CSK HIMACHAL PRADESH KRISHI VISHVAVIDYALAYA

CREDIT SEMINAR
ON

Drought Stress
Effects and Breeding Strategies

Speaker:
Nimit Kumar
A-2012-40-006

CONTENTS

- **Drought stress**
  - **What is stress…?**
  - **Effects**
  - **Drought mechanism**
- **Breeding strategies**
  - **Approaches**
  - **Methods of breeding**
- **Case studies**
- **Summary**

Stress

Stress is an external factor that exerts a disadvantageous influence on the plant and is measured in relation to plant survival, crop yield, growth (biomass accumulation), which are related to overall growth.

Stress

Biotic

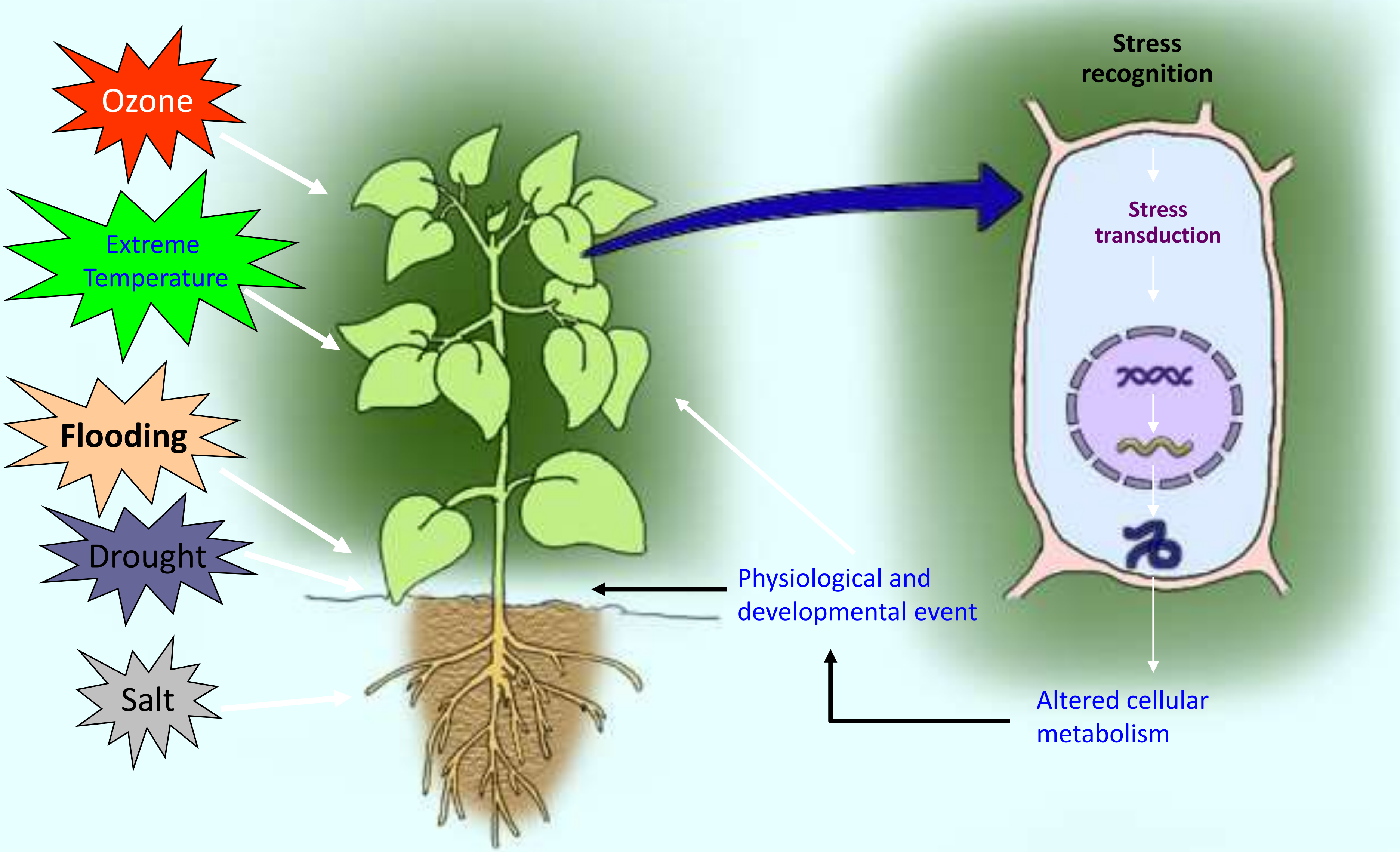
Disease, Insects & parasitic weeds

Abiotic

Drought,cold, Flooding, salinity & heat

Taiz and Zeiger 2006

Response of Plants to Various Stresses



Ozone

Extreme Temperature

Flooding

Drought

Salt

Stress recognition

Stress transduction

Altered cellular metabolism

Physiological and developmental event

The fraction of world arable land subjected to an abiotic stress

Abiotic stress	Fraction (%)of arable land
Drought	**26**
Mineral	**20**
Freezing	**15**
Salinity	**10**

Blum 1988

Drought

- **The inadequacy of water availability, including precipitation and soil moisture storage capacity, in quantity and distribution during life cycle of crop to restrict expression of its full genetic potential.**

(Sinha 1986)

- **"Drought stress accounts for more production losses than all other factors combined"**

(John Cushman, Biochemistry Professor at the University of Nevada, Reno)

Classification of drought

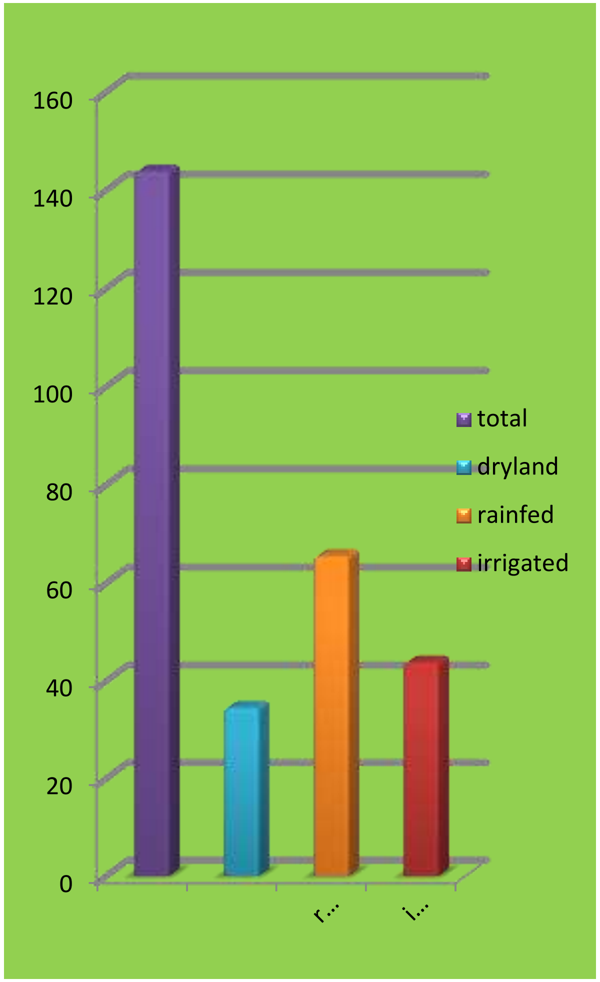
Types of stress	Water potential (MPa)	Reduction in RWC
Mild Stress	0.1	8-10%
Moderate Stress	(-1.2) – (-1.5)	>10<20%
Severe Stress	>(-1.5)	>20%

Hsiao 1973

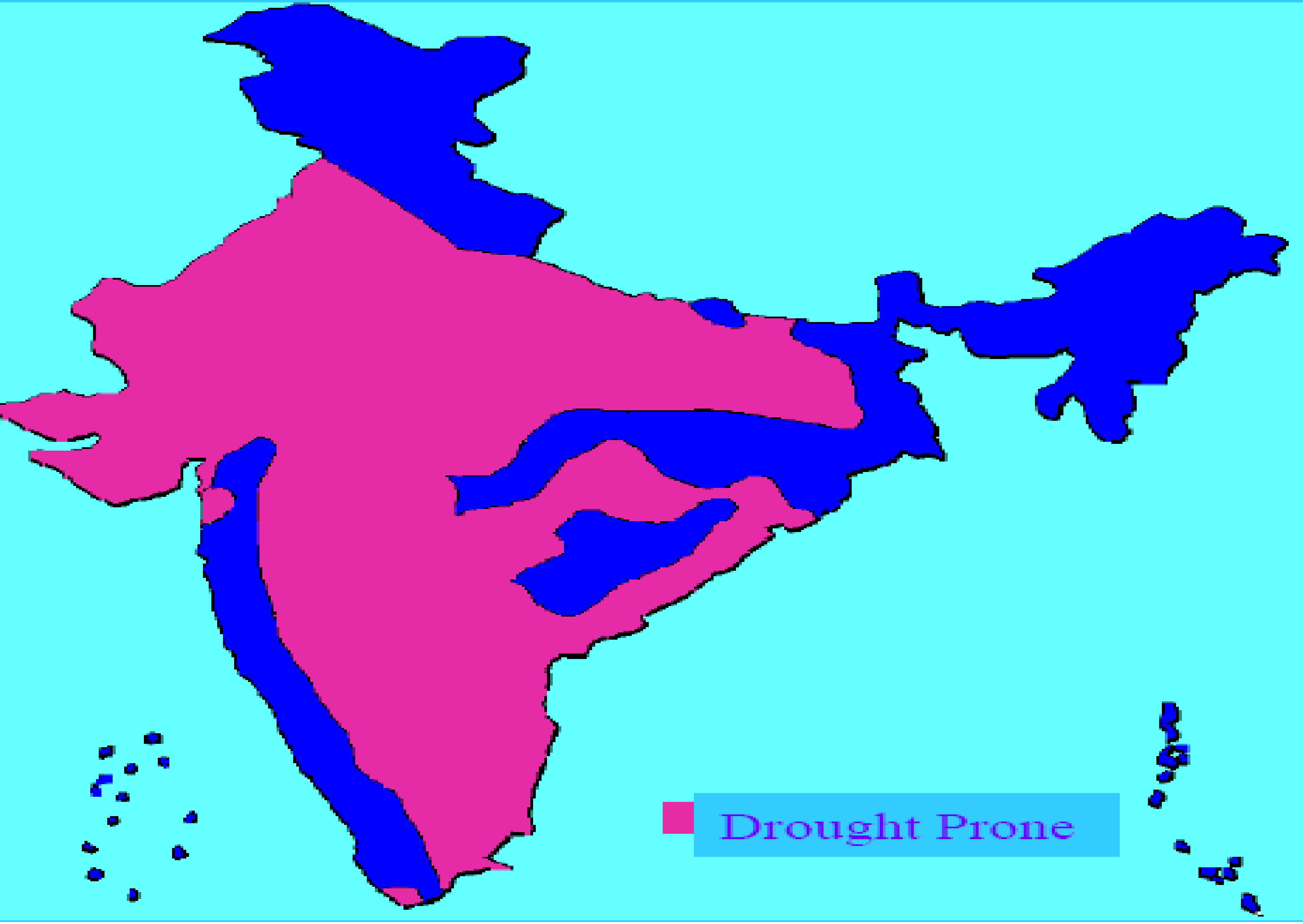
Scenario of Drought in India

Total arable area	**143.8 mha**
Irrigated area	**43.8 mha (30.5%)**
Rainfed area	**65.5 mha (45.5%)**
Dryland area	**34.5 mha (23.9%)**

In North-West Himalayan regions 81% is under rainfed



Anonymous 2012


🟥 Drought Prone

OCCURRENCE, POPULATION AFFECTED AND DAMAGE FROM DROUGHTS IN INDIA

1900-2002

Date	State, region or district	Population Affected (#)	Loss/ Deaths (Rs.)
July 2002	13 states	300 million	41000 million
May 2001	4 states	--	**20 deaths**
Nov. 2000	5 districts in Chattisgarh	--	--
April 2000	6 states	90 million	26500 million
March 1996	Rajasthan	-	-
March 1993	8 states	1.2 million	--
July 1987	Orissa	--	**110 deaths**
1987	6 States + 4 UT	300 million	**300 deaths**
April/1983	3 states	100 million	--
1973	Central India	100 million	2500 million
1972	Central India	100 million	2500 million
Aug. 1964	Mysore	166 million	--
1964	Rajasthan, Central India	0.5 million	--
1942	Kolkata, Bengal region	-	**15 lakh deaths**
1900	Bengal	-	**13 lakh deaths**

Samra, 2004

Drought disasters and their impacts

Years/impacts	Africa	Asia	South and Central America and Caribbean	North America	Europe	Australia
1970-1979						
Reported disasters	31	22	11	1	1	4
People affected	24,400,000	229,900,000	16,400,000	0	—	—
People died	119,000	81	0	0	0	0
Damages ($)	599,200	393,200	2,400,000	3,000,000,000	—	—
1980-1989						
Reported disasters	71	22	19	4	9	3
People affected	89,300,000	481,900,000	24,200,000	30,000	3,200,000	151,000
People died	552,000	2,200	0	0	0	0
Damages ($)	2,600,000	942,900	1,600,000	4,800,000	5,200,000	6,000,000,000

Cont……

Years/impacts	Africa	Asia	South and Central America and Caribbean	North America	Europe	Australia
1990-1999						
Reported disasters	56	31	29	3	15	9
People affected	87,400,000	196,500,000	16,700,000	0	9,200,000	7,900,000
People died	447	2,900	12	0	0	60
Damages ($)	2,200,000	19,100,000	2,600,000	2,100,000,000	11,700,000	4,800,000
2000-2007						
Reported disasters	64	41	28	4	11	2
People affected	108,900,000	585,300,000	3,400,000	0	1,100,000	0
People died	1,200	200	53	0	2	0
Damages ($)	900,000	9,100,000	2,400,000	4,400,000,000	2,800,000	2,000,000,000

Kallis 2008

MAJOR REASONs OF DROUGHT

- **Atmospheric factors**
  - High temperature
  - High wind velocities
  - Air pollution
- **Soil Factors**
  - Low temperature
  - Excessive soil salinity
  - Receding water content

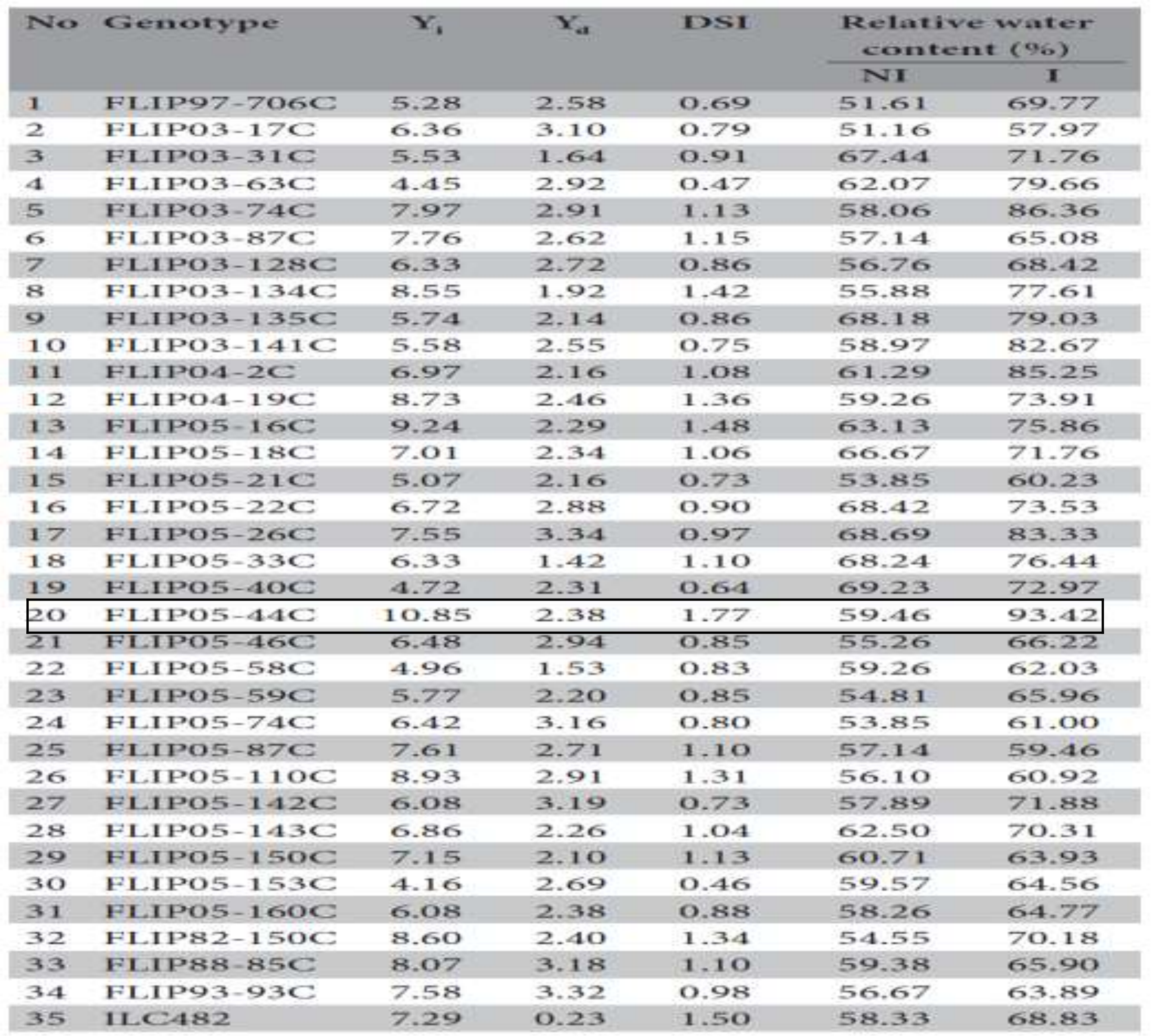
Different types of drought

1. **Meteorological drought**
2. **Agricultural drought**
3. **Hydrological drought**

- **Meteorological drought; due to prolonged period with less than average precipitation.**
- **Agricultural drought; which affect crop production or the ecology of the range.**
- **Hydrological drought; when the water reserves available in sources such as aquifers, lakes and reservoirs fall below the statistical average.**

EFFECTS OF DROUGHT STRESS

Effects of drought on RWC %



No	Genotype	Y_i	Y_d	DSI	Relative water content (%)	
					NI	I
1	FLIP97-706C	5.28	2.58	0.69	51.61	69.77
2	FLIP03-17C	6.36	3.10	0.79	51.16	57.97
3	FLIP03-31C	5.53	1.64	0.91	67.44	71.76
4	FLIP03-63C	4.45	2.92	0.47	62.07	79.66
5	FLIP03-74C	7.97	2.91	1.13	58.06	86.36
6	FLIP03-87C	7.76	2.62	1.15	57.14	65.08
7	FLIP03-128C	6.33	2.72	0.86	56.76	68.42
8	FLIP03-134C	8.55	1.92	1.42	55.88	77.61
9	FLIP03-135C	5.74	2.14	0.86	68.18	79.03
10	FLIP03-141C	5.58	2.55	0.75	58.97	82.67
11	FLIP04-2C	6.97	2.16	1.08	61.29	85.25
12	FLIP04-19C	8.73	2.46	1.36	59.26	73.91
13	FLIP05-16C	9.24	2.29	1.48	63.13	75.86
14	FLIP05-18C	7.01	2.34	1.06	66.67	71.76
15	FLIP05-21C	5.07	2.16	0.73	53.85	60.23
16	FLIP05-22C	6.72	2.88	0.90	68.42	73.53
17	FLIP05-26C	7.55	3.34	0.97	68.69	83.33
18	FLIP05-33C	6.33	1.42	1.10	68.24	76.44
19	FLIP05-40C	4.72	2.31	0.64	69.23	72.97
20	FLIP05-44C	10.85	2.38	1.77	59.46	93.42
21	FLIP05-46C	6.48	2.94	0.85	55.26	66.22
22	FLIP05-58C	4.96	1.53	0.83	59.26	62.03
23	FLIP05-59C	5.77	2.20	0.85	54.81	65.96
24	FLIP05-74C	6.42	3.16	0.80	53.85	61.00
25	FLIP05-87C	7.61	2.71	1.10	57.14	59.46
26	FLIP05-110C	8.93	2.91	1.31	56.10	60.92
27	FLIP05-142C	6.08	3.19	0.73	57.89	71.88
28	FLIP05-143C	6.86	2.26	1.04	62.50	70.31
29	FLIP05-150C	7.15	2.10	1.13	60.71	63.93
30	FLIP05-153C	4.16	2.69	0.46	59.57	64.56
31	FLIP05-160C	6.08	2.38	0.88	58.26	64.77
32	FLIP82-150C	8.60	2.40	1.34	54.55	70.18
33	FLIP88-85C	8.07	3.18	1.10	59.38	65.90
34	FLIP93-93C	7.58	3.32	0.98	56.67	63.89
35	ILC482	7.29	0.23	1.50	58.33	68.83

Talebi et al.2013

•Effect on Growth:

- Reduction in Turgor Pressure,
- Reduction in Cell size

→

Reduce growth

Farooq M et al. 2009

Growth characters of plants affected by water stress

	Plant height(cm)		No. of leaves/plant		No. of tillers/plant		Shoots dry weight/plant (g)		Roots dry weight/plant (g)		Leaf area/plant (cm2)		Flag Leaf area (cm2)	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
W0	70.2	62.10	16.53	13.60	3.13	2.93	3.17	3.14	0.70	0.56	206.12	182.20	36.59	24.30
W1	55.67	53.67	13.33	10.80	2.73	2.67	2.62	2.52	0.63	0.52	170.54	161.43	28.91	21.05
W2	48.20	45.03	10.93	9.27	1.53	1.67	1.83	1.71	0.50	0.40	141.74	120.98	23.94	17.18

W0, W1 and W2: Irrigation after depletion of 50%, 65% and 80% of available soil water, respectively

salwa et al. 2014

Economic yield reduction by drought stress in some representative field crops

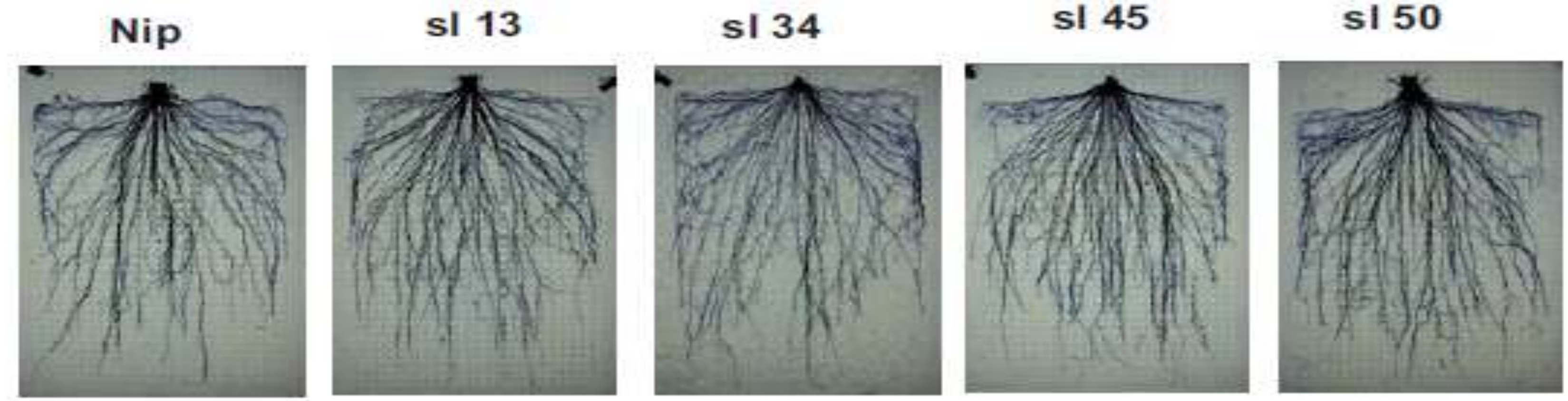
Crop	Growth stage	Yield reduction	References
Barley	Seed filling	49–57%	Samarah (2005)
Maize	Grain filling	79–81%	Monneveux et al. (2005)
Maize	Reproductive	63–87%	Kamara et al. (2003)
Maize	Reproductive	70–47%	Chapman and Edmeades (1999)
Maize	Vegetative	25–60%	Atteya et al. (2003)
Maize	Reproductive	32–92%	Atteya et al. (2003)
Soybean	Reproductive	46–71%	Samarah et al. (2006)
Cowpea	Reproductive	60–11%	Ogbonnaya et al. (2003)
Sunflower	Reproductive	60%	Mazahery-Laghab et al. (2003)
Canola	Reproductive	30%	Sinaki et al. (2007)
Potato	Flowering	13%	Kawakami et al. (2006)

Cont…

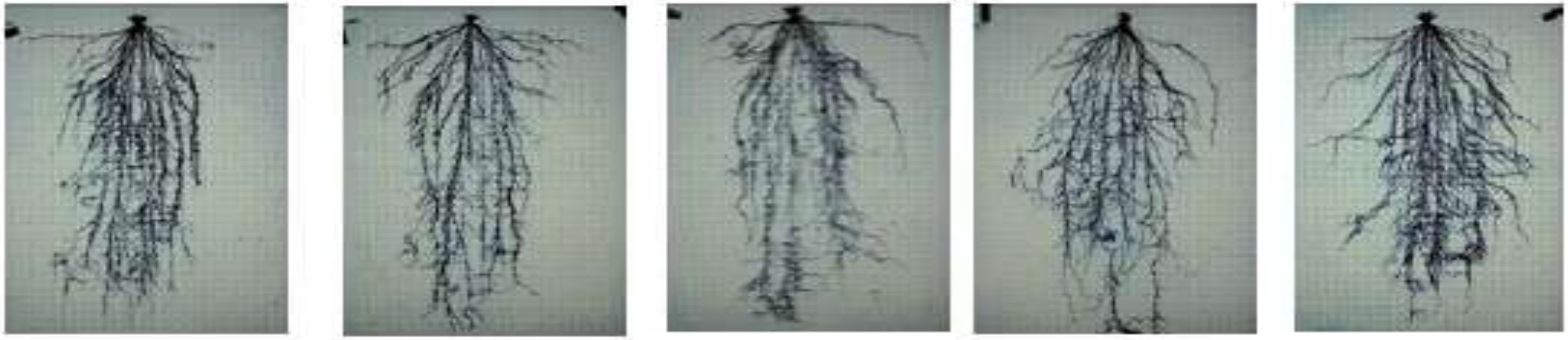
Crop	Growth stage	Yield reduction	References
Rice	Reproductive (mild stress)	53–92%	Lafitte et al. (2007)
Rice	Reproductive (severe stress)	48–94%	Lafitte et al. (2007)
Rice	Grain filling (mild stress)	30–55%	Basnayake et al. (2006)
Rice	Grain filling (severe stress)	60%	Basnayake et al. (2006)
Rice	Reproductive	24–84%	Venuprasad et al. (2007)
Chickpea	Reproductive	45–69%	Nayyar et al. (2006)
Pigeonpea	Reproductive	40–55%	Nam et al. (2001)
Common beans	Reproductive	58–87%	Martinez et al. (2007)

Farooq et al. 2009

Effects on root growth:



Well-watered

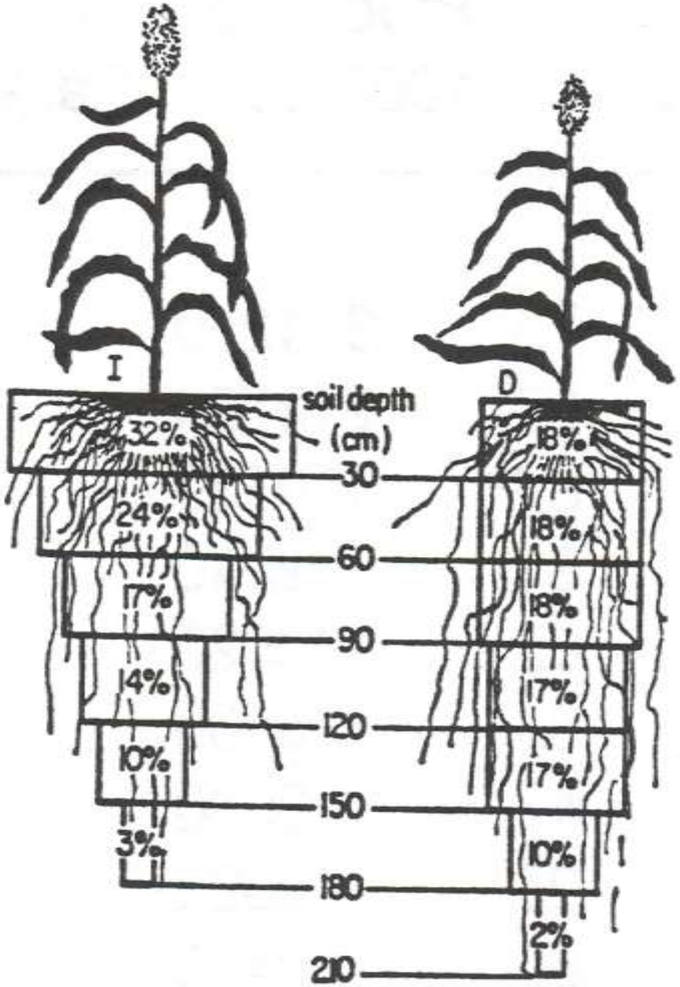


Drought stress

ROOT SYSTEM GROWTH

Irrigated

Rainfed

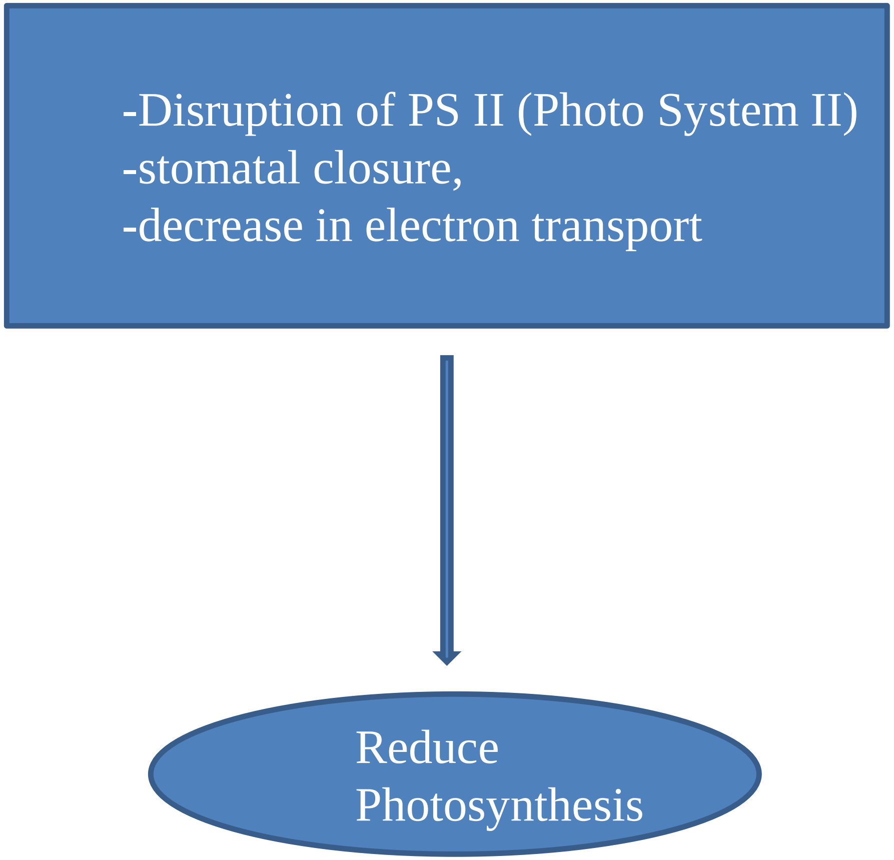


>50% water from 60cm

> 50% water from 90cm

Farooq et al. 2009

- **Effect on Photosynthesis:**



-Disruption of PS II (Photo System II)
-stomatal closure,
-decrease in electron transport

Reduce Photosynthesis

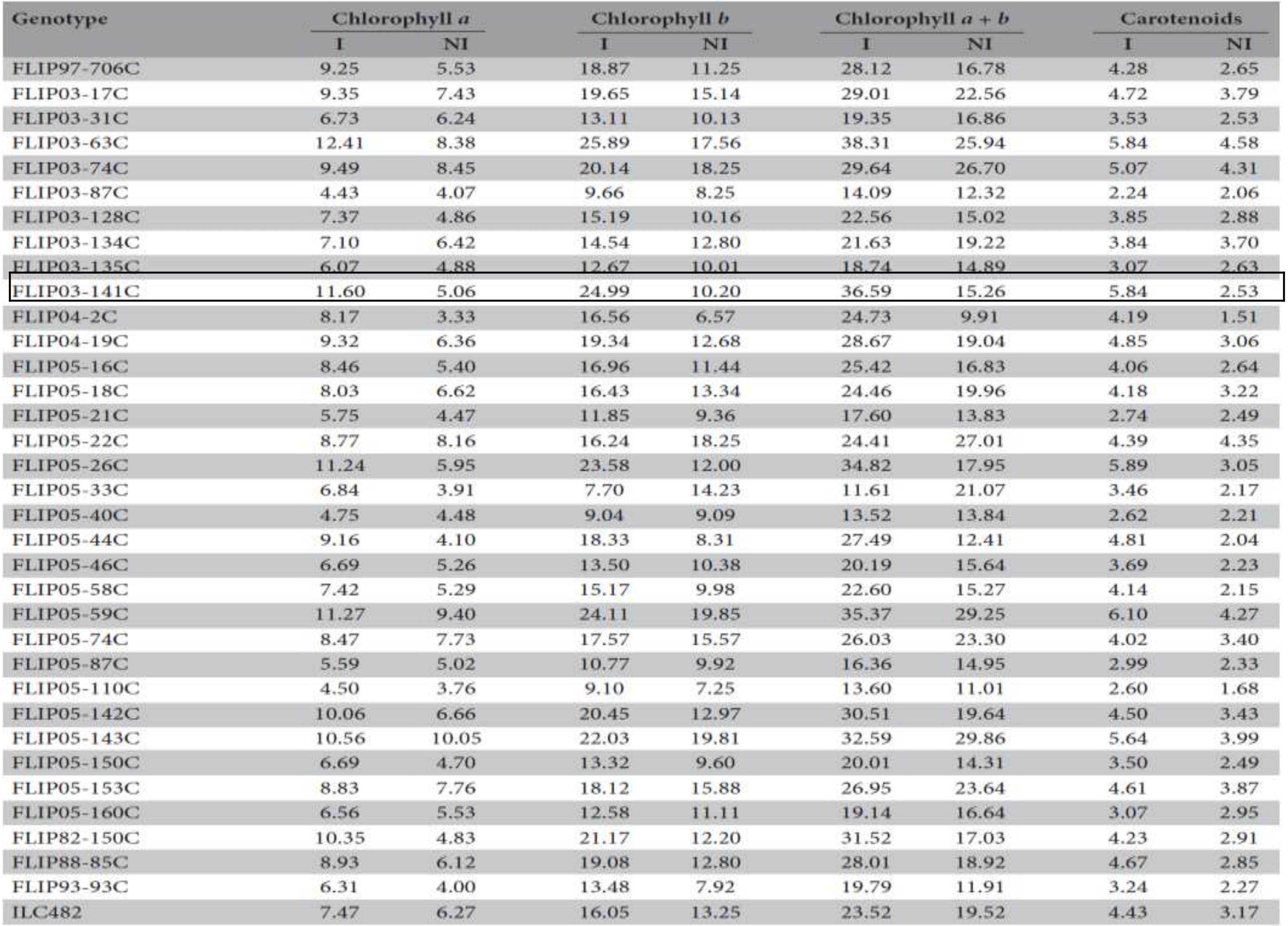
EFFECT OF DROUGHT ON PHOTOSYNTHETIC RATE (P_n) AND STOMATAL CONDUCTANCE (g_s)

Genotype	Treatment	14 DPA		21 DPA	
		P_n	g_s	P_n	g_s
WT	WW	19.46	0.214	17.35	0.185
	MD	15.31	0.139	12.87	0.099
	SD	11.32	0.092	7.56	0.055
PPDK	WW	26.33	0.210	24.36	0.189
	MD	24.98	0.177	21.18	0.148
	SD	19.48	0.123	15.67	0.076
PCK	WW	28.06	0.215	25.32	0.183
	MD	25.54	0.187	21.83	0.144
	SD	20.45	0.138	16.49	0.088

WW, MD and SD represent well watered, moderate drought and severe drought, respectively.

Gu et al.2013

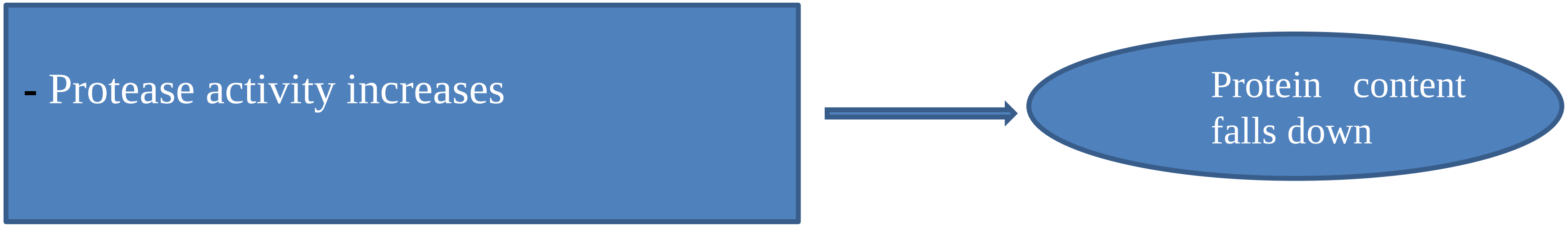
EFFECT OF DROUGHT ON CHLOROPHYLL CONTENT



Genotype	Chlorophyll *a*		Chlorophyll *b*		Chlorophyll *a* + *b*		Carotenoids	
	I	NI	I	NI	I	NI	I	NI
FLIP97-706C	9.25	5.53	18.87	11.25	28.12	16.78	4.28	2.65
FLIP03-17C	9.35	7.43	19.65	15.14	29.01	22.56	4.72	3.79
FLIP03-31C	6.73	6.24	13.11	10.13	19.35	16.86	3.53	2.53
FLIP03-63C	12.41	8.38	25.89	17.56	38.31	25.94	5.84	4.58
FLIP03-74C	9.49	8.45	20.14	18.25	29.64	26.70	5.07	4.31
FLIP03-87C	4.43	4.07	9.66	8.25	14.09	12.32	2.24	2.06
FLIP03-128C	7.37	4.86	15.19	10.16	22.56	15.02	3.85	2.88
FLIP03-134C	7.10	6.42	14.54	12.80	21.63	19.22	3.84	3.70
FLIP03-135C	6.07	4.88	12.67	10.01	18.74	14.89	3.07	2.63
FLIP03-141C	11.60	5.06	24.99	10.20	36.59	15.26	5.84	2.53
FLIP04-2C	8.17	3.33	16.56	6.57	24.73	9.91	4.19	1.51
FLIP04-19C	9.32	6.36	19.34	12.68	28.67	19.04	4.85	3.06
FLIP05-16C	8.46	5.40	16.96	11.44	25.42	16.83	4.06	2.64
FLIP05-18C	8.03	6.62	16.43	13.34	24.46	19.96	4.18	3.22
FLIP05-21C	5.75	4.47	11.85	9.36	17.60	13.83	2.74	2.49
FLIP05-22C	8.77	8.16	16.24	18.25	24.41	27.01	4.39	4.35
FLIP05-26C	11.24	5.95	23.58	12.00	34.82	17.95	5.89	3.05
FLIP05-33C	6.84	3.91	7.70	14.23	11.61	21.07	3.46	2.17
FLIP05-40C	4.75	4.48	9.04	9.09	13.52	13.84	2.62	2.21
FLIP05-44C	9.16	4.10	18.33	8.31	27.49	12.41	4.81	2.04
FLIP05-46C	6.69	5.26	13.50	10.38	20.19	15.64	3.69	2.23
FLIP05-58C	7.42	5.29	15.17	9.98	22.60	15.27	4.14	2.15
FLIP05-59C	11.27	9.40	24.11	19.85	35.37	29.25	6.10	4.27
FLIP05-74C	8.47	7.73	17.57	15.57	26.03	23.30	4.02	3.40
FLIP05-87C	5.59	5.02	10.77	9.92	16.36	14.95	2.99	2.33
FLIP05-110C	4.50	3.76	9.10	7.25	13.60	11.01	2.60	1.68
FLIP05-142C	10.06	6.66	20.45	12.97	30.51	19.64	4.50	3.43
FLIP05-143C	10.56	10.05	22.03	19.81	32.59	29.86	5.64	3.99
FLIP05-150C	6.69	4.70	13.32	9.60	20.01	14.31	3.50	2.49
FLIP05-153C	8.83	7.76	18.12	15.88	26.95	23.64	4.61	3.87
FLIP05-160C	6.56	5.53	12.58	11.11	19.14	16.64	3.07	2.95
FLIP82-150C	10.35	4.83	21.17	12.20	31.52	17.03	4.23	2.91
FLIP88-85C	8.93	6.12	19.08	12.80	28.01	18.92	4.67	2.85
FLIP93-93C	6.31	4.00	13.48	7.92	19.79	11.91	3.24	2.27
ILC482	7.47	6.27	16.05	13.25	23.52	19.52	4.43	3.17

Talebi et al. 2013

- **Effect on proteins:**



- Protease activity increases

Protein content falls down

Effect of drought stress on endopeptidase activity

	Irrigated			Drought Stress		
pH	A	A+15	A+20	A	A+15	A+20
4.8	14.04 ±0.07	39.03 + 0.23	29.59 ±0.14	22.17 ± 0.14	132.74 ± 0.09	608.52 ± 2.62
7.0	12.34 ±0.02	39.26 ±0.18	46.81 ±0.25	24.55 ± 0.03	47.33 ± 0.09	388.2 ± 5.25
8.5	17.26 ±0.06	60.7 ± 0.45	39.73 ± 0.28	22.31 ± 0.08	68.61 ± 0.09	710.82 ± 1.75

A= anthesis, A+15= 15 days after anthesis & A+20= 20 days after anthesis

Effect of drought stress on exopeptidase activity

	Irrigated			Drought Stress		
pH	A	A+15	A+20	A	A+15	A+20
4.8	1.51 ±0.01	2.67 ± 0.02	3.58 ± 0.02	1.6 ± 0.03	5.69 ± 0.04	32.48 ± 0.22
7.0	1.27 ±0.01	4.06 ±0.03	3.85 ± 0.01	2.14 ± 0.03	5.83 ± 0.04	43.50 ± 0.87
8.5	1.21 ±0.02	3.31 ±0.02	3.30 ± 0.07	1.76 ± 0.01	6.46 ± 0.05	46.73 ± 0.22

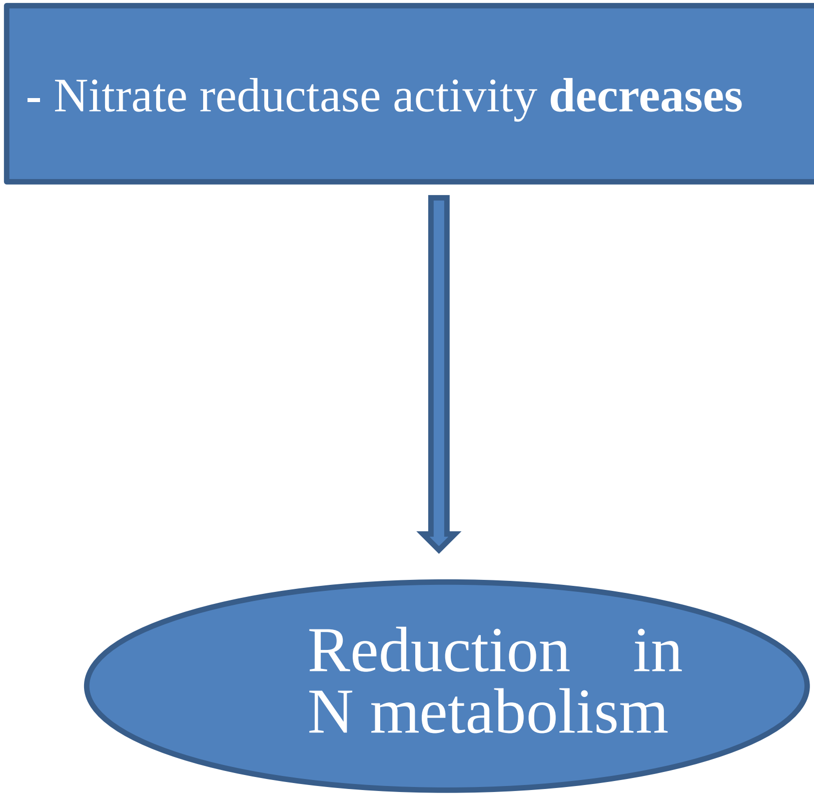
Effect of drought stress on total soluble protein

	Irrigated	Drought Stress
A	81.37 ± 0.43	60.92 ± 0.07
A+15	55.49 ± 0.14	53.60 ± 0.03
A+20	41.05 ± 0.17	6.06 ± 0.21

Srivalli et al. 1998

A= anthesis, A+15= 15 days after anthesis & A+20= 20 days after anthesis

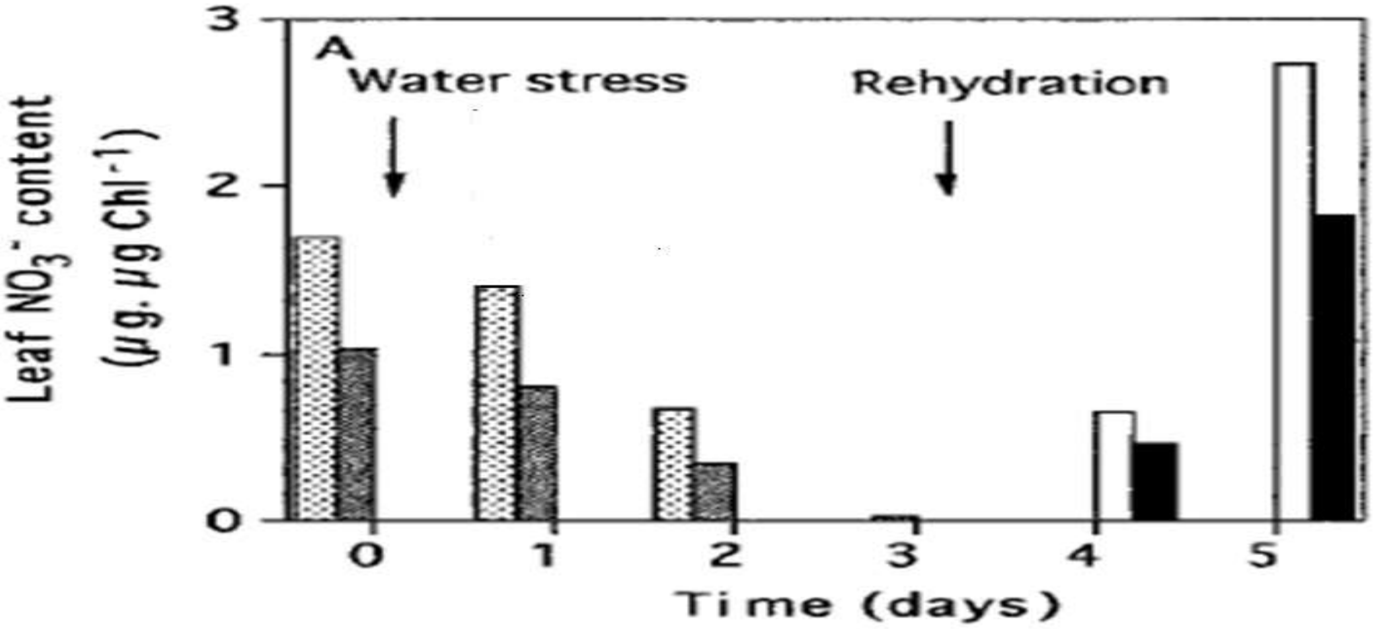
Effect on Nitrogen Metabolism:



- Nitrate reductase activity **decreases**

Reduction in N metabolism

The effect of water deprivation on the foliar NO_3^- content



Mery et al. 1998

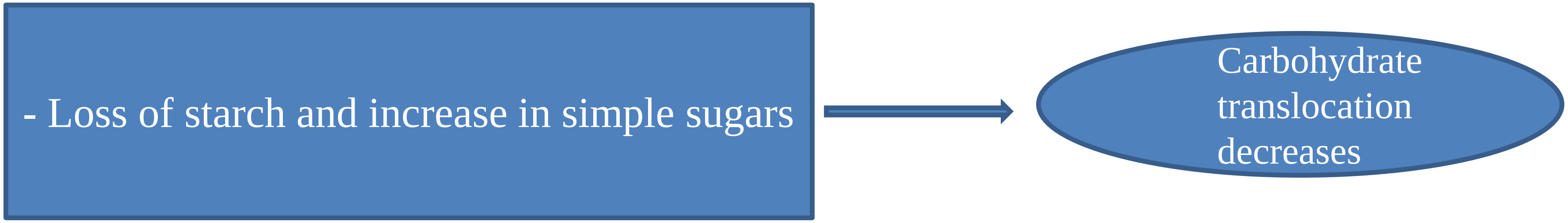
Effects of drought on N,P and K

	N%		N uptake (mg/plant)		P%		P uptake (mg/plant)		K%		K uptake (mg/plant)	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
W0	3.43	3.19	110.74	101.65	0.40	0.37	12.78	11.84	2.64	2.65	84.82	83.67
W1	3.38	3.14	89.16	80.07	0.36	0.31	9.64	7.92	2.61	2.36	69.71	60.40
W2	2.68	2.43	49.59	42.02	0.30	0.24	5.55	4.22	2.24	2.13	41.39	36.71

W0, W1 and W2: Irrigation after depletion of 50%, 65% and 80% of available soil water, respectively

salwa et al. 2014

- **Effect on Carbohydrate metabolism:**



- Loss of starch and increase in simple sugars

Carbohydrate translocation decreases

Effects of drought on carbohydrate

	Carbohydrate (%)	
	S1	**S2**
W0	**66.52**	**67.8**
W1	**66.48**	**67.73**
W2	**56.21**	**55.37**

salwa et al. 2014

W0, W1 and W2: Irrigation after depletion of 50%, 65% and 80% of available soil water, respectively

Physio-chemical parameters of plants affected by water stress

	Chl. a+b (mg/g D.W.)		Carotenoids (mg/g D.W.)		Total soluble sugars (mg/g D.W.)		Total carbohydrates (mg/g D.W.)		Total free amino acids (mg/g D.W.)	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
W0	4.99	5.41	1.50	1.69	29.03	29.10	251.48	244.83	15.21	14.97
W1	4.68	5.06	1.27	1.43	26.06	25.93	220.56	201.57	12.41	11.53
W2	3.76	3.75	1.16	1.25	17.74	16.45	185.88	160.18	10.54	9.67

salwa et al. 2014

W0, W1 and W2: Irrigation after depletion of 50%, 65% and 80% of available soil water, respectively

How plants cope with drought stress

Different survival mechanisms of plants at dry sites:

1) Drought escape

2) Dehydration avoidance

3) Dehydration tolerance

Levitt 1980

Drought escape

Ability of plant to complete its life cycle before on set of severe water deficit

Rapid development of plant

- Early maturing varieties – Terminal drought stress
- Late maturing varieties – Early season drought stress

Early or Late maturation of a crop variety has an adverse effect on its economic yield

Drought (dehydration) avoidance

Maintain realtively high water potential as long as possible under water stress.

Two groups of drought avoiders:

i) **Water savers**
  - -Reduce water loss
  - -Leaf characteristics
  - -Stomatal senstivity

ii) **Water spenders**
  - -Increase water uptake
  - -Root characteristics

Anatomical and morphological traits help the plant to avoid drought.

Drought (dehydration) tolerance

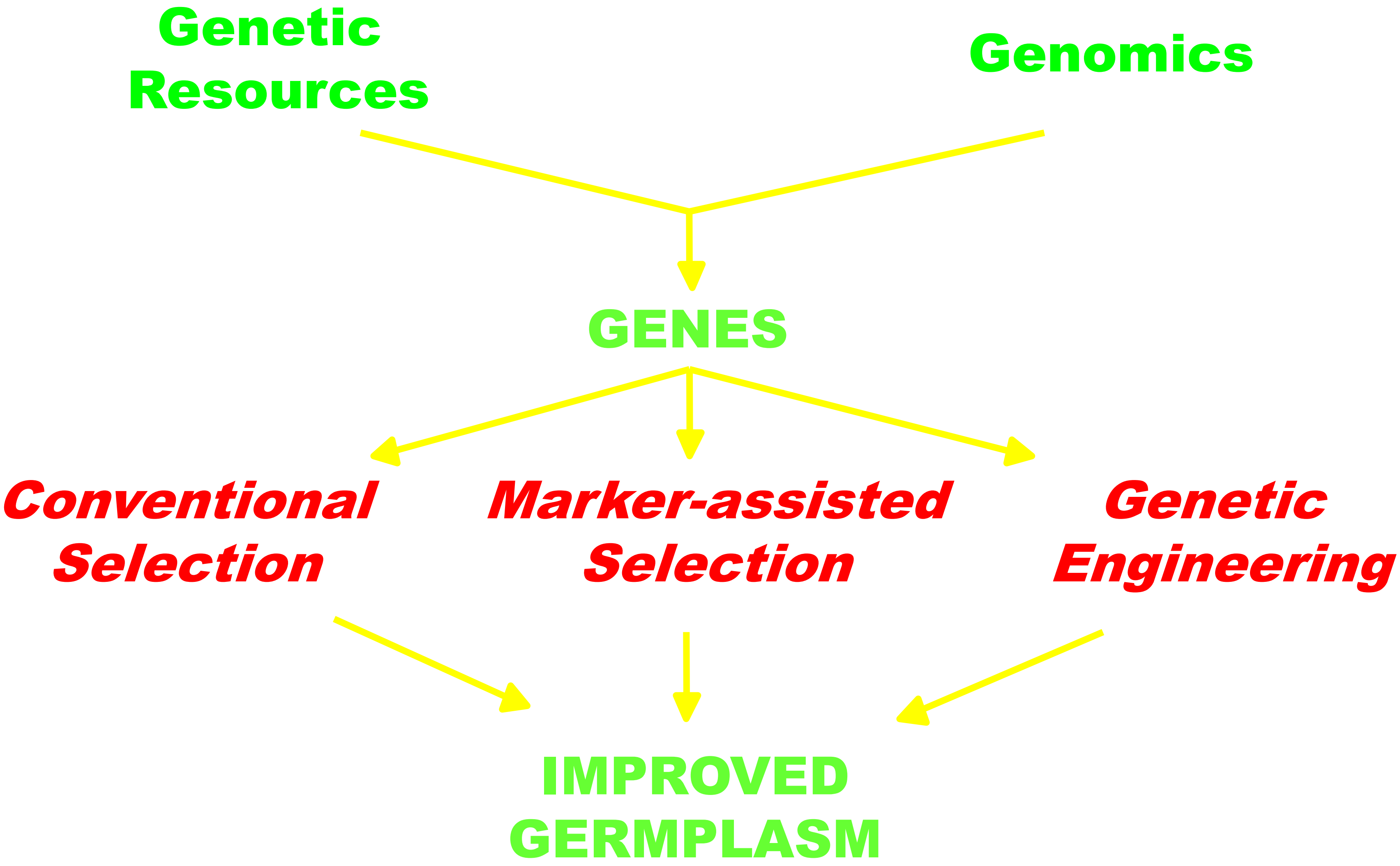
- Ability to tolerate the water stress by the biochemical and physiological changes
- Capacity of protoplasm to tolerate severe water loss
- Physiological processes proceed even at high dehydration levels
- Tolerance mechanisms take over when tissues are no longer protected by avoidance mechanisms
- Drought tolerance usually found in xerophytes
- Tolerance aims at plant survival rather than plant growth

Scoring of drought tolerance at vegetative and reproductive stage in rice

Scale	Drought tolerance at veg. stage	Spikelet fertility (%) at Reproductive Stage	Plant Recovered
0	No symptom	-	-
1	Slight tip drying	>80	90-100
3	Tip drying extended upto ¼ length in most leaves	61-80	70-89
5	¼ to ½ of all leaves dried	41-60	40-69
7	More than 2/3 of all leaves dried	11-40	20-39
9	All plants apparently dead	<11	0-19

Datta 1988

Crop Improvement through various approach



Genetic Resources

Genomics

GENES

Conventional Selection

Marker-assisted Selection

Genetic Engineering

IMPROVED GERMPLASM

Fundamentals of Breeding

Two Principles of plant breeding

Genetic variation

Selection

Genetic sources

- Cultivated varieties
  - Adapted variety
  - No compromise on yield
- Landraces
  - problem of undesirable linkages
  - Subjected to artificial and natural selection
- Wild relatives
  - Aim is to survive not the yield
  - Transfer of trait is major problem
- Transgenes
  - Cloning of target gene
  - Transfer requires technical expertise

Aegilops Squarrosa

Imperata cylindrica

Breeding approach

FOUR APPROACHES

Breeding for high yield under optimum condition

- No intentional selection for drought tolerance
- Breeding for other characters indirectly effect drought
- Screening for drought is done
- Lines perform well in optimal condition show decline in yield under drought

Breeding for High yield under Stress condition

- Choice of Parents
- Selection under the stress environment
- Drought varies from year and location

Breeding for High yield under both stress and non-stress environment

- Simultaneous selection
- Use of conventional method

Multi disciplinary approach

- Integrate drought tolerant mechanisms
- Use of genomic tools

Breeding methods for drought tolerance

1. **Conventional methods**

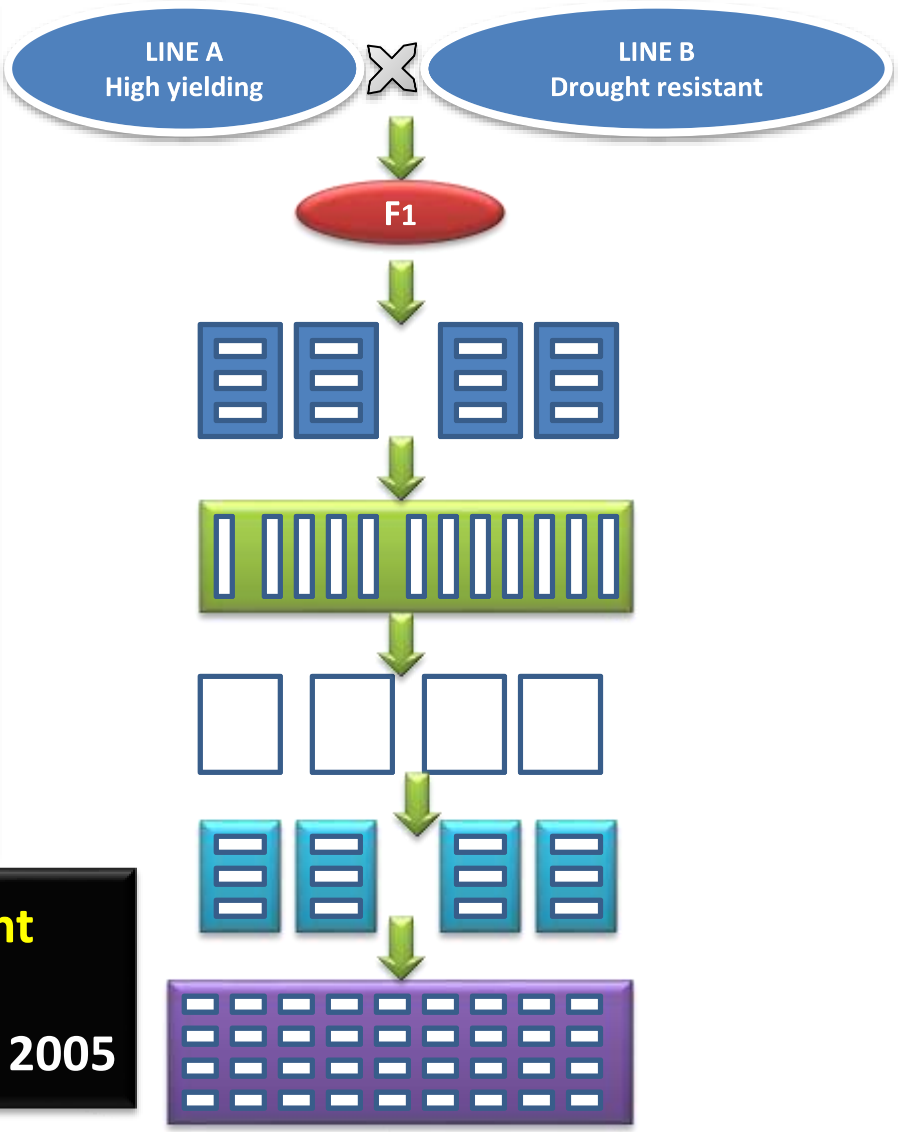
2. **Nonconventional methods**

CONVENTIONAL METHODS

- **INTRODUCTION**
  - **Primary**
  - **Secondary**
- **SELECTION**
  - **Desirable**
  - **Adaptation**
- **HYBRIDIZATION**

Conventional breeding focus on **drought avoidance** than **drought tolerance**

Blum 2005



NON-CONVENTIONAL METHODS

- ☐ **BIOTECHNOLOGY**
  - ✓ **GENETIC ENGINEERING**
    - ***Agrobacterium*** **mediated gene transfer**
    - **Particle Bombardment (Gene Gun)**
    - **Electroporation of protoplast**
  - ✓ **MAS**
  - ✓ **QTL**
  - ✓ **Molecular Cytogenetics**

SEARCHED FOR ASSOCIATIONS WITH TRAITS OF INTEREST

- **Drought tolerance is quantitative trait**

To map QTL for a particular trait, highly inbred homozygous parents are chosen.

↓

These are crossed to produce heterozygous F1 seed

↓

An F1 plant is grown from a single seed, self-fertilised, and the resultant F2 seed

↓

A tissue sample is taken from each F2 plant for analysis using DNA markers and the individual segregating plants are self-fertilised and bulked to produce progenies

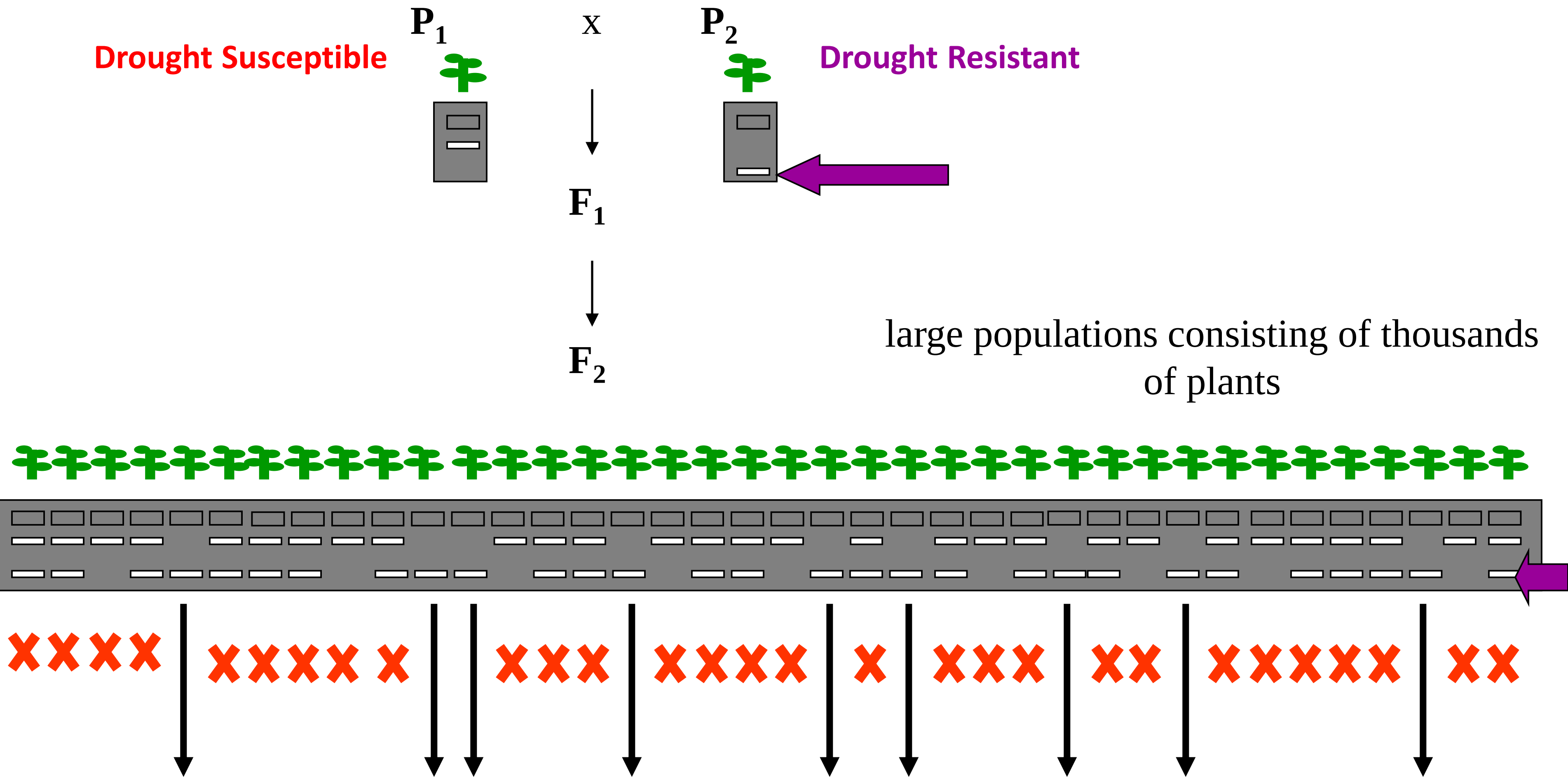
↓

For each individual cross, a skeleton genetic map is developed with loci that are polymorphic between the two parents of the cross

↓

The bulk progenies are screened for drought tolerance in a wide range of environments

MARKER-ASSISTED BREEDING



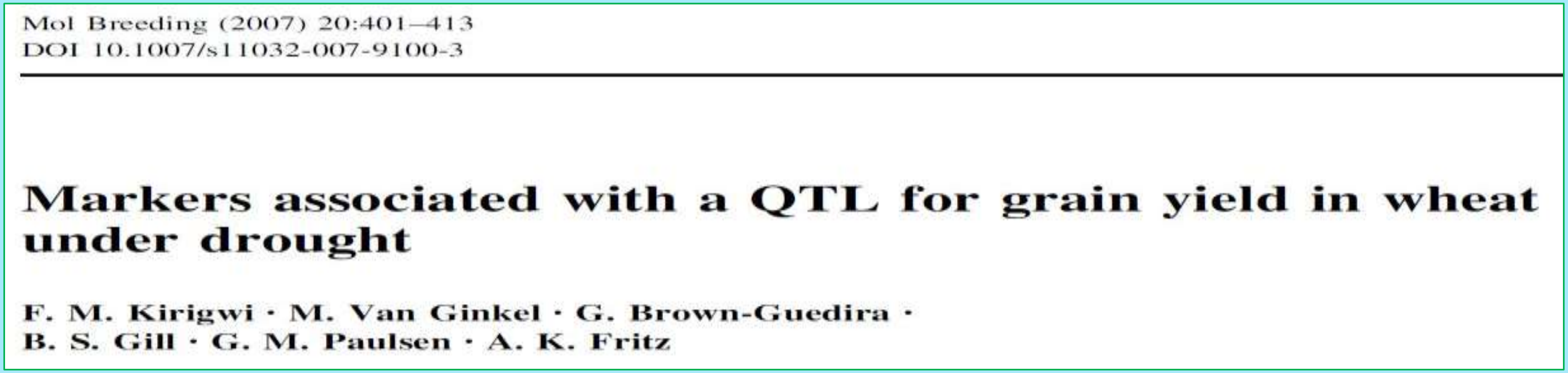
Drought Susceptible P_1 x P_2 Drought Resistant

F_1

F_2

large populations consisting of thousands of plants

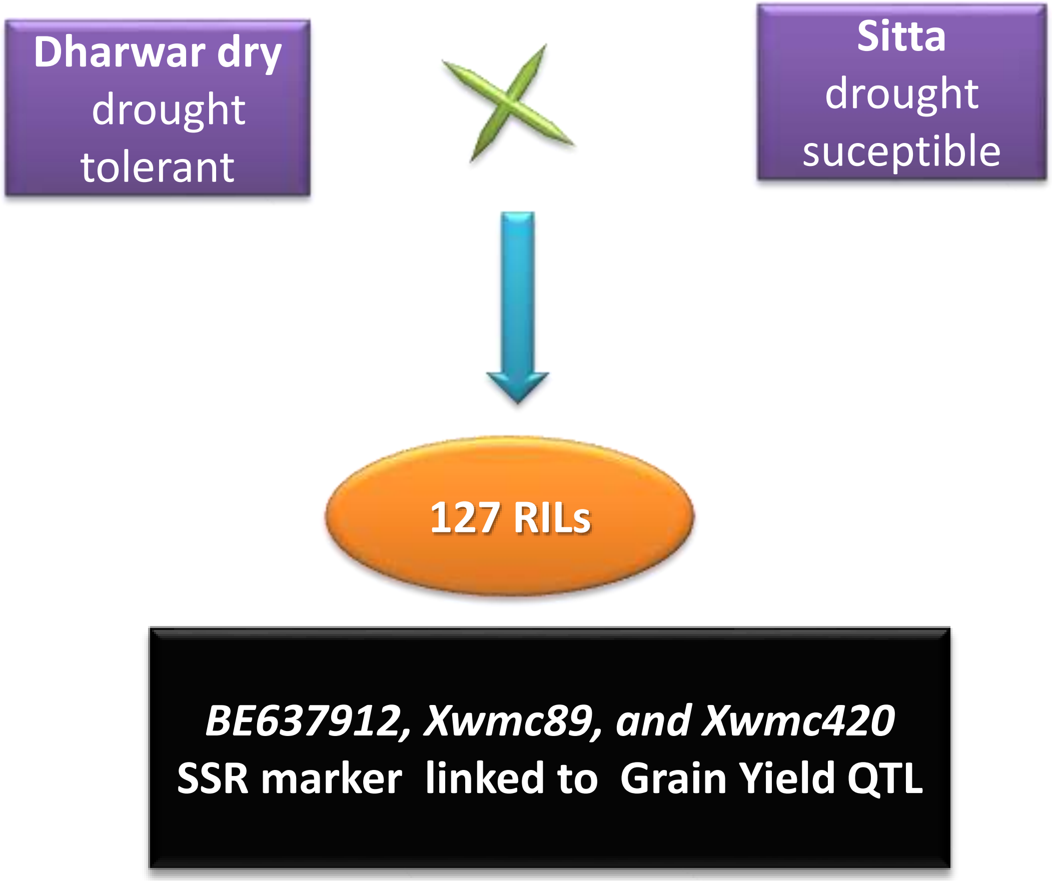
MARKER-ASSISTED SELECTION (MAS)



Mol Breeding (2007) 20:401–413
DOI 10.1007/s11032-007-9100-3

Markers associated with a QTL for grain yield in wheat under drought

F. M. Kirigwi · M. Van Ginkel · G. Brown-Guedira ·
B. S. Gill · G. M. Paulsen · A. K. Fritz



Dharwar dry
drought
tolerant

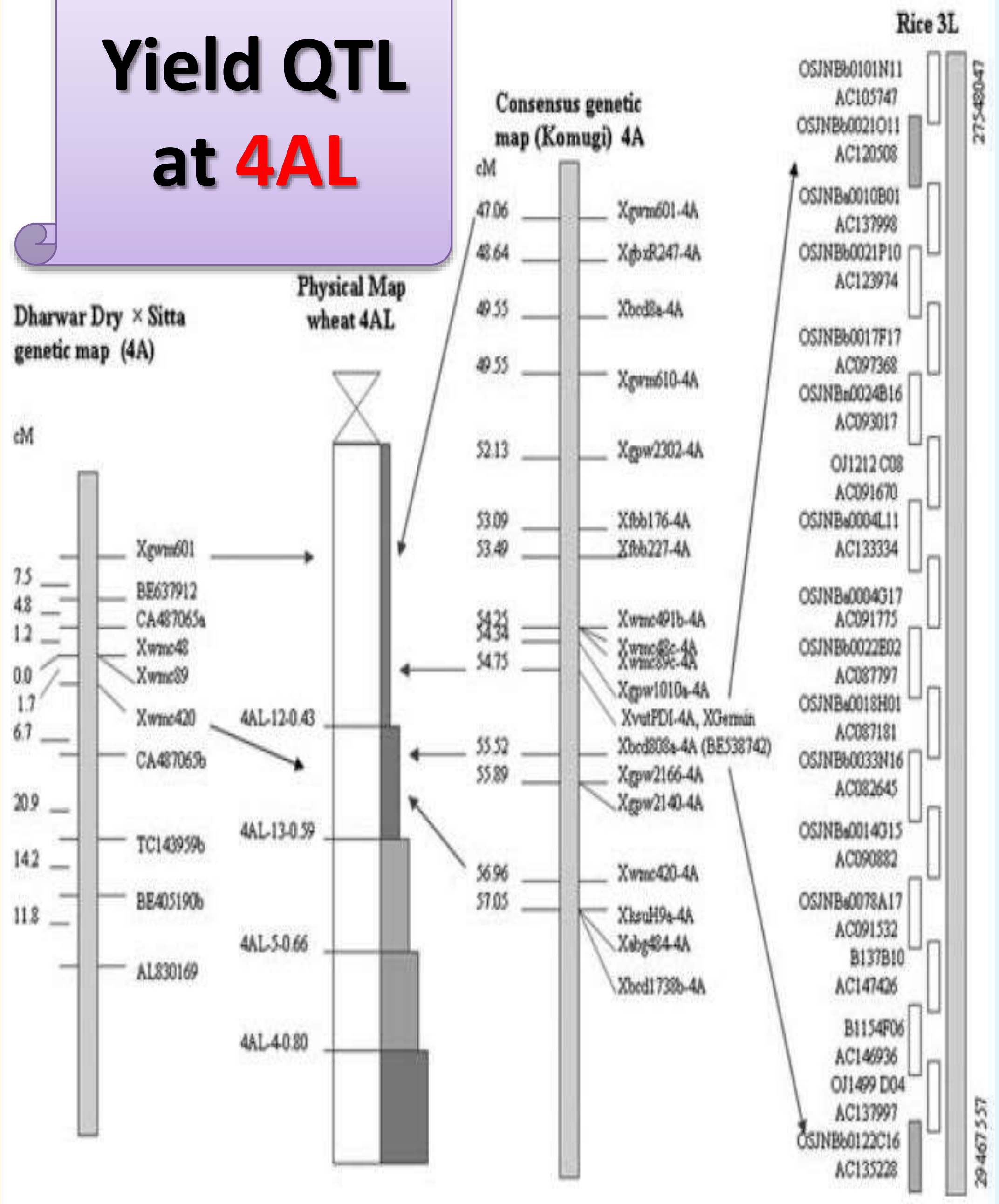
×

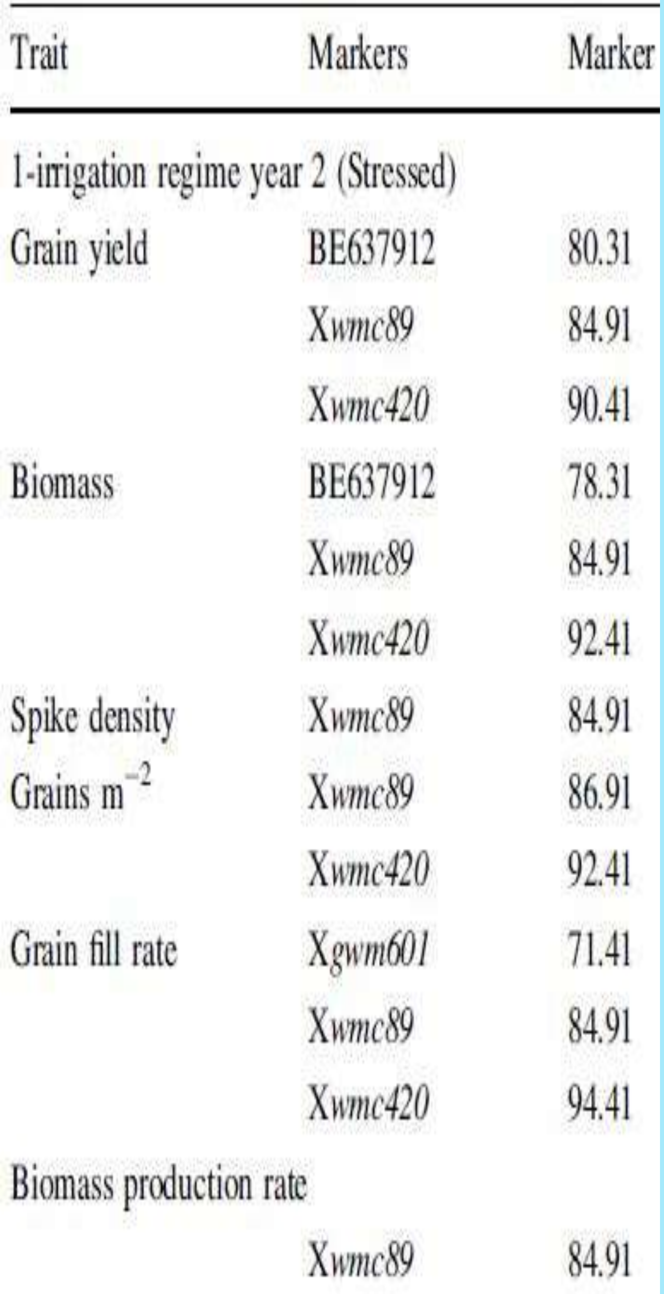
Sitta
drought
suceptible

127 RILs

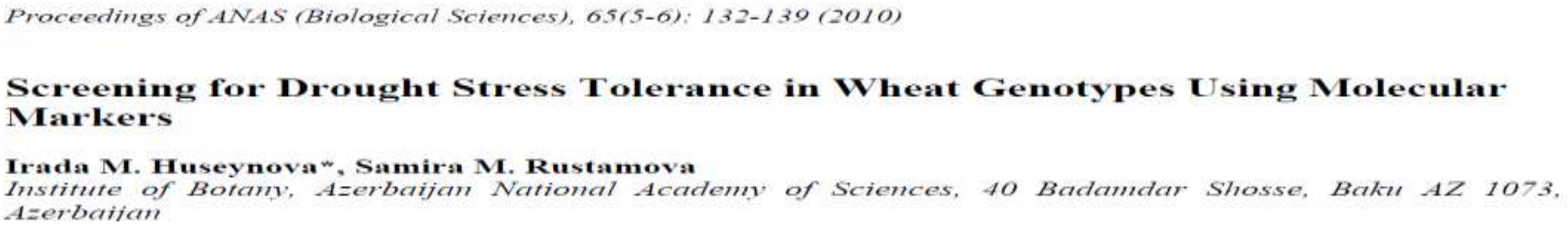
BE637912, Xwmc89, and Xwmc420
SSR marker linked to Grain Yield QTL

Yield QTL at 4AL





Trait	Markers	Marker
1-irrigation regime year 2 (Stressed)		
Grain yield	BE637912	80.31
	Xwmc89	84.91
	Xwmc420	90.41
Biomass	BE637912	78.31
	Xwmc89	84.91
	Xwmc420	92.41
Spike density	Xwmc89	84.91
Grains m^{-2}	Xwmc89	86.91
	Xwmc420	92.41
Grain fill rate	Xgwm601	71.41
	Xwmc89	84.91
	Xwmc420	94.41
Biomass production rate		
	Xwmc89	84.91


Proceedings of ANAS (Biological Sciences), 65(5-6): 132-139 (2010)

Screening for Drought Stress Tolerance in Wheat Genotypes Using Molecular Markers

Irada M. Huseynova*, Samira M. Rustamova
Institute of Botany, Azerbaijan National Academy of Sciences, 40 Badamdar Shosse, Baku AZ 1073, Azerbaijan

Table 1. Wheat genotypes and their drought tolerance status

No	Genotype name	Ploidity level and genomes	Reaction to drought
		Triticum durum L.	
1	Barakatli-95	Tetraploid (AABB)	Tolerant
2	Garagylchyg-2		Sensitive
3	Gyrmyzy bugda		Tolerant
		Triticum aestivum L.	
4	Azamatli-95	Hexaploid (AABBDD)	Tolerant
5	Giymatli-2/17		Sensitive
6	Gobustan		Tolerant
7	Gyrmyzy gul		Semi-tolerant
8	Tale-38		Semi-tolerant
9	Ruzi-84		Tolerant
10	12nd FAWWON No 97 (130/21)		Sensitive
11	4tn FEFWSN No 50 (130/32)		Semi-tolerant
12	Saratovskaya		Tolerant

Table 2. Primer nucleotide sequence used to amplify DNA

Primer designation	Sequence 5′ → 3′
P6	TCGGCGGTTC
P7	CTGCATCGTG

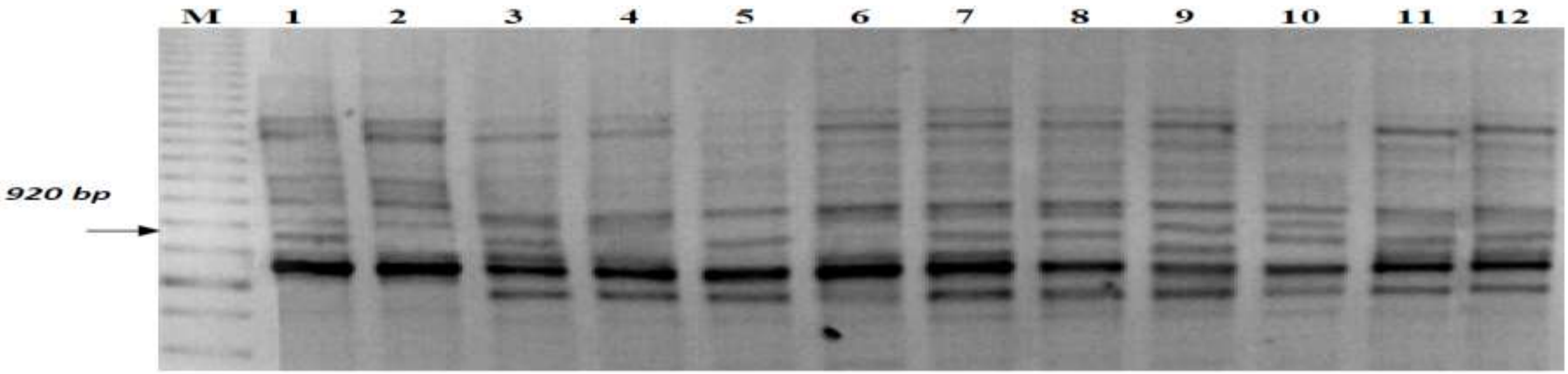


Figure 1. PCR amplification profiles of *Triticum* L. wheat genotypes using P6 primer

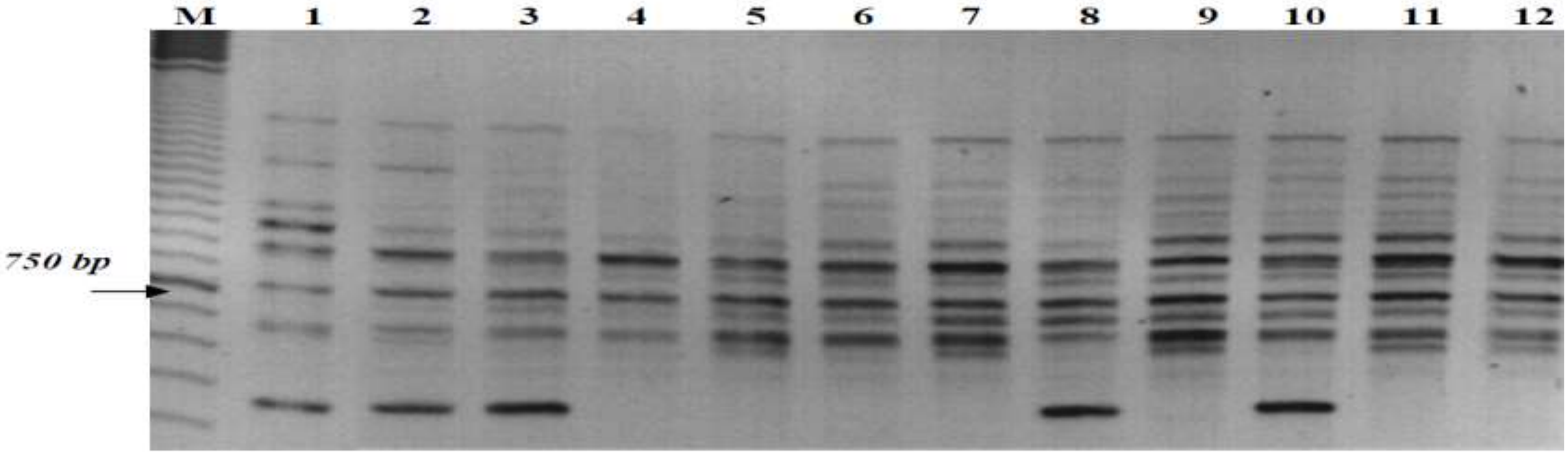


Figure 2. PCR amplification profiles of wheat genotypes *Triticum* L. using a primer P7

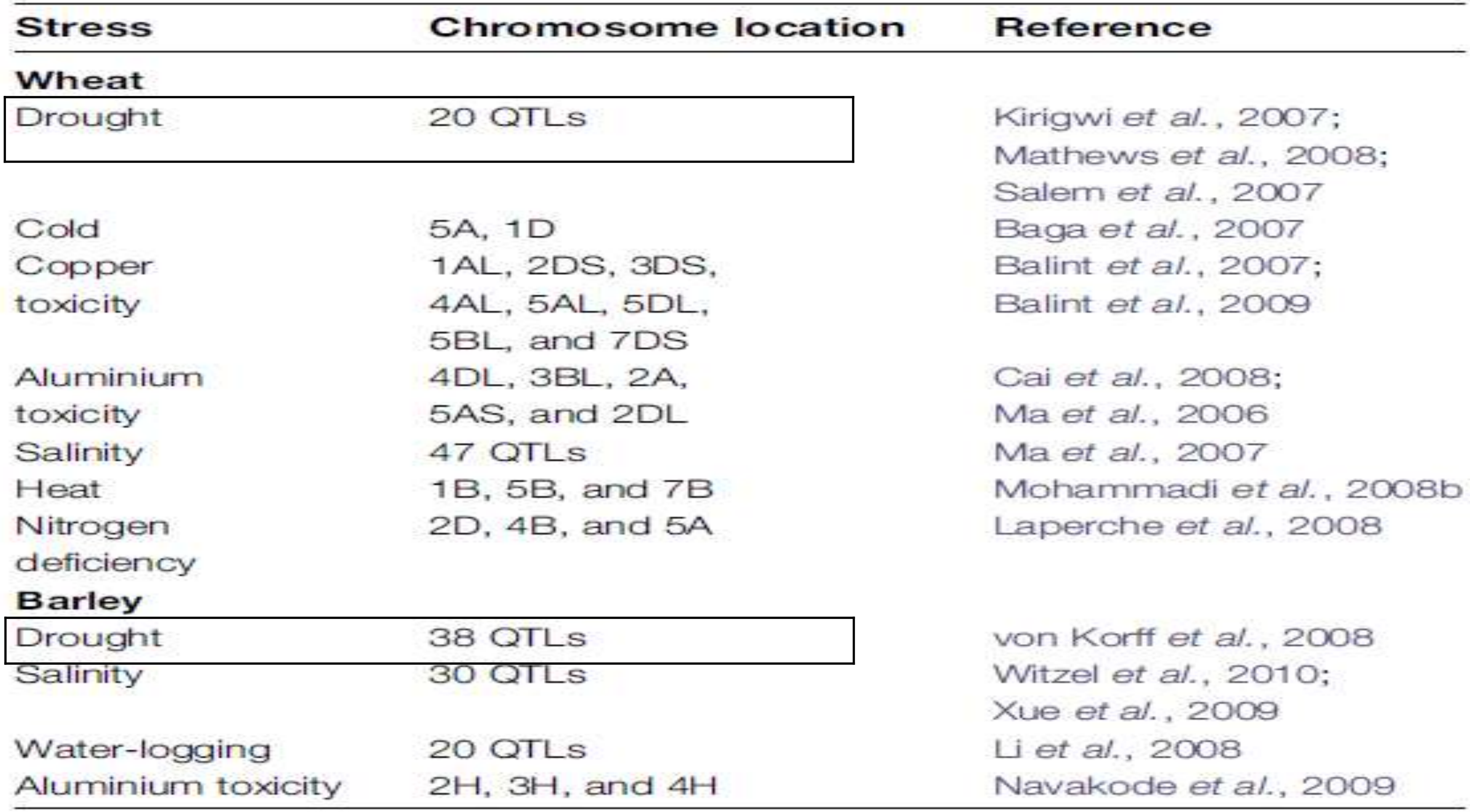
Journal of Experimental Botany, Vol. 61, No. 12, pp. 3211–3222, 2010
doi:10.1093/jxb/erq152 Advance Access publication 4 June, 2010

Journal of
Experimental
Botany
www.jxb.oxfordjournals.org

REVIEW PAPER

Genetic and genomic tools to improve drought tolerance in wheat

Delphine Fleury[1,*], Stephen Jefferies[2], Haydn Kuchel[2] and Peter Langridge[1]



Stress	Chromosome location	Reference
Wheat		
Drought	20 QTLs	Kirigwi *et al.*, 2007; Mathews *et al.*, 2008; Salem *et al.*, 2007
Cold	5A, 1D	Baga *et al.*, 2007
Copper toxicity	1AL, 2DS, 3DS, 4AL, 5AL, 5DL, 5BL, and 7DS	Balint *et al.*, 2007; Balint *et al.*, 2009
Aluminium toxicity	4DL, 3BL, 2A, 5AS, and 2DL	Cai *et al.*, 2008; Ma *et al.*, 2006
Salinity	47 QTLs	Ma *et al.*, 2007
Heat	1B, 5B, and 7B	Mohammadi *et al.*, 2008b
Nitrogen deficiency	2D, 4B, and 5A	Laperche *et al.*, 2008
Barley		
Drought	38 QTLs	von Korff *et al.*, 2008
Salinity	30 QTLs	Witzel *et al.*, 2010; Xue *et al.*, 2009
Water-logging	20 QTLs	Li *et al.*, 2008
Aluminium toxicity	2H, 3H, and 4H	Navakode *et al.*, 2009

Plant Biotechnology Journal

Plant Biotechnology Journal (2011) **9**, pp. 408–417

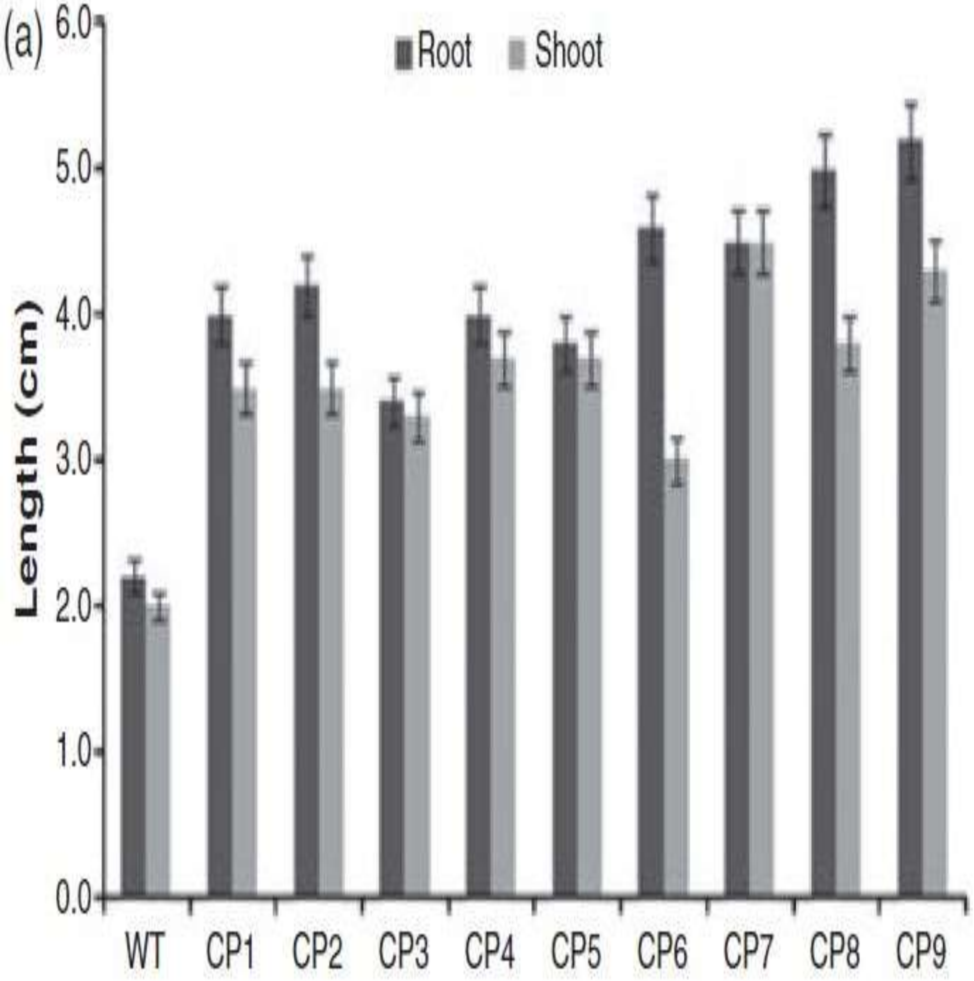
doi: 10.1111/j.1467-7652.2010.00561.x

Use of doubled haploid technology for development of stable drought tolerant bread wheat (*Triticum aestivum* L.) transgenics

Harsh Chauhan and Paramjit Khurana*

Department of Plant Molecular Biology, Delhi University, New Delhi, India

- **Braley *HVA1* gene is introduced in bread wheat**
- ***Agrobacterium-mediated* genetic transformation**



African Journal of Biotechnology Vol. 10(55), pp. 11340-11344, 21 September, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.700
ISSN 1684–5315 © 2011 Academic Journals

Review

Potentials of molecular based breeding to enhance drought tolerance in wheat (*Triticum aestivum* L.)

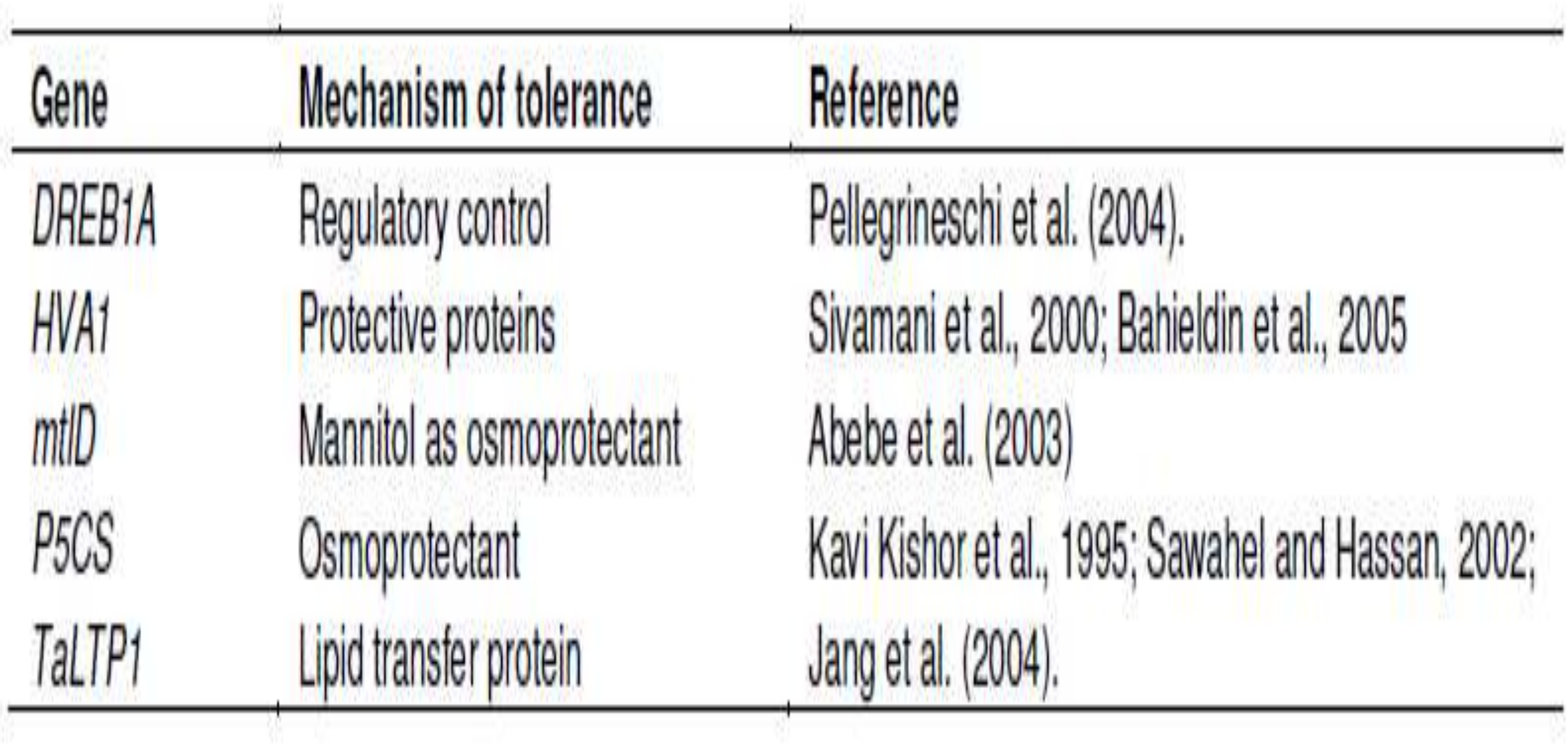
Mueen Alam Khan[1]*, Muhammad Iqbal[1], Moazzam Jameel[1], Wajad Nazeer[2], Sara Shakir[1], Muhammad Tabish Aslam[1] and Bushra Iqbal[1]

Table 1. Summary of QTLs associated with drought tolerance in wheat[a]

Cross	Trait	QTL Mapping	Number of QTL	Reference
Chinese Spring x Ciano 67	ABA concentration	DHL*	1	Quarrie et al. (1994)
Songlen x Cobdor 4/3Ag14	Osmoregulation under drought	RIL*	1	Morgan and Tan (1996)
Trident x Molineux	Yield interaction with water supply and hot conditions	DHL	1	Kuchel et al. (2007)
Durum x Wild emmer	Various morpho-physiological traits	RIL	many	Peleg et al. (2009)
Seri M82 x Babax	Various productivity and physiological traits	RIL	many	McIntyre et al. 2010; Suzuky Pinto et al., 2010.

*DHL= doubled haploid; RIL= recombinant inbred lines; [a]Similar studies reported in the text were not included in this table.

Genes associated with drought



Gene	Mechanism of tolerance	Reference
DREB1A	Regulatory control	Pellegrineschi et al. (2004).
HVA1	Protective proteins	Sivamani et al., 2000; Bahieldin et al., 2005
mtlD	Mannitol as osmoprotectant	Abebe et al. (2003)
P5CS	Osmoprotectant	Kavi Kishor et al., 1995; Sawahel and Hassan, 2002;
TaLTP1	Lipid transfer protein	Jang et al. (2004).

QTL analysis of drought tolerance for seedling root morphological trait in an advance backcross population

- **32 QTLs identified**
- **Seven root traits**

1.Average root diameter (AVD)(1)

2.Number of root crossings (CRS)(4)

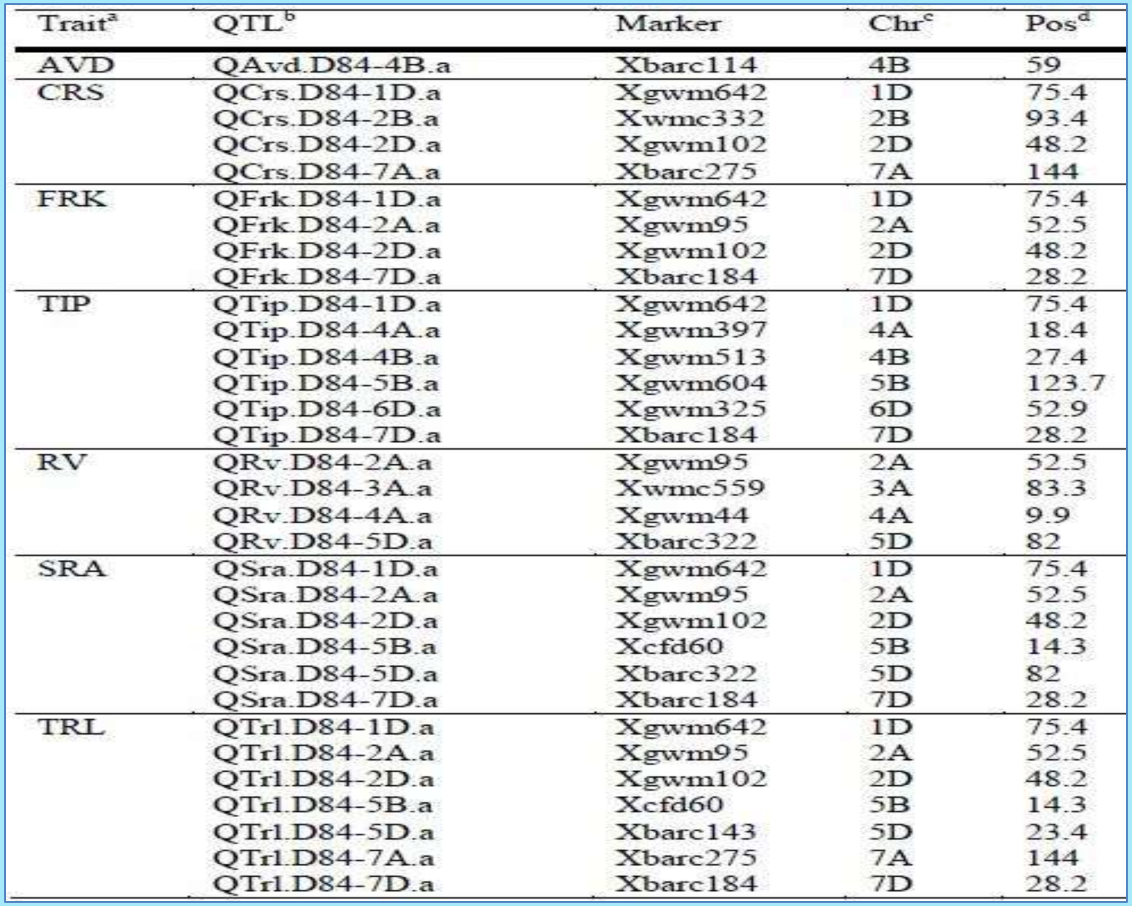
3.Number of root forks (FRK)(4)

4.Number of root tips (TIP)(6)

5.Root volume (RV)(4)

6.Surface root area (SRA)(6)

7.Total root length (TRL)(7)



Trait[a]	QTL[b]	Marker	Chr[c]	Pos[d]
AVD	QAvd.D84-4B.a	Xbarc114	4B	59
CRS	QCrs.D84-1D.a	Xgwm642	1D	75.4
	QCrs.D84-2B.a	Xwmc332	2B	93.4
	QCrs.D84-2D.a	Xgwm102	2D	48.2
	QCrs.D84-7A.a	Xbarc275	7A	144
FRK	QFrk.D84-1D.a	Xgwm642	1D	75.4
	QFrk.D84-2A.a	Xgwm95	2A	52.5
	QFrk.D84-2D.a	Xgwm102	2D	48.2
	QFrk.D84-7D.a	Xbarc184	7D	28.2
TIP	QTip.D84-1D.a	Xgwm642	1D	75.4
	QTip.D84-4A.a	Xgwm397	4A	18.4
	QTip.D84-4B.a	Xgwm513	4B	27.4
	QTip.D84-5B.a	Xgwm604	5B	123.7
	QTip.D84-6D.a	Xgwm325	6D	52.9
	QTip.D84-7D.a	Xbarc184	7D	28.2
RV	QRv.D84-2A.a	Xgwm95	2A	52.5
	QRv.D84-3A.a	Xwmc559	3A	83.3
	QRv.D84-4A.a	Xgwm44	4A	9.9
	QRv.D84-5D.a	Xbarc322	5D	82
SRA	QSra.D84-1D.a	Xgwm642	1D	75.4
	QSra.D84-2A.a	Xgwm95	2A	52.5
	QSra.D84-2D.a	Xgwm102	2D	48.2
	QSra.D84-5B.a	Xcfd60	5B	14.3
	QSra.D84-5D.a	Xbarc322	5D	82
	QSra.D84-7D.a	Xbarc184	7D	28.2
TRL	QTrl.D84-1D.a	Xgwm642	1D	75.4
	QTrl.D84-2A.a	Xgwm95	2A	52.5
	QTrl.D84-2D.a	Xgwm102	2D	48.2
	QTrl.D84-5B.a	Xcfd60	5B	14.3
	QTrl.D84-5D.a	Xbarc143	5D	23.4
	QTrl.D84-7A.a	Xbarc275	7A	144
	QTrl.D84-7D.a	Xbarc184	7D	28.2

Ibrahim et al. 2012

Drought Tolerance in Modern and Wild Wheat

Hikmet Budak, Melda Kantar, and Kuaybe Yucebilgili Kurtoglu

Biological Sciences and Bioengineering Program, Faculty of Engineering and Natural Sciences, Sabanci University, 34956 Tuzla, Istanbul, Turkey

Correspondence should be addressed to Hikmet Budak; budak@sabanciuniv.edu

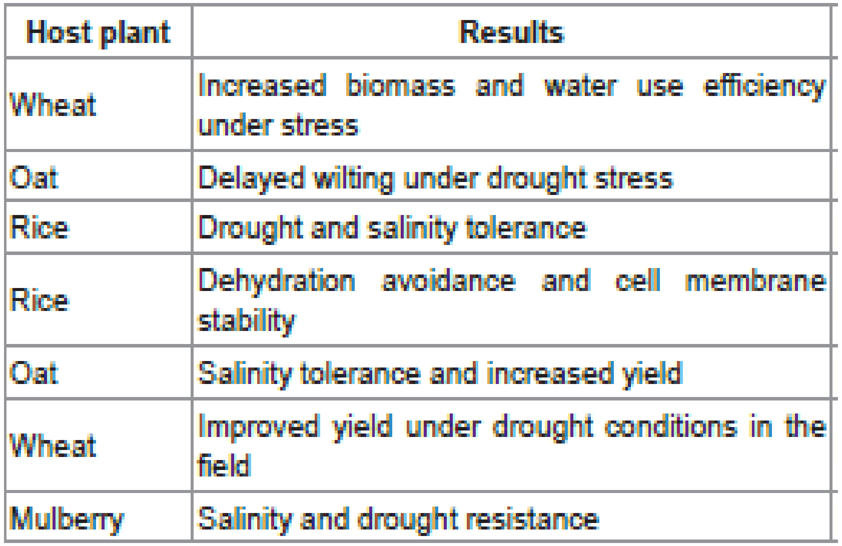
Received 5 March 2013; Accepted 3 April 2013

TABLE 2: List of identified and characterized drought related genes

Gene	Function	Related mechanism/stress
TaPIMP1	Transcription factor: R2R3 type MYB TF	Drought
TaSRG	Transcription factor: *Triticum aestivum* salt response gene	Drought
TaMYB3R1	Transcription factor: MYB3R type MYB TF	drought
TaNAC (NAM/ATAF/CUC)	Transcription factor: plant specific NAC (NAM/ATAF/CUC) TF	Drought
TaMYB33	Transcription factor: R2R3 type MYB TF	Drought
TaWRKY2, TaWRKY19	Transcription factor: WRKY type TF	Drought
TdicDRF1	Transcription factor: DRE binding protein	Drought
TaABC1	Kinase: protein kinase ABC1 (activity of bc(1) complex)	Drought
TaSnRK2.4	Kinase: SNF1 type serine/threonine protein kinase	Drought
TaSnRK2.7	Kinase: SNF1 type serine/threonine protein kinase	drought
TdTMKP1	Phosphatase: MAP kinase phosphatase	Drought
TaCHP	CHP rich zinc finger protein with unknown function	ABA-dependent and -independent pathways
TaCP	Protein degradation: cysteine protease	Drought
TaEXPR23	Cell wall expansion: expansin	Water retention ability and osmotic potential
TaL5	Nucleocytoplasmic transport of 5S ribosomal RNA: ribosomal L5 gene	Drought
TdPIP1;1, TdPIP1;2	Protective protein: aquaporin	Drought
TdicATG8	Autophagy: autophagy related gene 8	Drought
TdicTMPIT1	Autophagy: integral transmembrane protein inducible by TNF-α	Drought
Era1, Sal1	Enhanced response to ABA, inositol polyphosphate 1-phosphatase	Drought

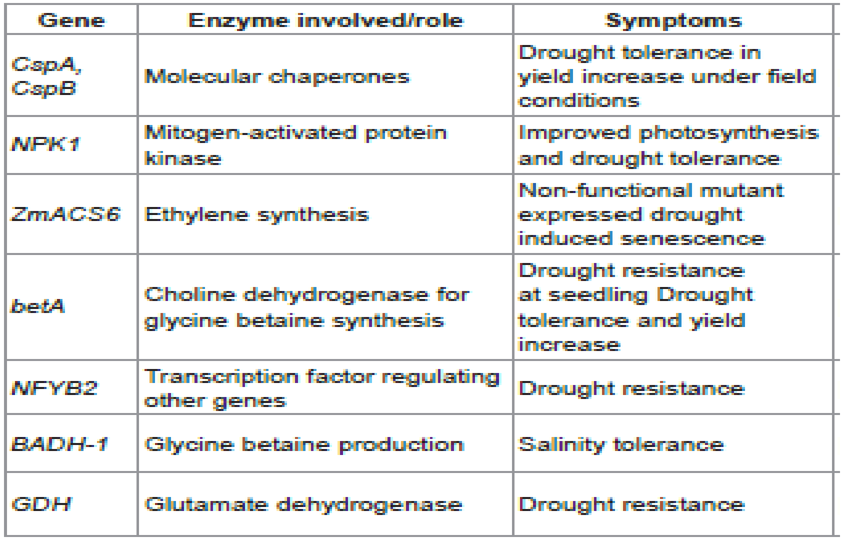
Ta: *Triticum aestivum*; Td: *Triticum durum*; Tdic: *Triticum dicoccoides*; DRE: drought related element; SNF: Sucrose nonfermenting; MAP: mitogen activated protein; ABA: abscisic acid; CHP: cysteine histidine proline; TNF-α: tumor necrosis factor α; PIMP: pathogen induced membrane protein; CP: cysteine protease; EXPR: expansin; PIP: plasma membrane intrinsic proteins.

Barley HVA1 Gene Confers Drought and Salt Tolerance in Transgenic Crop species



Host plant	Results
Wheat	Increased biomass and water use efficiency under stress
Oat	Delayed wilting under drought stress
Rice	Drought and salinity tolerance
Rice	Dehydration avoidance and cell membrane stability
Oat	Salinity tolerance and increased yield
Wheat	Improved yield under drought conditions in the field
Mulberry	Salinity and drought resistance

Table 1: Expression of barley *HVA1* gene in different transgenic crop species.



Gene	Enzyme involved/role	Symptoms
CspA, CspB	Molecular chaperones	Drought tolerance in yield increase under field conditions
NPK1	Mitogen-activated protein kinase	Improved photosynthesis and drought tolerance
ZmACS6	Ethylene synthesis	Non-functional mutant expressed drought induced senescence
betA	Choline dehydrogenase for glycine betaine synthesis	Drought resistance at seedling Drought tolerance and yield increase
NFYB2	Transcription factor regulating other genes	Drought resistance
BADH-1	Glycine betaine production	Salinity tolerance
GDH	Glutamate dehydrogenase	Drought resistance

Table 2: A summary of genes previously transferred into maize genome for development of drought and/or salinity tolerance.

Nguyen et al. 2013

AtDREB1A gene greatly improves drought stress tolerance in transgenic indica rice

- *AtDREB1A* gene is transferd in rice
- *Agrobacterium-mediated* genetic transformation

Morphology of transgenic rice plants during the water stress period

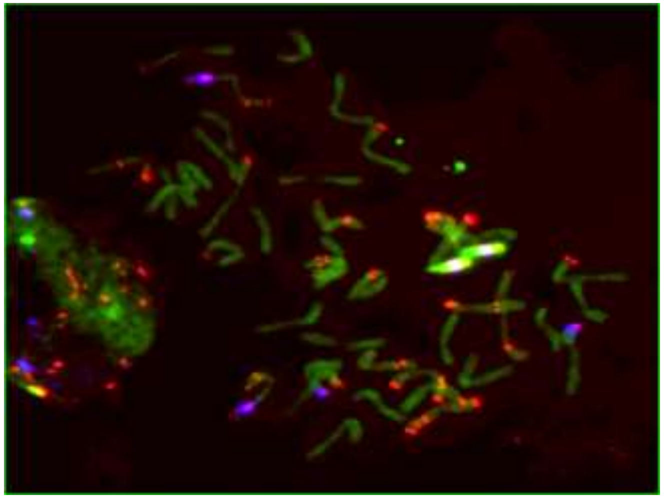
Line number	Average tiller	number Leaf rolling on treatment day 7	Leaf drying on treatment day 7	Leaf rolling on treatment day 14	Leaf drying on treatment day 14	Recovery after 7 days (%)	Observed phenotype
BD-33-24-4	**10**	**H**	**N**	**H**	**N**	**90–100**	**HT**
BD-33-24-5	**12**	**H**	**N**	**H**	**N**	**90–100**	**HT**
BD-33-24-6	**15**	**H**	**N**	**H**	**N**	**90–100**	**HT**
BD-33-24-7	**10**	**H**	**N**	**H**	**N**	**90–100**	**HT**
BD-33-24-9	**10**	**H**	**N**	**H**	**N**	**90–100**	**HT**
BD-33-29-1	**9**	**D**	**T**	**H**	**L**	**70–89**	**MT**
BD-33-30-1	**10**	**D**	**T**	**H**	**L**	**70–89**	**MT**
BD-33-34-1	**10**	**D**	**T**	**H**	**L**	**70–89**	**MT**
WILD TYPE	**12**	**T**	**A**	**C**	**A**	**0**	**SC**

H Healthy, T tightly rolled, L leaf margin touching, D deep V shape rolling, N no drying, A apparently dead, t tip drying started,C completely wilted, L little drying, HT highly tolerant, MT moderate tolerant, SC susceptible,

Ravikumar et al. 2014

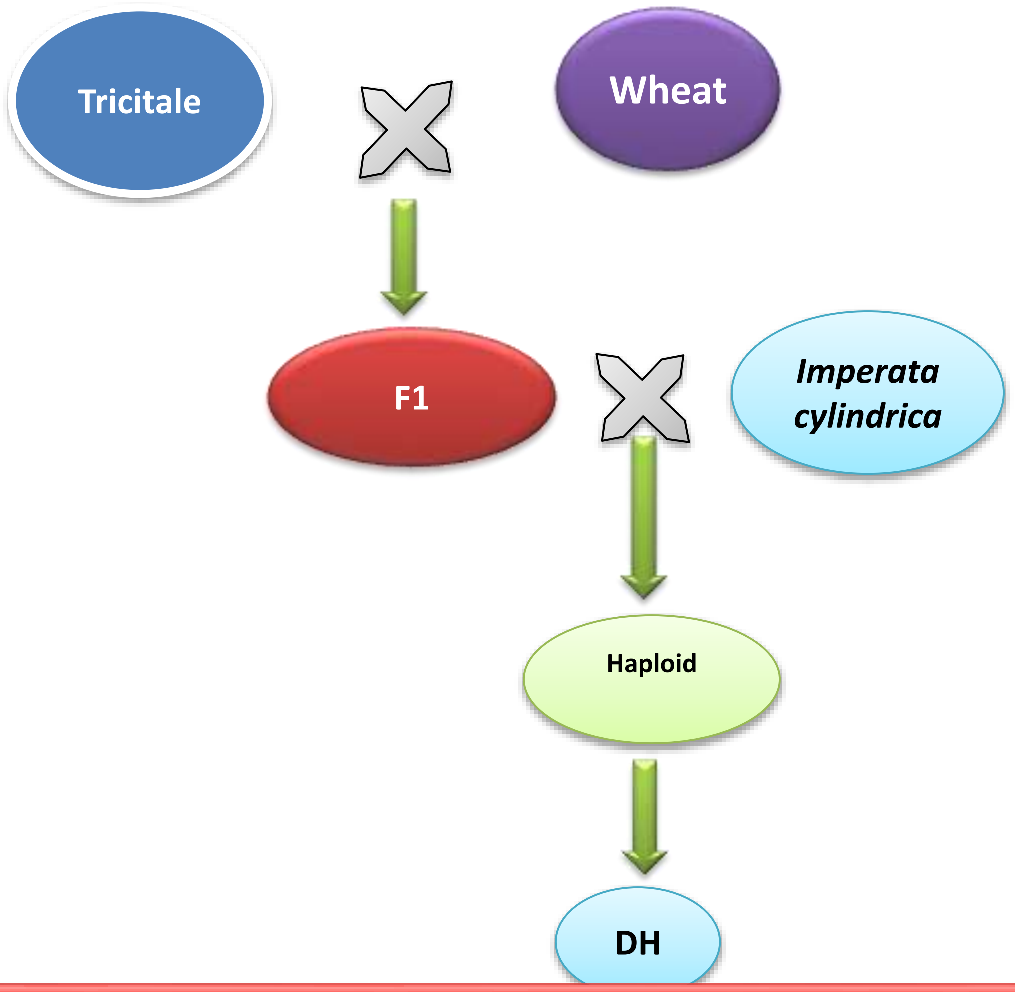
Work done at CSKHPKV

- Rye is an ultimate source of drought tolerance
- 1RS translocations
- Himalayan rye source



Chaudhary HK and Mukai 2007

Recombinant Wheat with Rye Introgressions



Chaudhary H.K., Sethi G.S., Singh S., Pratap A. and Sharma S. 2005. Efficient haploid induction in wheat by using pollen of *Imperata cylindrica. Plant Breeding* 124(1): 96-98.

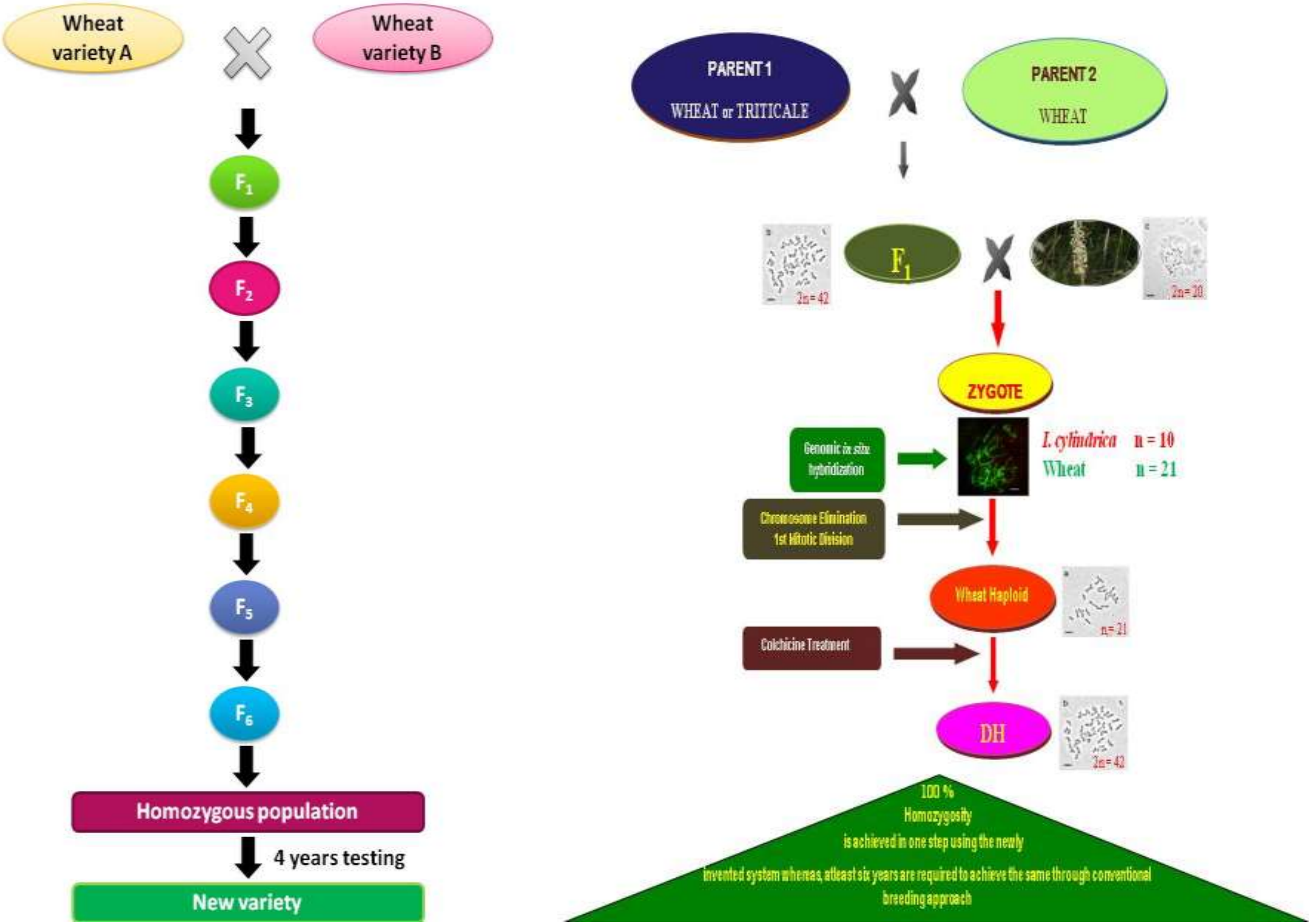

Wheat variety A
Wheat variety B
F1
F2
F3
F4
F5
F6
Homozygous population
4 years testing
New variety
PARENT 1
WHEAT or TRITICALE
PARENT 2
WHEAT
2n = 42
F1
2n = 20
ZYGOTE
Genomic in situ hybridization
I. cylindrica n = 10
Wheat n = 21
Chromosome Elimination 1st Mitotic Division
Wheat Haploid
n = 21
Colchicine Treatment
DH
2n = 42
100 %
Homozygosity
is achieved in one step using the newly
invented system whereas, atleast six years are required to achieve the same through conventional
breeding approach

Fig. 1

Isolation of the drought tolerant & susceptible lines

Highly tolerant	Highly susceptible
DH 100	DH 5
DH 106	DH 52
DH 114	DH150
DH 40	DH144
DH 65	
DH89	
C 306	
VL 829	
KWS 29	

Dixit and Chaudhary 2009

Summary

- **In the days of global warming, the effect of drought stress on crop productivity is expected to increase**

- **The crop plants have evolved certain resistance mechanism against drought stress**
    - **we should identify those mechanisms and traits**
    - **and introgress them into susceptible genotypes**

- **Only conventional breeding is not sufficient in development of drought tolerant variety**

- **Non conventional approaches i.e. Molecular breeding can play a significant role in the sphere of abiotic stress mainly drought tolerance**

- **Genomic regions carrying drought tolerant gene can contribute for abiotic stress tolerance**

THANK YOU