EFFECTS OF CLIMATE CHANGE ON SUGARCANE PRODUCTION, AND ROLE OF TISSUE CULTURE TECHNOLOGY IN THEIR MITIGATION

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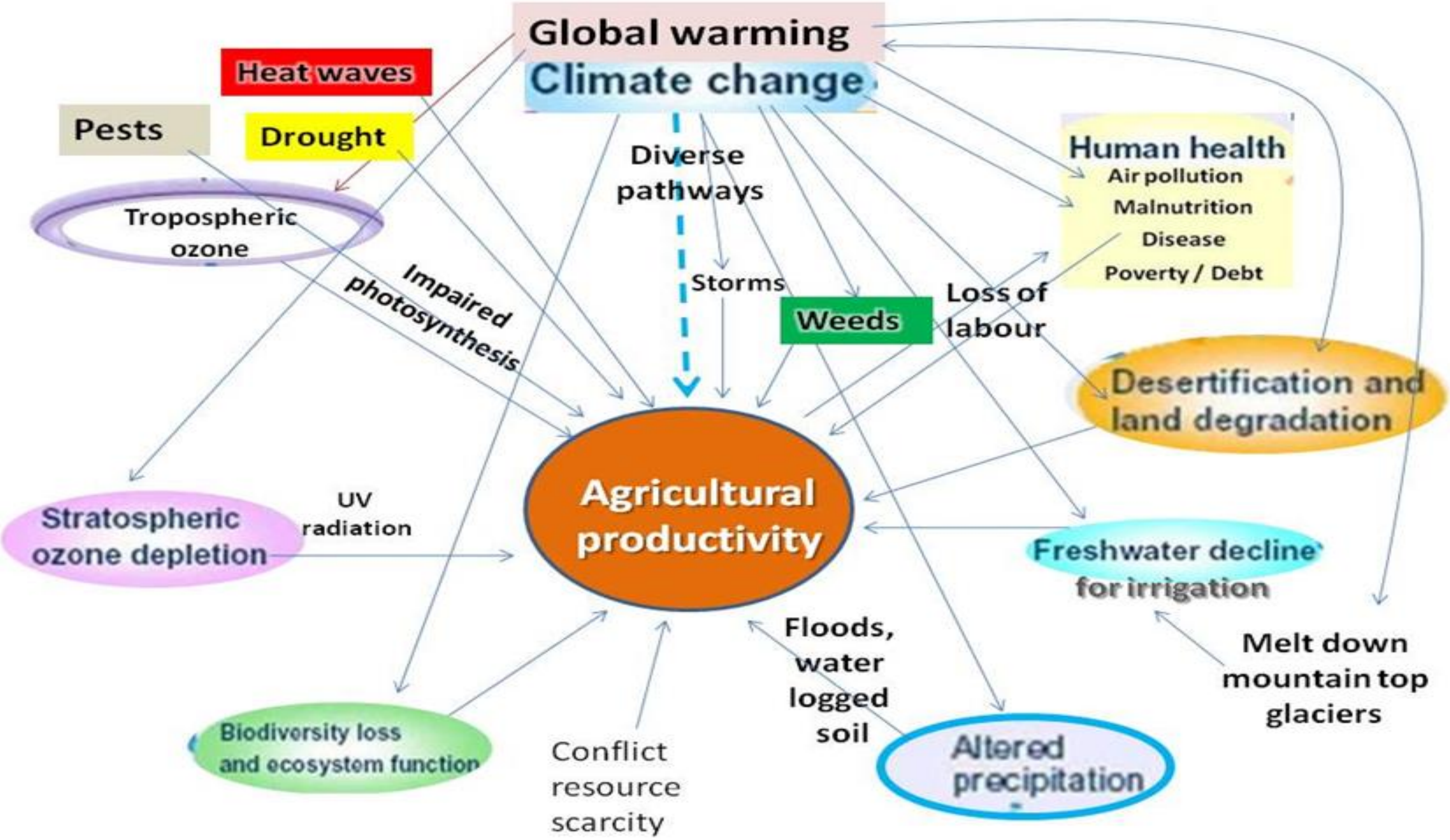
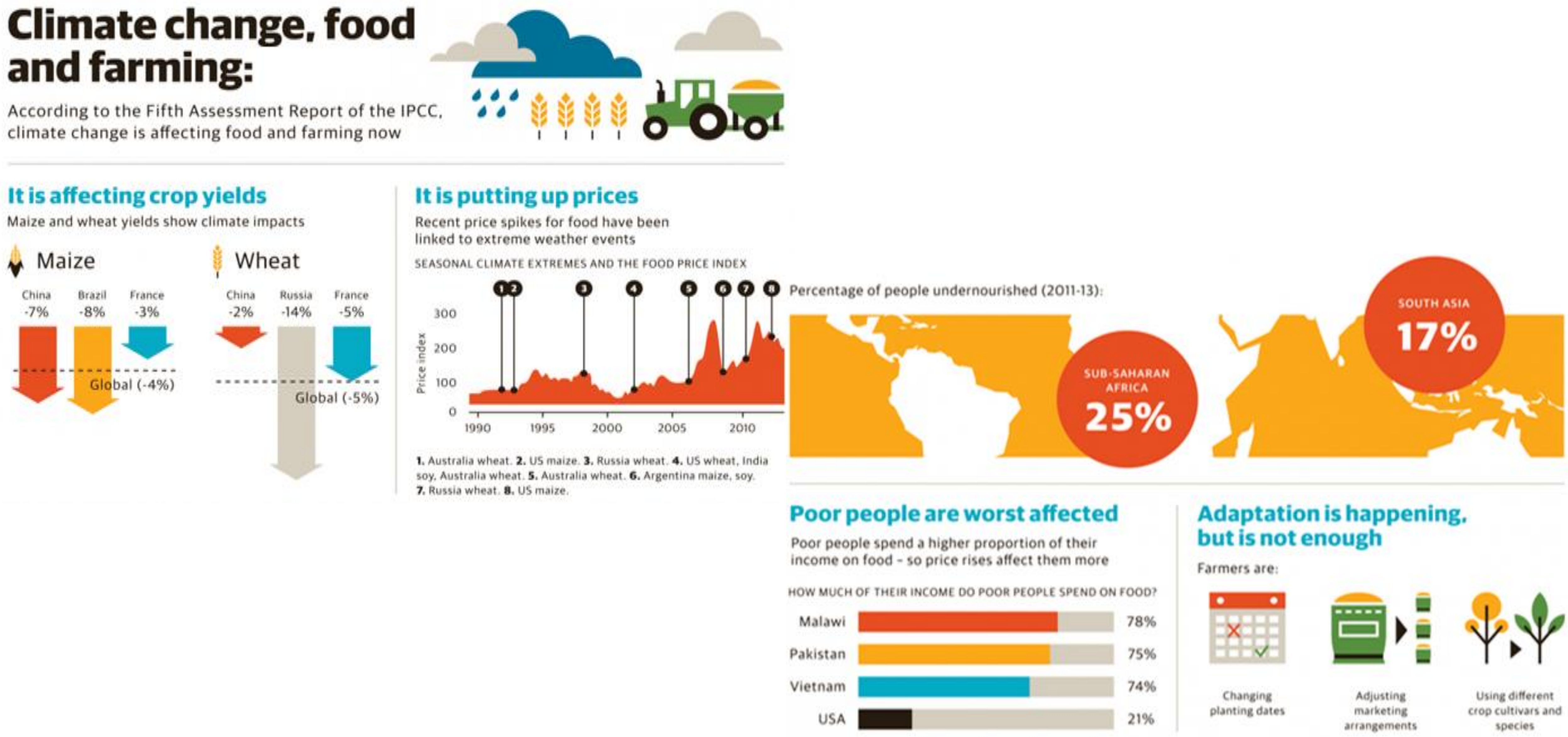
Climate Change

- **Major area of concern of scientific community**
- **Poses greater threat than terrorism**
- **As per Dr. David King- Every economic decision has a climate consequence, and every climate decision has an economic consequence.**

- **Rising surface temperature: Last century- 0.6-1.0 °C; – Projections for 2100- 1.6-5.8 °C**
- **Increasing atmosphere [CO_2] 280 ppm (1789); 380 ppm (2004); 550 ppm (2050)**
- **Rainfall patterns**
- **Rising sea levels**

Impact of Climate Change on Agriculture




Climate change, food and farming:
According to the Fifth Assessment Report of the IPCC, climate change is affecting food and farming now
It is affecting crop yields
Maize and wheat yields show climate impacts
Maize
China -7%
Brazil -8%
France -3%
Global (-4%)
Wheat
China -2%
Russia -14%
France -5%
Global (-5%)
It is putting up prices
Recent price spikes for food have been linked to extreme weather events
SEASONAL CLIMATE EXTREMES AND THE FOOD PRICE INDEX
Price index
300
200
100
0
1990
1995
2000
2005
2010
1. Australia wheat. 2. US maize. 3. Russia wheat. 4. US wheat, India soy, Australia wheat. 5. Australia wheat. 6. Argentina maize, soy. 7. Russia wheat. 8. US maize.
Percentage of people undernourished (2011-13):
SUB-SAHARAN AFRICA 25%
SOUTH ASIA 17%
Poor people are worst affected
Poor people spend a higher proportion of their income on food - so price rises affect them more
HOW MUCH OF THEIR INCOME DO POOR PEOPLE SPEND ON FOOD?
Malawi 78%
Pakistan 75%
Vietnam 74%
USA 21%
Adaptation is happening, but is not enough
Farmers are:
Changing planting dates
Adjusting marketing arrangements
Using different crop cultivars and species

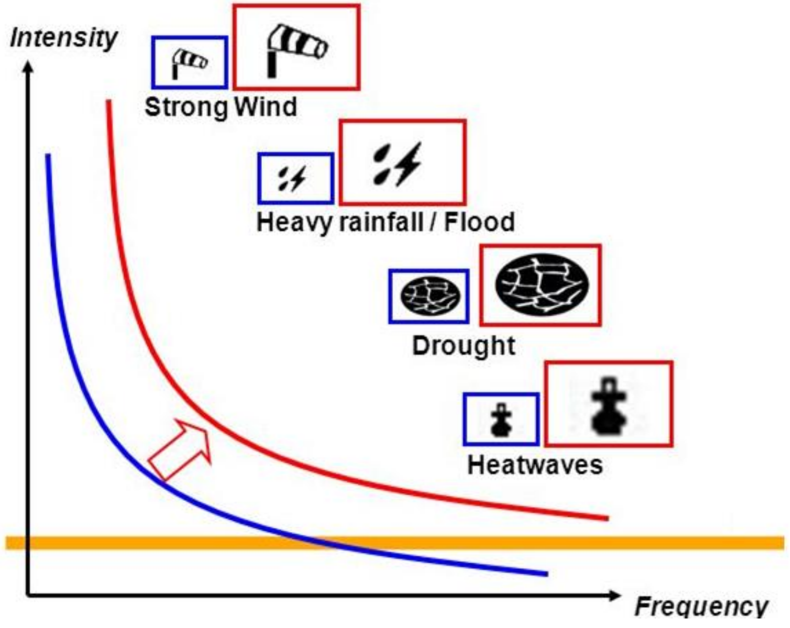
Climate Change in Pakistan

- **Among top 10 countries effected by climate change**
- **Listed as one of the most vulnerable countries in the world to climate change, UNDP**
- **List of countries at most risk of climate related threats**
  - **Floods**
  - **Agriculture**
- **Droughts are more intense**
- **Glaciers are melting in the region**
- **Freshwater availability is also projected to decrease**
- **Climate change is estimated to decrease crop yields in Pakistan which in turn will affect livelihoods and food production**

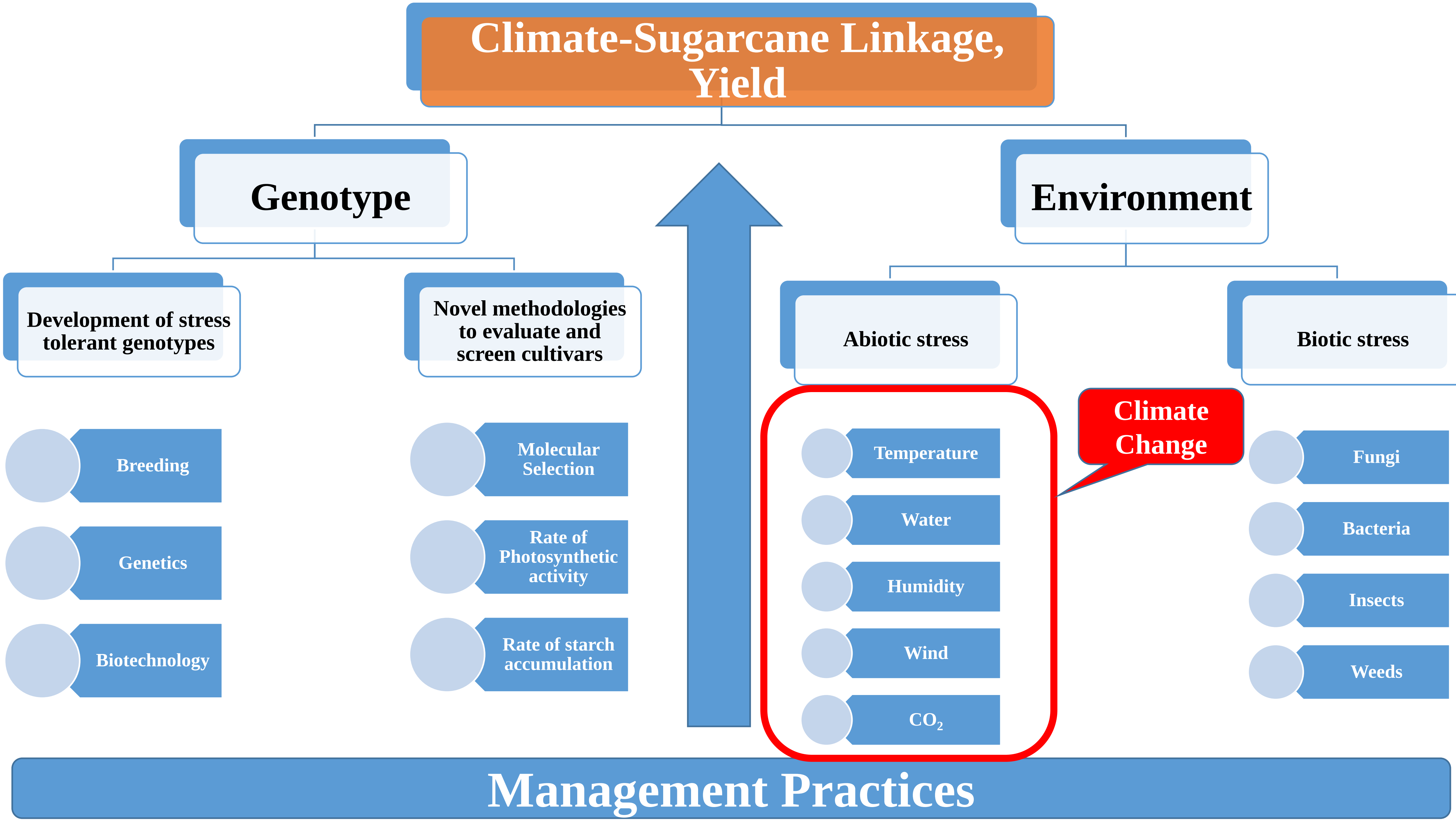
Verisk Maplecroft, UK; UNDP, 2015; IPCC Report;

Effects on Sugarcane Production

- **World's largest commodity with respect to production; 70% global sugar production**
- **Major cash crop of Pakistan, 0.7% value addition in GDP , 3.4 % in agriculture sector, 99% sugar production**
- **Water stress**
  - **Reduction of rainy days (400 -700 mm); Dry seasons**
- **Increasing temperature**
  - **Cane and sugar yield decline 10% for every 1°C increase**
  - **Irrigation demand 10% for an increase in 1°C**
- **Precipitation extremes**
- **Winds**
- **Sudden weather changes**
- **Higher input costs- pesticides, fuels, water**



Zhao and Li, 2015


Climate-Sugarcane Linkage, Yield
Genotype
Environment
Development of stress tolerant genotypes
Novel methodologies to evaluate and screen cultivars
Abiotic stress
Biotic stress
Climate Change
Breeding
Genetics
Biotechnology
Molecular Selection
Rate of Photosynthetic activity
Rate of starch accumulation
Temperature
Water
Humidity
Wind
CO_2
Fungi
Bacteria
Insects
Weeds
Management Practices

Mitigation of Climate Impact on Sugarcane

- **Climate is the key factor determining sugarcane production**
- **Adaptive, and stress tolerance capacity**
- **Development of the stress tolerant and high yielding sugarcane cultivars that can contribute to adaptation to climate change events**
- **Tissue Culture, Conventional Breeding, GM Sugarcane**
- **Irrigation efficiency**
- **Management practices**
- **Nutrient use efficiency**
- **Agricultural weather information systems; climate predictions**

Production, Area, and Yield, in Sugarcane Growing Countries of the World

Country	Production (Million Tonnes)	Rank	Area (X1000 ha)	Rank	Yield ($t\ ha^{-1}$)	Rank
Brazil	739.27	1	9835.2	1	75.17	29
India	341.20	2	5060.0	2	67.43	40
China	126.14	3	1827.3	3	69.03	39
Thailand	100.10	4	1321.6	4	75.74	26
Pakistan	63.75	5	1128.8	5	56.48	51
Mexico	61.18	6	782.8	6	78.16	25
Colombia	34.88	7	405.7	9	85.95	19
Indonesia	33.70	8	450.0	7	74.89	31
Philippines	32.00	9	435.4	8	73.49	37
USA	27.91	10	368.6	11	75.71	27
World total	2165.23		26522.7		81.64	

Ranked at 8th position in sugar recovery and sugar yield (9.2 %, 4.63 t/ ha; against 13.8 %, and 13.85 t/ ha of Australia, and 9.9 %, 6.62 t/ ha of India)

FAO, United Nations, FAOSTAT, and Factfish

Options for Sugarcane Improvement to Cope with Changing Climatic Conditions

- **Conventional breeding?**
- **Non flowering or sporadic flowering with poor seed setting under natural conditions**
- **If seed setting occurs, germination is very poor and mortality rate is very high**
- **Lack of facilities for induction of flowering by artificial means**
- **<u>Solution: Biotechnology, Exotic germplasm evaluation, Mutagenesis,</u>**

Methods and Objectives

Parent Plant

(NIA-2010)

Callus Culture Technology

using 2,4-Dichlorophenoxyacetic acid

Preliminary Selection

Morphological and Molecular Selection

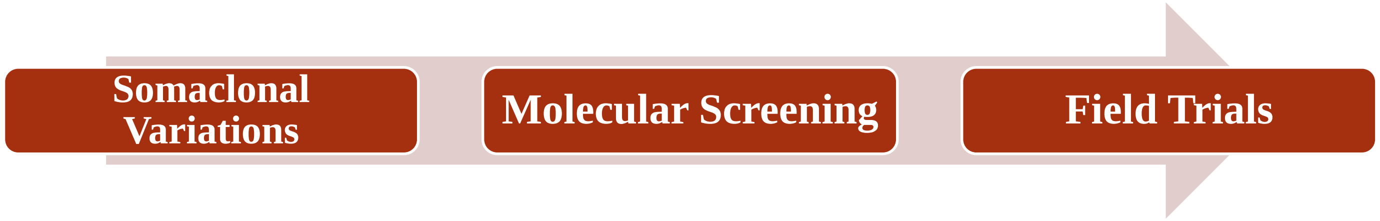
Field Trials

Performance of selected plantlets in field

- Tolerance to different stresses in climate change.
- High cane yield
- High sugar content
- Early maturity

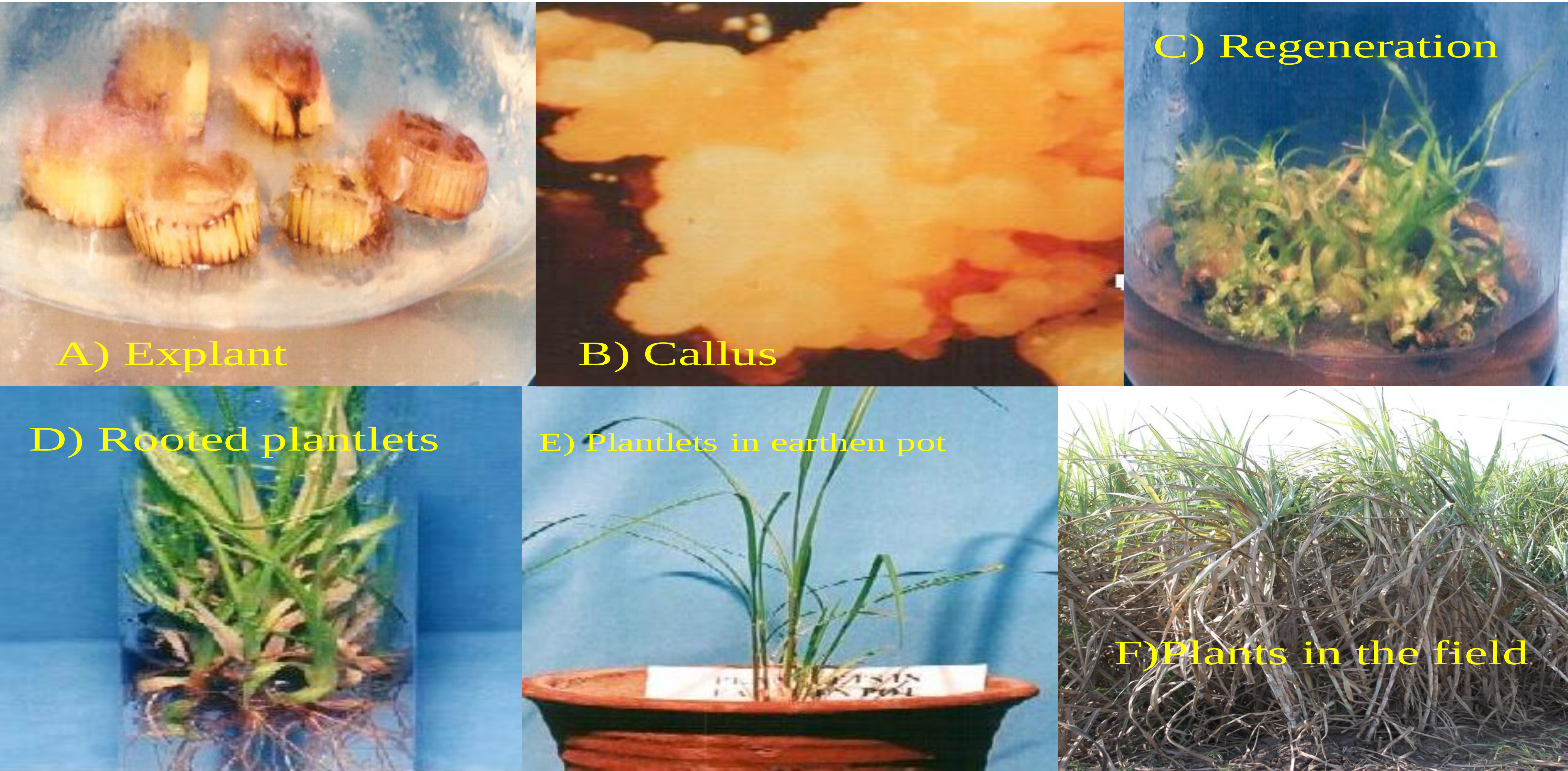
Methodology Cont.

- NIA-2010, Pedigree of the parent: CP67-1026
- Apical meristematic region on agar solidified medium containing 1-5 mg/L 2,4-D, aseptic conditions
- Callus induction; Somaclonal variations through different cycles
- Shoot multiplication was done by transferring the embryogenic calli with induced shoot into MS medium containing recommended concentrations of hormones
- Root induction- hormonal concentrations changed
- Molecular and morphological selection
- Field evaluation; Randomized complete block design
- Determination of qualitative and quantitative parameters
- Statistical, correlation and cluster analysis



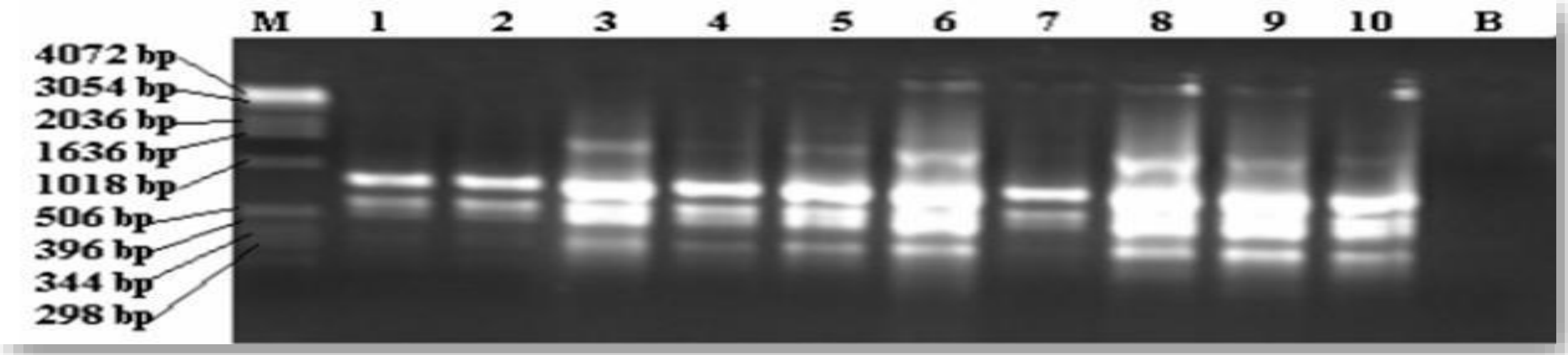
Murashige and Skoog, 1962
Yasmeen et al., 2013

Callus Culture in Sugarcane

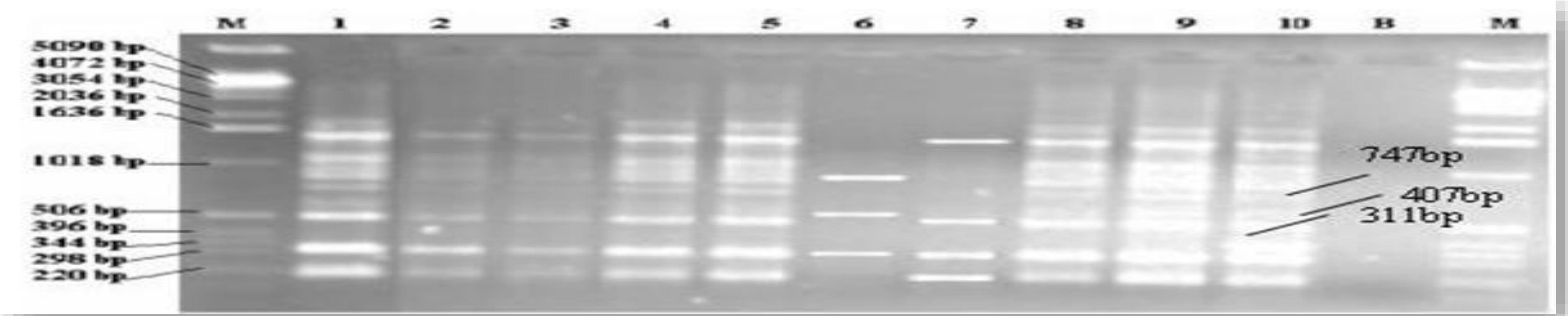


Molecular Selection of Low Water Requiring Somaclones

- Random Amplified Polymorphism (RAPD) markers- to confirm genetic diversity in somaclones
- Target Region Amplification Polymorphism (TRAP) and Sequence-Tagged Site (STS) markers- to assess the sucrose content and low water requirement
- TRAP markers- genetic polymorphism for sucrose gene
- Dehydration-responsive element-binding protein (DREB) STS Marker- determination of drought tolerance



Results of RAPD-PCR with primer C-02; M=DNA marker, 1=Parent, 2=SC2, 3=SC3, 4=SC6, 5=SC7, 6=SC8, 7=SC11, 8=SC12, 9=SC13, 10=SC14, B= Blank



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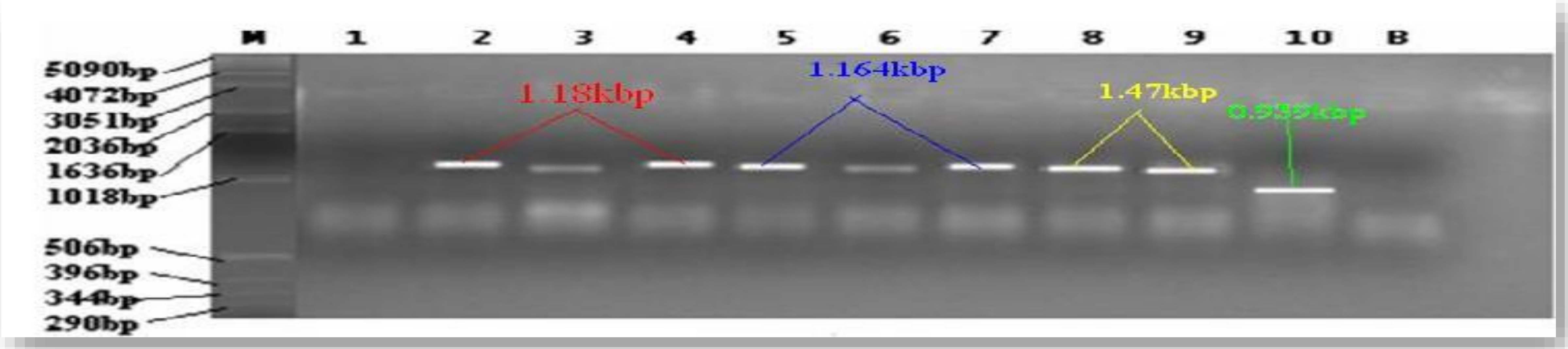
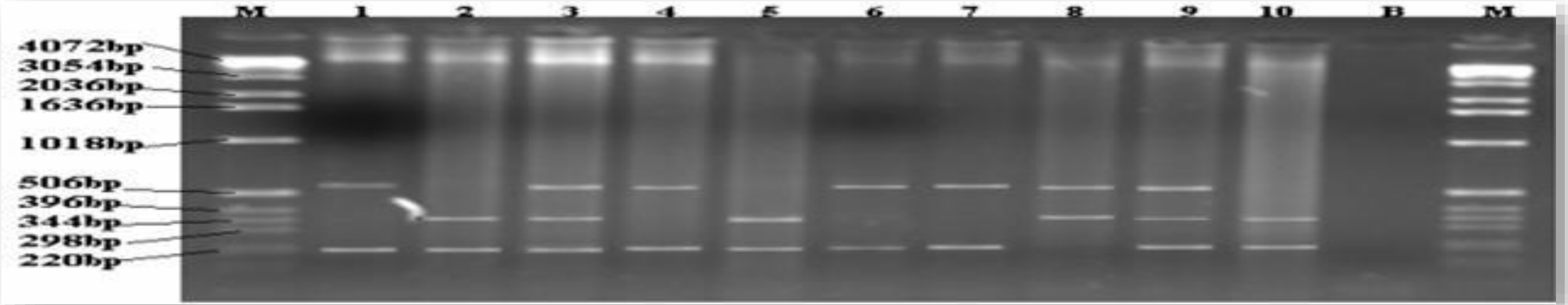


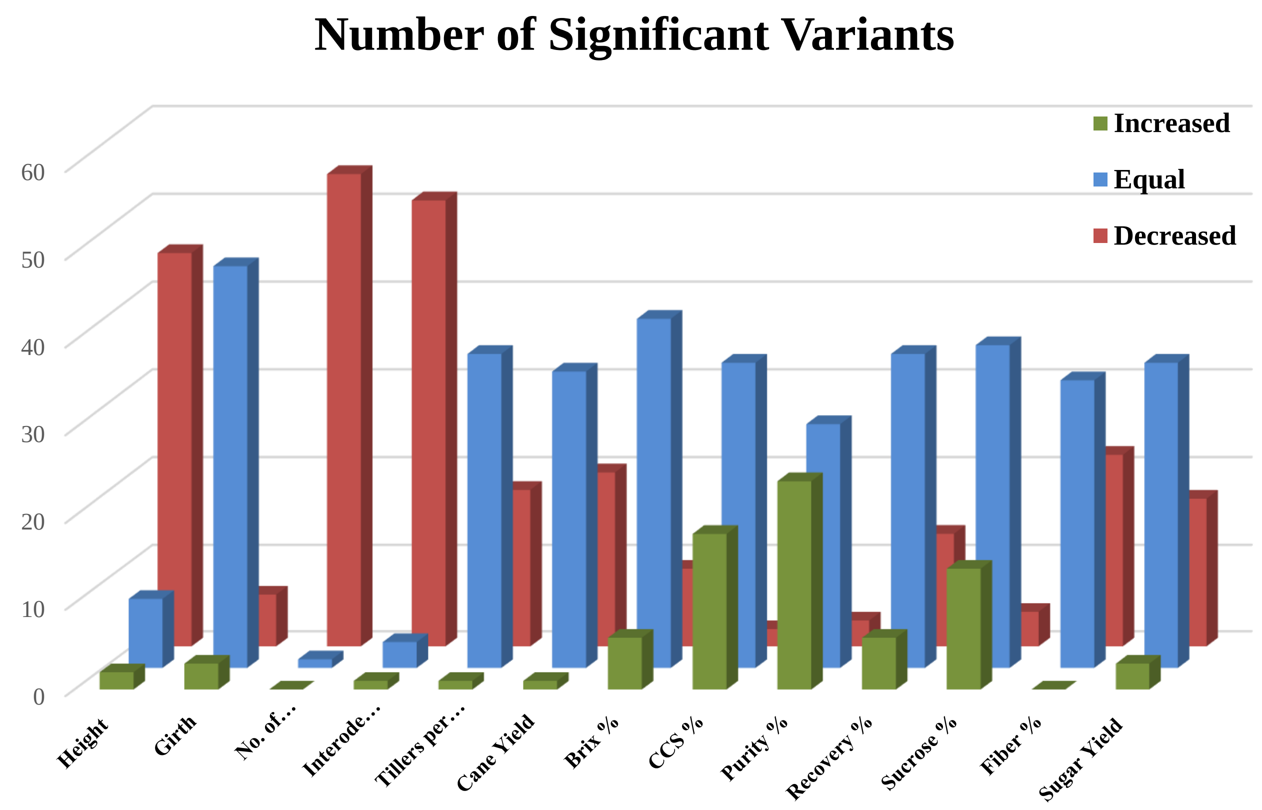
STS profile of sugarcane genotype using DREB sequence; M=DNA marker, 1=Parent, 2=SC2, 3=SC3, 4=SC6, 5=SC7, 6=SC8, 7=SC11, 8=SC12, 9=SC13, 10=SC14, B= Blank



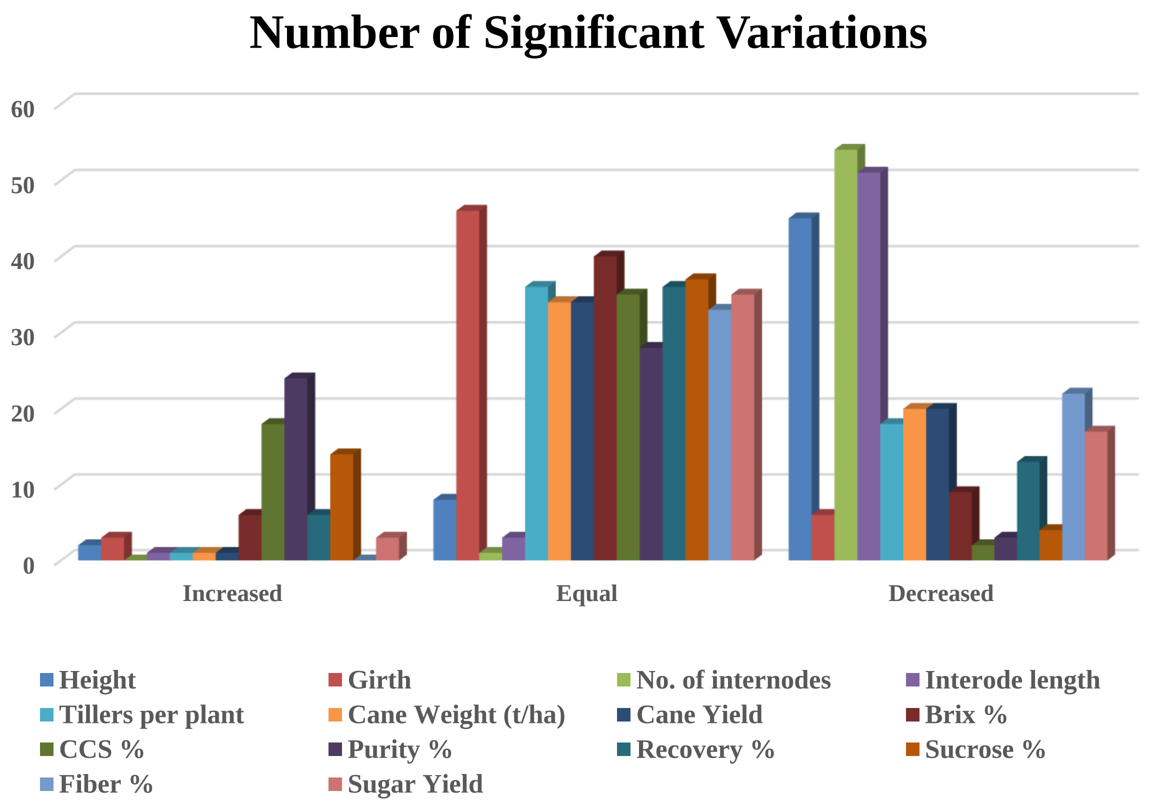
TRAP profile of sugarcane genotype using Sucrose Synthase; M=DNA marker, M=DNA marker, 1=Parent, 2=SC2, 3=SC3, 4=SC6, 5=SC7, 6=SC8, 7=SC11, 8=SC12, 9=SC13, 10=SC14, B= Blank

Range of Parameters of Tissue Culture Derived Somaclones against the Parent

Parameter	Parent	Range in Somaclones
Plant Height	303.67	95.2 - 385.7
Girth	2.43	2.0 - 3.3
Tillers per Plant	6.76	3.3 - 7.2
Number of Internodes	30.00	8.7 - 29.0
Internodes Length	15.89	4.7 - 19.1
Stool Weight	6.79	2.2 – 6.9
Cane Yield	66.96	24.3 - 71.2
CCS %	8.08	4.9 - 11.33
Brix%	16.01	12.8 – 21.6
Sucrose %	13.18	8.0 - 15.9
Fiber %	14.52	9.1 - 17.0
Purity	70.2	59.0 - 91.1
Sugar Recovery	8.12	5.1 - 11.9
Sugar Yield	4.63	3.0 – 6.89



Number of Significant Variants
Increased
Equal
Decreased
60
50
40
30
20
10
0
Height
Girth
No. of…
Interode…
Tillers per…
Cane Yield
Brix %
CCS %
Purity %
Recovery %
Sucrose %
Fiber %
Sugar Yield

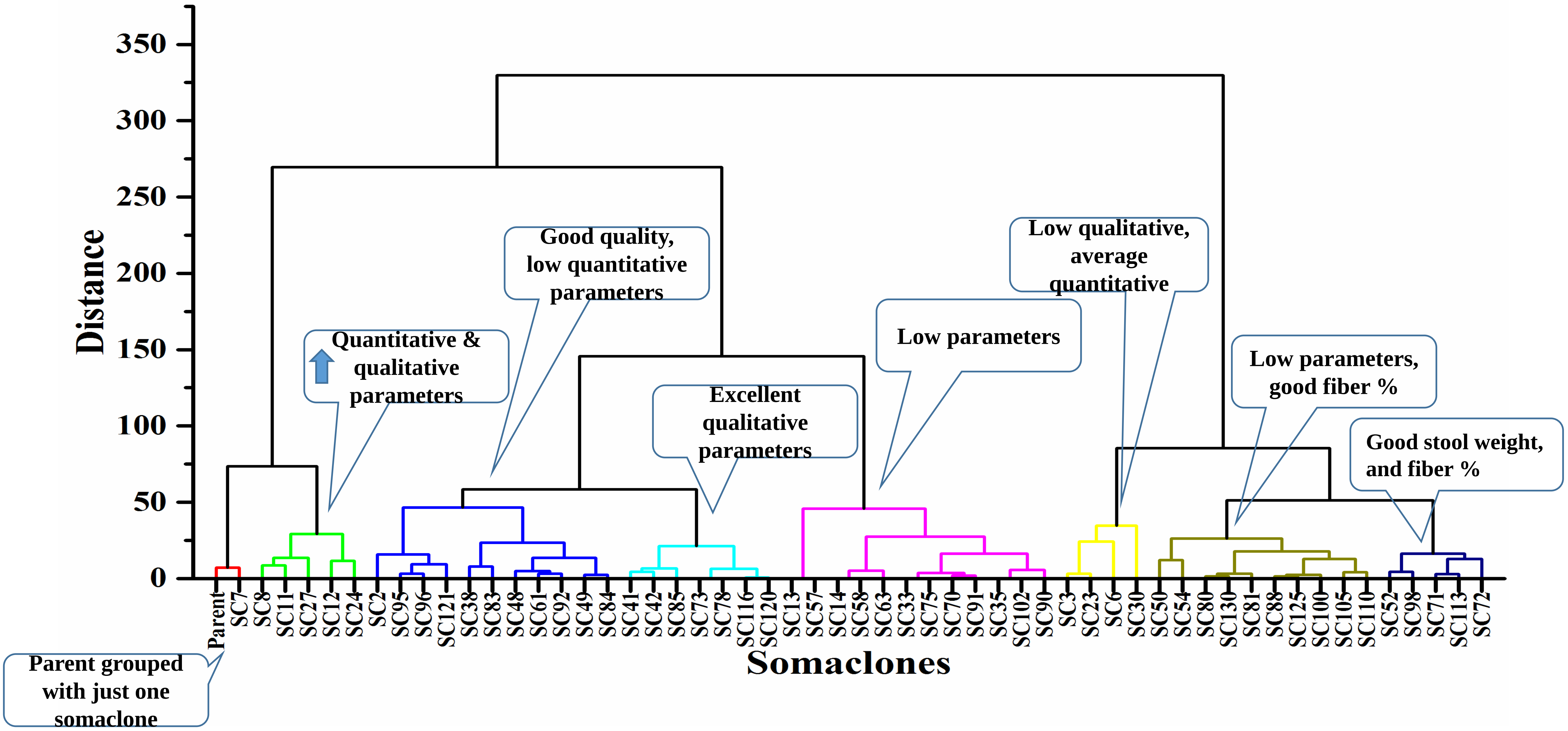


Number of Significant Variations
60
50
40
30
20
10
0
Increased
Equal
Decreased
Height
Girth
No. of internodes
Interode length
Tillers per plant
Cane Weight (t/ha)
Cane Yield
Brix %
CCS %
Purity %
Recovery %
Sucrose %
Fiber %
Sugar Yield

Pearson Correlation Analysis

	Height	Girth	Tillers per Plant	No. of Internodes	Internodes Length	Stool Weight	Cane Yield	CCS%	Brix %	Sucrose %	Fiber %	Purity	Sugar Recovery
Girth	0.342**												
Tillers per Plant	0.025	0.162											
No. of Internodes	0.704**	0.228	0.098										
Internodes Length	0.878**	0.279*	0.098	0.487*									
Stool Weight	0.287*	0.507**	0.604**	0.292*	0.228								
Cane Yield	0.287*	0.507**	0.604**	0.292*	0.227	1**							
CCS %	-0.243	-0.013	-0.230	-0.188	-0.111	-0.183	-0.183						
Brix %	0.003	0.294*	0.119	-0.065	0.150	0.146	0.146	0.784**					
Sucrose %	-0.1823	0.115	-0.066	-0.147	-0.043	-0.048	-0.048	0.958**	0.916**				
Fiber %	0.0451	0.147	0.412**	0.274*	-0.070	0.25	0.250	-0.436**	-0.183	-0.274*			
Purity	-0.362**	-0.297*	-0.422**	-0.143	-0.318*	-0.426**	-0.426**	0.757**	0.224	0.588**	-0.292*		
Sugar Recovery	-0.212	-0.010	-0.210	-0.135	-0.067	-0.157	-0.157	0.992**	0.788**	0.956**	-0.425**	0.744**	
Sugar Yield	0.364**	0.344**	0.347**	0.106	0.075	0.667**	0.667**	0.586**	0.665**	0.657**	-0.096	0.25	0.711**

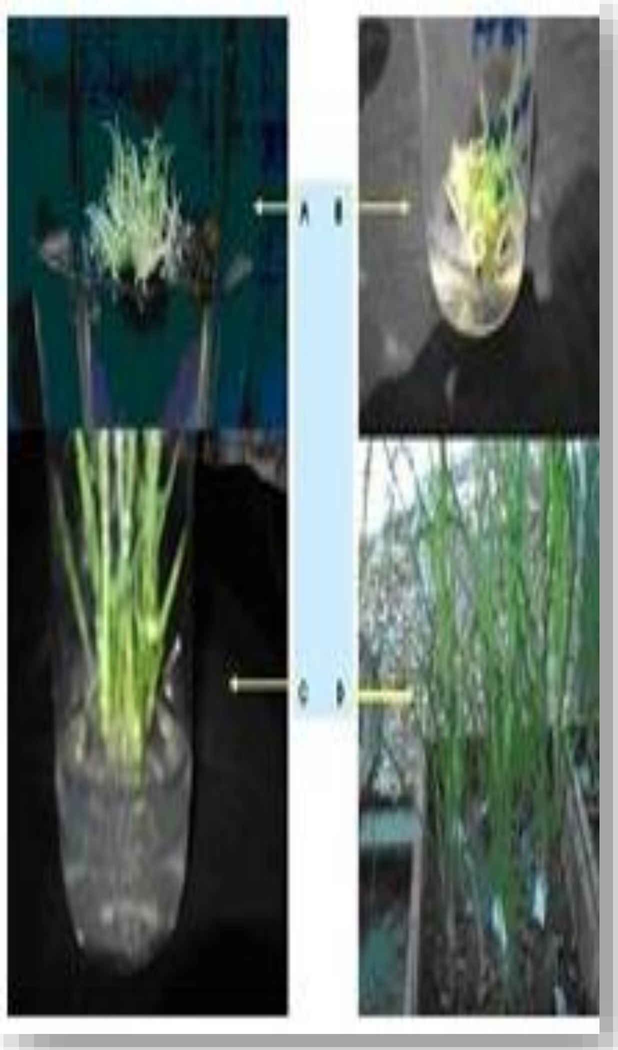
Cluster Analysis, Ward's Linkage



In vitro Culture Studies in Sugarcane

Callus Culture

Micropropagation



Direct Regeneration

Growth Room

Biotech. Lab

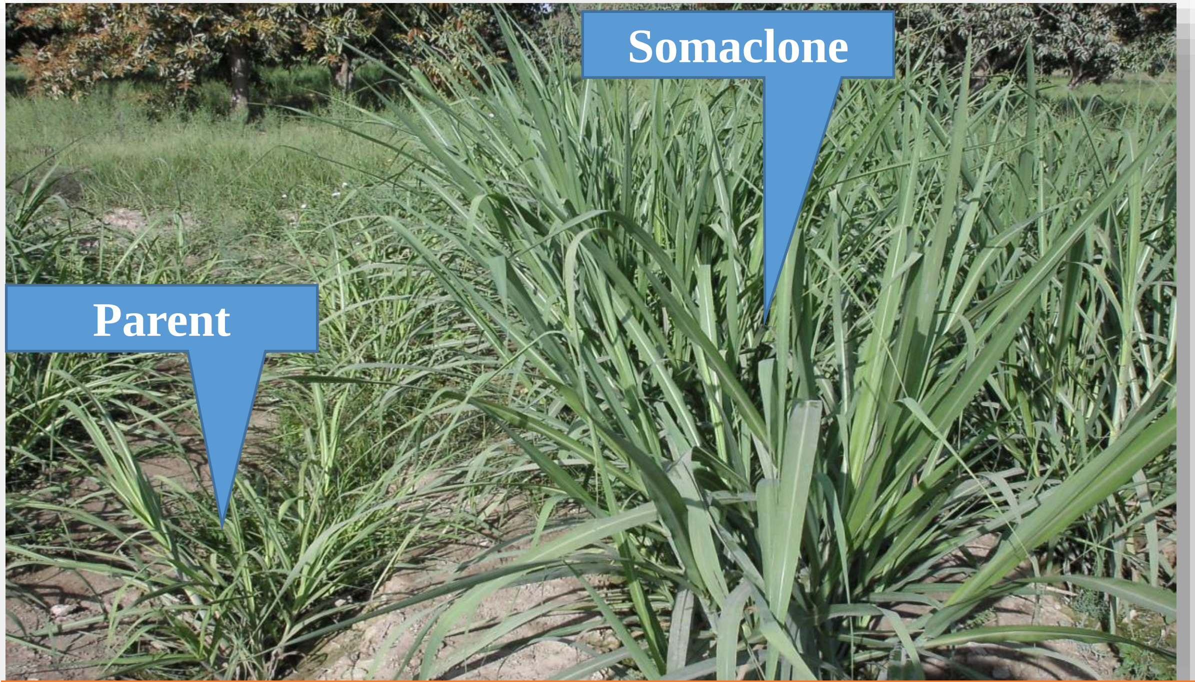
Tissue Cult. Lab

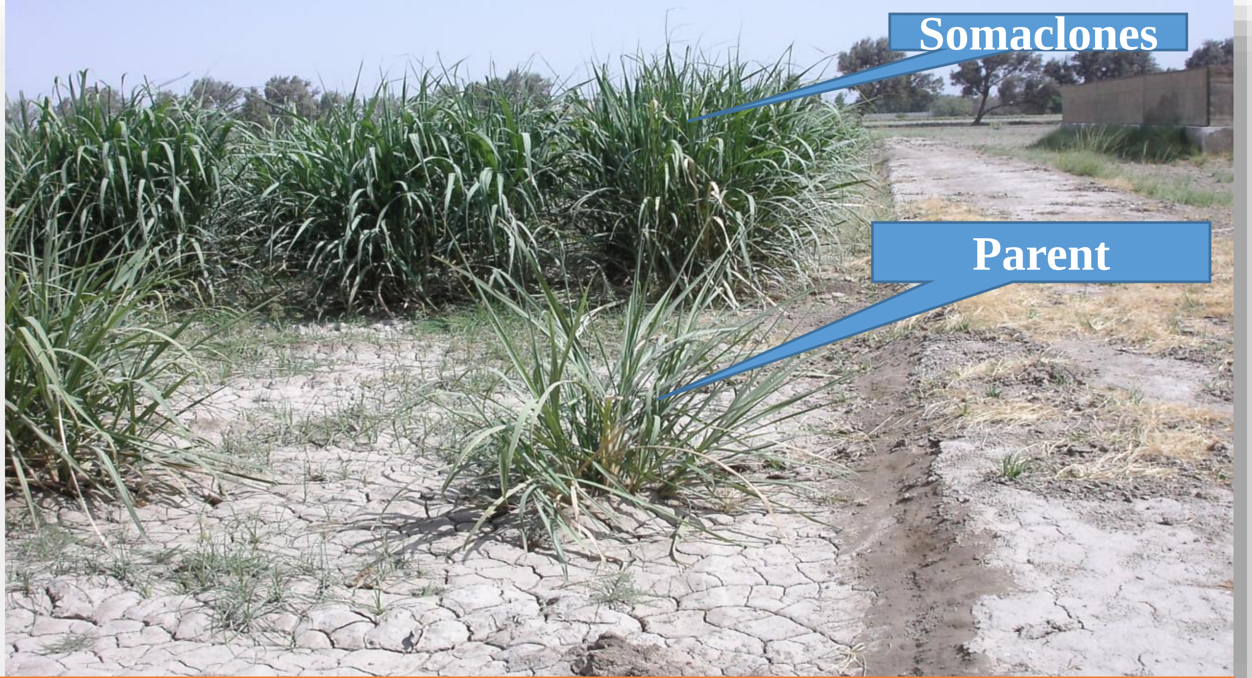
SUGARCANE BIOTECHNOLOGY GROUP, NIA

Biochemical Analysis Lab

Biotech. Lab

Molecular Analysis Facility





Sugarcane Fields, NIA

Sugarcane Improvement Against Climate Change

Stress Resistance

High Cane /Sugar Yield

Early Sugar Recovery

Erect Stand

The Global Goals 2030, UN Sustainable Development

Climate change effects sugarcane production

Solution lies in stress tolerant genotypes

Tissue culture technology can serve the purpose of getting genetic diversity in sugarcane

Stress tolerant varieties need to be adopted

Conclusions

Discussion

Thank You!

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