Abiotic Stress Management for Sustainable Agriculture

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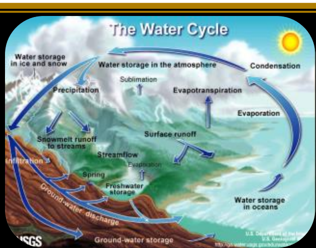
Outline

- Abiotic stresses at a glance
- Sustainable Agriculture
- Need for Abiotic Stress Management
- Abiotic stress research priorities
- Abiotic stress management strategies and options
- Summary

Abiotic Stresses



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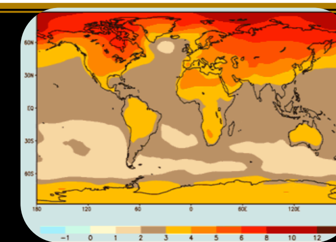


वातावरण पानी मिट्टी

अतिरिक्त या आवश्यकता से कम

Abiotic stress

Atmosphere Water Soil

Excess or Deficit; Low or high

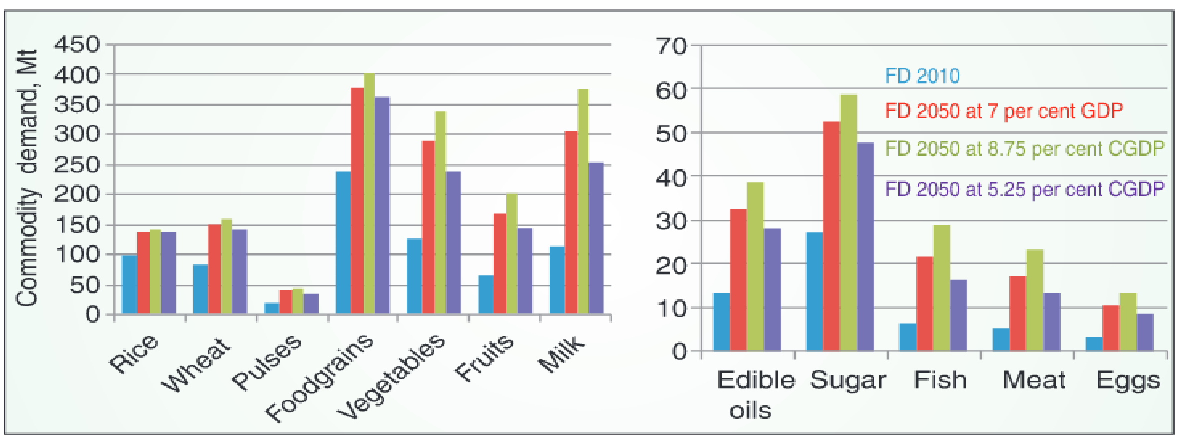
Sustainable Agriculture

- Definition:
  - "An integrated system of plant and animal production practices having a site-specific application that will last over the long term",
- to satisfy
  - human food and fiber needs
- to enhance
  - environmental quality and the natural resource base
- to make the most efficient use of
  - non-renewable and on-farm resources and integrate natural biological cycles and controls
- to sustain
  - the economic viability of farm operations,
- to enhance the quality of life for farmers and society

(From Wikipedia online)

Human food needs & food production

- Enhanced several folds since 1950 with the increase in population
  - Food grains by 5-fold, horticultural crops -6-fold, fish -12fold milk by 8-fold, and eggs by 27-fold
- Food production needs to be doubled by2050



Source: ICAR Vision 2050

Constraints for doubling the production to ensure food security

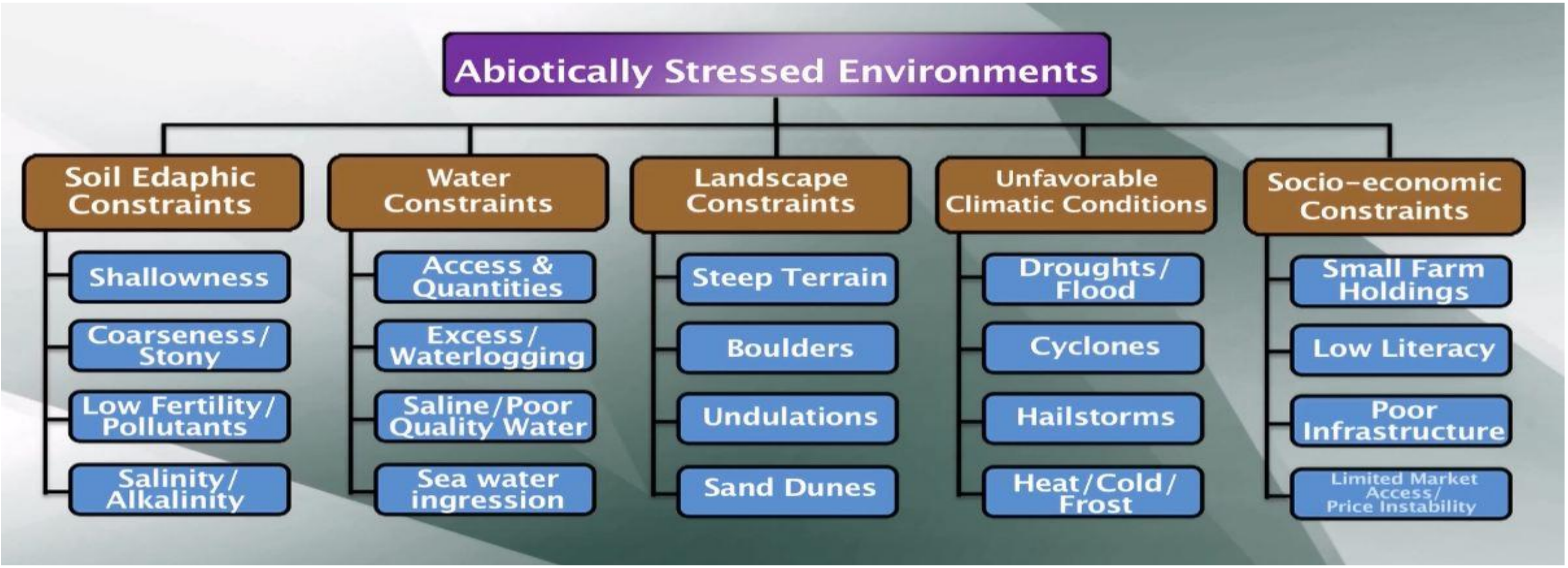
The food production needs to be doubled by 2050 with

Commodity	2009-10*	Projection for 2050*	Increase (times)
Cereals	196.4	358.7	1.8
Pulses	17.8	46.3	2.6
Foodgrains	214.2	405.0	1.9
Edible oils	15.7	39.0	2.5
Sugar	22.0	58.3	2.7
Vegetables	131.8	342.2	2.6
Fruits	71.2	305.3	4.3
Milk	111.5	401.4	3.6

*million tons

- no area expansion in agriculture
- declining productivity of land
- no/less impact on environment
- less water for agriculture due to
  - Population growth
  - Expansion of industries
  - Climate change

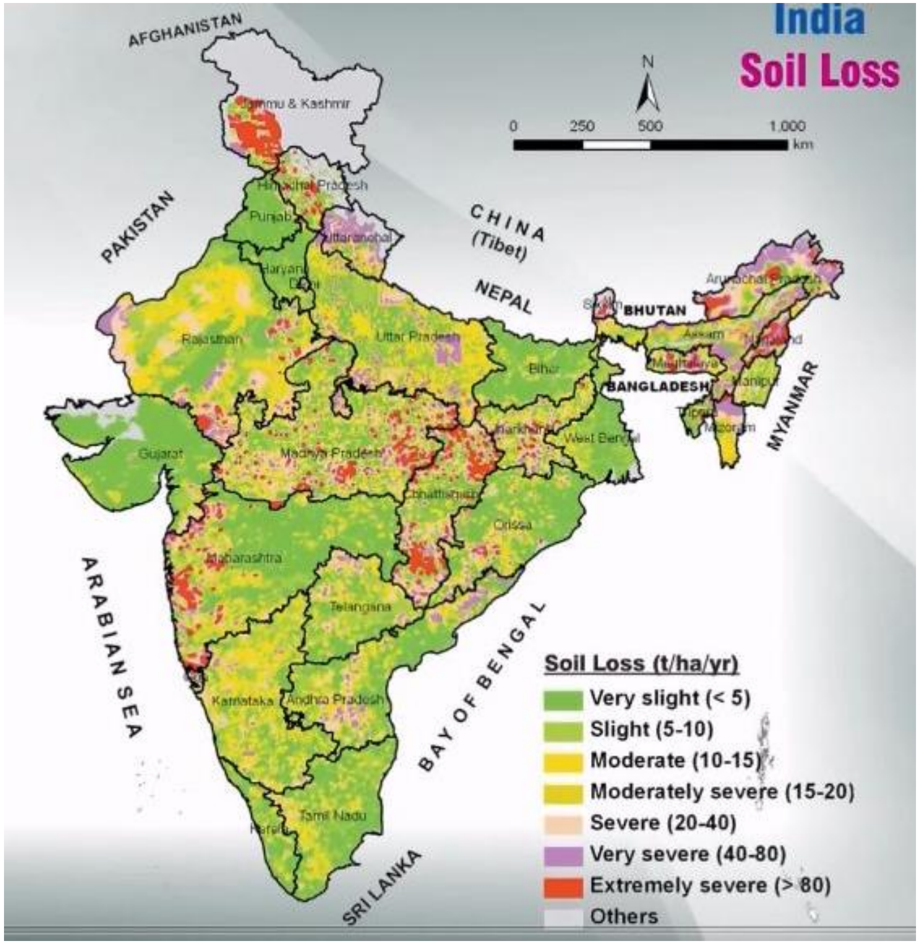
Abiotic stresses & magnitude of losses at Global level



Abiotic factors cause 50% yield losses

- high temperature (20%),
- salinity (10%),
- drought (8%),
- low temperature (7%),
- Others (5%)

Abiotic stresses & magnitude: Indian Context



- **Extreme Temperature**
  - Heat waves
  - Cold waves
- **Drought**
  - 68% of the cultivated area highly prone
  - Frequency per decade increased
- **Edaphic stresses**
  - Land degradation : 120.8 million ha (36.5 %)
  - soil erosion
  - salinity/alkalinity,- 8 million ha
  - soil acidity,
  - water logging

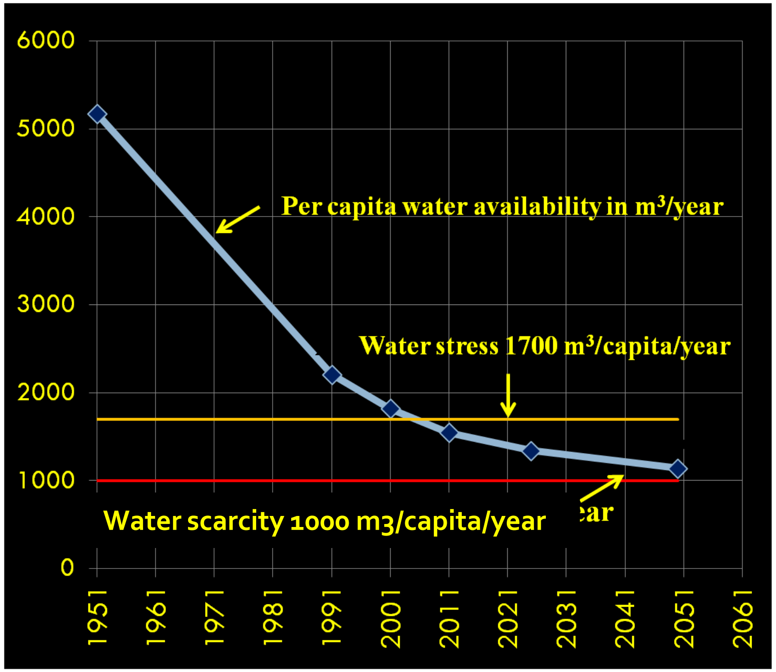
Resources for agriculture

Resources	Present	Projected 2050	Meeting food demands
Land (Cultivated, M ha)	141.4	142.6	4 fold productivity
Water (Irrigated, M ha)	62.0	88	3 fold productivity
Manpower (Workforce M)	244 (53.2%)	171 (27.2%)	6 fold increase in productivity
Energy (P Joules)	750	1520	Doubling the efficiency

Figures in parenthesis are for percent share of agriculture

Reducing per capita water availability (m³/capita/year)

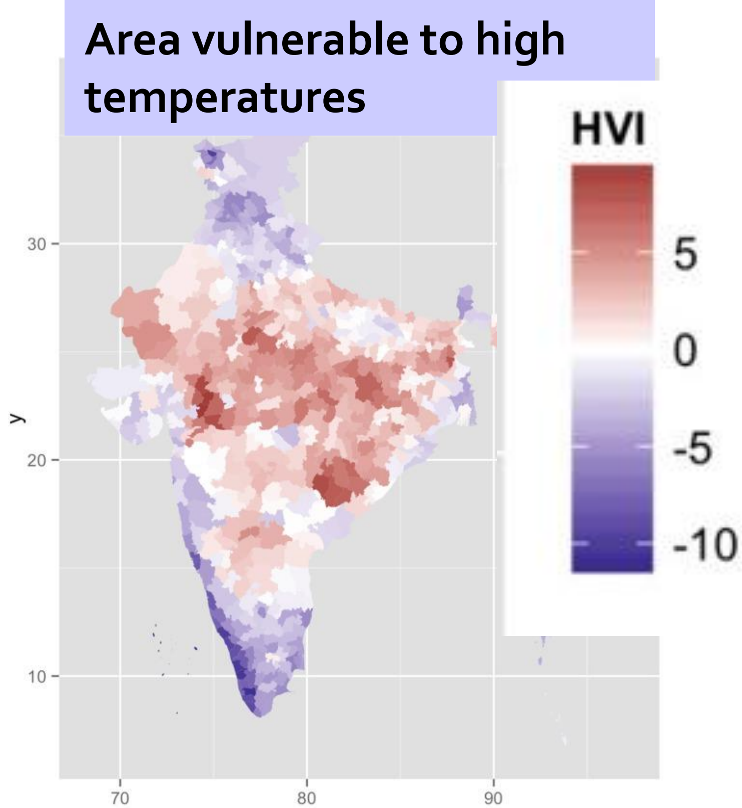
- Relative to 1951, Water availability will be reduced by 5 times by 2051
- At present the water availability is below water stress level (<1700 m³/capita/year)



Impact of high temperature

- 3-7% yield decline due to 1 °C increase temperature
  - wheat, soybean, mustard, groundnut and potato are expected (Agarwal 2009)
  - Initiation and formation, bulb and fruit size, qualities affected- in onion and tomato

➢Water Use Efficient Vegetable crops highly essential as more water lost due to enhanced evapo-transpiration

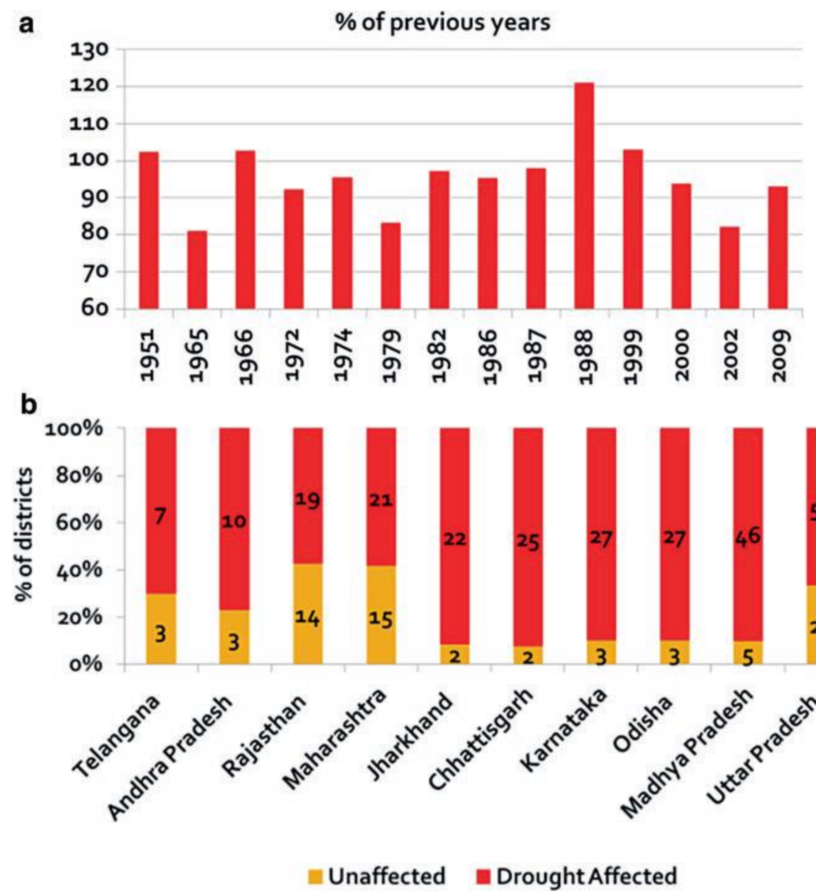


Int J Environ Res Public Health. 2017 Apr; 14(4): 357.

Drought

- Since Independence, India has experienced 15 droughts
  - 3 severe,
  - 7 moderate
  - 5 slight intensity
- 13.3–49.2% of total geographical area of the country (DAC 2009)
- In 2015–2016, > 40% of the area of 10 states - severely affected

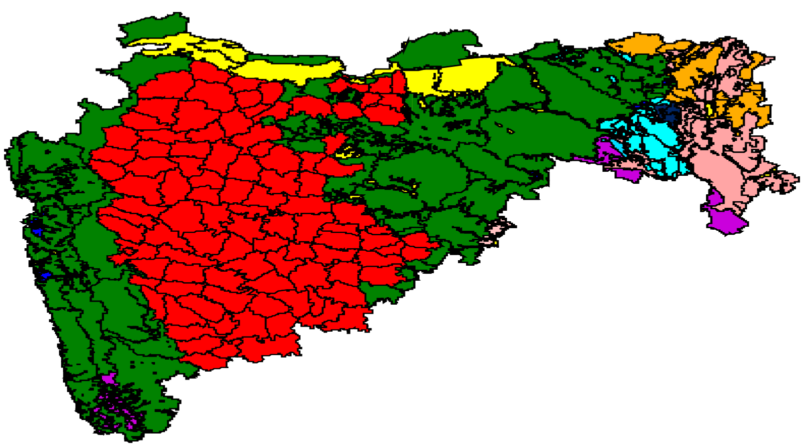
➢Fruit and Vegetable cultivation has to depend on recycled water
➢Sugarcane and cotton may have to depend on drip



(Reviewed byRane and Minhas, 2017)

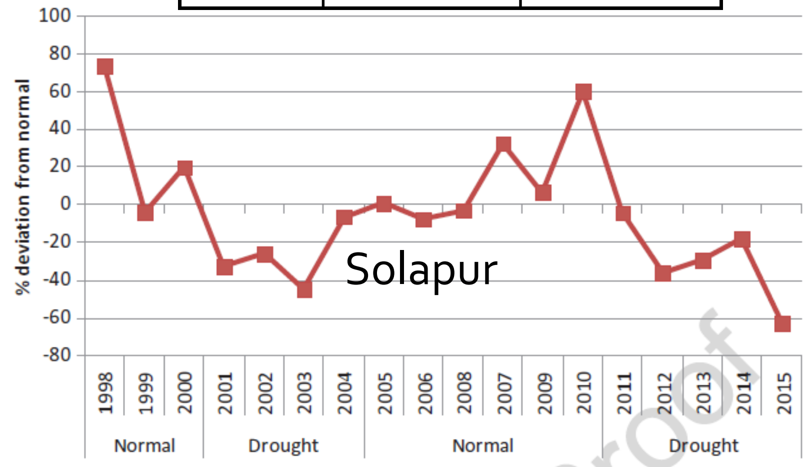
Drought Cycle

- In states like Maharashtra drought occurs after every 3 to 4 normal years
- Drought cycle based crop management is crucial



Drought Prone Areas

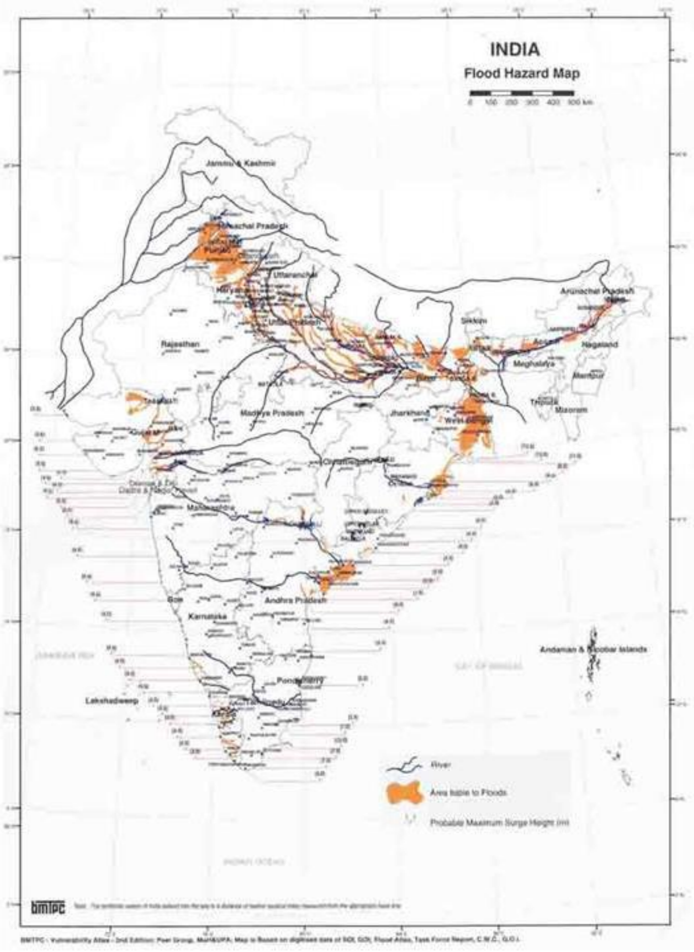
No. of Dists.	No. of Talukas	%
25	148	52



Reviewed by Rane and Minhas 2017

Vulnerability to flood

- Over 40 million hectares
  - (12 % land) is prone to floods and river erosion
- Covers major river basins



➤Waterlogging tolerant legumes and vegetables cultivars essential

NDMA Website

Edaphic stresses

- Micronutrient deficiency
  - Zinc(49%), boron (33%), molybdenum(13 %), iron(12%), manganese(5%), and copper(3%) (Sharma and Singh 2012).
- Shallow soils (26.4 million ha)
- Soil hardening (21.4 million ha)
- Low water-holding capacity(13.75 Million ha)

➢Warrants Location Specific Integrated Nutrient Management

Reviewed by Minhas 2017

Abiotic stress research priorities

- Enhanced clarity of target environments
- Identifying/developing adaptation options
- Mitigating stress
- Policy support
- Multidisciplinary and multi institutional Platform for research network

Sustainable agriculture :
to sustain the economic viability of farm operations

Abiotic Stress Management Options

to reduce losses and enhance farmers income

Abiotic stress management to reduce losses in agriculture

Options

Policies | Extension

Technologies

- Adaptation
  - Stress tolerant crop or commodity
  - Stress tolerant varieties Strains
- Mitigation
  - In season options Crop management
  - Resource Management Water Soil Consvn

Harnessing tolerance to stress: In crop plants and livestock

- Stress tolerant crops
  - Dragon fruit
- Stress tolerant cultivars of crops
  - High temperature and drought tolerant
  - Cold tolerant
  - Waterlogging tolerant
  - Salinity tolerant
- Stress tolerant livestock
  - Local land races
  - Small ruminants
  - Kadkanath -poultry

Dragon Fruit: Wonder crop for rocky barren lands and water scarce areas

- **Suitability:**
  - Potential to spread in unutilized area of degraded lands of Deccan region to improve the socio-economic status of farmers
- **Limitation:**
  - Initial investment of Rs 6.0-7.5 lakhs per ha.
- **Income Generation:**
  - Rs 3-4 lakhs/ha / year during 2nd and 3rd year
  - Rs. 8-9 lakhs/ha / year from 4th year onwards
- **Impact/ Transfer of technology:**
  - demonstrated within 2 years (2015 to 2017)
  - sold almost 30000 quality planting materials costing approximately ₹ 6. 5 Lakhs

Need scientific interventions:

- To manage fruit bearing

(Singh et al., 2017. NIASM Bulletin)

In season stress management

- Irrigation management
  - Water conservation technologies
  - Life saving irrigation
  - Water is the best cure for high temperature and also frost
- Plant bioregulators
  - Thiourea
  - KNO_3
  - Salicylic acid
  - Biostimulants

Every drop of water

राअस्ट्रैप्रसं
NIASM

saved and used efficiently contributes to sustainable agriculture

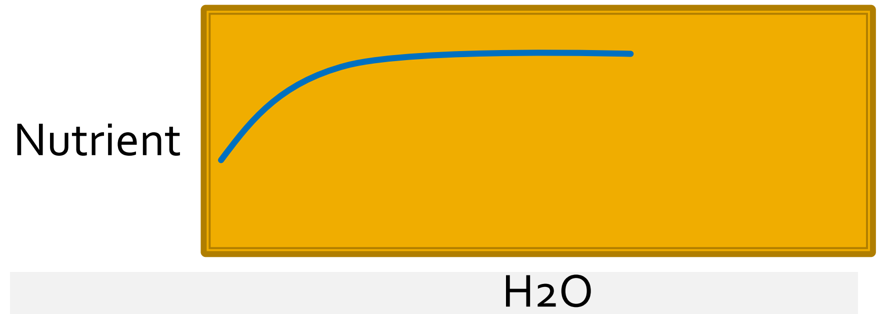
Rainfed area in India are thirsty and hungry

- **Nutrient deficiency**
  - 3622 soil samples from farmers' fields
  - Zn, Boron and Sulphur along with Nitrogen
  - 7 states
    - Andhra Pradesh, Rajasthan, Madhya Pradesh, Gujarat, Tamil Nadu, Kerala and Karnataka
    - 80-100% farmers fields
- **Effect of nutrient management**
  - Zn, B and S increased crop yields by 30 to 80%
  - Balanced fertilizer application increased crop yields upto 240% (Wani et al., -ICRISAT)

Optimum crop nutrition and use of plant bio regulators

- Plant nutrients and water are complementary
- Water productivity could be increased up to a certain level by increasing supply of water at given nutrient level or *vice-versa*
- Even higher water productivity with lesser quantity of water could be achieved

Karam et al. (2009)



Bioregulators and plant nutrient for alleviation of water stress in wheat

- 5.9 to 20.6 % high grain yield and h4.8–15.3% high biomass by
  - thiourea, salicylic acid, potassium nitrate, gibberellic acid and ortho-silicic acid.
- Water productivity -1.20–1.35 kg m^{-3}
  - against 1.18 kg m^{-3} without PBR at 19–56% lesser irrigation water
- PBR can save 25.2–49.7% of irrigation water
  - without yield penalty in sorghum

(Wakchaure et al., 2016b).

Comparative irrigation efficiencies under different method of irrigation

Irrigation efficiencies	Irrigation efficiencies (%)		
	Flood	Sprinkler	Drip
Conveyance	40-50 (canal); 60-70 (well)	100	100
Application	60-70	70-80	90
Overall	30-35	50-60	80-90

Rajput and Patel, 2015

Can biostimulants further increase the water use efficiency ?

Adaptation to less water scenarios: Water production functions-soybean

- Relative yield (RY) was 91.6, 83.8, 78.4, 70.3 and 62.4 % with Available water (AW) of 29.0, 25.9, 22.7, 19.9 and 17.2 cm as compared to 31.8 cm, respectively
- **The yield improvement with salicylic acid was 8-11 %**
- Wide variation in soil moisture pattern for 15, 30 and 45 cm soil depth was observed with application of irrigation water levels using line source sprinkler system

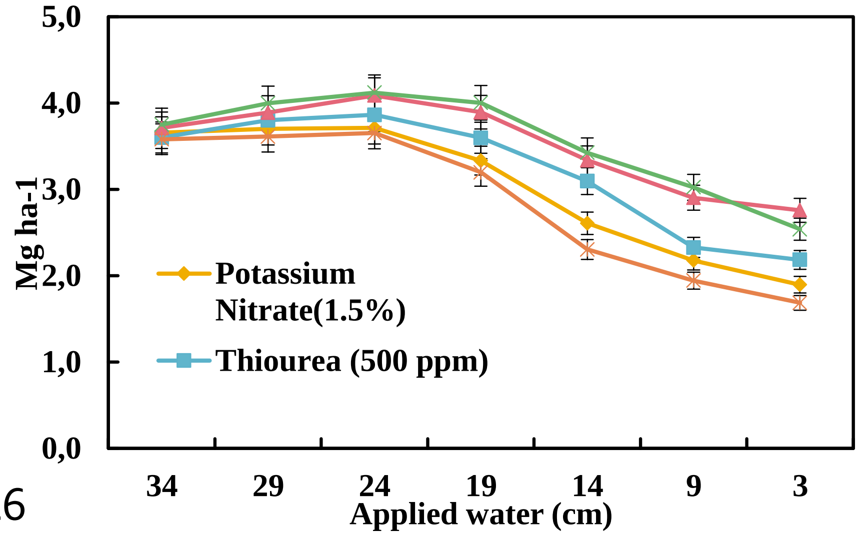
Adaptation to less water scenarios: Water production functions-Sorghum

- Yield was 94.2, 97.9, 92.2, 68.8 and 43.9% with Applied Water 34.1, 29.0, 18.8, 13.6, 8.5 and 3.4 cm as compared to 23.9 cm, respectively

- The yield improvement with salicylic acid and sodium benzoate were 18.7 & 19.6 per cent, respectively

Wackchaure et al., 2016

Salicylic acid (10 μM)



Effect of Vigore (Bioformulation) on Wheat

Multi-purpose Machine for Ratoon Sugarcane: Can help conserve water + other benefits

Challenges in ratoon sugarcane:

- High load (10-15 t ha^{-1}) of trash
- Higher tiller mortality
- Low NUE and reduced productivity

to address these issues**, a multi-purpose machine has been developed and demonstrated at farmers fields**

Trash Burning is a common practice results in:

- Loss of organic carbon
- GHGs emission
- Environmental pollution

SORF machine can perform - **Stubble shaving**, **off-baring**, **root pruning** and **band placement of fertilizers** in soil while retaining the trash

Benefits of using SORF Machine

- Ratoon cane yield increased up to **30 %**
- Net profit increased up to **₹ 50,000/ ha**
- Water productivity increased up to **39 %**
- NUE improved up to **13 %**

Farmers benefitted-14,000

Deficit Irrigation as an option for tomato under edaphic challenges

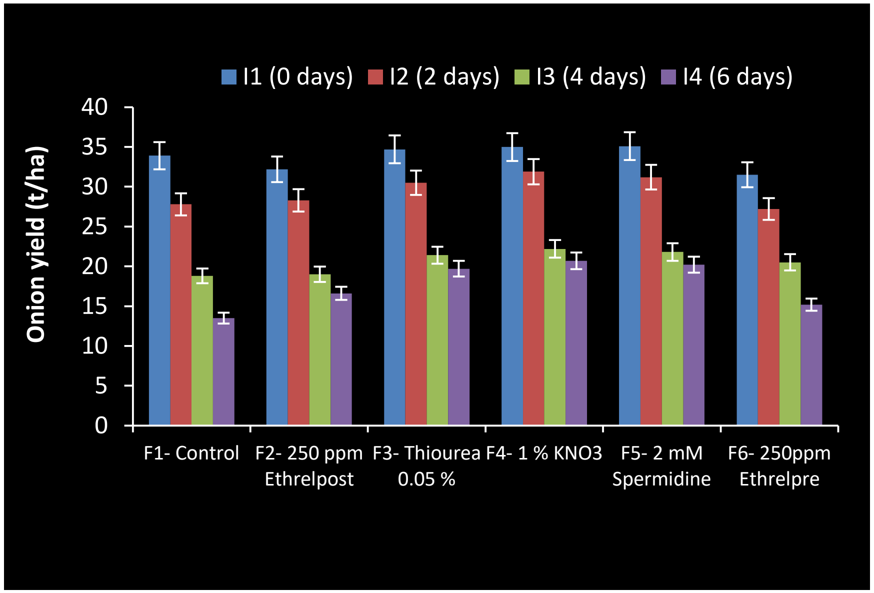
- Regulated deficit irrigation ($RDI_{0.8}$ i.e 0.8ETc)
  - ✓ No significant effect on yield
  - ✓ =Full Irrigation 78.0 Mg ha^{-1}).
- $RDI_{0.6}$ at flowering stage reduces yield(by 7%) but not at vegetative stage
- The crop was able to tolerate interruptions of irrigation for 15 days at early growth stage (only 3-7% decline in yield)

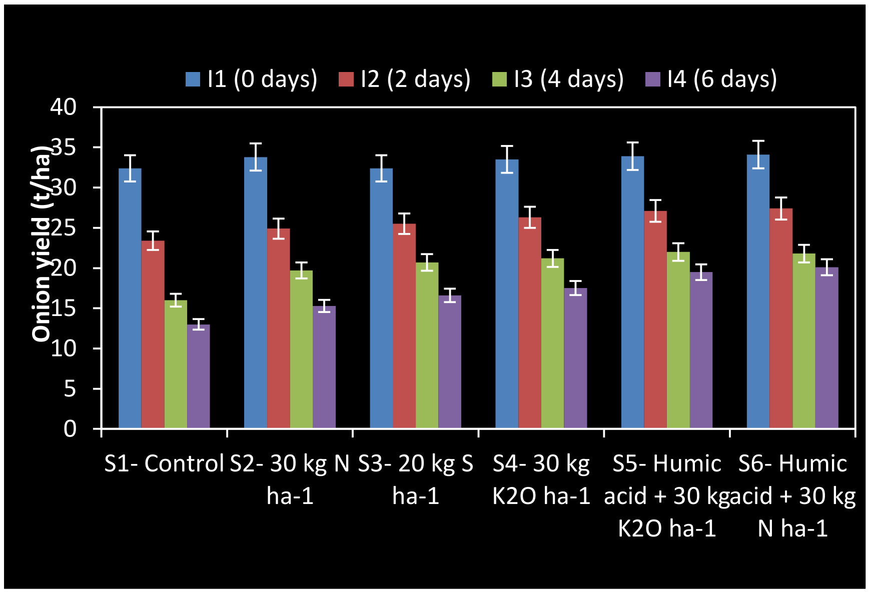
Nangare et al, 2016

Effect of bioregulators on waterlogging tolerance in onion

6 days Ponding				
4 days Ponding				
0 days ponding (No Ponding)				
	1% KNO3	2 mM Spermidine	0.05% Thiourea	Control

Impact of bio-regulators and nutrients in alleviating intermittent waterlogging stress in onion

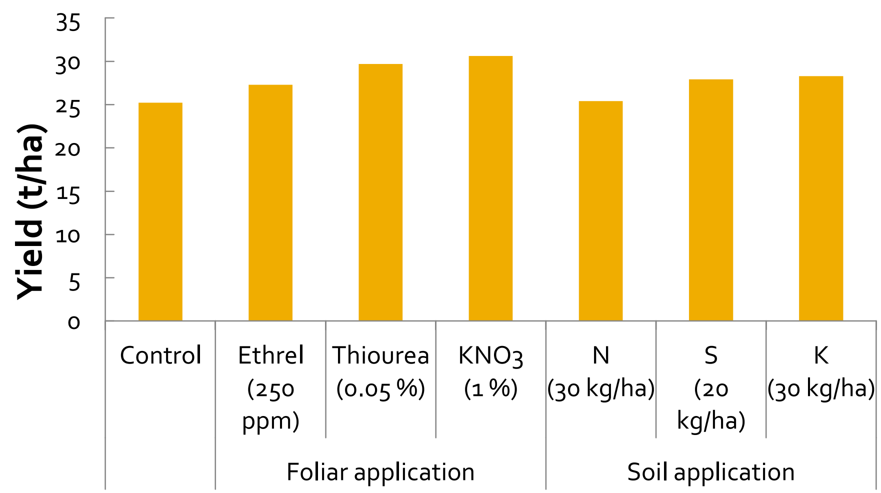




Foliar application of KNO_3, spermidine and thiourea reduce yield losses in onion

Bio-regulators and nutrients for alleviating water logging stress in onion

Foliar application of Thiourea and KNO_3 alleviate waterlogging stress



Effect of sea weed extract on tomato

			
0.4 ET	0.6 ET	0.4 ET + Sea weed extract foliar spray twice	0.8 ET

3 foliar spray (prior to flowering and after flowering i.e. 30, 45 & 60 Days After Planting)of Sea weed extract @ 2ml(Megafol)/litre produced yield comparable to 0.6 ET resulted in 26.8 % higher water productivity.

Pomegranate: drought tolerant crop need management to save orchard

Consequence of abiotic stresses need attention

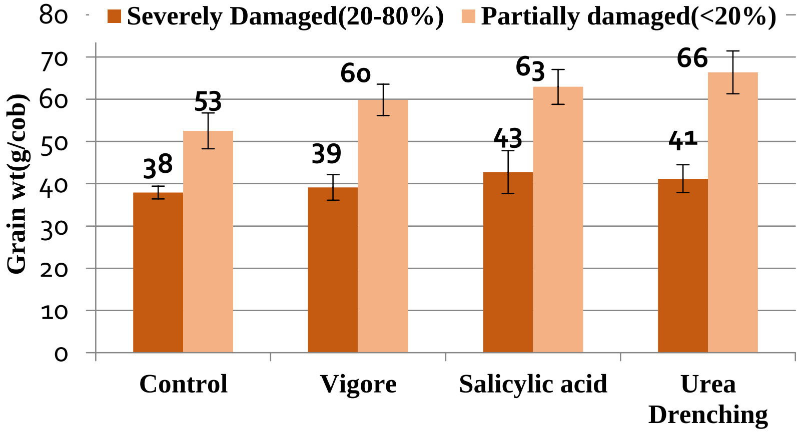
Aril browning

Fruit cracking

Effect of bio-regulators:
in maize damaged by Hailstorm

- Grain weight of cobs increased due to salicylic acid and urea when damage to cob was < 20 %

- No recovery when damage >20%



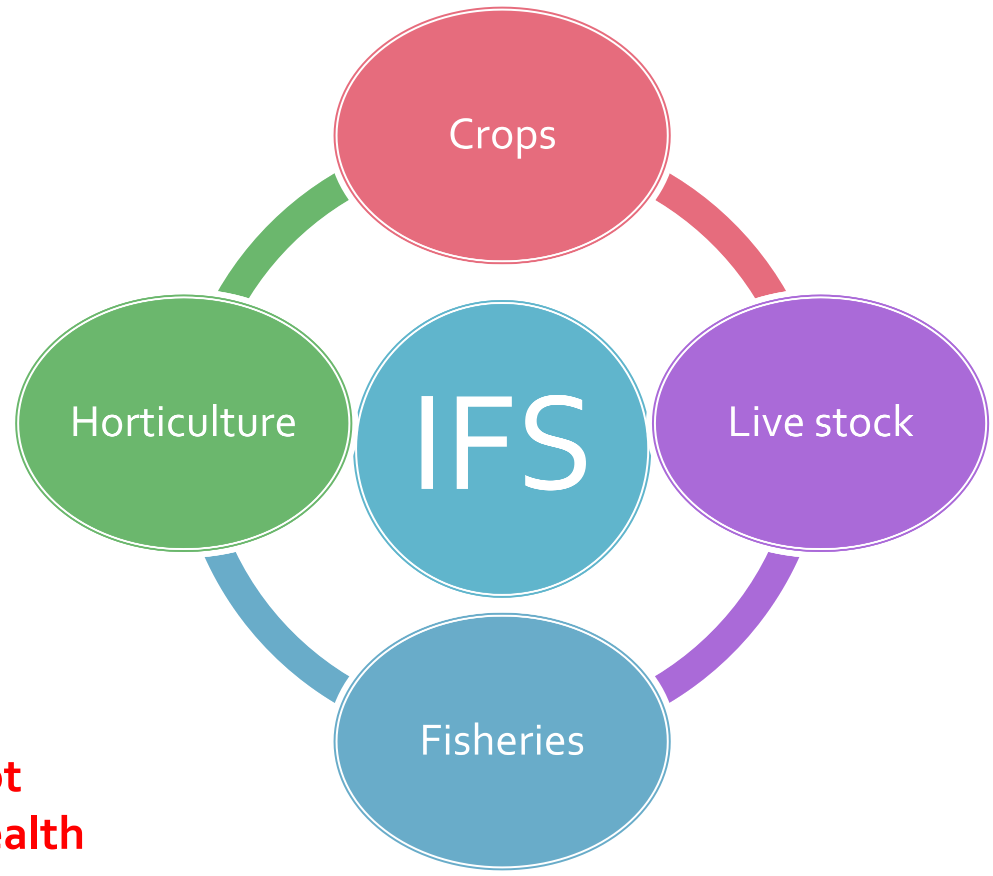
Effect of bio-regulators in Pomegranate damage caused by Hailstorm

- Effect of hailstorm
  - Totally defoliated,
  - Broken twigs
  - Flowers and fruits withered
- Post disaster management for recovery with biostimulants
  - Copper oxychloride was sprayed the day after hailstorm to prevent secondary infection
  - Treated with cytozyme product (100 ppm), vigore (0.1%), thiourea (0.02%), potassium nitrate (2%), hydrogen cyanamide (0.02%), silixol (4 ml l^{-1}), C7 (bio-formulation which can prevent fungal infection and stimulate the growth).

Pomegranate orchard on the day(a) and 26 days after(b) hailstorm

Location specific Integrated Farming System

- Sustainable agriculture to make the most efficient use of
  - non-renewable and on-farm resources and integrate natural biological cycles and controls



The approach demands plant bioreglators/stimulant that can not compromise with food safety & health of both human and livestock

Take to home message

- Enhabced versions of atmospheric, water related and edaphic stresses can affect cultivation of crops due to climate change
- Mitigation and adaptation options for management of abiotic stresses essential
- Insight into stress tolerance mechanisms can help in genetic improvement for adaptation
- Penalty on crop yield due to water saving can be addressed through plant bioregulators/biostimulants
- Promising bioregulators/stimulants and techniques to identify them can provide stress mitigation options
- Demonstrated technologies should reach farmers

Acknowledgement

- Valagro
- NIASM