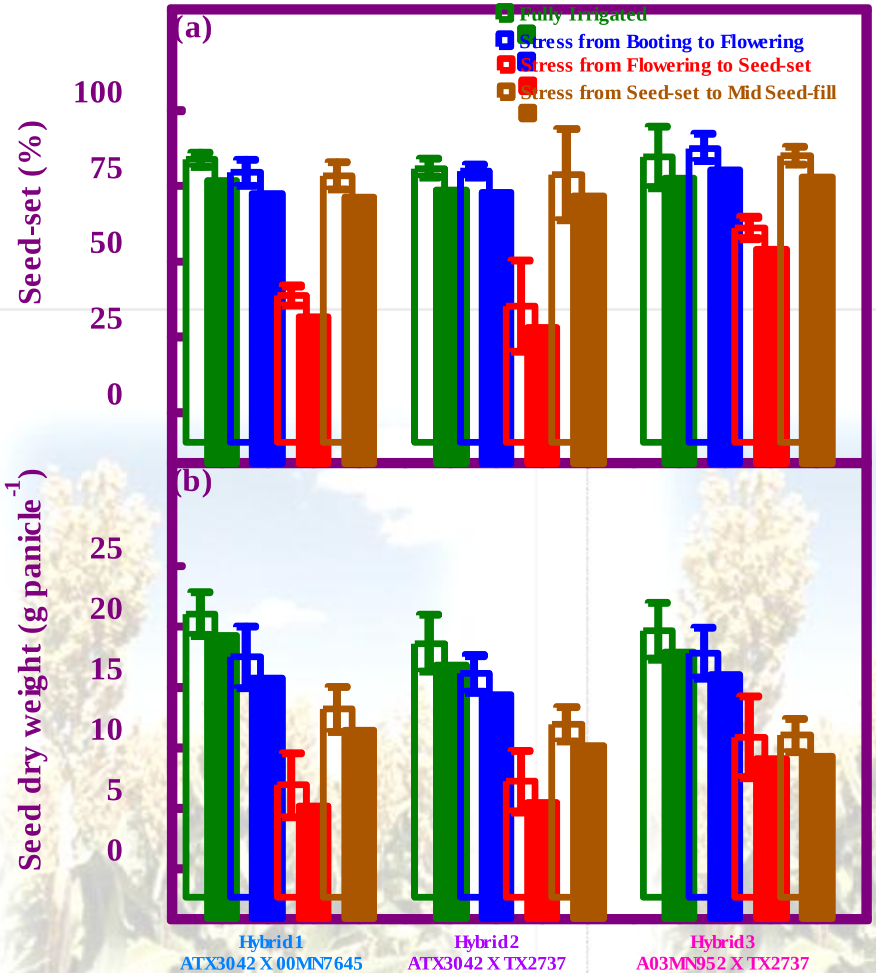
Prasad et al., 2006. Agric. For. Meterol. 139: 237-251.

High temperatures decreased seed yield.

Elevated CO_2 increased yields at 32/22 C,

but not at high temperatures (36/26; or 40/30 C).

Sorghum: Drought Stress on Yield Components



Control

Drought at flowering

Seed dry weights were decreased by 14, 63 and 43% when drought was imposed during panicle emergence, flowering or early seed-filling period, respectively.

Drought from flowering to seed-set decreased seed-set.

Drought during flowering and post flowering decreased seed yield.

Maize: High Temperature Stress – Pollination and Seed-set

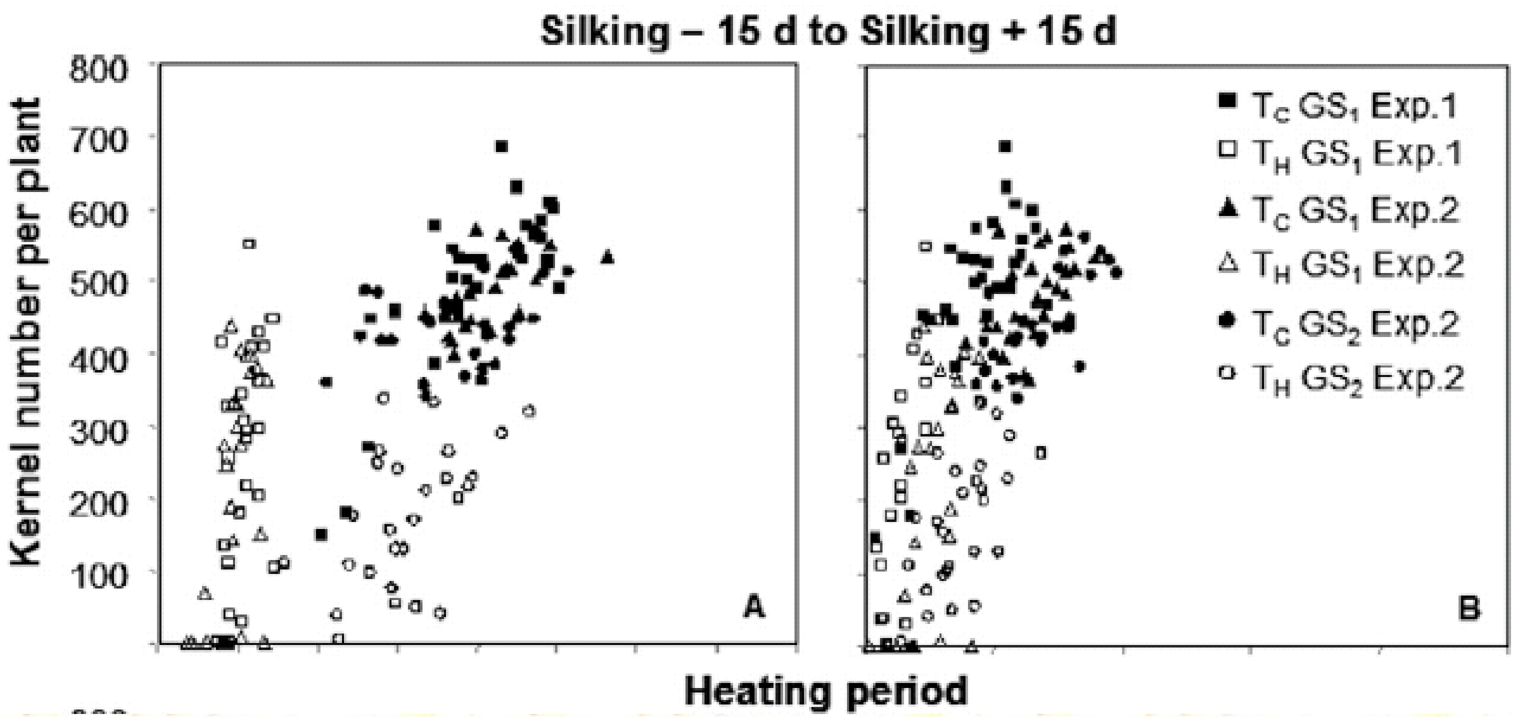
Photo Courtesy : Nick Roy, Kentucky

Photo Courtesy : Ohio State University

The blank or unfilled kernels on these ears are from poor pollination and decreased seed set. Heat stress is the most likely culprit.

High temperature stress decreased pollination and seed set in maize. Mainly caused by decreased pollen viability and stigma receptivity.

Maize: High Temperature – Seed number (seed-set)



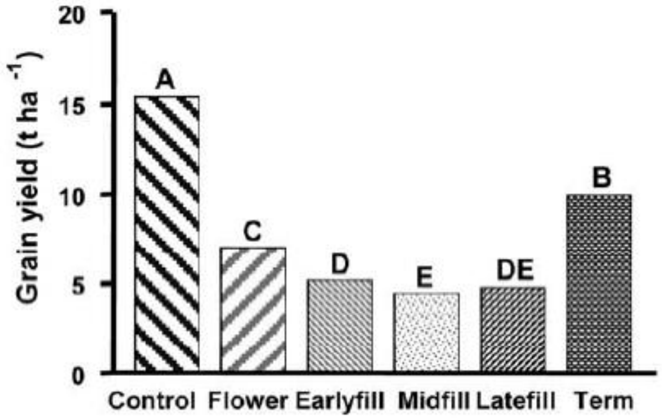
(Cumulative heat stress temperature units **15 – 20** vs. about **280 - 290**)

Cicchino et al. (2010) Crop Sci. 50: 1438-1448

High temperature stress decreased seed-set and kernel numbers per plant.

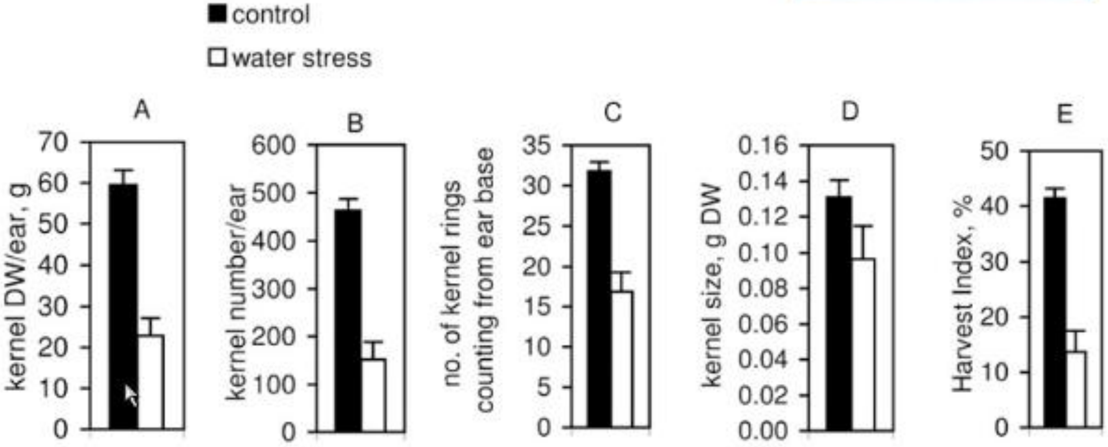
Maize: Drought Stress on Yield Components

H. Campos et al./Field Crops



(A)

Post-pollination water deficit
Water stress from 3 to 8 days after pollination



Setter TL, Parra R (2010) Crop Science 50: 980-988

Reproductive stages are relatively more sensitive to drought stress.

Drought decreased kernel number and dry weights.

Maize: Drought Stress on Yield Components

Ear from a maize plant produced under favorable growing conditions (far left) compared with four abnormal ears from plants subjected to protracted drought stress (late vegetative stages through grain fill)

Photo Courtesy : Ohio State University

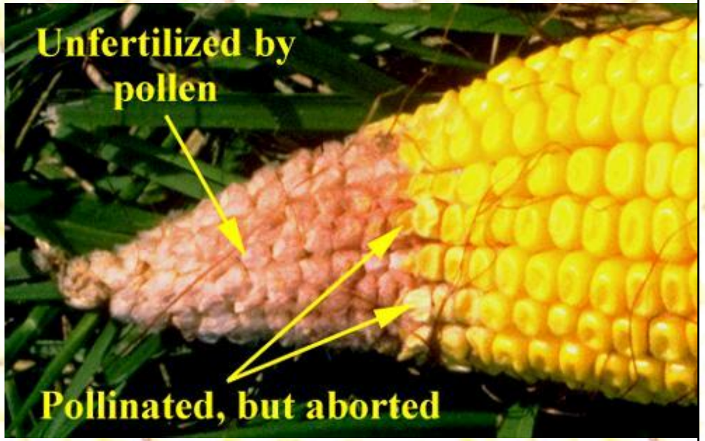
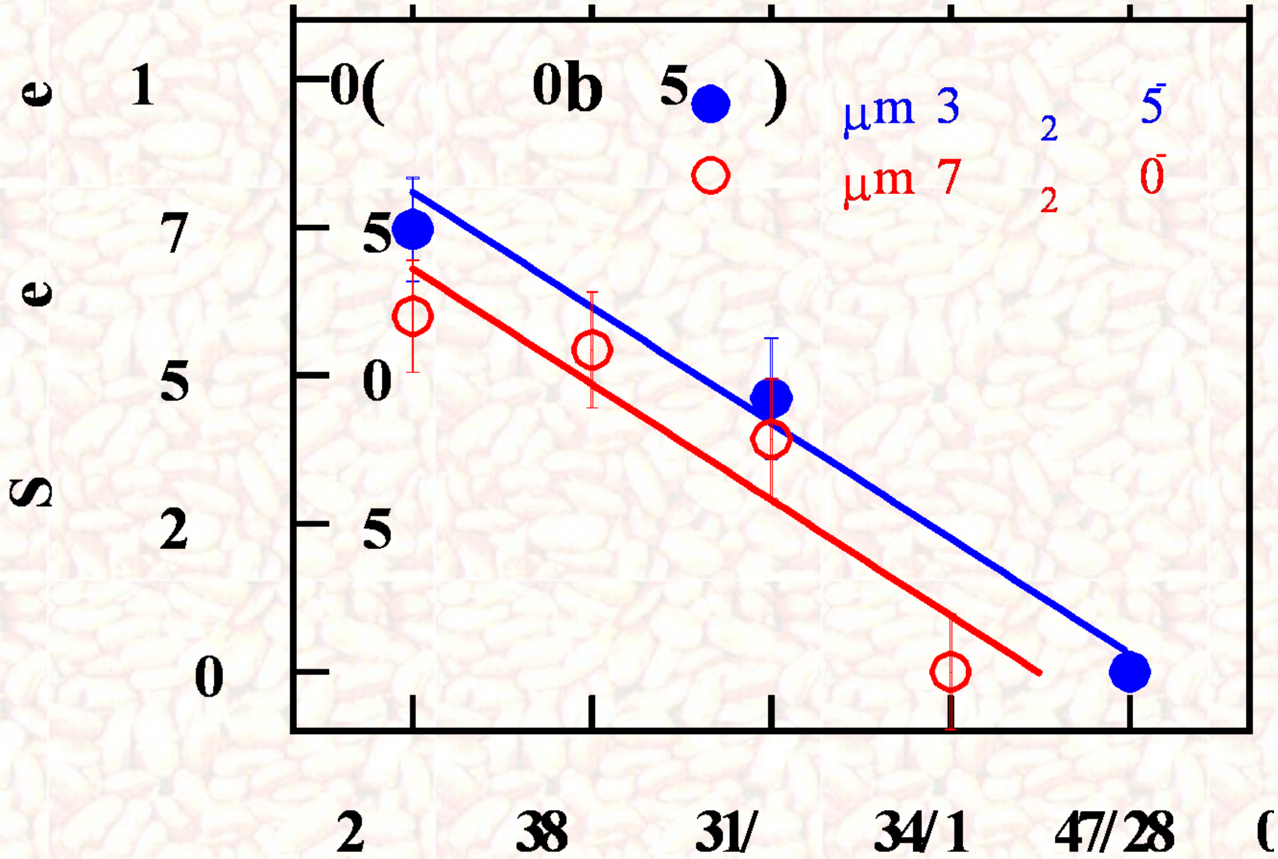


Photo Courtesy : Dr. R.L. Nielsen, Purdue University

Drought stress decreased kernels numbers and kernel size.

Experimental Evidence: Dry Bean
Season Long Temperature Stress

Dry Bean: Seed - set

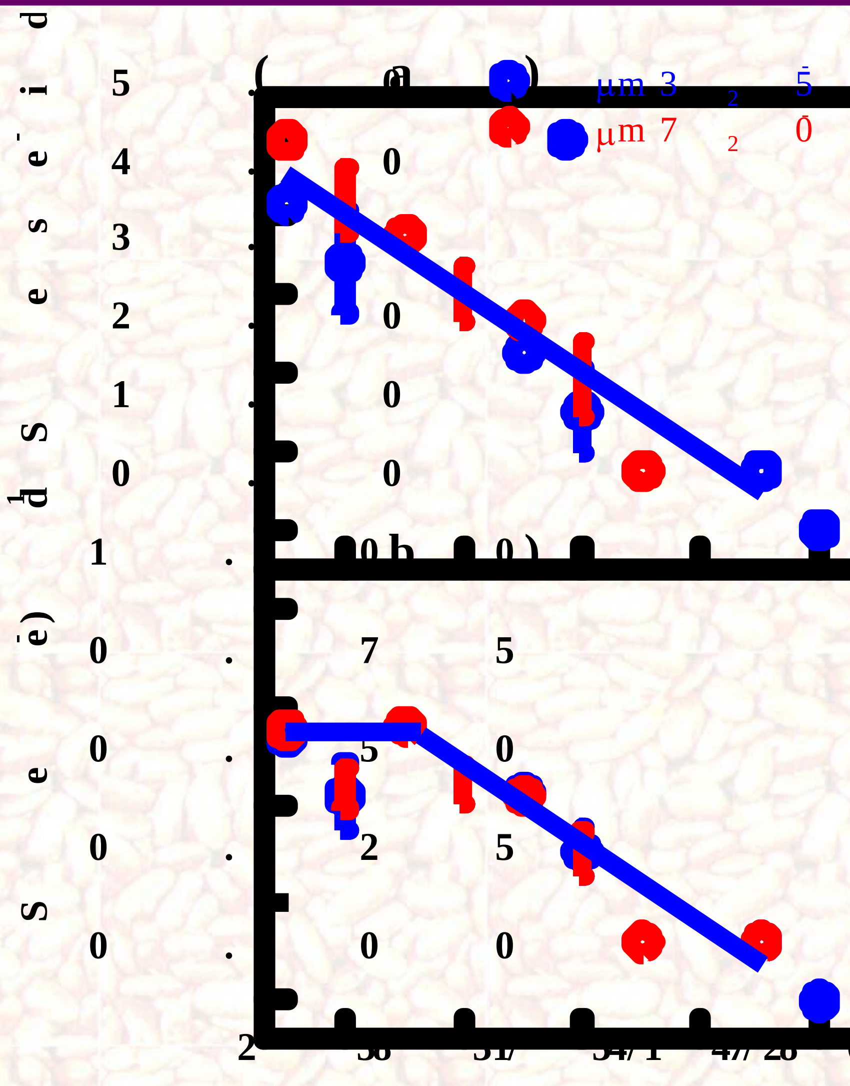


Prasad et al. (2002). Global Change Biol. 8: 710-721.

Temperatures > 28/18°C decreased seed-set.

Elevated CO_2 also decreased seed-set.

Dry Bean: Seed Number and Seed Size

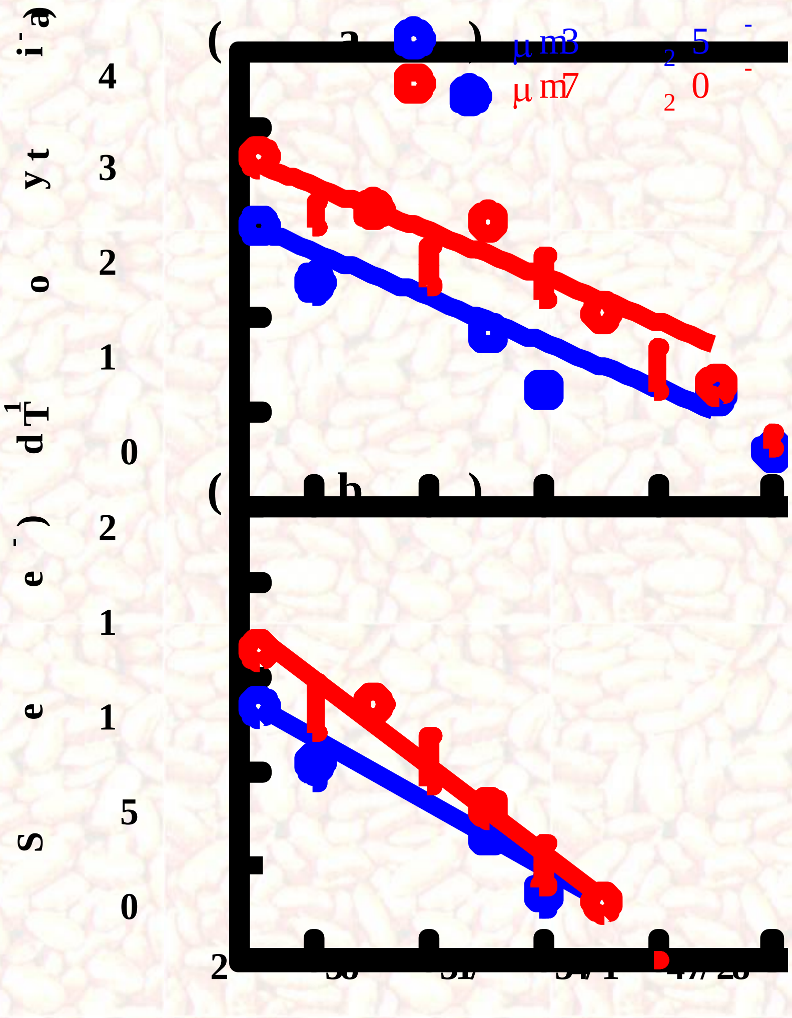


Prasad et al. (2002). Global Change Biol. 8: 710-721.

Temperatures > 28/18°C decreased seed number and seed size.

Elevated CO_2 did not influence seed number or seed size.

Dry Bean: Biomass and Seed Yield



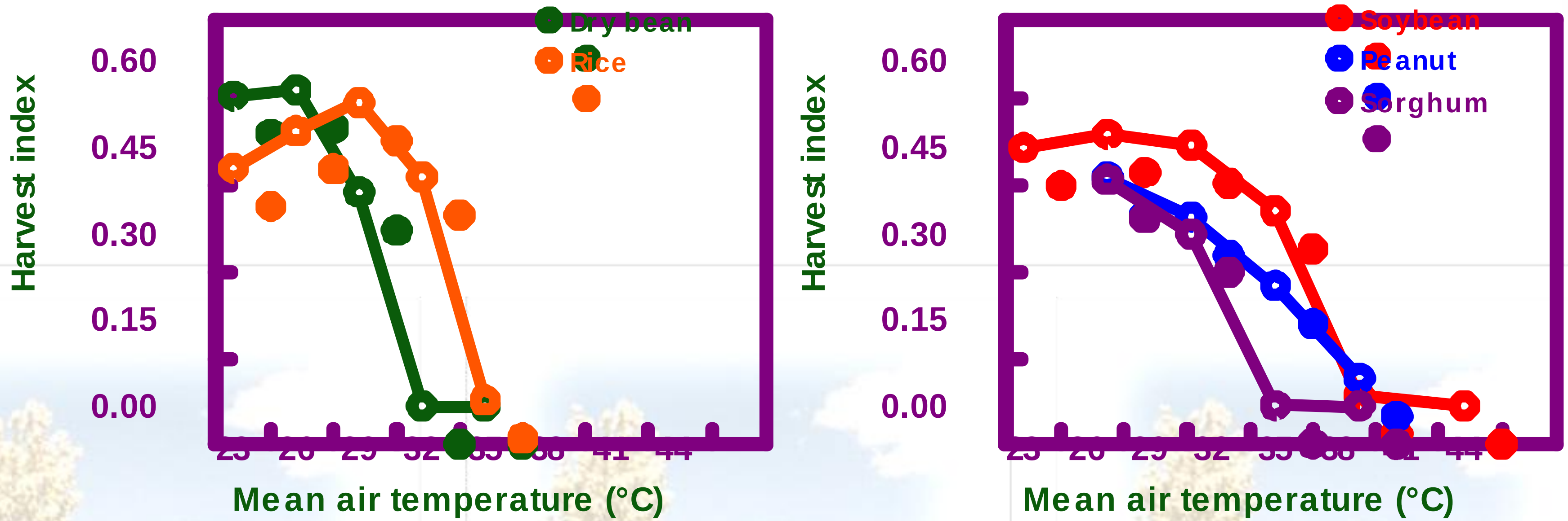
Prasad et al. (2002). Global Change Biol. 8: 710-721.

Temperatures > 28/18°C decreased biomass.

Elevated CO_2 increased biomass.

Benefits of elevated CO_2 decreased with increasing temperatures.

Crop Responses to Temperature



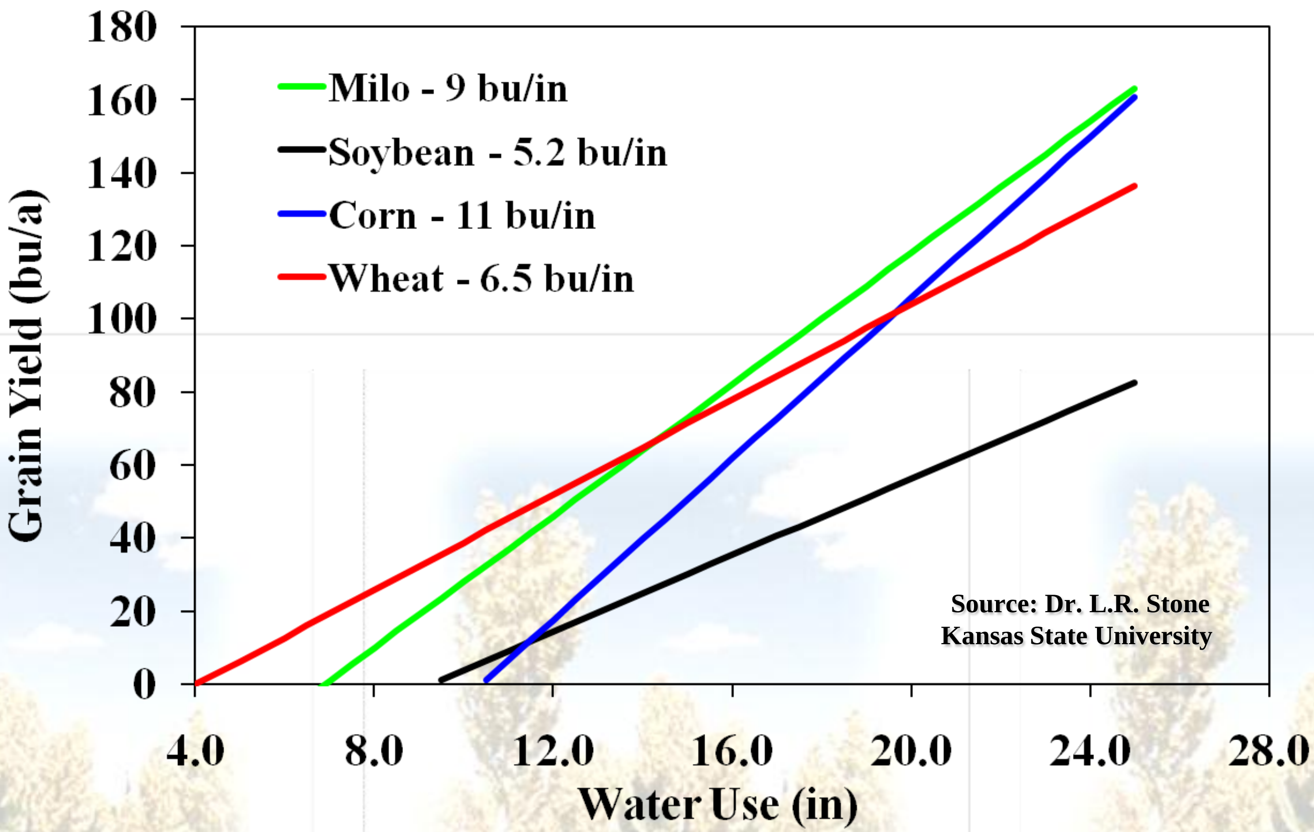
Daily temperature (day and night)

Season long elevated temperatures decreased harvest index due to lower seed yields caused by decreased seed-set.

Different crops have different optimum and ceiling temperatures. Therefore selection of crop is also very important.

Bean: Prasad et al., 2002. Global Change Biol. 8: 710-721.
Peanut: Prasad et al., 2003. Global Change Biol. 9: 1775-1787.
Sorghum: Prasad et al., 2006. Agric. For. Meterol. 139: 237-251.
Rice: Snyder, 2000. MSc Thesis, University of Florida.
Soybean: Pan, 1996; Thomas, 2001. PhD Thesis, Univ. Florida.

Crop Responses to Water Use



Grain yield is proportional to water use for most grain crops.

The amount of water used for the first bushel of yield is lowest for wheat followed by sorghum (milo), soybean and maize (corn).

However productivity of corn per unit water used is greater for maize followed by sorghum, wheat and soybean.

Part V: Opportunities for Crop Management



Crop Management: Opportunities

- Adjust planting dates to avoid high temperature or drought stress during sensitive stages of reproductive development (pollen development, flowering, early grain filling).
- Depending upon location, use of shorter duration genotypes to avoid stress; or using of longer (full season) genotypes with longer grain filling duration can minimize risk.
- Diversify with different crops (sorghum vs. maize vs. millet) or (dry bean vs. soybean vs. cowpea) and genotypes (different pollination periods, flowering habit and maturities).
- If irrigation available, apply during critical stages (pollination and early grain filling).
- Manage crop with optimum fertilizer and pest control for better growth.
- High temperature and drought tolerant genotypes will play important role in improving yields.

Crop Simulation Model: Opportunities

Grain Sorghum / Maize

- Crop modeling tests suggested that earlier planting sorghum (April 15 vs. May 15) can improve yields.
- Using longer season genotypes or increasing grain filling duration will improve grain yields.

Dry Bean

- Later planting (August vs. September) increased yields.
- Increasing seed filling duration and seed size can increase seed yield.

Part VI: Genetic Variability: Opportunities for High Temperature and Drought Tolerance in Dry Bean, Sorghum and Maize



Dry Bean: High Temperature : Genotypic Differences

Table 2: Analysis of the geometric mean (GM), heat susceptibility index (HSI) and heat tolerance index (HTI) on seed yield for three trials under high temperature stress conditions[1]

Genotype	Field 2005 GM	Field 2005 HSI	Field 2005 HTI	Field 2005 Rank[2]	Greenhouse 2004 GM	Greenhouse 2004 HSI	Greenhouse 2004 HTI	Greenhouse 2004 Rank	Greenhouse 2005 GM	Greenhouse 2005 HSI	Greenhouse 2005 HTI	Greenhouse 2005 Rank	Average across trials HSI	Average across trials HTI
SRC1-12-1-182	116.7	0.83	0.82	3	1.07	1.01	0.02	2	7.02	0.48	0.88	1	0.77	0.57
Amadeus	95.7	1.17	0.55	5	NT	NT	NT	NT	4.86	1.09	0.42	3	1.13	0.49
SRC1-12-1-48	117.4	0.59	0.83	2	0.24	1.02	0.00	8	4.51	0.98	0.36	5	0.86	0.40
98020-3-1-7-2	110.4	0.83	0.74	4	0.56	0.99	0.01	7	4.80	1.05	0.41	4	0.96	0.38
98012-3-1-2-1	119.2	0.76	0.86	1	0.00	1.02	0.00	9	3.26	1.14	0.19	8	0.97	0.35
IJR	46.1	0.72	0.13	11	3.15	0.94	0.21	1	4.36	0.71	0.34	6	0.79	0.23
G 122	13.0	1.45	0.01	13	0.79	0.80	0.01	5	5.14	0.75	0.47	2	1.00	0.16
EAP 9503-32A	68.8	1.04	0.29	6	0.88	0.92	0.02	4	1.46	1.21	0.04	12	1.06	0.11
DOR 557	NT[3]	NT	NT	NT	1.05	1.01	0.02	3	3.40	1.10	0.21	7	1.06	0.11
VAX 6	61.3	1.25	0.23	9	0.00	1.02	0.00	10	2.21	1.12	0.09	10	1.13	0.10
Tio Canela	63.0	0.99	0.24	7	0.00	1.02	0.00	11	0.80	1.25	0.01	14	1.09	0.08
EAP 9503-32B	62.0	1.17	0.23	8	0.00	1.02	0.00	12	0.90	1.25	0.01	13	1.15	0.08
Morales	49.7	1.26	0.15	10	0.00	1.02	0.00	13	2.40	1.15	0.10	9	1.15	0.08
Montcalm	28.7	1.14	0.05	12	0.73	0.99	0.01	6	1.85	1.01	0.06	11	1.05	0.04
X_p, X_s	128.5, 44.3				6.8, 0.2				7.5, 1.7					
HII[4]	0.66				0.98				0.77					

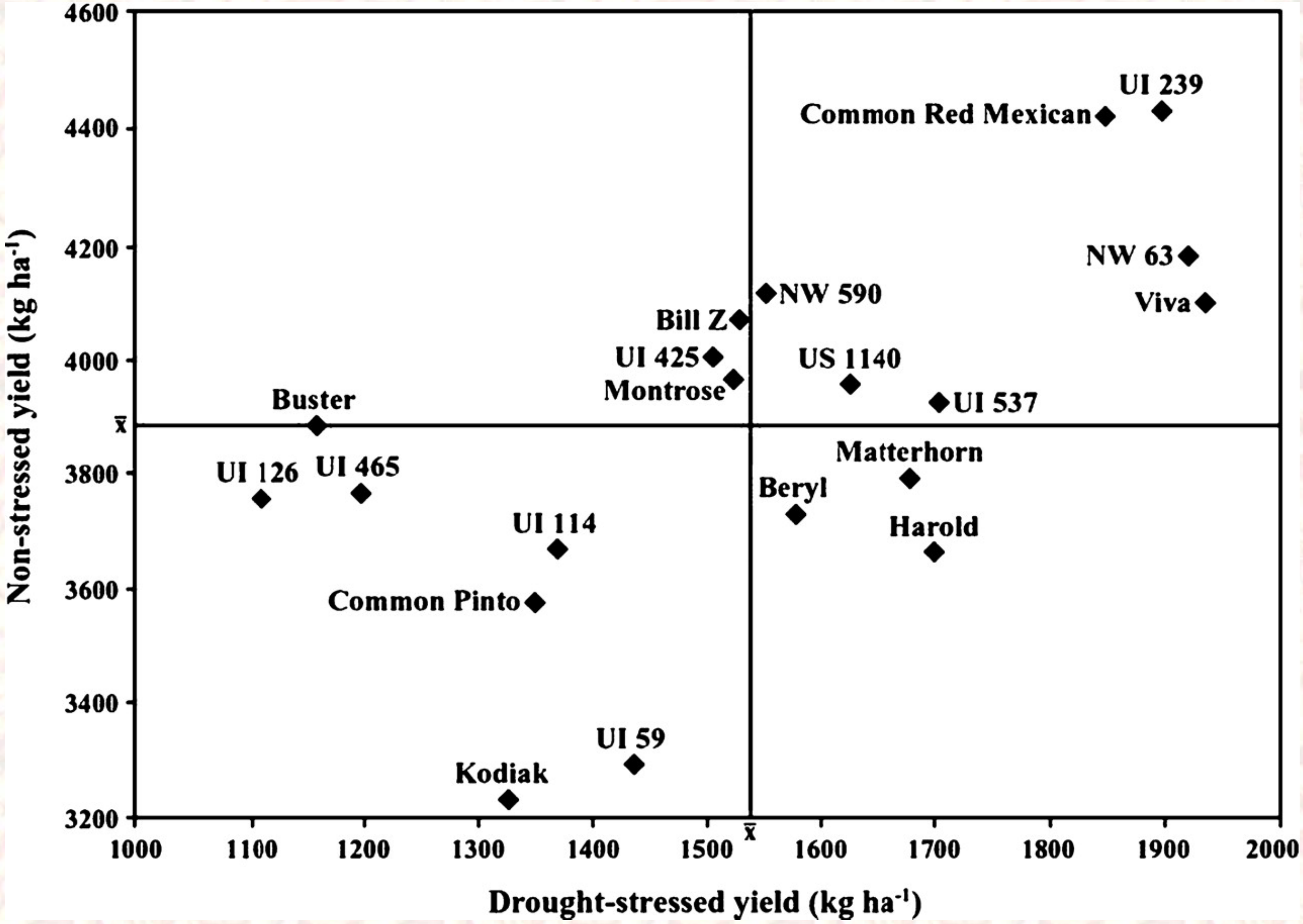
Seed yield/plant (greenhouse) or seed yield/plot (field) (g)

[1] $GM = (Y_s \times Y_p)^{1/2}$; $HSI = (1 - (Y_s/Y_p))/(1 - (X_s/X_p))$; $HTI = (Y_p \times Y_s)/X_p^2$, where Y_s and Y_p indicate genotypic yield under stress and non-stress conditions (respectively), and X_s and X_p are the mean yield of all genotypes per trial under stress and non-stress conditions respectively.
[2] Ranked by HTI.
[3] NT, not tested.

J. Agronomy & Crop Science 192, 390—394 (2006)

Genotypes varied in response to high temperature.

Dry Bean: Drought : Genotypic Differences



Shree P Singh (1996) Agronomy Journal 99:1219-1225

Genotypes varied in response to drought.

Maize: Drought : Genotypic Differences

Differences in Elite Germplasm

Figure 1. Pictured, a corn field with two corn hybrids. The hybrid on the left is exhibiting a typical sign of drought stress, rolled leaves.

Figure 2. Pictured are two corn hybrids with varying degrees of drought stress. Hybrid on the right exhibits more drought tolerance than the hybrid on the left.

Technology Development by MONSANTO

Genotypes vary in response to drought.

Maize: Drought : Advancement – e.g. Monsanto

Differences in Elite Germplasm

MONSANTO BREEDERS CHARACTERIZE GERMPLASM FOR RESPONSE TO DROUGHT STRESS

- Drought tolerance is a complex characteristic to convey in plants
- Many mechanisms and genes are involved in complex traits
- Pairing specific combinations of germplasm and biotech trait may do more to address the many mechanisms impacting quantitative traits
- Our approach to helping farmers manage drought is a systems-based approach
  - Traditional plant breeding / native genes
  - Agronomic components
  - Biotechnology traits

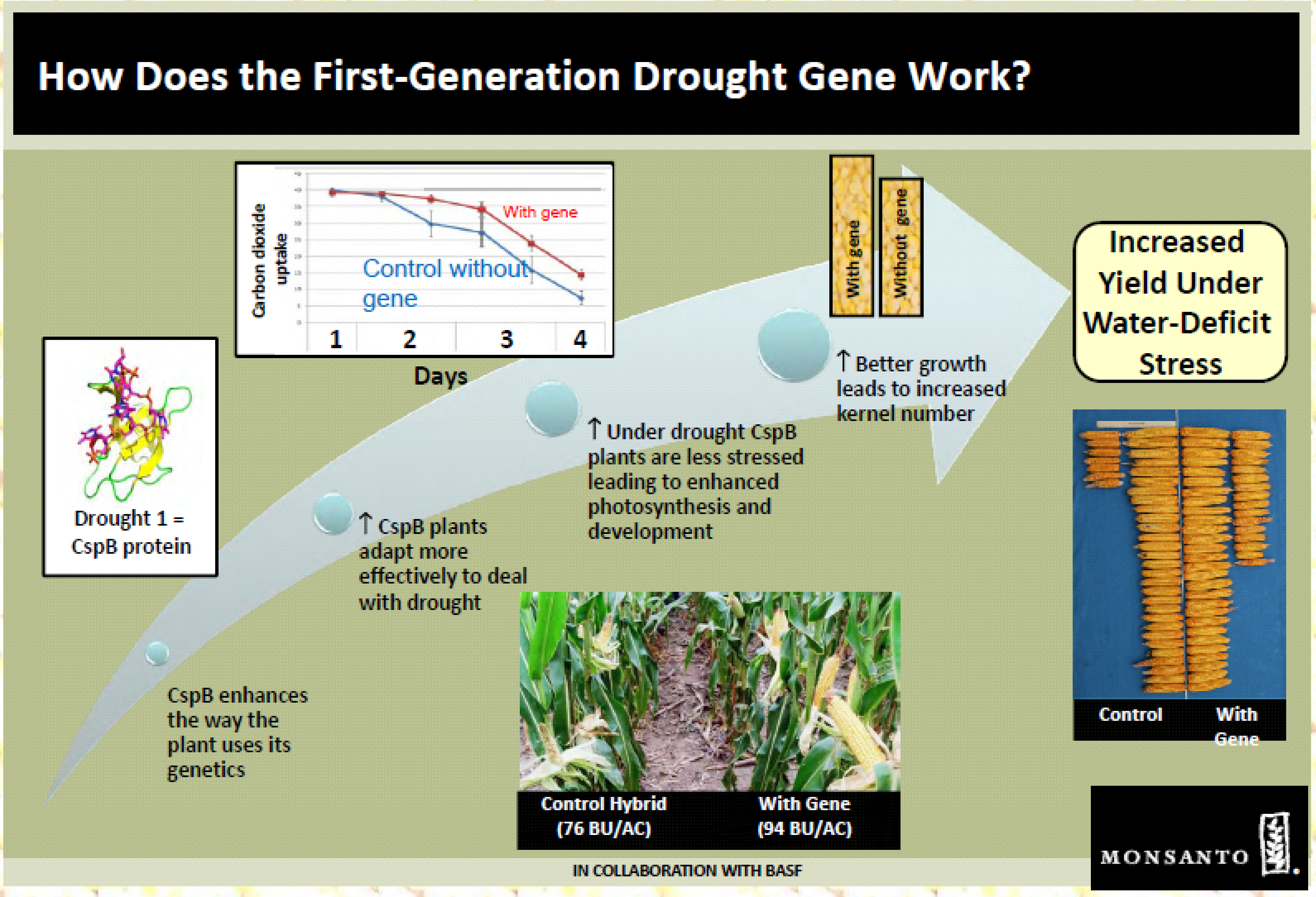
GENETIC VARIATION FOR STRESS TOLERANCE EXISTS IN ELITE GERMPLASM PO

MONSANTO

Genotypes vary in response to drought.

Maize: Drought : Advancement – e.g. Monsanto

Future: Transgenic Events / New GM Trait

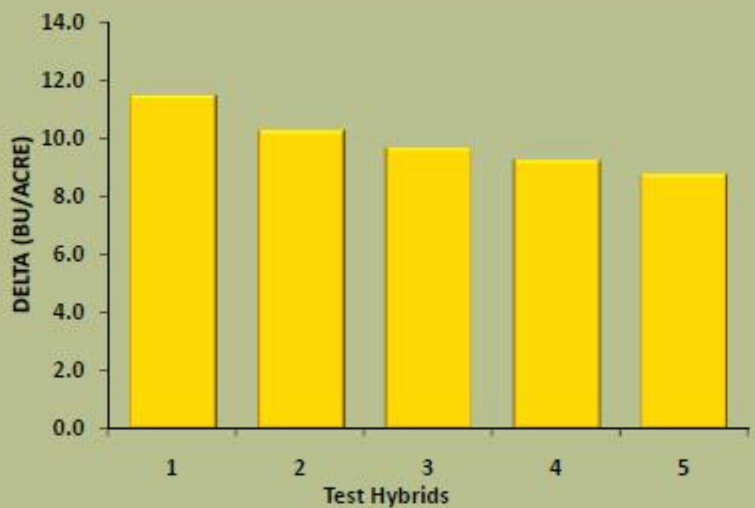


Maize: Drought : Advancement – e.g. Monsanto / BASF

Future: Transgenic Events / New GM Trait

First-Generation Drought Gene Performs in Elite Germplasm Combinations Despite Limited Drought Pressure

2009 FIELD TEST DATA



Data from sites identified as having drought stress
All differences significant at .05 level

2010 FIELD TESTING (Garden City, KS)

Control Hybrid | Hybrid with Gene

Discovery	Phase 1 Proof of Concept	Phase 2 Early Development	Phase 3 Adv. Development	**Phase 4 Pre-Launch**	Launch

IN COLLABORATION WITH BASF

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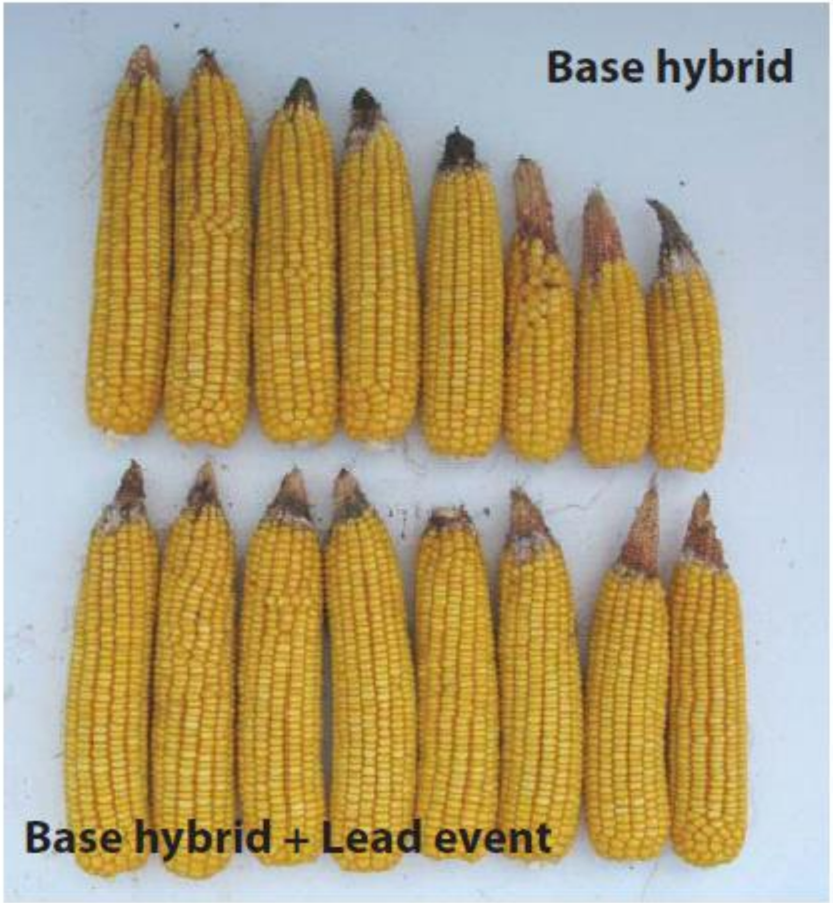
Maize: Drought : Advancement – e.g. Pioneer

Future: Transgenic Events / New GM Trait

New corn hybrid (right) tolerant to drought. (Pioneer photo)



Improvement in kernel number under drought stress.

PIONEER®
A DUPONT BUSINESS

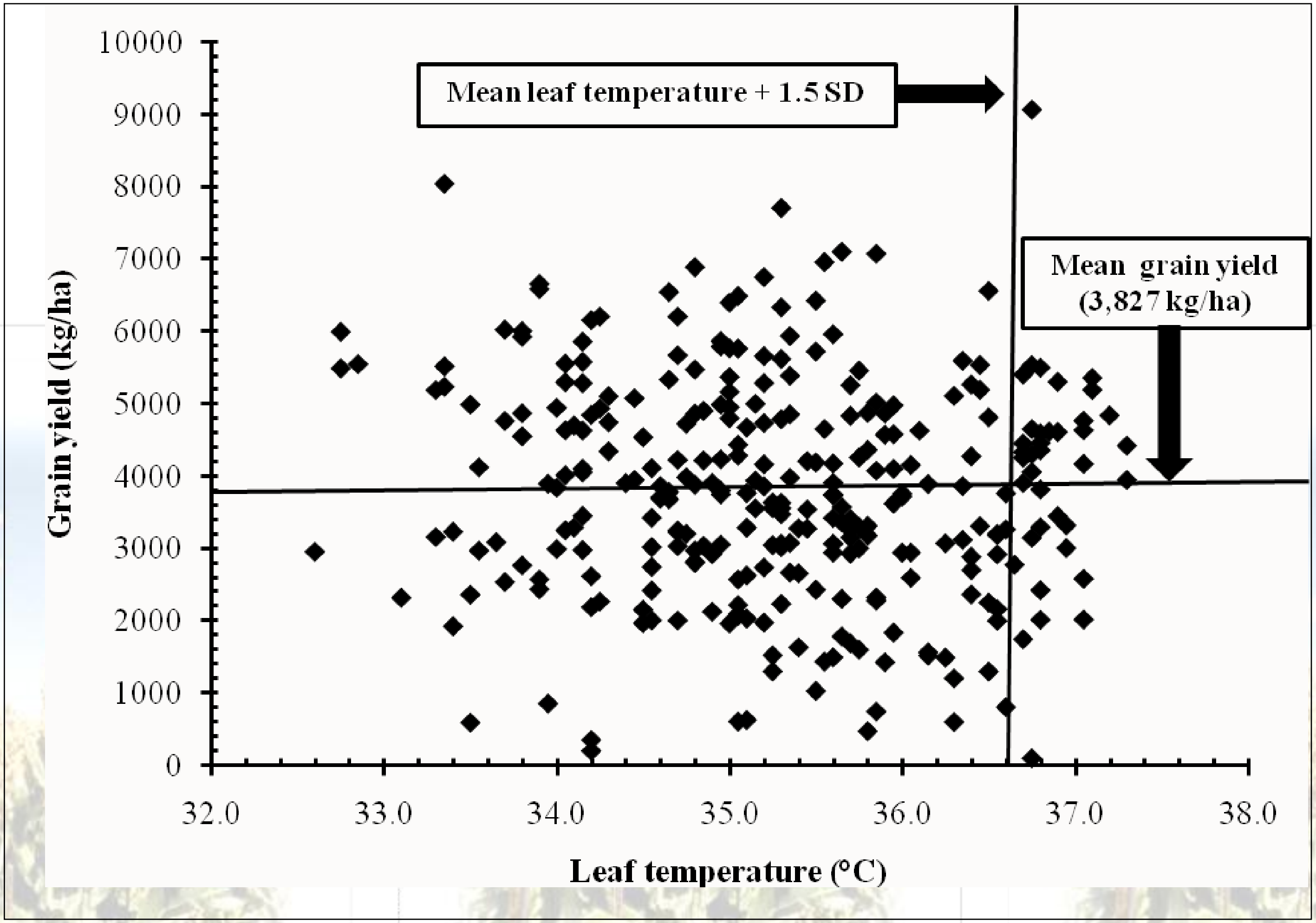
Sorghum: High Temperature Stress: Genotypic Differences

Influence of short episodes (10 d) of high temperature stress starting 10 d prior to flowering on seed-set

Genotype / Hybrid	Optimum Temperature (OT)	High Temperature (HT)	% Decrease from OT
	(32/22°C)	(38/28°C)	
DK-28-E	92	25	73[A]
DKS-29-28	82	34	55[B]
DK-54-00	52	53	42[C]
Pioneer 84G62	55	55	40[C]

Hybrids varied in response to high temperature for seed-set percentage.

Sorghum: Leaf Temperature vs. Yield



Air Temperature = 32 C

Mutava 2008. MS Thesis, KSU

Lines showing high leaf temperature and high yield under irrigated conditions in high vapor pressure deficit environment may inherently conserve water without yield penalty, thus could be drought / heat tolerant. (slow wilting trait)

Genetic Diversity – Germplasm Resources



There is large genetic diversity in dry bean, maize and sorghum that needs to be exploited for tolerance to drought and temerature.

Concluding Remarks (Take Home Messages)

- ✓High temperature and drought stress decrease yield of sorghum, bean and maize.
- ✓Reproductive processes of grain sorghum, maize and dry bean are sensitive to high temperature or drought stress.
- ✓Models predict increases in maximum and minimum temperatures and more dry spells for El Salvador. However, there are uncertainties in models and scenarios.
- ✓Crop simulation models predicts that in future climates sorghum and maize yields can decrease up to 20%; and dry bean yield up to 50%.
- ✓There are opportunities to combat yield losses by adjusting planting dates, selection of genotypes and improving genetics; and other management practices.

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KANSAS STATE UNIVERSITY

INTSORMIL

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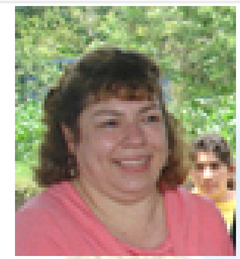
Thank You and Questions

Gracias!!
CENTA





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