Assessment and management of extreme weather events (moisture and thermal regimes) on agricultural crops – Examples of a few case studies

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Among the weather parameters, rainfall and temperature fluctuations always affect the crop growth and development

Extreme weather events in respect of moisture and thermal regimes result in floods or severe droughts during kharif (Rainy) season and thermal stress resulting in stunted growth or frost damage in winter (rabi) season

Flood occurrence is instantaneous while drought is a creeping effect. With some assessment of the drought occurrence with climatological and medium range weather forecasting techniques, drought can well be managed.

In view of this the agricultural drought assessment and management techniques that are developed in India are highlighted

Historical drought analysis – All India

- All India droughts during past 200 years

Period	Drought years	No. of years
1801-25	1801,04,06,12,19,25	6
1826-50	1832,33,37	3
1851-75	1853,60,62,66,68,73	6
1876-1900	1877*+,91,99*+	3
1901-25	1901*,04,05*,07,11,13,15,18*+,20,25	10
1926-50	1939,41*	2
1951-75	1951,65*,66,68,72*+,74	6
1976-02	1979*,82,85,87*+,2002	5

*Severe drought years = 10 (>39.5% area affected)
+Phenomenal drought years = 5 (>49.5% area)

Source: Kulshrestha

Impacts of drought

Environmental

- Moisture stress
- Drinking water shortage
- Degradation of resources
- Increased pollution (both air and water)

Societal

Economic

- Fall in Ag. Production
- Reduced income
- Loss of livestock
- Fall in output
- Unemployment
- Shortage of essential goods

Social

- Malnutrition
- Ill-health
- Migration
- Debts

There are several specificities in Agricultural droughts like

- Soil texture (water holding capacity)
- Topography (Effective rainfall)
- Crop and crop variety (drought tolerance)

Crop stage (Water need)

And also

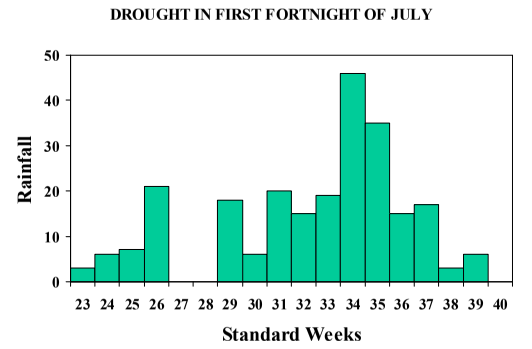
- Socio-Economic conditions (investment capacity)

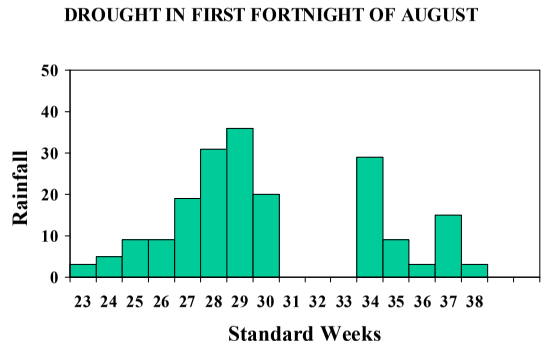
Types of Agricultural Droughts

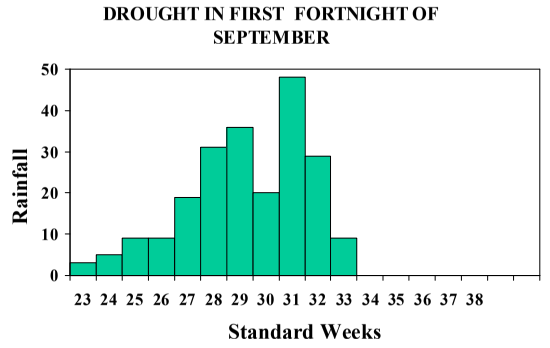
Early season: Delayed onset, prolonged dry spells after onset

Mid-season: Inadequate soil moisture between two rain events

Late season: Early cessation of rains or insufficient rains







(Source: Ramakrishna Y.S., CRIDA, Hyderabad)

Assessment of agricultural drought

Agricultural drought as mentioned has many specificities and the main requirement for assessing the agricultural drought is

moisture availability and its requirement at different growth stages of different crops.

One important index to assess the moisture requirement at different growth stages is the Moisture Adequacy Index (Ima) or AE/PE

Depending upon the requirement of Ima (AE/PE) at different growth stages of a given crop the drought and its impact is assessed

Some examples of assessing the impact of drought on crops are illustrated here

Impact of Agricultural Drought on rice productivity in Raipur district of Chhattisgarh state

Rainfed direct seeded rice under biasi system of cultivation

In eastern India in general and Chhattisgarh in particular rice is grown under direct seeded biasi system in more than 3 million hectares.



Biasi operation

Some assumptions for assessing the impact of drought on rainfed rice crop

The requirement of Ima at different growth stages is

Seedling	75 per cent
Vegetative	100 per cent
Reproductive	100 per cent
Maturity	75 per cent

Ima was computer through Thornthwaite's water balance techniques modified for bunded rice fields

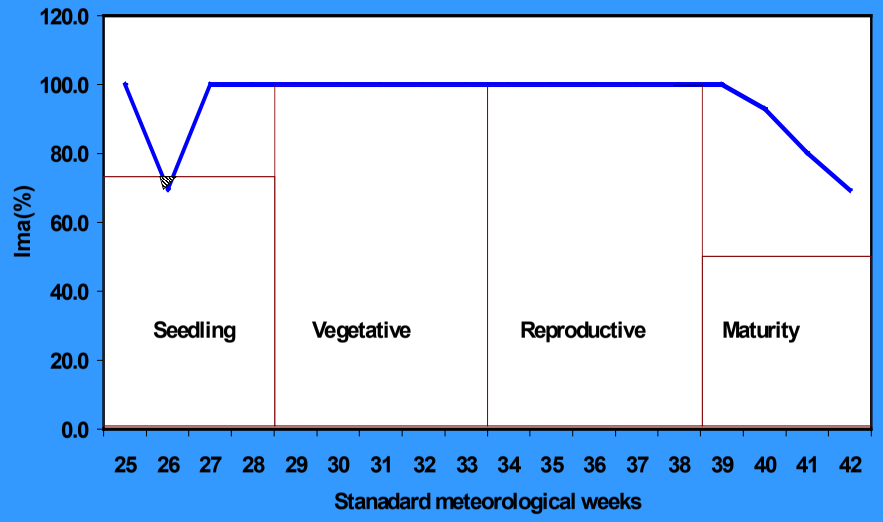
Assessment must be made with and without drought in consecutive years in order to avoid technological influence

Drought at Seedling Stage

Agricultural drought impact on Rice Productivity

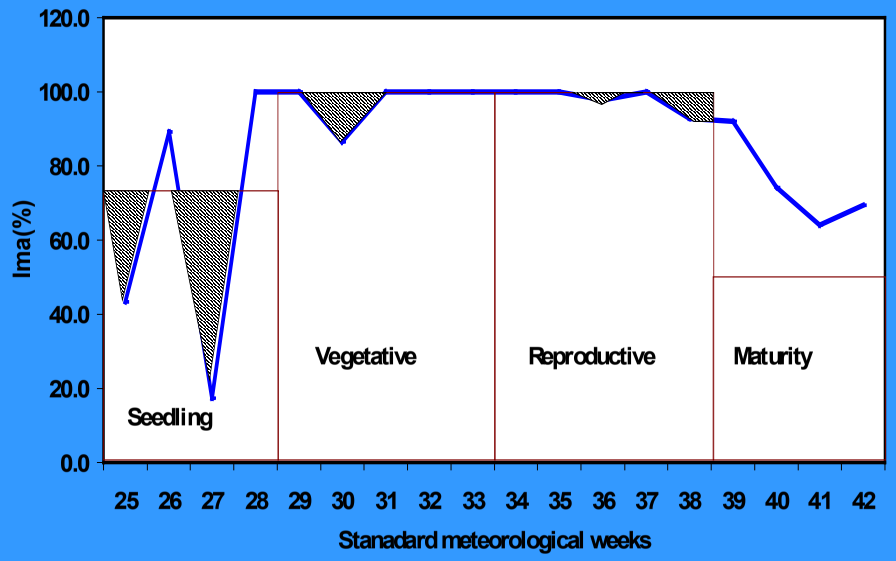
1981 and 1982

1981



(990 kg/ha)

1982



(772 kg/ha)

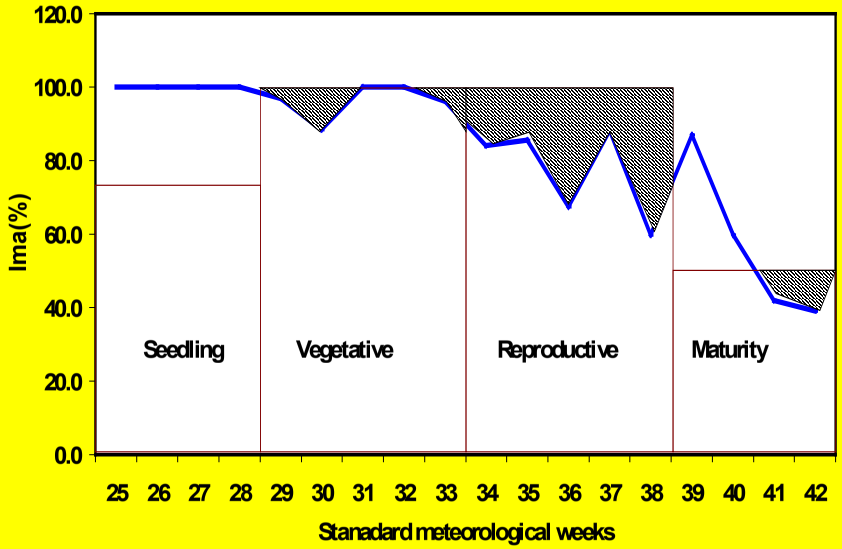
A decrease of 22%

Drought at Reproductive Stage

Agricultural drought impact on Rice Productivity

1979 and 1980

1979

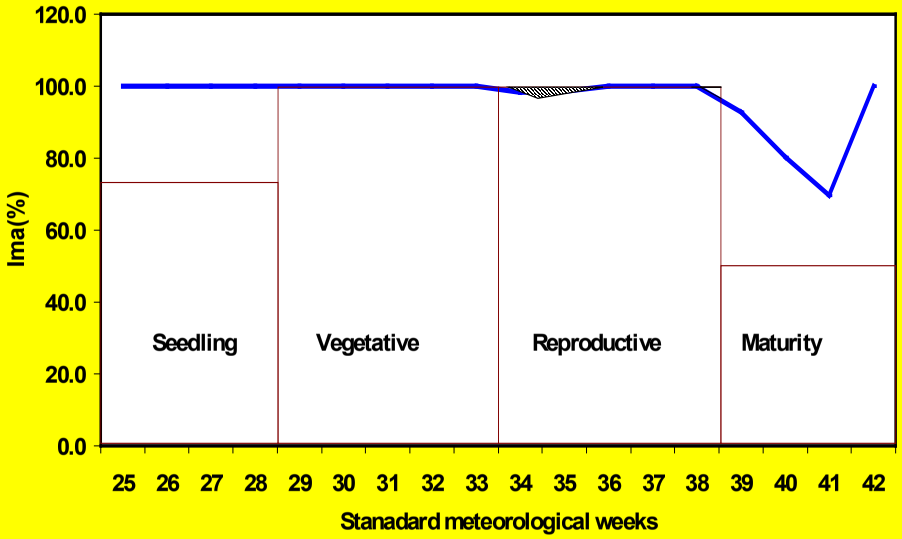


(892 kg/ha)

(549 kg/ha)

A decrease of 38.4%

1980

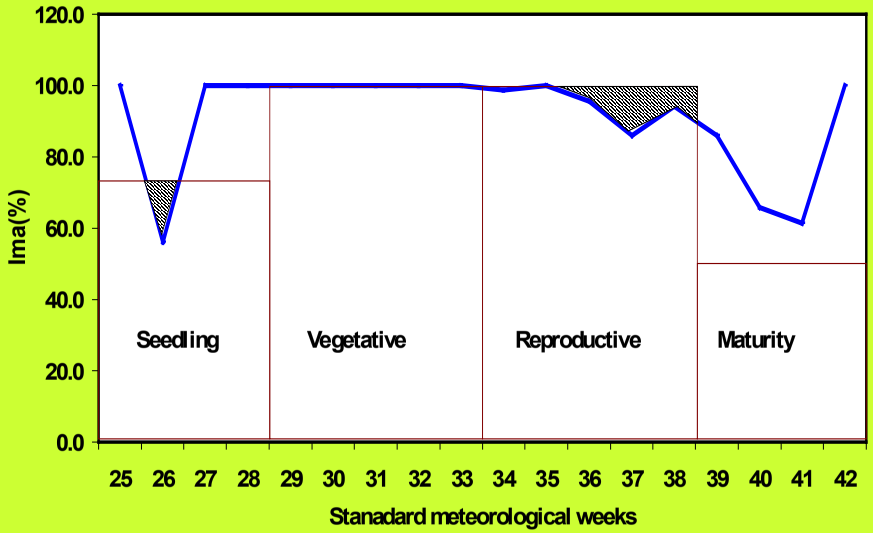


Relative impact of drought at seedling stage as compared to reproductive stage

Agricultural drought impact on Rice productivity

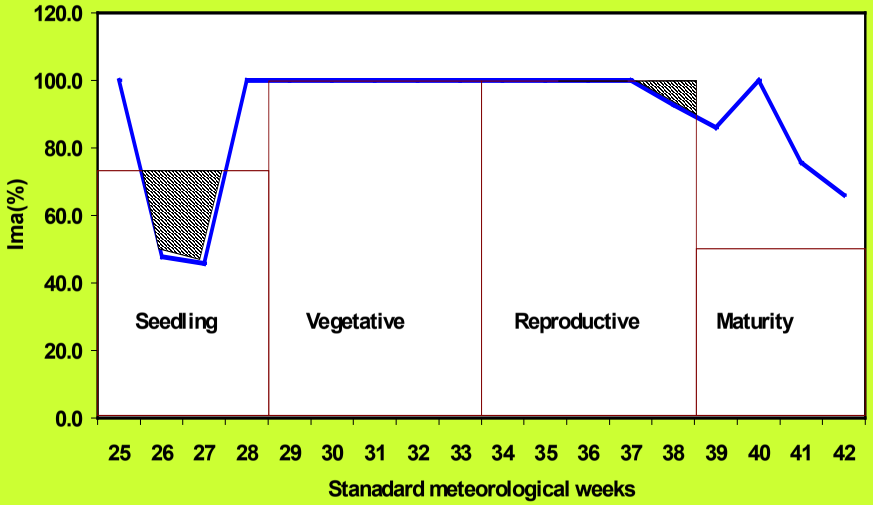
1995 and 1996

1995



(1524 kg/ha)

1996



(1304 kg/ha)

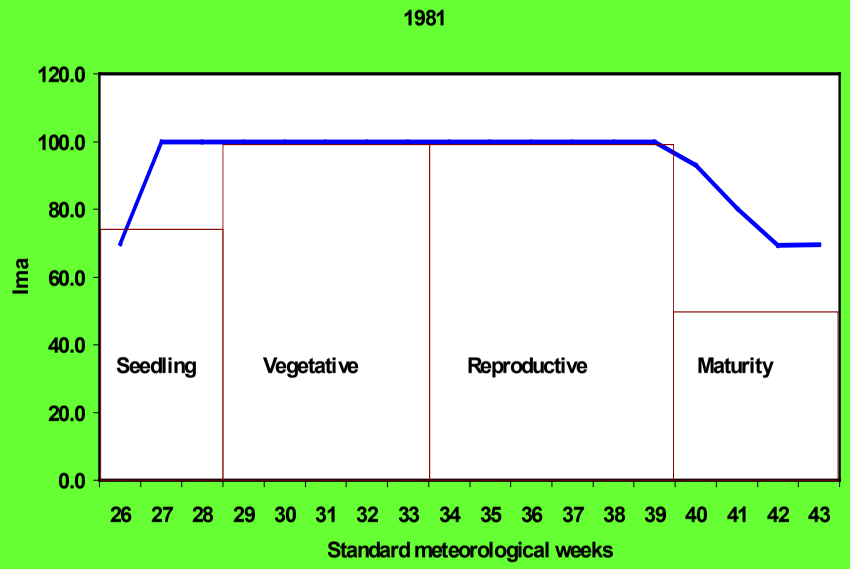
A decrease of 14.4%

Impact of Agricultural Drought on soybean productivity

Drought at Seedling stage

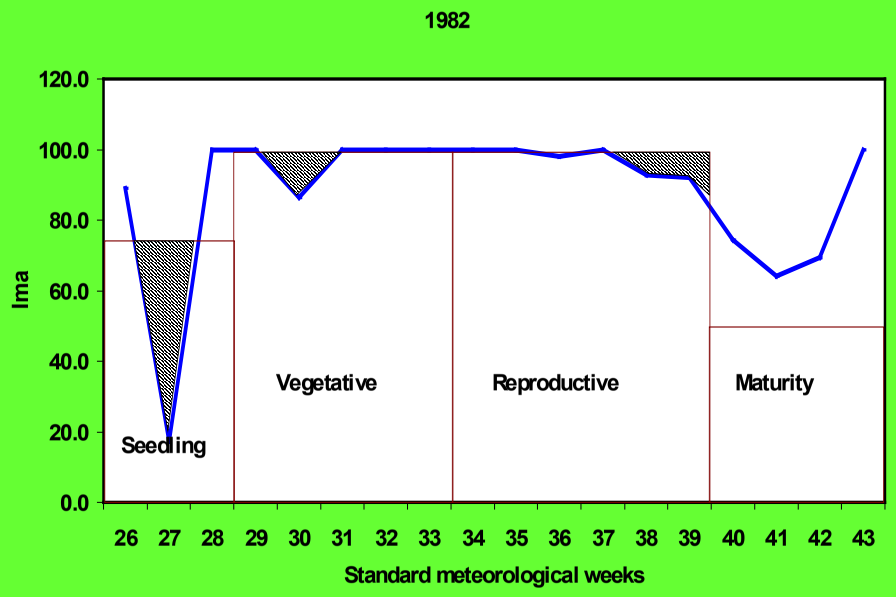
Agricultural drought impact on Soybean productivity

(1981 and 1982)



(714 kg/ha)

(620 kg/ha)

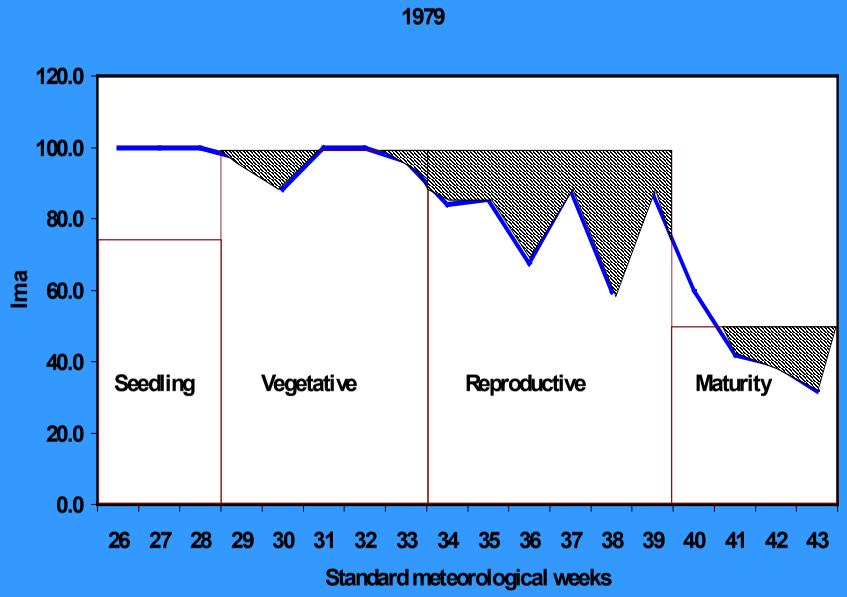


A decrease of 13.2%

Impact of drought at reproductive stage

Agricultural drought impact on Soybean productivity

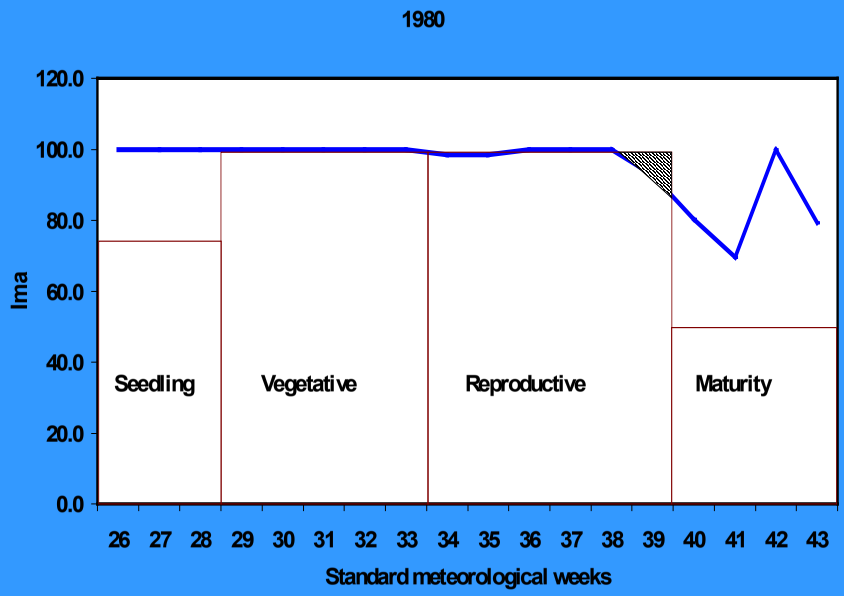
(1979 and 1980)



(389 kg/ha)

(159 kg/ha)

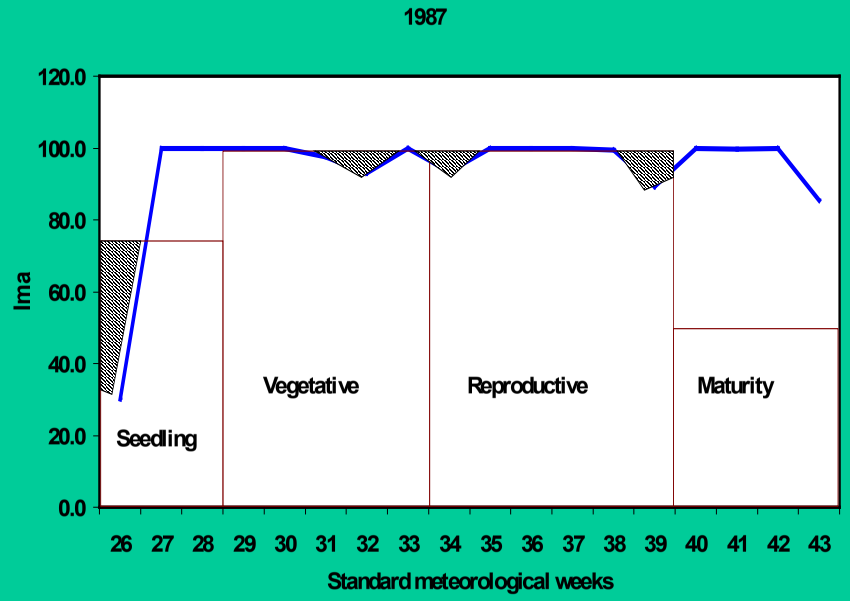
A decrease of 59%



Relative impact of drought at seedling stage as compared to vegetative stage

Agricultural drought impact on Soybean productivity

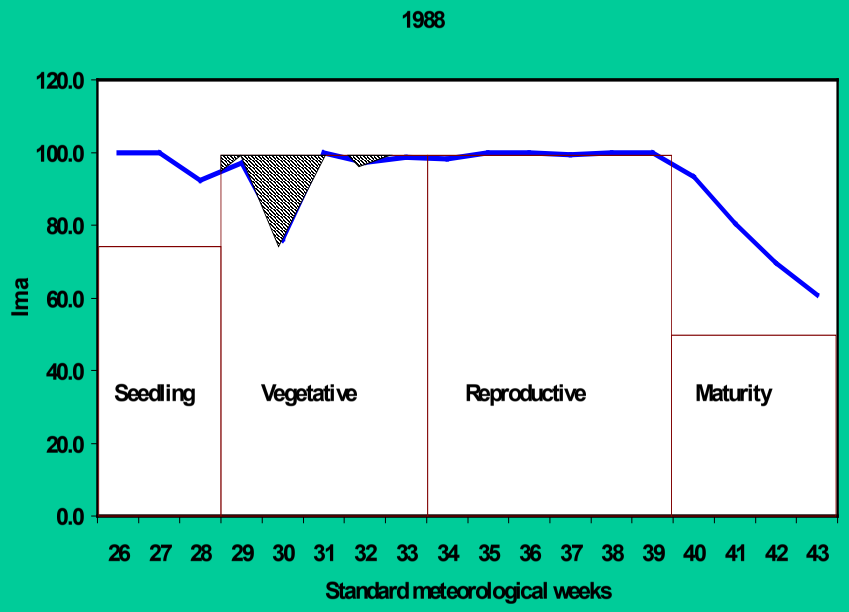
(1987 and 1988)



(603 kg/ha)

(711 kg/ha)

A decrease of 15%



Onset of Monsoon

Some times delayed onset of monsoon also creates drought conditions

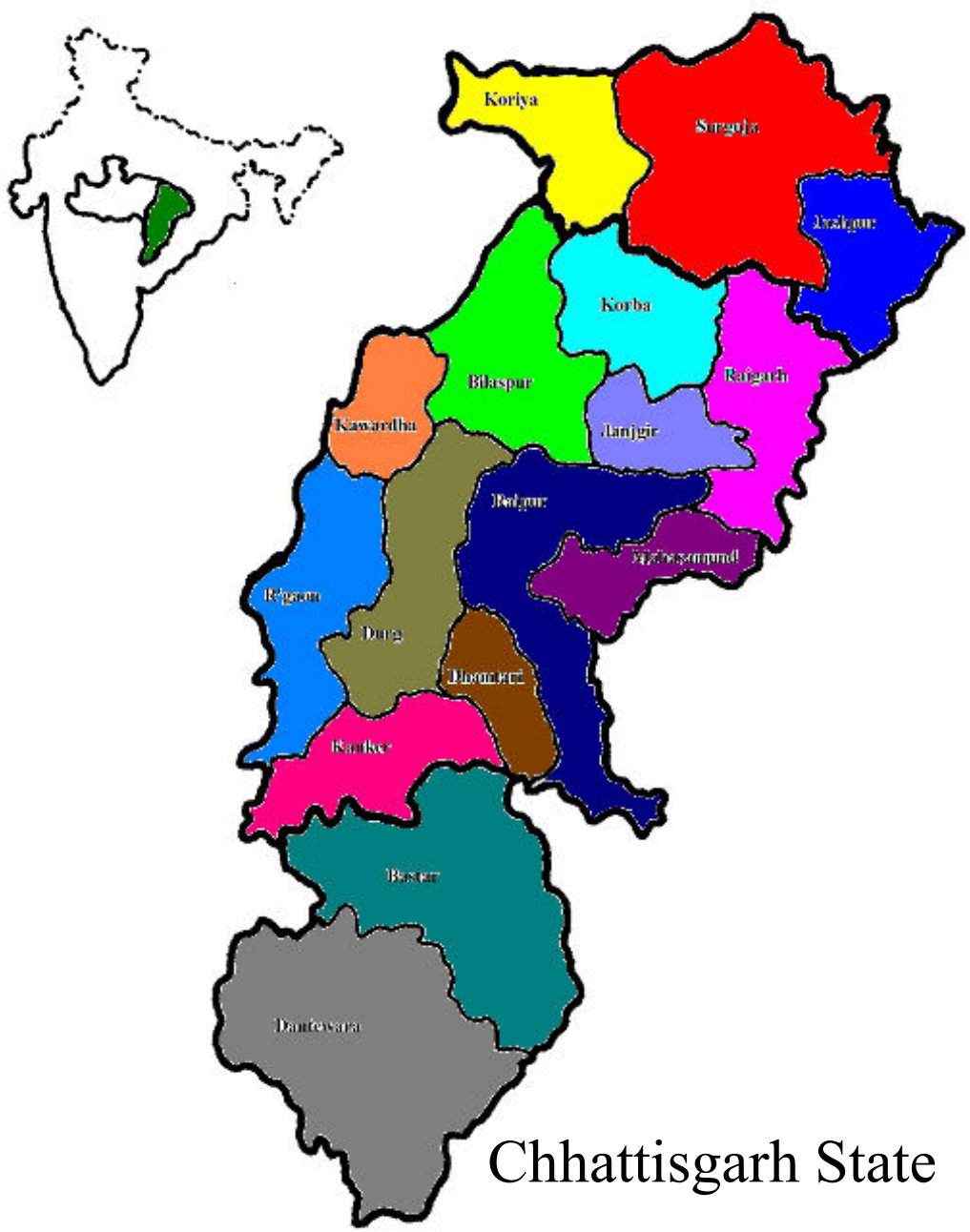
Monsoon onset	Rainfall (mm)	Length of Humid period (days) (R<PET)	Average rice productivity (t/ha)
Early	1607	127	1.18
Normal	1366	115	1.15
Late	1044	91	0.84

Due to late onset of monsoon the rainfall decreased by 23% and the productivity decreases by 27%.

Atmospheric Conditions Favorable for Droughts in India

Year	Rainfall departure from LPA	ENSO	SOI	Winter Eurasian snow cover	April 500 hPa ridge along 75° E	Surface pressure anomaly
1951	-13%	Warm	Negative	Excess	South	Positive
1965	-15%	Warm	Negative	Excess	South	Positive
1966	-12%	Normal	Normal	Normal	Normal	Positive
1972	-25%	Warm	Negative	Excess	South	Positive
1974	-11%	Normal	Normal	Excess	South	Normal
1979	-15%	Normal	Normal	Excess	South	Normal
1982	-13%	Warm	Negative	Excess	South	Normal
1986	-13%	Normal	Normal	Excess	South	Positive
1987	-19%	Warm	Negative	Excess	North	Positive
2002	-19%	Warm	Negative	Excess	NA	NA

Data Source: Sikka et al.



Chhattisgarh State

El Nino and Southern oscillation

The relation between southern oscillation Index (SOI)
and rainfall in different months of different districts of Chhattisgarh revealed that March month SOI has a very strong relation with June and July rainfall and also seasonal rainfall

Relation between March SOI and rainfall in different months

District	June	July	August	September	Seasonal
Surguja	HS	HS	HS	HS	HS
Korea	HS	HS	-	S	S
Bilaspur	HS	HS	S	-	S
Dantewara	HS	HS	-	-	HS
Dhamtari	HS	HS	S	-	S
Durg	HS	HS	-	-	S
Jagdalpur	HS	HS	-	.	HS
Janjgir	HS	HS	-	-	HS
Jashpur	HS	HS	-	-	HS
Kanker	HS	HS	S	-	HS
Kawardha	HS	HS	-	-	HS
Mahasamund	HS	HS	-	-	HS
Raigarh	HS	HS	-	-	HS
Raipur	HS	HS	-	S	HS
Rajnandgaon	HS	HS	-	-	HS

Effect of different intensities of El Niño on monsoon rainfall

Strong El Niño

Districts	June	July	August	September	Seasonal
Surguja	-12.84	-14.95	-12.45	-8.74	-12.74
Koriya	-10.91	-20.35	-13.83	-8.65	-14.71
Bilaspur	-11.29	-19.39	-14.21	-8.76	-14.47
Dantewara	-11.67	-19.57	-14.33	-10.72	-14.92
Dhamtari	-11.38	-19.96	-12.00	-8.82	-13.71
Durg	-12.94	-15.13	-8.85	-6.43	-11.06
Jagdalpur	-10.91	-19.51	-14.92	-6.12	-13.75
Janjgir	-9.57	-15.66	-10.31	-9.15	-11.64
Jashpurnagar	-11.70	-18.96	-13.06	-8.08	-13.92
Kanker	-10.43	-12.16	-10.17	-8.03	-10.36
Kawardha	-11.94	-16.06	-9.16	-7.05	-11.48
Mahasamund	-11.44	-19.91	-12.84	-9.68	-14.28
Raigarh	-12.52	-18.59	-12.49	-7.07	-13.50
Raipur	-12.37	-13.19	-8.97	-8.17	-10.77
Rajnandgaon	-10.91	-13.47	-12.45	-8.21	-11.63

Moderate El Niño

Districts	June	July	August	September	Seasonal
Surguja	-4.34	-9.25	-6.68	-3.74	-6.66
Koriya	-3.68	-12.30	-9.54	-5.19	-8.75
Bilaspur	-4.20	-11.93	-7.91	-3.02	-7.76
Dantewara	-5.08	-11.62	-8.92	-7.33	-8.94
Dhamtari	-3.70	-12.36	-9.22	-4.80	-8.44
Durg	-5.59	-9.32	-5.66	-2.19	-6.09
Jagdalpur	-3.88	-11.53	-9.46	-5.88	-8.28
Janjgir	-2.97	-10.70	-5.51	-5.20	-6.63
Jashpurnagar	-4.63	-11.14	-7.88	-3.60	-7.62
Kanker	-4.49	-8.54	-5.92	-3.70	-5.91
Kawardha	-5.19	-10.36	-7.81	-5.34	-7.81
Mahasamund	-5.14	-12.56	-8.28	-5.95	-8.68
Raigarh	-5.47	-10.64	-8.89	-5.24	-8.33
Raipur	-5.02	-8.29	-5.96	-4.22	-6.35
Rajnandgaon	-4.12	-9.13	-6.37	-4.84	-6.52

Effect of SOI on rice yields

(data base 1971-2000)

Districts	Contribution of SOI on rice yields
Durg	42 %
Surguja	39 %
Rajnandgaon	36 %
Bilaspur	32 %
Raipur	31 %
Raigarh	28 %

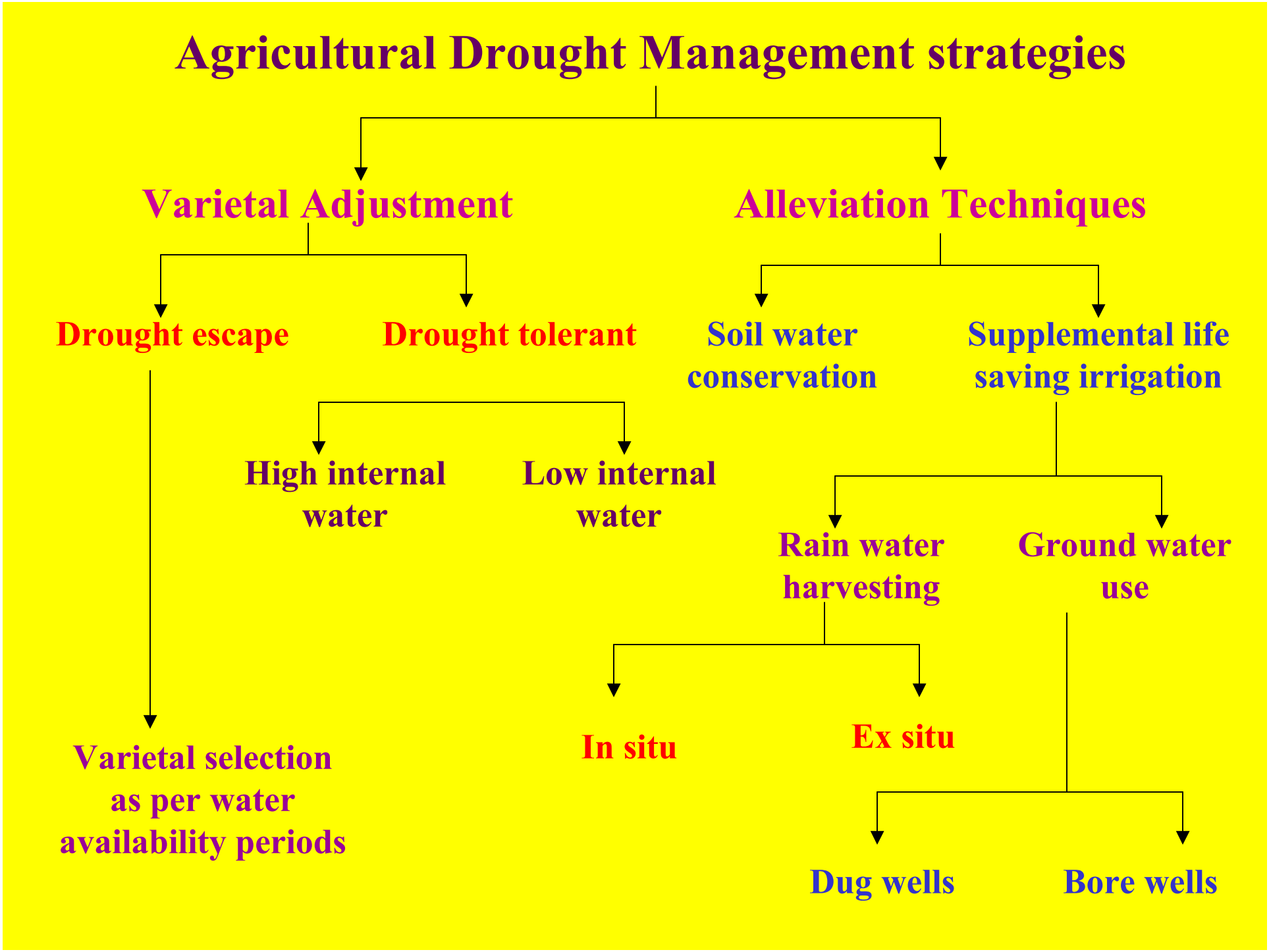
Social Implications of dorught

The implications are on both societal and economical fronts.

One of the main causes of concern on societal front is large scale migration of land-less labors and marginal farmers.



Agricultural Drought Management


Agricultural Drought Management strategies
Varietal Adjustment
Alleviation Techniques
Drought escape
Drought tolerant
Soil water conservation
Supplemental life saving irrigation
High internal water
Low internal water
Rain water harvesting
Ground water use
Varietal selection as per water availability periods
In situ
Ex situ
Dug wells
Bore wells

Case studies for Drought Management

Varietal Manipulation

In a project on Farmers' Participatory Breeding Programme (FPB) in collaboration with IRRI varieties were identified based on the yield reduction due to early and terminal droughts as compared to fully irrigated crop. The drought tolerance classified as

% Yield reduction due to drought	Drought tolerance
0-20	High
21-30	Large
31-40	Moderate
41-50	Low
>50	Least

Rice varieties tolerant to Early and Terminal Drought (Total 32 Varieties tested)

Early season drought	Terminal drought
Early Maturity Group	
•Chapti	IR 703-1-52-1
•IR 422232	IR 42253
•IR 423442	IR 422232
•Madhuri	Kranti
•IR 36	
•R 703-1-52-1	
•R 288-650	
Medium/Late Maturity Group	
•Rau-1306	R- 827-287
•Safri-17	
•Kishori	
•R-650-18-17	
•Rajshree	
•R 738-1-64	

Soil ConservationTechnologies for Drought Management

Technologies for Drought Management

Sand application to cultivated land : Kurnool,Andhra Pradesh



Application of Sand Mulch of 10 cm : Bijapur, Karnataka



In situ moisture conservation



Conservation furrows + deep tillage in sunflower. Yield benefit 25% over farmers practice

Ridges and furrows system in cotton. Additional yield of 500 kg/ha over farmers practice





Compartmental bunding in rabi sorghum. 25% additional yield over farmers practice

Rainwater Harvesting contd…

Construction of Checkdams across the streams and *in-situ* water harvesting in the fields through trenching and bunding are some of the measures for combating droughts





Rainwater Harvesting for Drought mitigation

- On farm reservoir (OFR) technology in Chhattisgarh, Orissa and Jharkhand created major impact on drought management during kharif



- The Government of Chhattisgarh included the technology in the drought relief programme



Village tanks play a very key role not only for



Irrigation use

but also for

Domestic use



Water Harvesting potentials of village tanks under excess, normal and deficit rainfall years

For assessing the water harvesting potentials of village tanks under different rainfall conditions, in different districts of Chhattisgarh One storage Index was developed

storage index

$$\text{Storage Index (SI)} = \frac{\text{Annual surplus water}}{\text{Annual average rainfall}} \times 100$$

Average rainfall is taken in the denominator only to compare the annual surplus water (or run-off) in different years as a percentage ratio of average rainfall.

Storage indices in different districts of Chhattisgarh during normal, excess and deficit years (As a percentage to normal rainfall)

	Normal	Water harvesting potential (%)		
Districts	Rainfall (mm)	Excess	Normal	Deficit
1. Raipur	1306.7	63	30.5	8.4
2. Durg	1187.6	53	24.6	1.9
3. Mahasamund	1332.1	74.5	42.7	5.8
4. Dhamtari	1268.6	57.1	30.1	5.8
5. Rajnandgaon	1330.8	64.1	27.1	7.1
6. Kawardha	1047.6	30.7	12.3	1.3
7. Bilaspur	1231.1	62.1	35.1	11.4
8. Janjgir	1337.3	70.3	45.1	23.7
9. Korba	1422.1	75.1	47.0	27.2
10. Raigarh	1510.9	74.1	44.4	16.4
11. Surguja	1521.2	76.2	47.6	26.3
12. Koriya	1327.9	64.9	44.6	17.6
13. Jashpur	1604.4	74.8	45.0	15.2
14. Jagdalpur	1504.2	80.4	41.5	20.8
15. Dantewara	1387.8	85.8	43.7	17.7
16. Kanker	1222.6	71.0	42.4	15.5

Storage Index under Excess Rainfall Condition

Lowest : 30.7 % Kawardha district

Highest : 85.8 percent in Dantewara closely followed by Jagdalpur

For ramaining districts is between 50 to 70 percent

Chhattisgarh : 67.3

Storage Index under Normal Rainfall years

Lowest : 12.3 % in Kawardha district

Highest : 47.6 percent in Ambikapur closely followed by Korba

For ramaining districts it is between 30 to 40 percent

Chhattisgarh : 37.3 %

Storage Index under Deficit Rainfall years

Lowest : 1.3 % in Kawardha and 1.9% in Durg district.

Highest : 27.2 percent in Ambikapur closely followed by 26.3% in Korba

For ramaining districts it is between 6 to 18 percent

Chhattisgarh : 13.9 %

But during the deficit rainfall years, when severe drought conditions prevail, these village tanks fail not only to provide life saving irrigation but also for domestic purpose too.



Hence, in areas where the harvestable water is very meagre during deficit rainfall years, crop diversification is the only alleviating technology

Thermal stress in crops

The thermal sensitive of any crop is expressed in terms of

- Crop phenology
- Crop height
- Crop total duration
- Crop Yield

For assessing the thermal stress in crop varieties a thermal sensitivity index has been developed.

Evaluation of thermal sensitivities in crop genotypes

Thermal Sensitivity Index (TSI)

$$TSI = \frac{\text{Range of duration to maturity}}{\text{Average duration}} \times 100$$

Thermal Sensitivity Analysis:

Based on the 4 dates of sowing each in the three years of experimentation the thermal sensitivity is analyzed as follows:

TSI value	Thermal Sensitivity
< 5	Insensitive
5.1 – 10.0	Moderately insensitive
10.1 – 15.0	Moderately sensitive
> 15.0	Sensitive

If moderately sensitive and sensitive are categorized as sensitive and moderately insensitive and insensitive are categorized as insensitive then the wheat genotypes under these categories are as follows:

Sensitive	Insensitive	Fluctuating
C-306	HI-1077	Lok-I
N-112		HD-2189
N-4		
WH-147		
Sujata		

Using a thermal sensitive index (TSI) the thermal sensitivity of various rice varieties was evaluated based on 3-year experiment with 4 dates of sowing.

Rice Variety with different thermal sensitive

Thermal Sensitivity	Genotypes
Insensitive	Annada, IR42342-40-3-3-2-2
Moderately Sensitive	Tulsi, IR36, Vikas, IR-64, Abhaya, Surekha, Salavahana, IR422-35, IR363-1-23
Highly Sensitive	Kalinga-3, Ratna, R370-1, Ruchi, R370-2
Very Highly Sensitive	Vanaprabha, R281-8831-1, Madhuri, Kranti, R371-1, R320-300, Jaya, R321-7


Thank you