The Role of Sulphur in Plant Nutrition and Polyhalite Experiments in India

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13th IPI-CAU-ISSAS International Symposium

6th November 2019, Kunming, China

Topics

- Challenges Faced by Indian Agriculture
- S availability in Indian Soils
- Role of Sulphur in Crop Production in India
- Polyhalite –Introduction to a multi-nutrients fertilizer
- Results from Polyhalite experiments done in India
- Conclusions

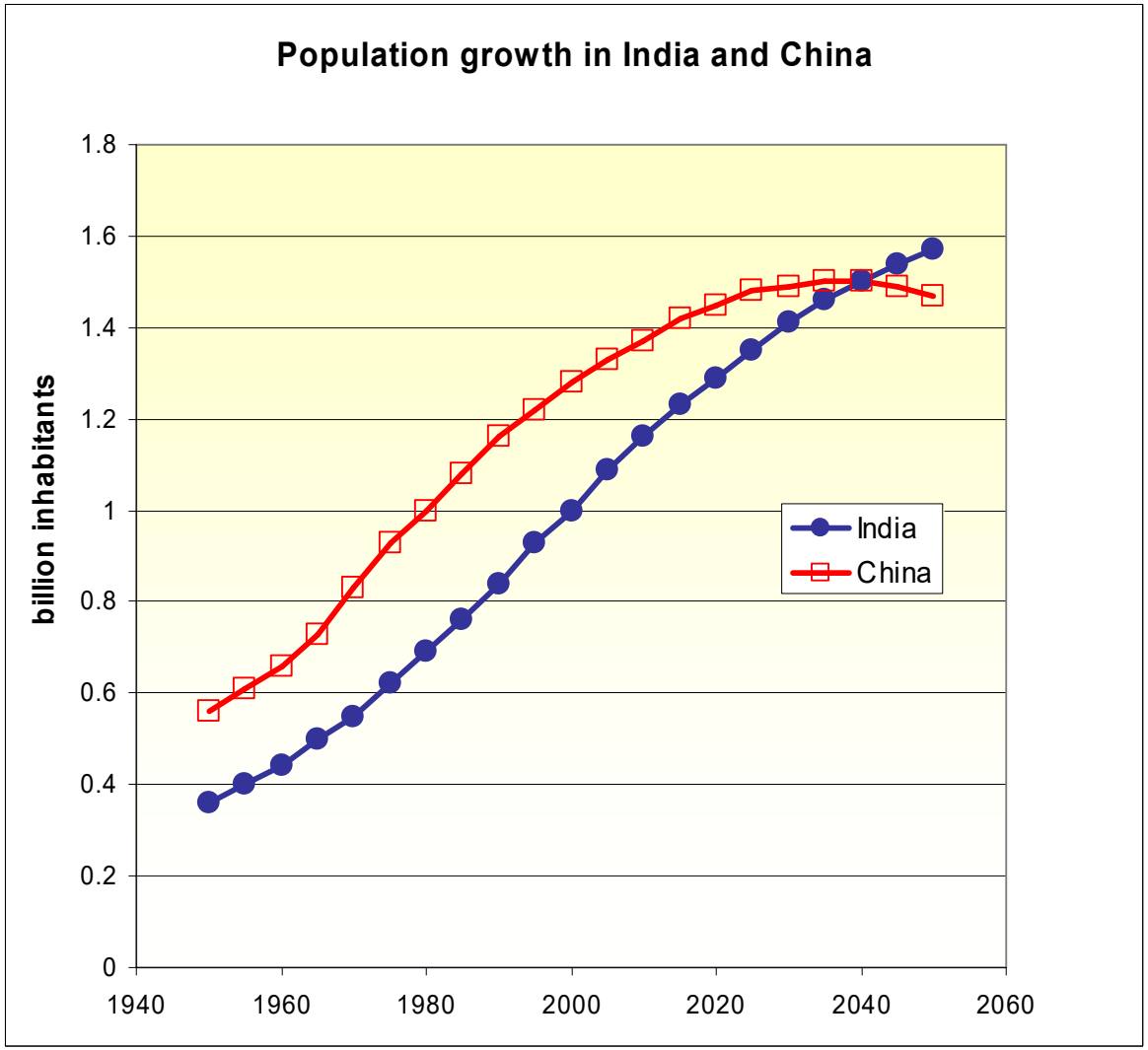
- **Increasing Population and Food Demand**

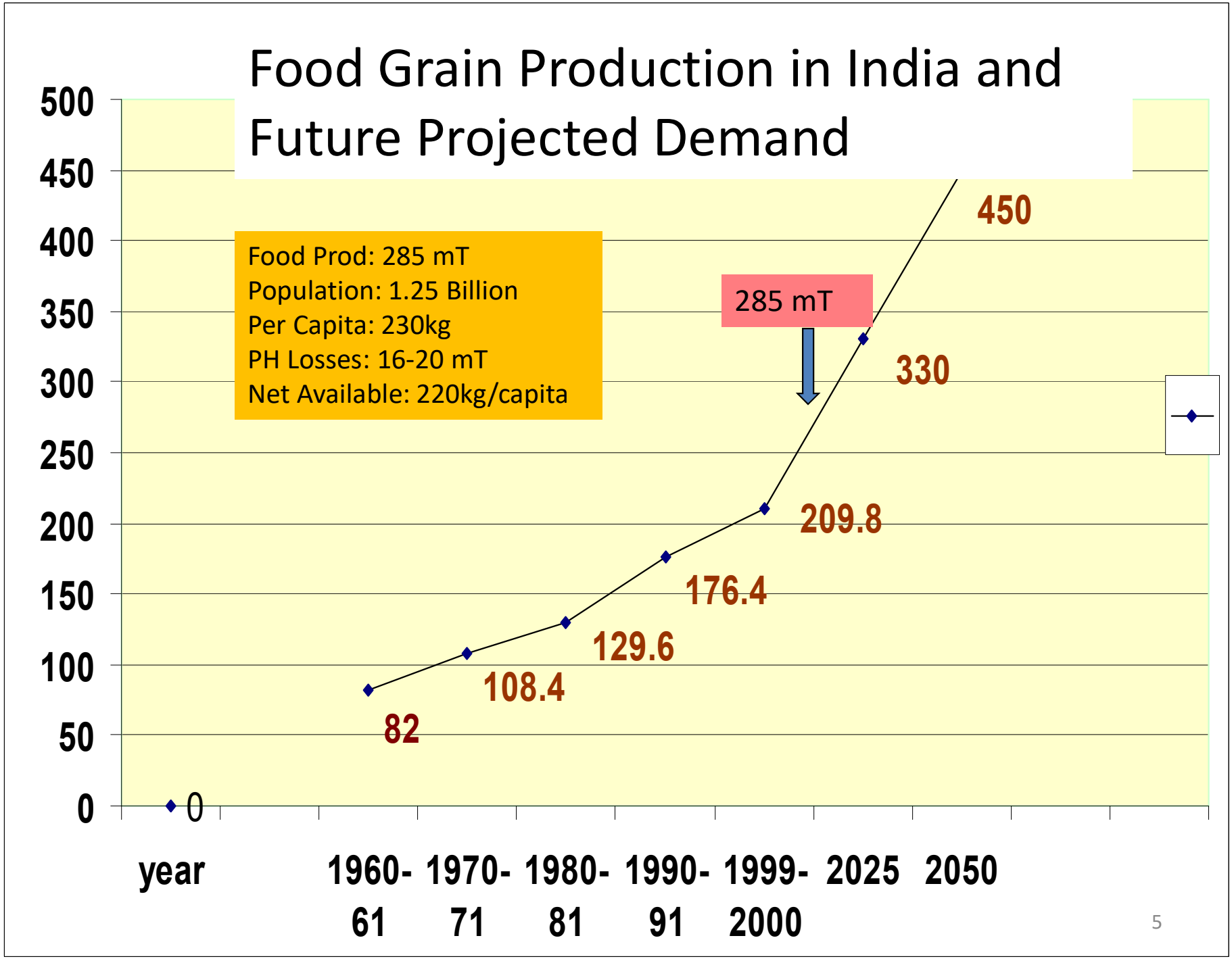
Population Problem

> more people …., i.e. need for more food.

> More food production means more demand for inputs including fertilizers.

> More food production means more stress on the soils.




Food Grain Production in India and Future Projected Demand
Production (in MT)
500
450
400
350
300
250
200
150
100
50
0
Food Prod: 285 mT
Population: 1.25 Billion
Per Capita: 230kg
PH Losses: 16-20 mT
Net Available: 220kg/capita
285 mT
450
330
209.8
176.4
129.6
108.4
82
0
year
1960-61
1970-71
1980-81
1990-91
1999-2000
2025
2050

Some facts and figures

Demand

- From 2003 to 2050, food consumption in India (g/capita/day) will increase by
  - Cereals – 15%
  - Meat – 84%
  - Milk – 68%
  - Vegetables – 40%
  - Fruit – 42%
  - Potatoes – 81% (Kearney, 2010)

Productivity

- Productivity needs to increase by
  - For Wheat: An average increase of about 7.5% per annum
  - For Pulses: 5.3% per annum (NAAS, 2006).

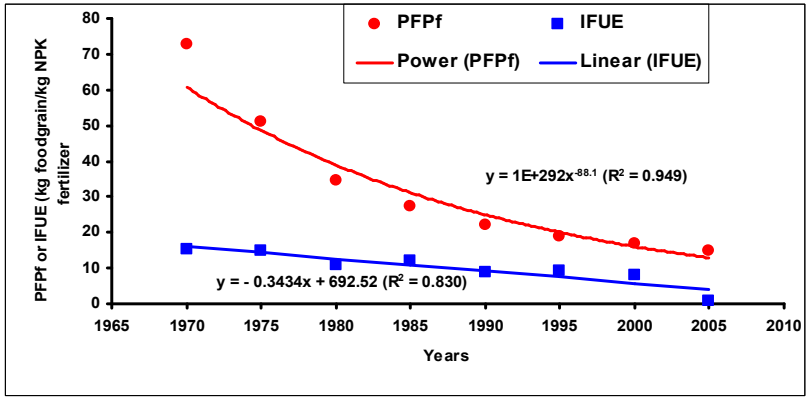
Resources

- While per capita
  - Arable land will decrease (Swaminathan 2006)
  - Water table in Northern India is falling (Kerr, 2009)

- **Challenges before the Indian Agriculture:**

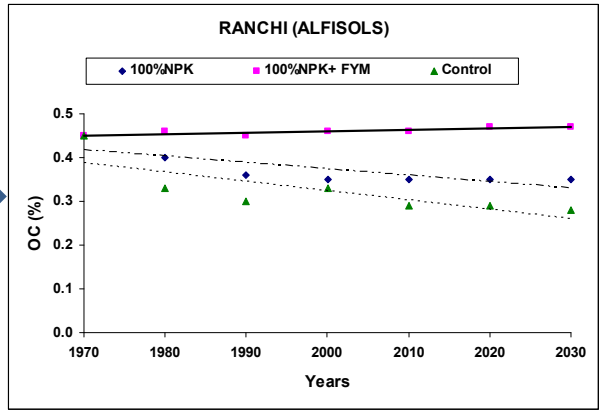
1. **Keep pace with increase in population**
2. **Provide diverse food for fast urbanization**
3. **Increase in food production need to be vertical as little scope for horizontal expansion.**
4. **Sustain soil and crop health**

The concern

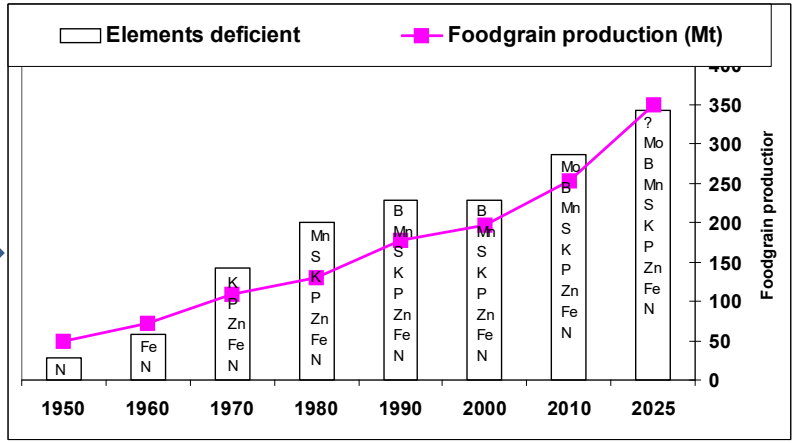


Declining partial factor productivity

Declining organic matter status

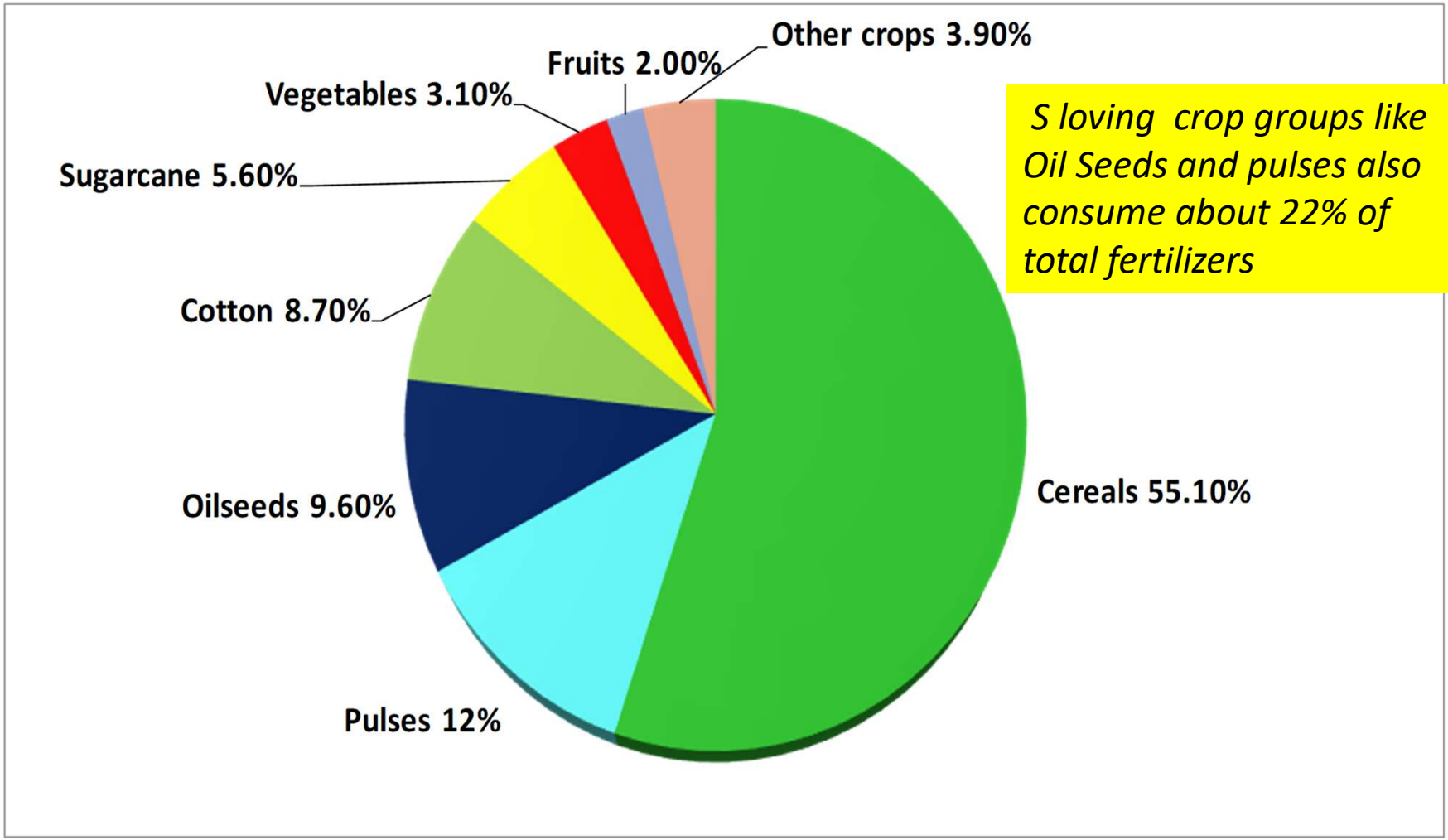


Emerging Multi-nutrient deficiencies



- **Role of S in Indian Agri**

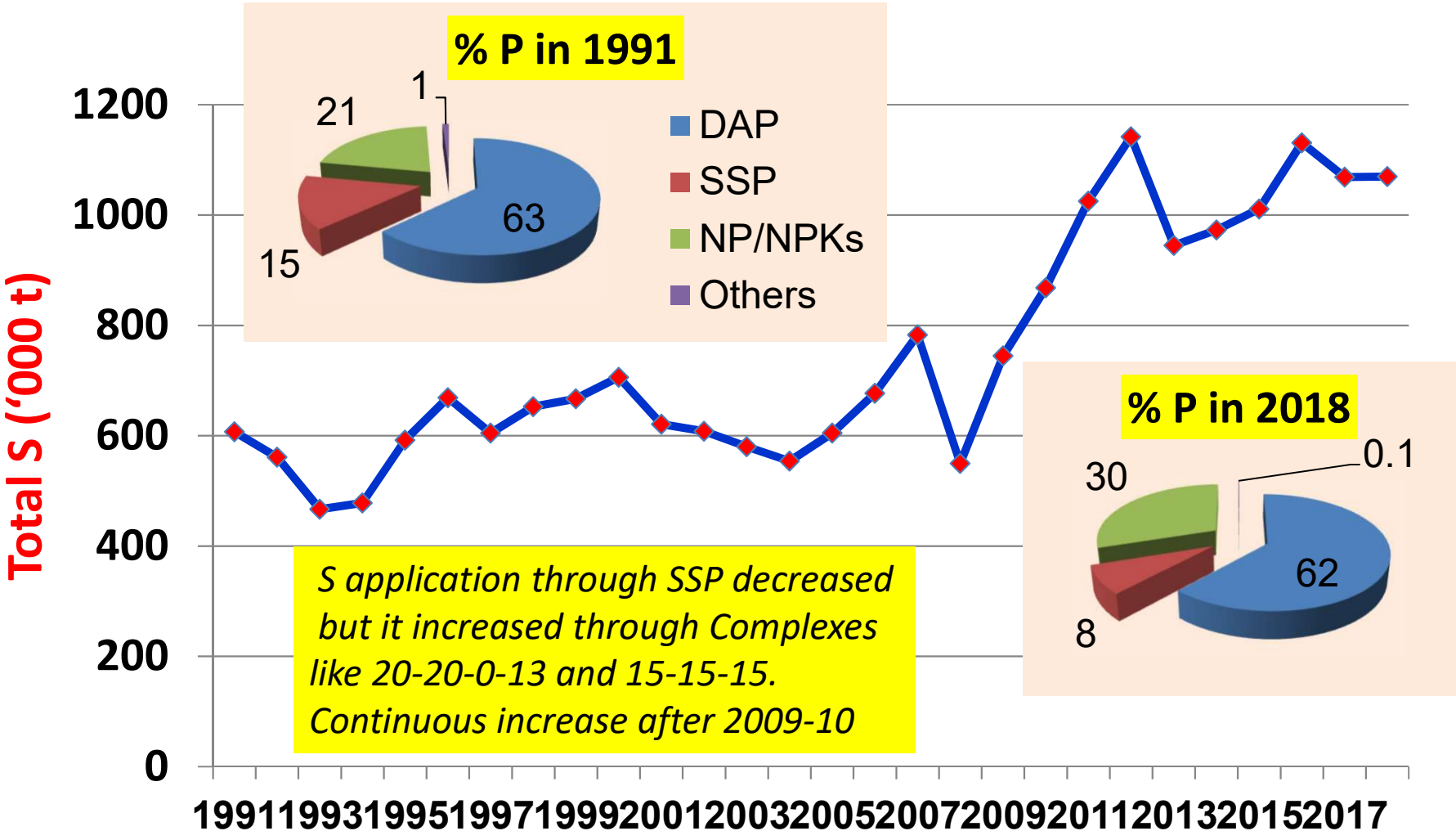
Fertiliser Use by Crops in India



S loving crop groups like Oil Seeds and pulses also consume about 22% of total fertilizers

Source: Adapted from All-India Report on Input Survey, 2011-12, DAC, Agricultural Census Division

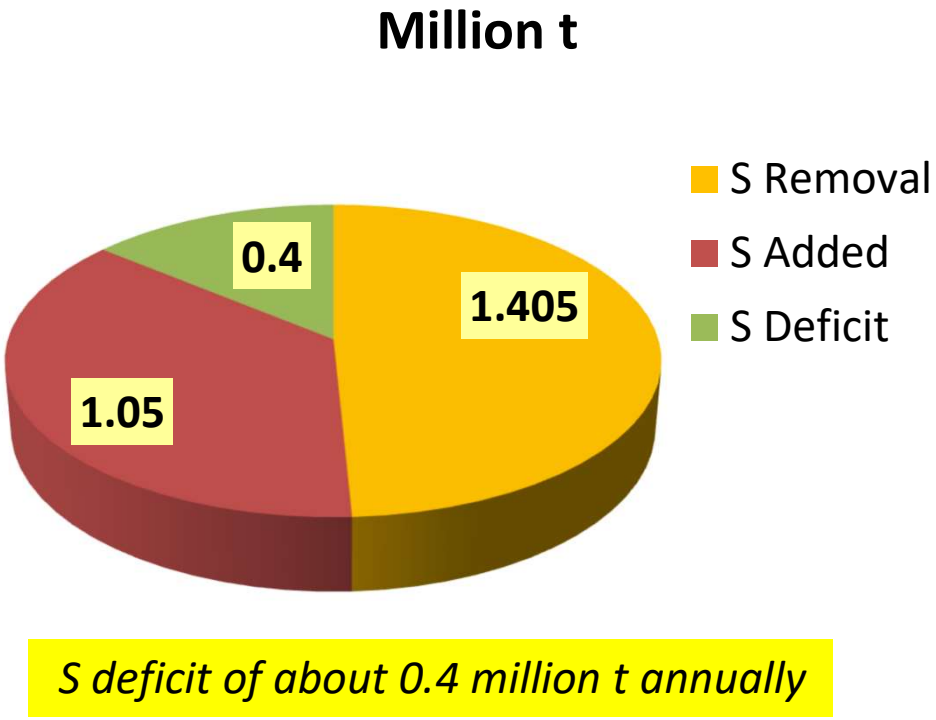
P (%) and S consumption from fertilizer sources in India ('000 t)*



Source: FAI 2019

*Other than Gypsum, pyrites, etc

Annual Uptake of S by Food crops in India is Estimated at 1.405 million t



S deficit of about 0.4 million t annually

Cereals
@ 3.5 kg S/t=0.91 million t

Pulses
@ 7 kg S/t=0.17 million t

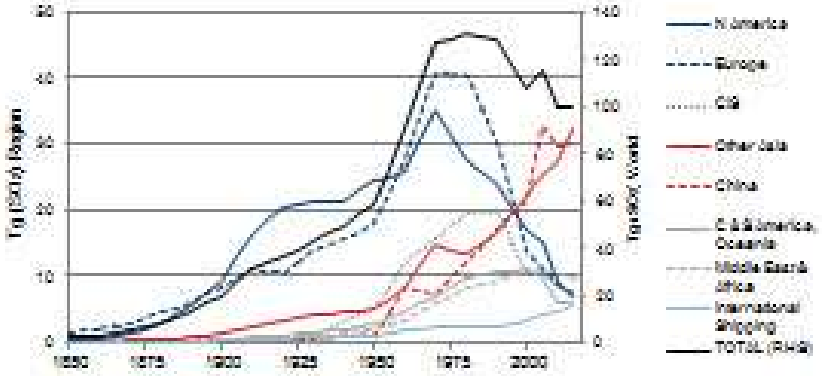
Oil Seeds
@ 10 kg S/t=0.32 million t

Source: DOS, Govt of India 2015

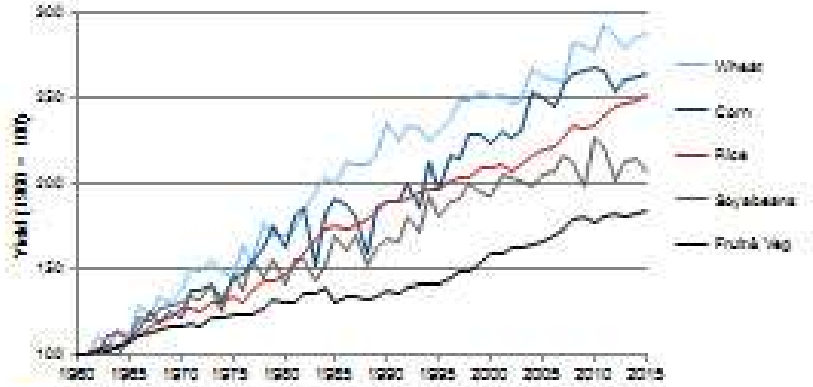
Reasons for Increasing S Deficiency Globally

Sulphur Deficiency

1. Anthropogenic SO2 Emissions: 1850 - 2015



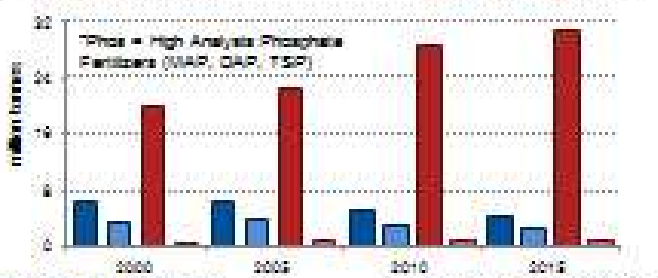
2. Rising Crop Yields: 1960 - 2015



3. Increased Use of High Analysis Fertilizers

N : AS v Urea

P : SSP v Phos*



K : SOP v MOP

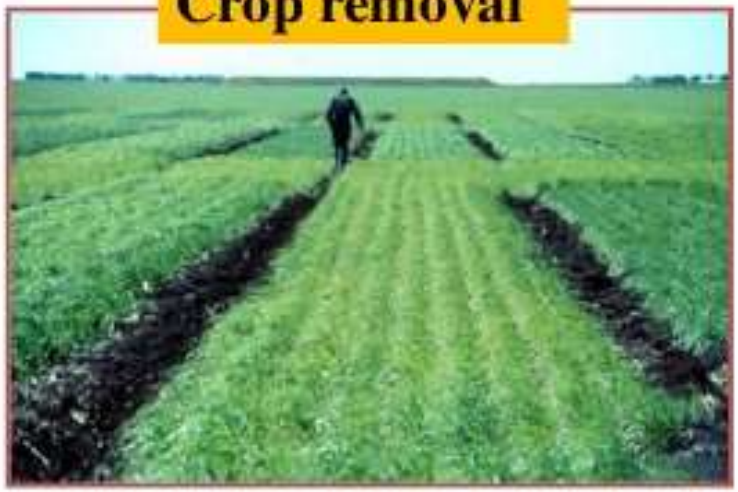
Data – CRU, European Geosciences Union, IEA, NT = nutrient tonnes, ST = Sulphur tonnes

Common Reasons for S Deficiency in Indian Soils

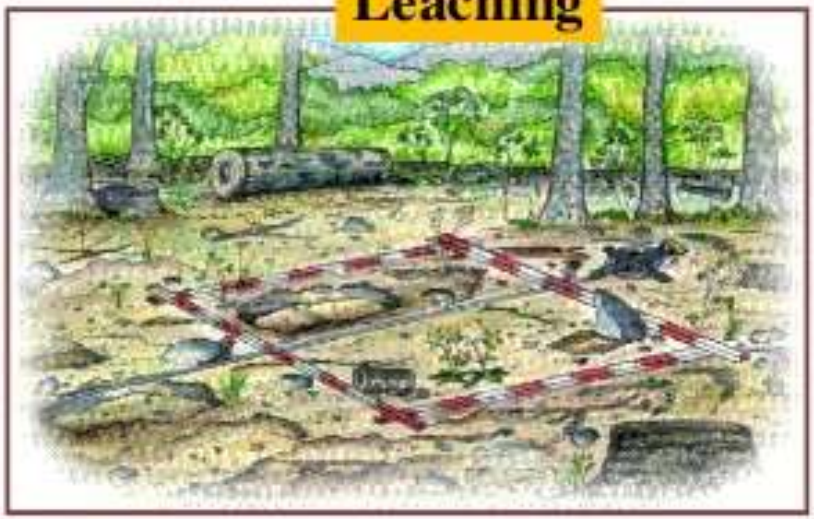
- Continuous use of S free fertilizers like Urea, DAP, etc.
- Decrease in the use of Organic manures such as FYM, Green Manuring, Compost, etc.
- Use of High Yielding Varieties
- Leaching Losses

Losses of sulphur from soil

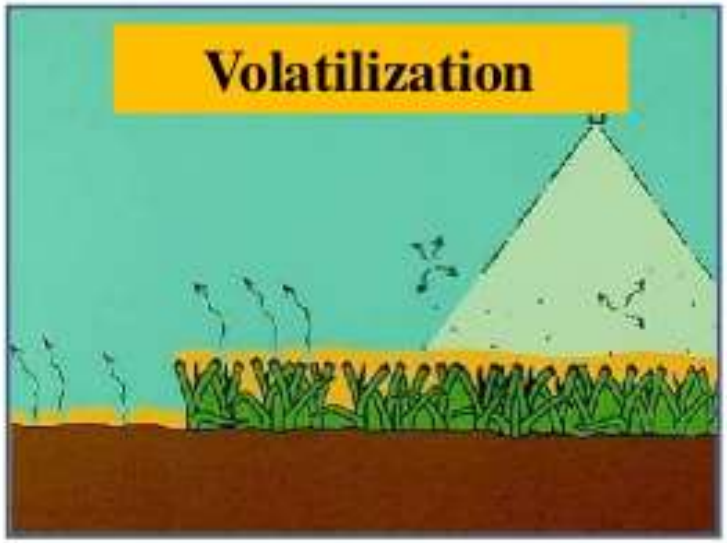
Crop removal



Leaching



Volatilization

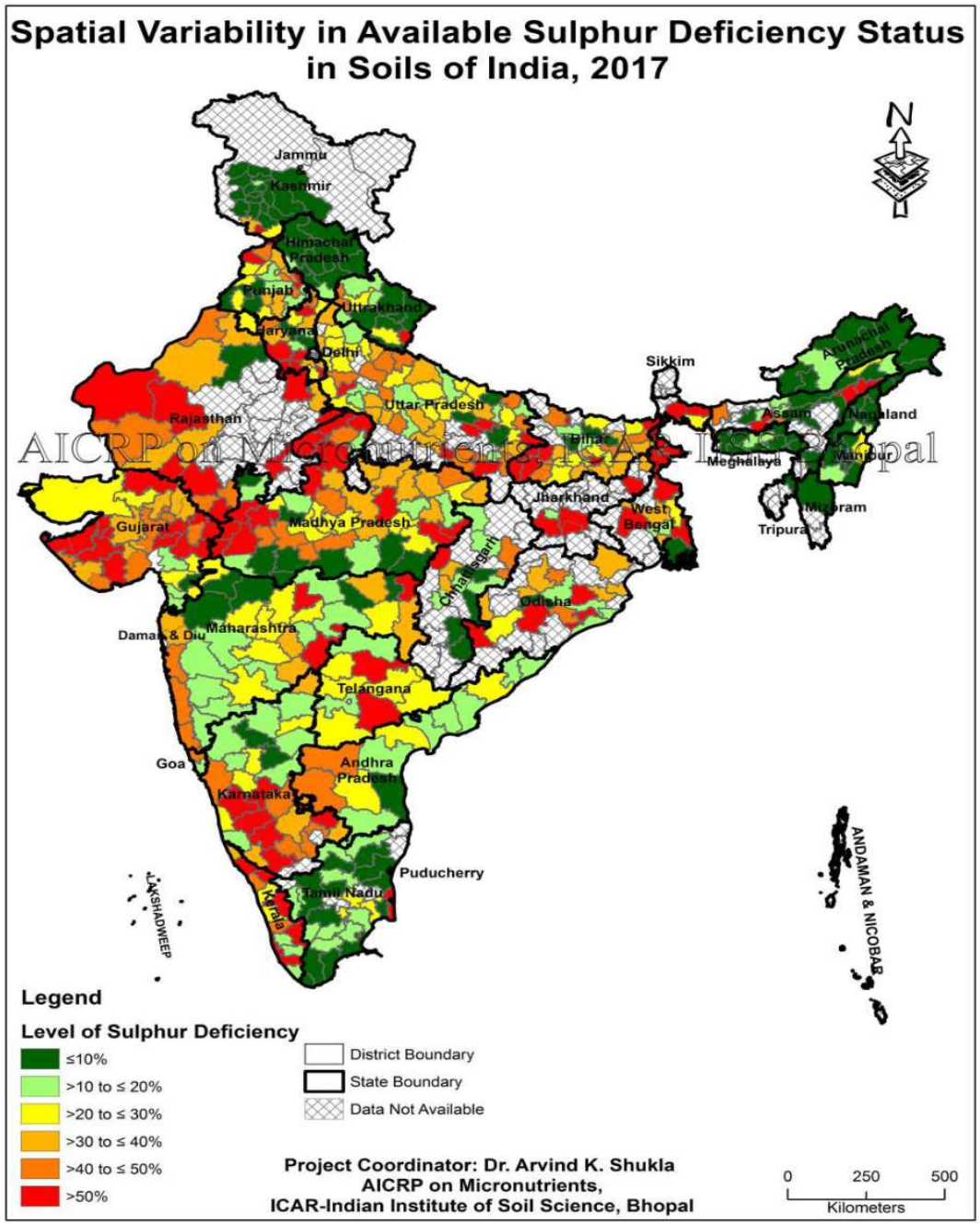


Soil erosion

Ram Lakkhan Raghuwanshi had a bad harvest last monsoon. The farmer from Shyampur village, Guna district, cultivated soybean, wheat and mustard in 121 hectare (ha), of which he sowed soybean in 61 ha. Despite the high-quality seeds sowed, the yield was a meagre 15 quintals per ha.

"I got my land tested and found that the low yield was because of low sulphur (essential nutrient) content in the soil. Earlier, I used to get 25 quintals per ha," he says. Other farmers in the state share the same woes.

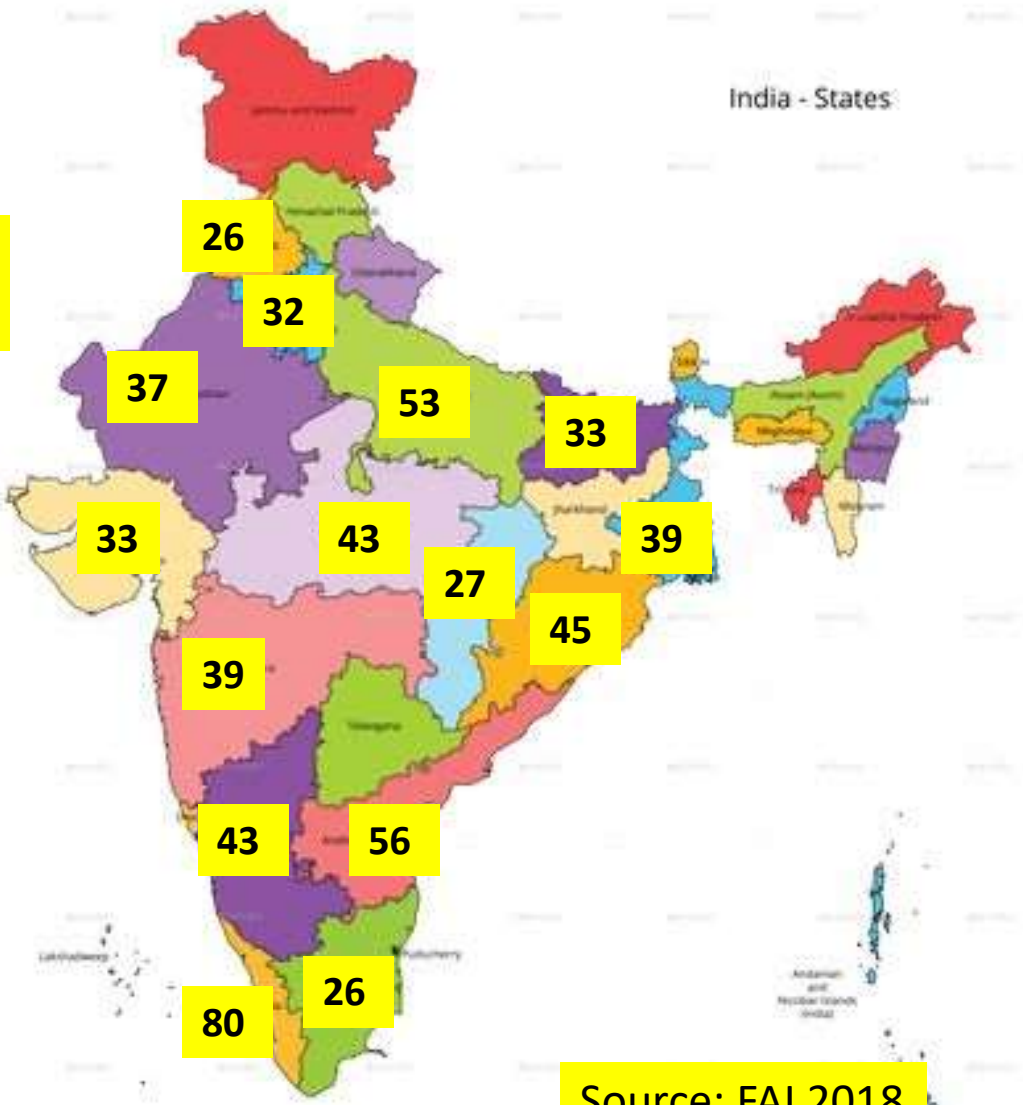
Experts say the low output has been triggered by a mild to severe sulphur deficiency in soil. A study by the Bhopal-based Indian Institute of Soil Sciences (iiss) says that more than 40 per cent of agricultural soils in the 48 districts--mostly rainfed--of the state are sulphur deficient. "All the districts face the problem, with the magnitude depending on the intensity of cropping,"



*Note-External boundaries of India are indicative only

Percent S Deficiency in Indian States

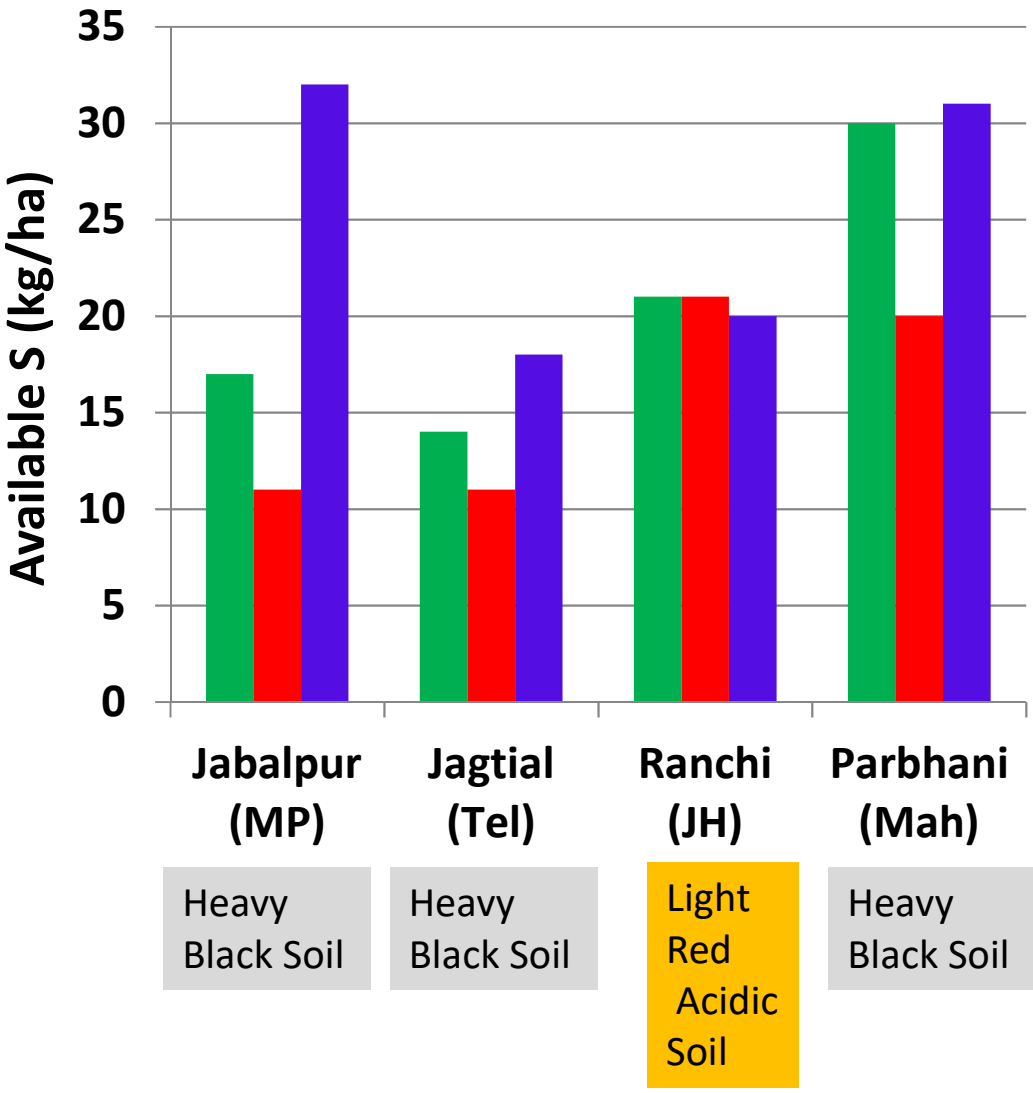
S deficiency is more in the Tropical Southern India



Source: FAI 2018

*Note-External boundaries of India are indicative only

Soil Available S status under Long Term Cropping of >30 years and Fertilizer Application



S was applied @ 20-30 kg /ha to both the crops

No change in available S status in acidic Red soils due to poor Crop yields and low S removal. Application of Sufficient S Maintains soil S levels

Source: Singh, M *et al* 2016

- **Crop Responses to S**

Crops need S, Because

- It is required for the synthesis of S containing Amino Acids like Cystein, Cystine and Methionine and for Protein Synthesis
- It activates certain proteolytic enzymes such papainase and synthesis of papain
- It is a constituent of certain vitamins viz., Thiamine and Biotin, co-enzymes and glutathione, Acetyl co-enzyme A (precursor for fatty acid synthesis), etc.
- It is present in the crops like Onion, Mustard, cabbage and Cauliflower, etc as Polysulfides

Crops need S, Because

- It increases oil content in crops like Mustard, Soybean, Groundnut, etc
- Sulfhydral (-SH) groups in plants are related to increased cold resistance
- It is required for N-fixation in legumes and is a part of nitrogenase enzyme system
- Indirect nutritive value as soil amendments (calcareous and saline alkali soils)

S Deficiency Symptoms in Indian Crops

Rice

Mustard

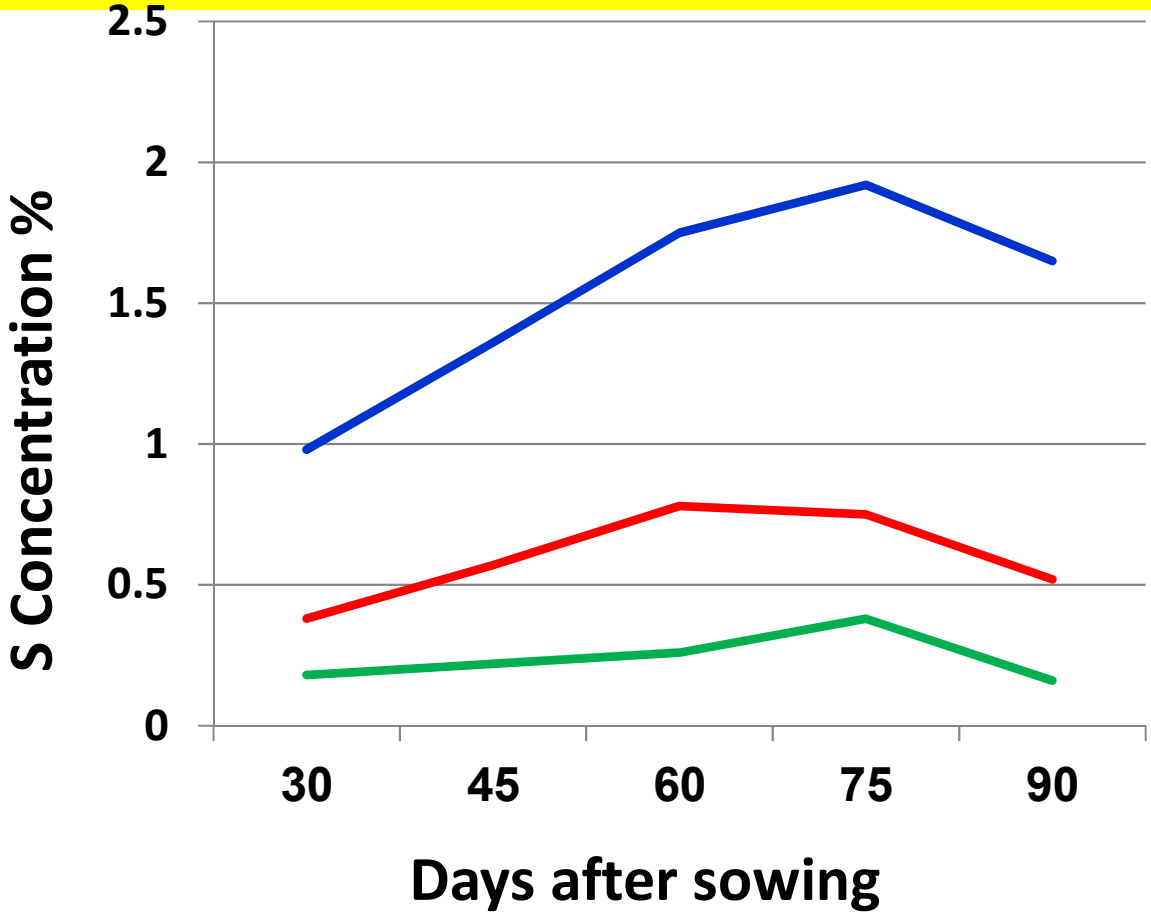
Maize

Turmeric

Tomato

Tobacco

Sulphur Content in Indian Mustard At different growth stages



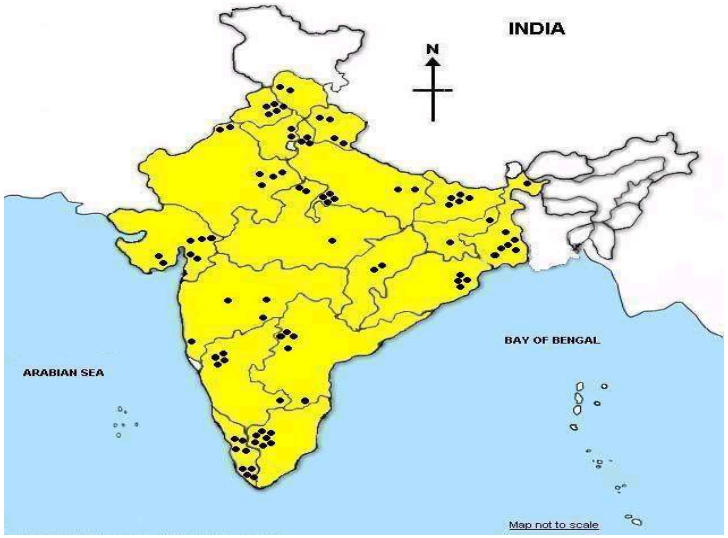
Peak S Concentration In Leaf is at the Flowering stage

Leaf
Stem
Root

Source: Rathore *et al* 2015

TSI-FAI-IFA Project - Highlights

- Project launched in May 1997 and continued upto 2006 in 3 phases



- Covered 18 states
- No. of Experimental Sites: 75

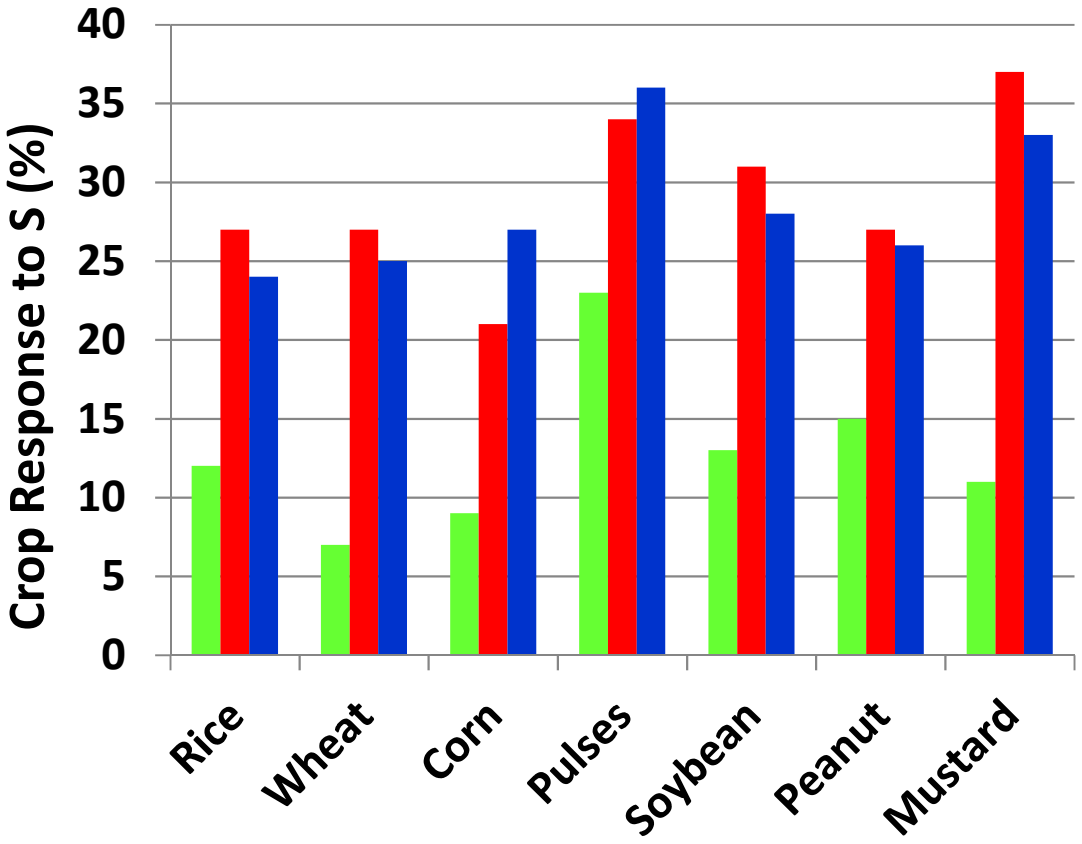
- No. of collaborative institutes: 26
  - SAUS- 19, ICAR Instt-3, Fert. Cos.- 3, State -1
- No. of Soil Samples analyzed: over 49,000

Crop Response – Salient Findings of the Project

- Response to S application was significant and varied widely under different soil and crop situations.
- Increase in crop yields from direct application of S varied from 14 to 60%.
- Residual effect on yield of succeeding crops varied from 3 to 81%
- Optimum S dose varied between 30 and 45 kg/ha in most of the states
- Agronomic efficiency varied from 6 to 30 kg/kg S applied.
- Economic returns from S fertilizer use were very attractive and they ranged between 12 and 24%.

Some Glimpses from the FAI-TSI-IFA Project Activities

Long Term Changes in S Response by Different Crops (1990-2016)- Results from large number of field trials (from 67 for wheat to 286 for Rice)

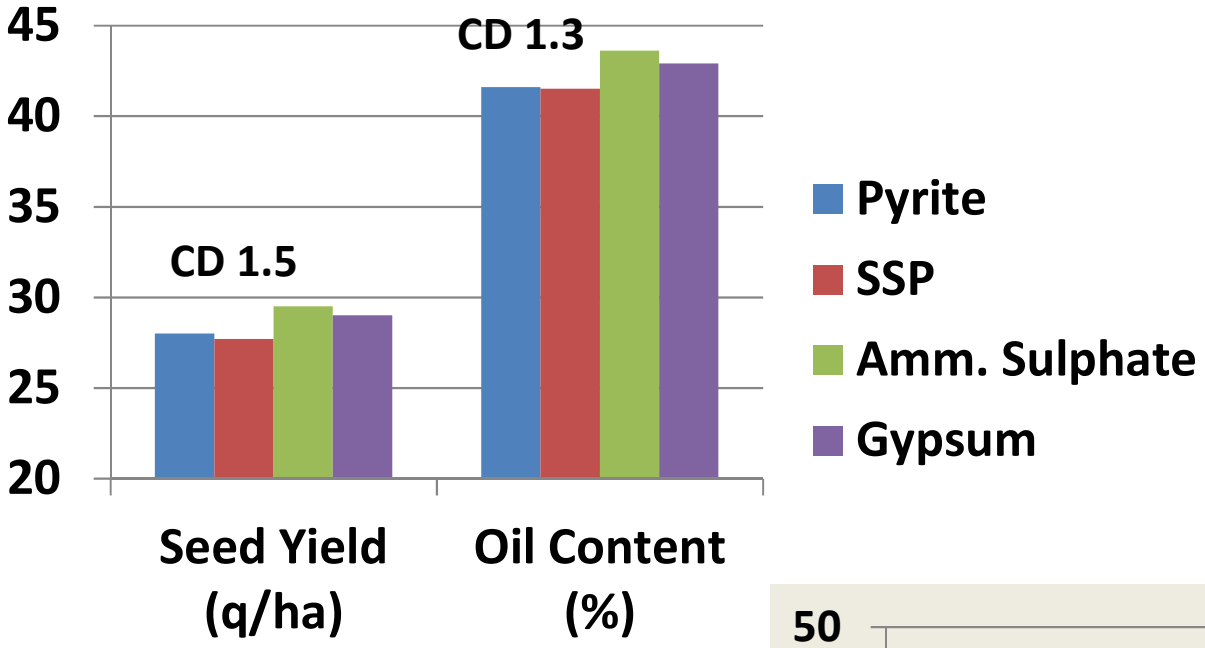


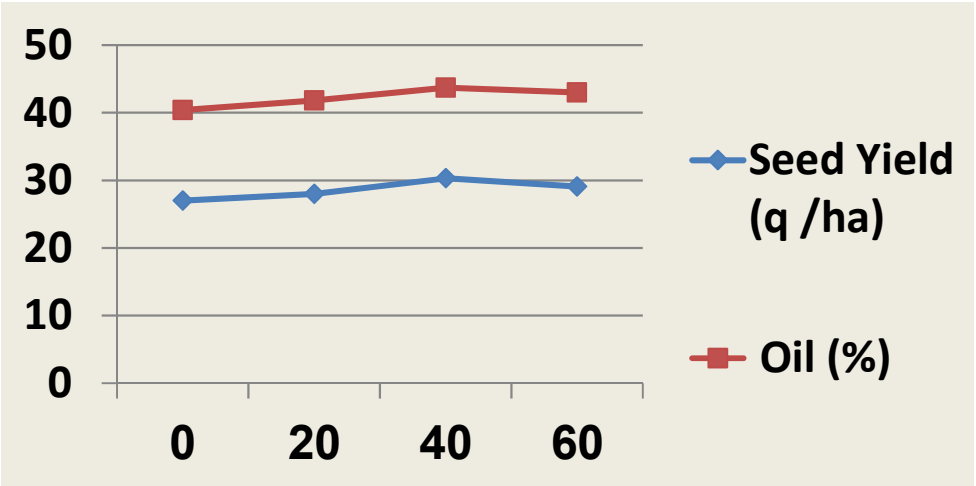
S was applied @ 20-40 kg /ha to all the crops

While response to cereals was less and for oil seeds and pulses, much more. Response was higher In the period 1997-2006 than 1990-1997. Response of Rice increased from 11 to 21% while from 14 to 37% for Mustard

Source: Shukla and Bahera 2019

Effect of S Sources on Seed yield and Oil Content in Mustard (*Brassica juncea*) at Gwalior (India)





Available Soil S = 9.0 kg/ha (Low)
Soil- Sandy loam

SOURCE- BANSAL 2011

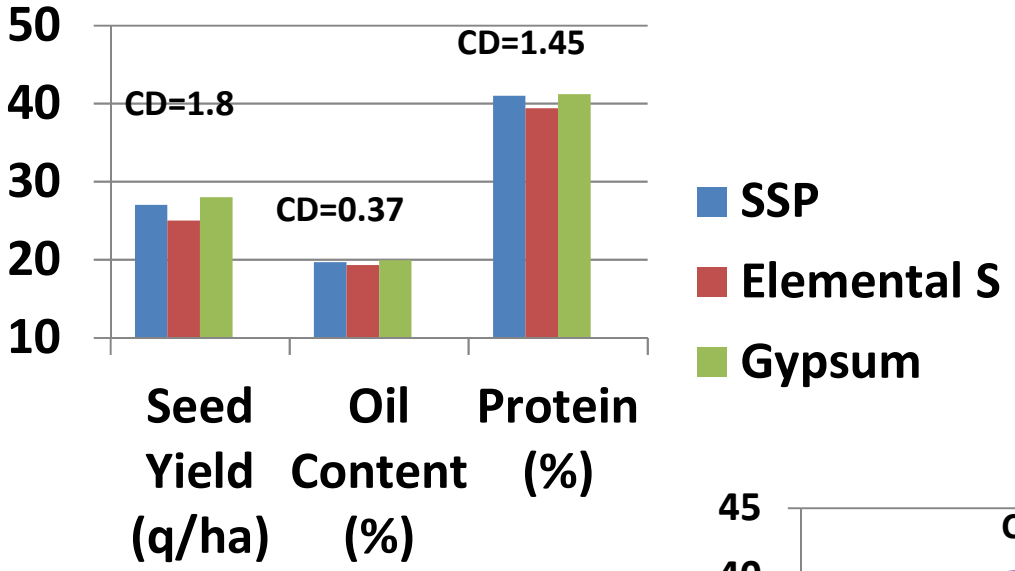
Effect of S on Quality Parameters of Mustard at Bharatpur (Rajasthan) 2013-2015

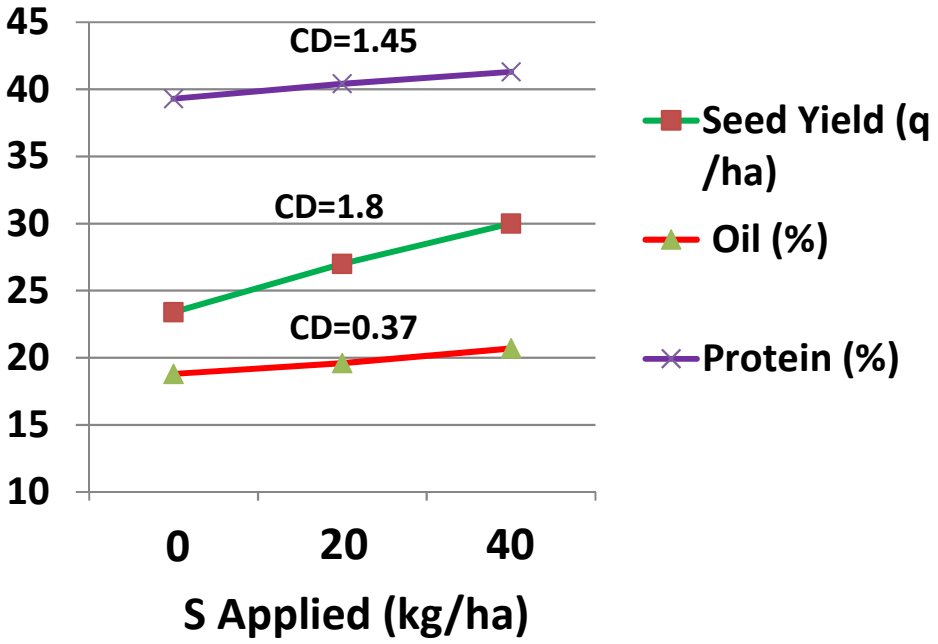
S Level (kg/ha)	Oil Content (%)	Oil yield (kg/ha)	Sinigrin Glucosinolate (%)	Iodine value (no.)
0	38.5	537.3	1.85	104.9
15	39.4	594.0	1.92	106.1
30	40.0	655.6	2.00	107.2
45	**40.4**	**696.0**	**2.08**	**109.3**
CD at 5%	**0.31**	**32.2**	**0.06**	**0.74**

Available Soil S = 14.0 kg/ha (Low)
Soil- loamy sand
Source of S= Elemental S

SOURCE- Rathore et al 2016

Effect of S Sources on Seed yield and Oil Content in Soybean at Parbhani, Maharashtra (India)

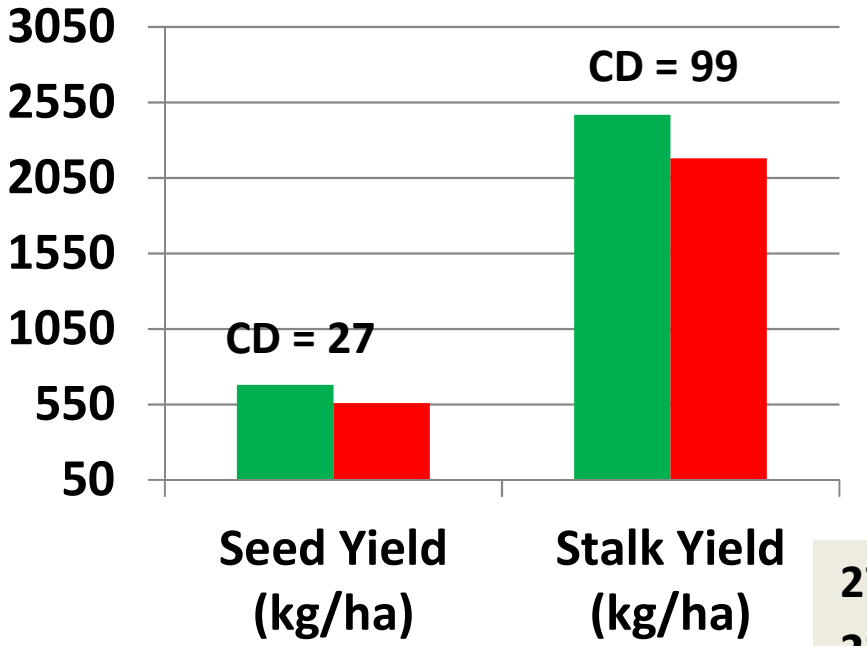


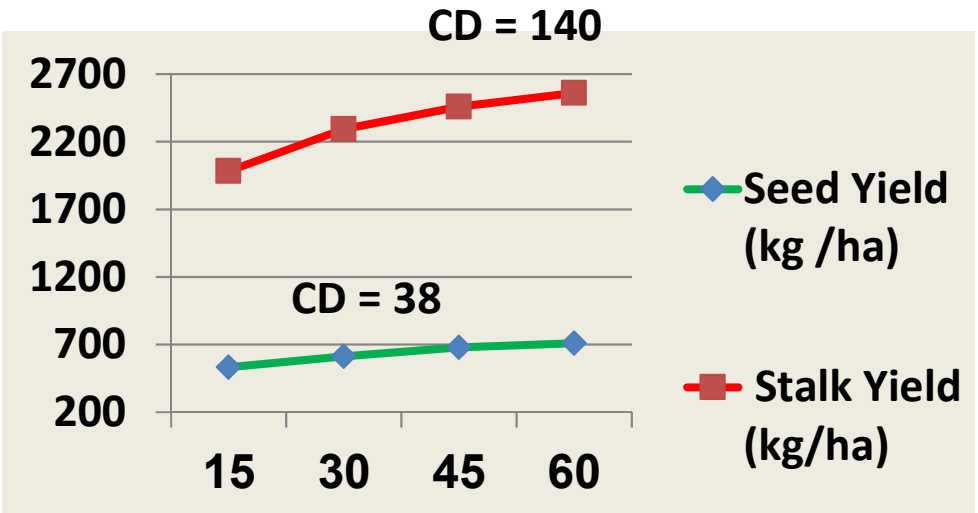


Available Soil S = 18.0 kg/ha (Low)
Soil- Deep Black, pH 8.5

SOURCE- Gokhale et al 2006

S and Sesame Yield in a Loamy sand Soil at Bharatpur in Rajasthan, India during 2010-2012





Available Soil S = 13.0 kg/ha (Low)
Soil- loamy sand

SOURCE- Meena, 2013

Effect of S Application on Seed yield and Oil Content in Sunflower at Dharwad, Karnataka (India) during 2010-2012

Treatments	Seed Yield (kg/ha)	Oil Yield (kg/ha)	B:C Ratio
Control (0 S)	1404	482	2.07
10 kg S/ha	1650	607	2.38
20 kg S/ha	1813	686	2.56
30 kg S/ha	1955	761	2.71
CD at 5%	76	36	0.11

Available Soil S = 14.0 kg/ha (Low)
Soil- Red Sandy Loam
S Source= Elemental S

SOURCE- Pujari et al 2013

Effect of S on Economics of Linseed at Banaras (UP) during 2010-2011

S Application (kg/ha)	Oil Content (%)	Oil Yield (kg/ha)	Cost of Cultivation (Rs/ha)	Gross Return (Rs/ha)	Net Return (Rs/ha)	Benefit: Cost Ratio
0	39.3	453	17167	25593	8425	1:49
20	41.1	584	17916	31416	13500	1:75
40	41.3	584	18665	31278	12612	1:67
CD at 5%	0.38	25		1320	1320	0.07

Source of S: Elemental S

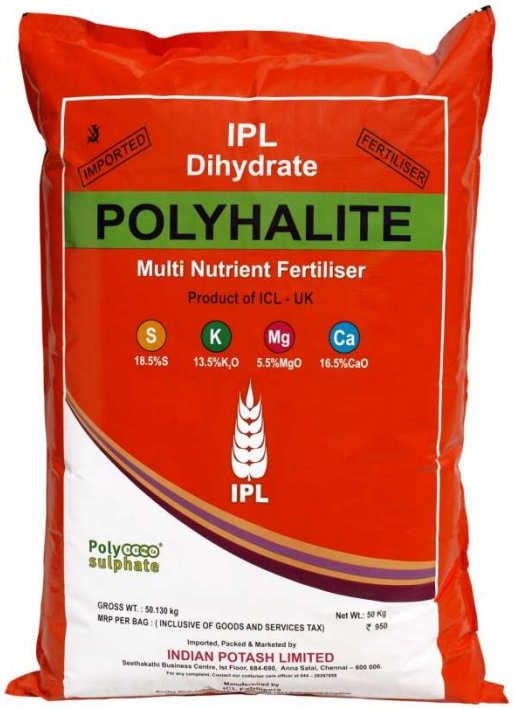
Source: Singh 2013

Fertilizer S Recommendations Based on Available S Status of Soils

Available S in Soil (mg/kg)	S Fertility Class	Expected increase in yield (%)	Amount of S Fertilizer Added (kg/ha)		
			Cereal	Oilseeds	Legumes (Pulses)
<5	Very Low	50-85	60	40	30
5-10	Low	20-50	45	30	20
10-15	Medium	5-20	30	20	15
15-20	High	1-5	15	10	10
>20	Very High	0	0	0	0

Source: Patel *et al* 2013

Field Trials on Polyhalite (Polysulphate) in India



What is polyhalite?

3

Polyhalite (dihydrate) is a single complex crystal with two molecules of water of crystallization; **it is not a mixture of sulphates**.

The new 4-in-1 fertilizer

Polyhalite (mineral) $K_2Ca_2Mg(SO_4)_4 \cdot 2(H_2O)$

19%	13.5%	6%	17%
S	K_2O as from sulphate of potassium (11.6% K)	MgO as from magnesium sulphate (3.6% Mg)	CaO as from calcium sulphate (12.2% Ca)

Field Trials on Polyhalite in India

Field experiments were conducted or being conducted for testing the bio-efficacy of polyhalite on different crops .

1. Oilseed crops at CSAUA&T Kanpur
2. Mustard and soybean at IISS Bhopal
3. Cabbage and cauliflower at IIHR Bangalore.

4. Vegetables at TNAU,
5. Turmeric at Annamalainagar,
6., Cassava at CTCRI Trivandrum etc.

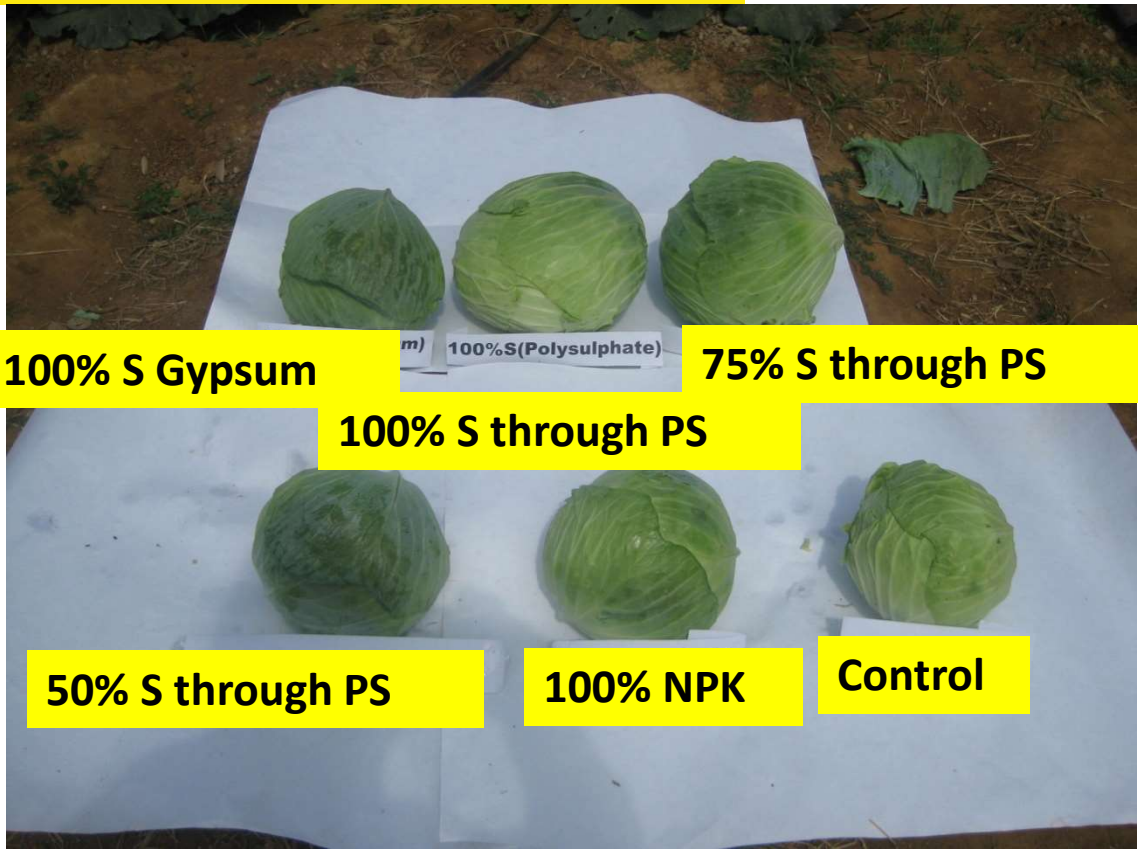
Field Trials on Polyhalite at IIHR Bangalore, Karnataka

Field experiments were conducted for testing the bioefficacy of polysulphate on cole crops namely, cabbage and cauliflower at experimental research farm of Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru, Karnataka during period from October 2013 to March 2014.

Effect of treatments on Cabbage, 60 days

NPK+100% S through PS

Control



100% S Gypsum

75% S through PS

100% S through PS

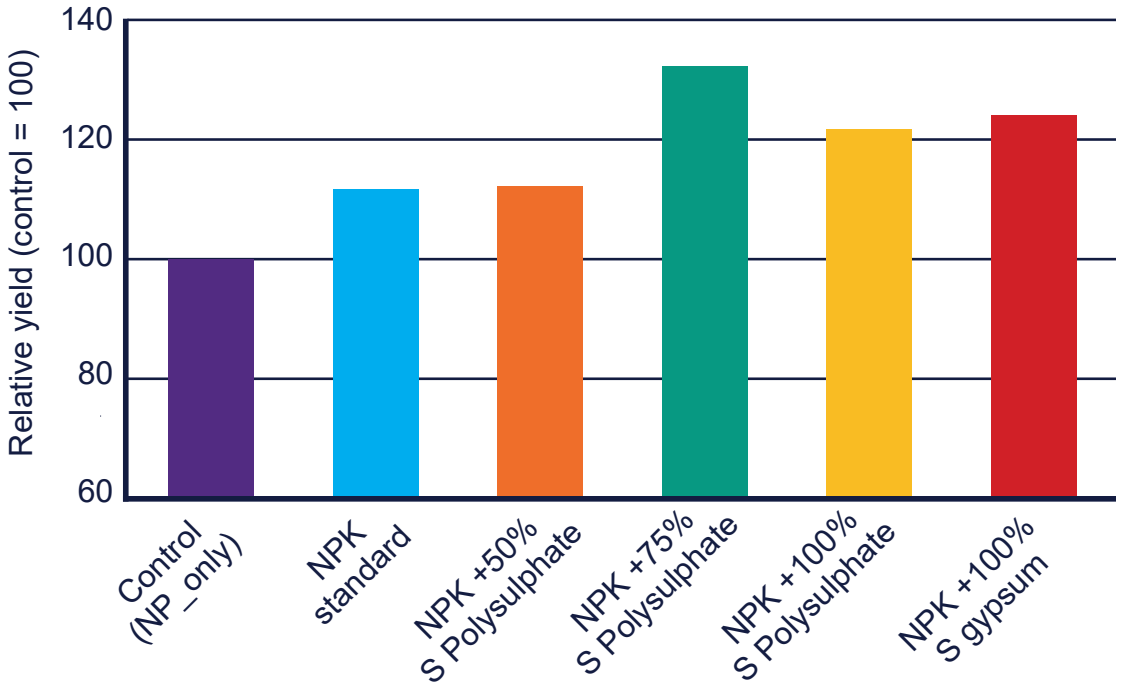
50% S through PS

100% NPK

Control

India

Effect of sulphate and the effectiveness of Polysulphate on cabbage yield



N=150 kg/ha, P=100 kg/ha, K=125 kg/ha, S=20 kg/ha, FYM 25 t/ha.

What can we learn?

Application of K added additional 10% yield over NP.

Low level of S (10 kg/ha) did not affect yield.

S from Polysulphate was more effective or equal to S from gypsum.

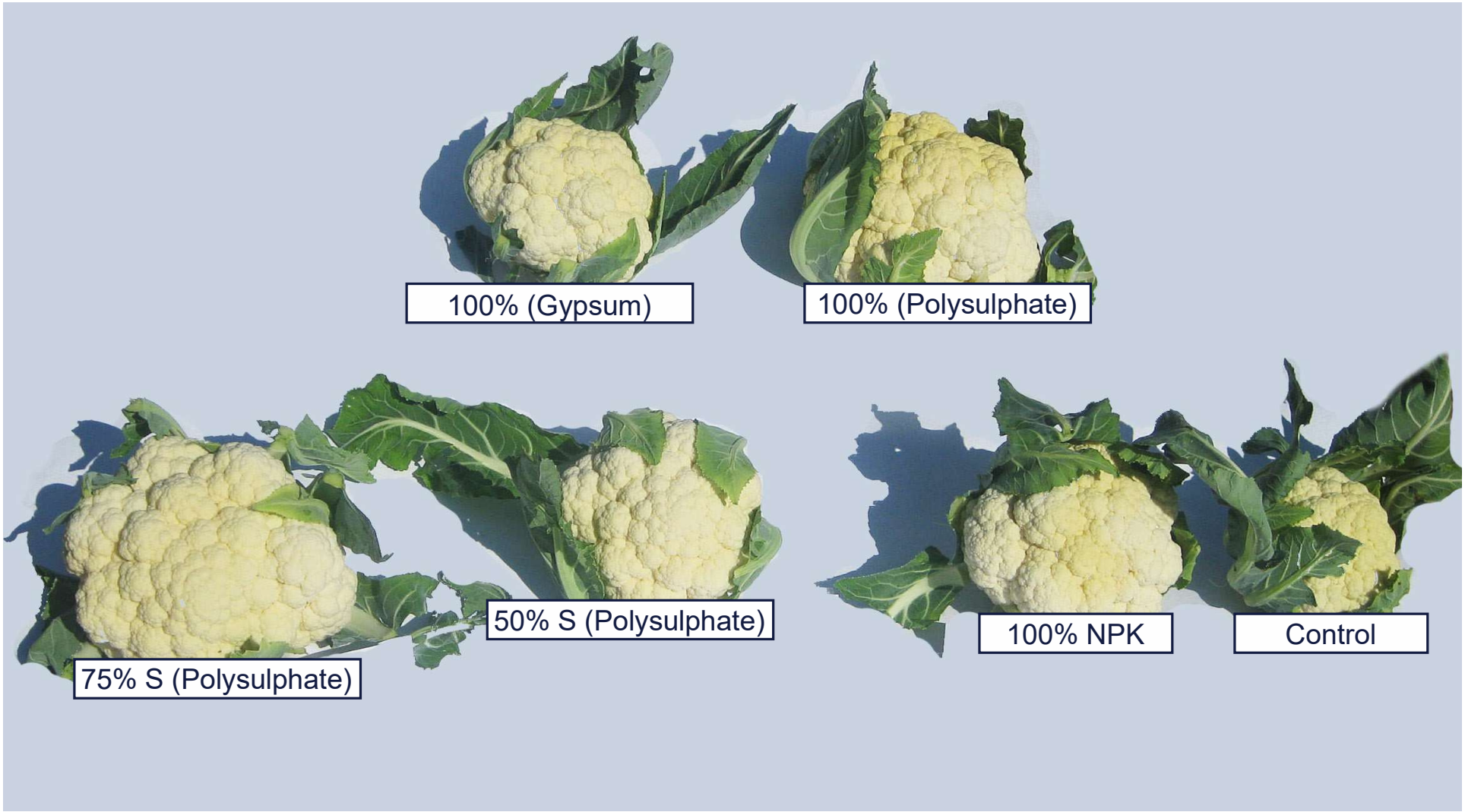
Effect of treatments on Cauliflower, 60 days

100% NPK+S through Polysulphate

100% NPK

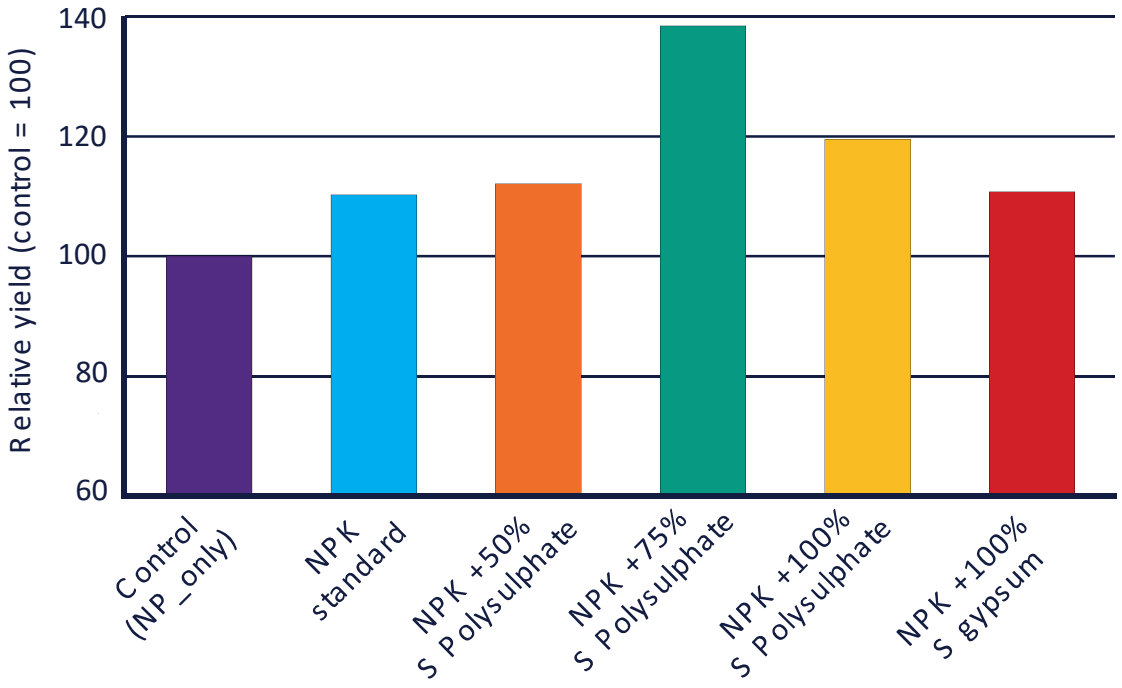
Effect of treatments on Cauliflower, 60 days

India



India

Effect of sulphate and the effectiveness of Polysulphate on Cauliflower yield



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What can we learn?

Application of K added additional 10% yield over NP.

Low level of S (10 kg/ha) did not affect yield.

S from Polysulphate was more effective than S from gypsum.

CONCLUSIONS from trials at Bangalore

- **Application of 100% NP + 75% K through polysulphate (balanced K through MOP to make 100% recommended K) recorded significantly higher yield of cabbage (45.74 t/ha) and cauliflower (26.12 t/ha), accounting for 32.81 and 39.53 per cent increase in yield respectively over control without S and K fertilization.**

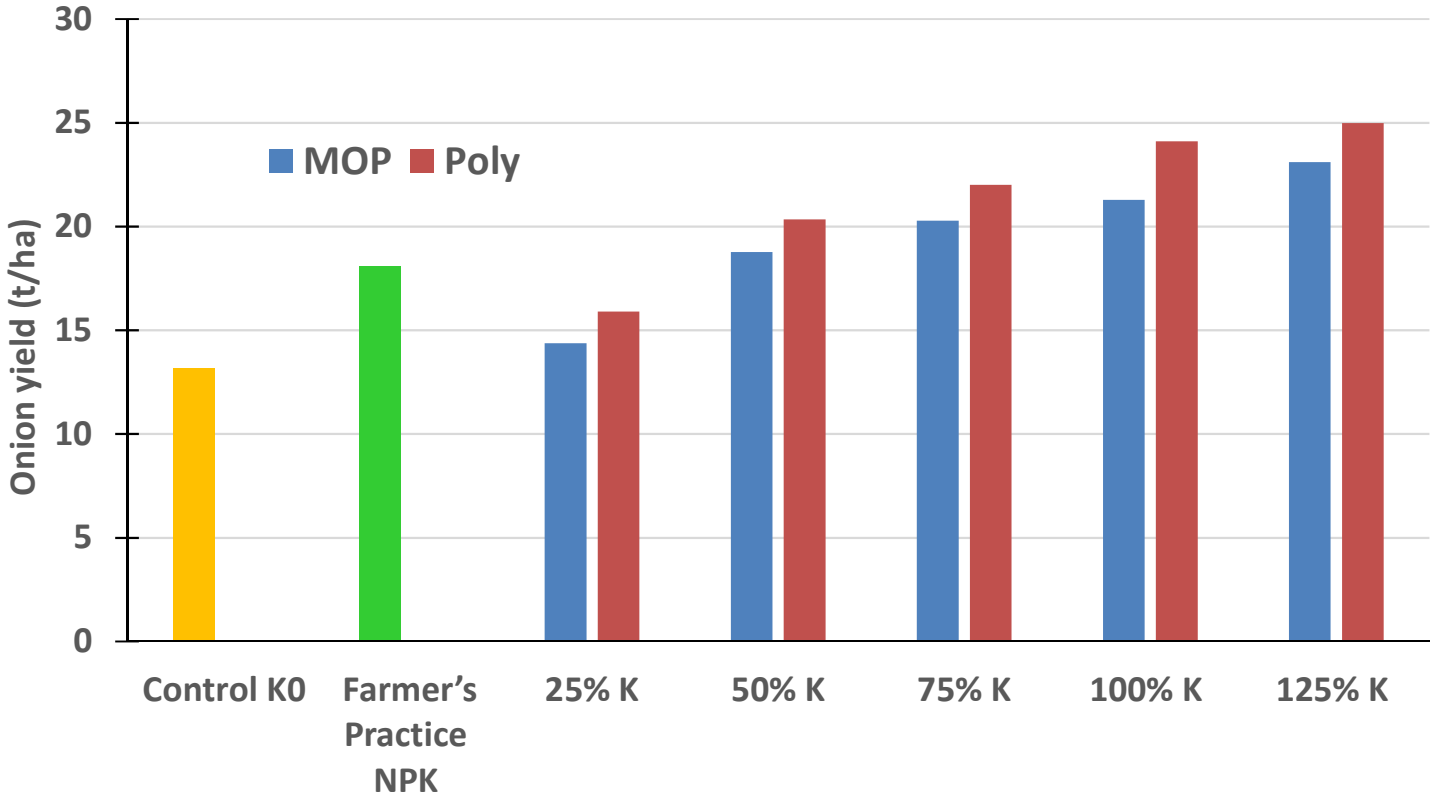
- **Beneficial effect of S through polysulphate also increase the quality attributes of cabbage and cauliflower especially with regard to crude protein and ascorbic acid.**

Polyhalite on Vegetables – TNAU, Madurai (Started in 2018)

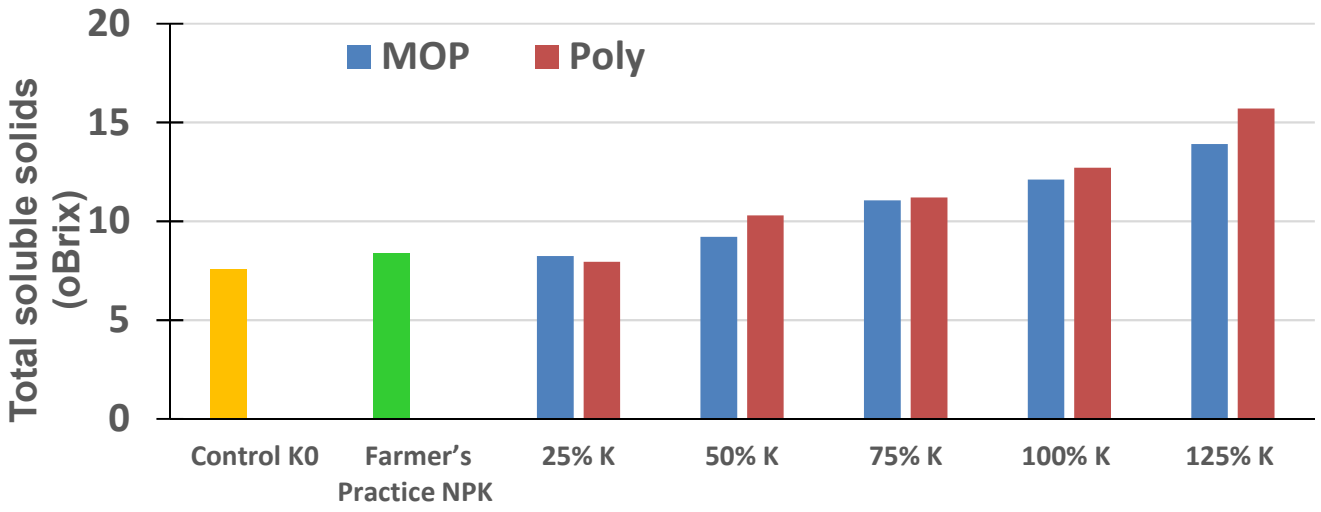
- **Experiments:**
  - Sulphur, calcium and magnesium were supplemented through elemental sulphur, calcium chloride and magnesium chloride respectively.
  - Recommended dose of N and P were applied uniformly to all the treatments
  - Design: RBD
  - Replication: Three
  - Field experiments were conducted at farmer's holdings

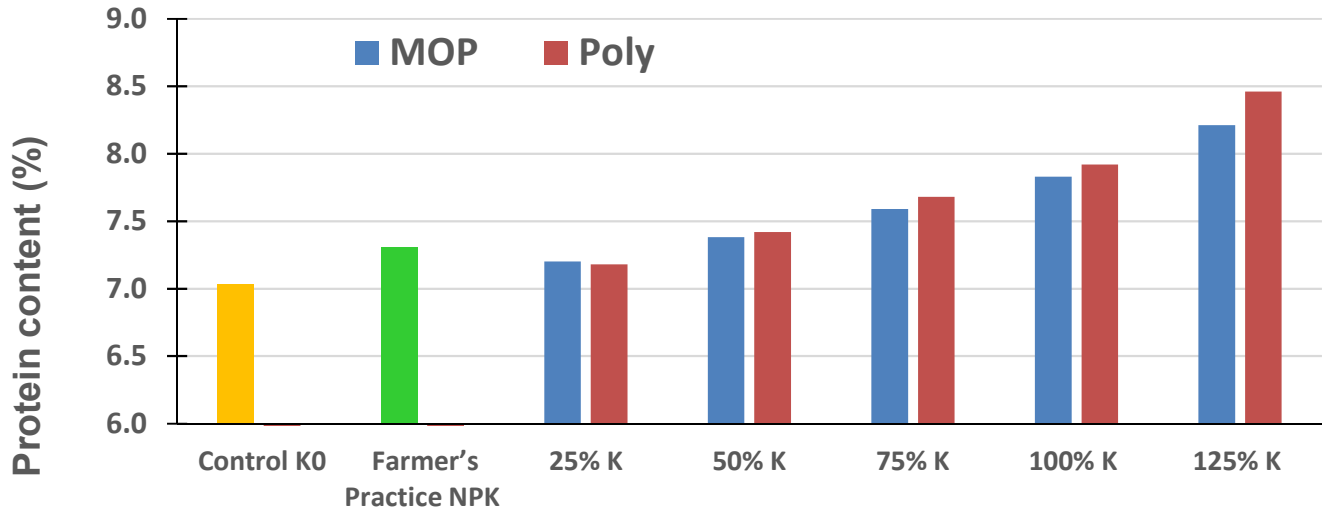
Polyhalite on Onion-Field trial – TNAU

Effect of Polyhalite on Onion yield – TNAU

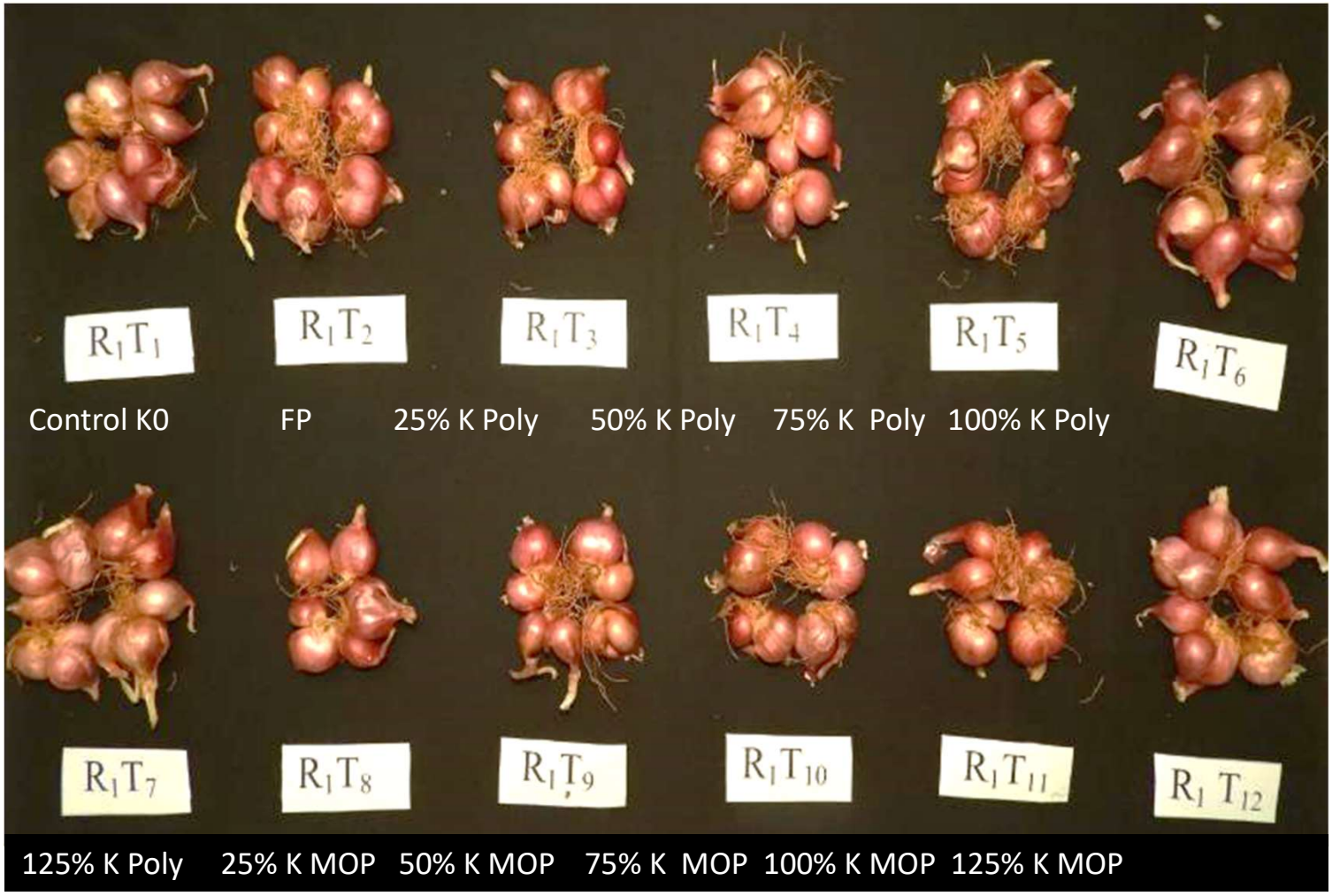


❶ Polyhalite on Onion quality – TNAU

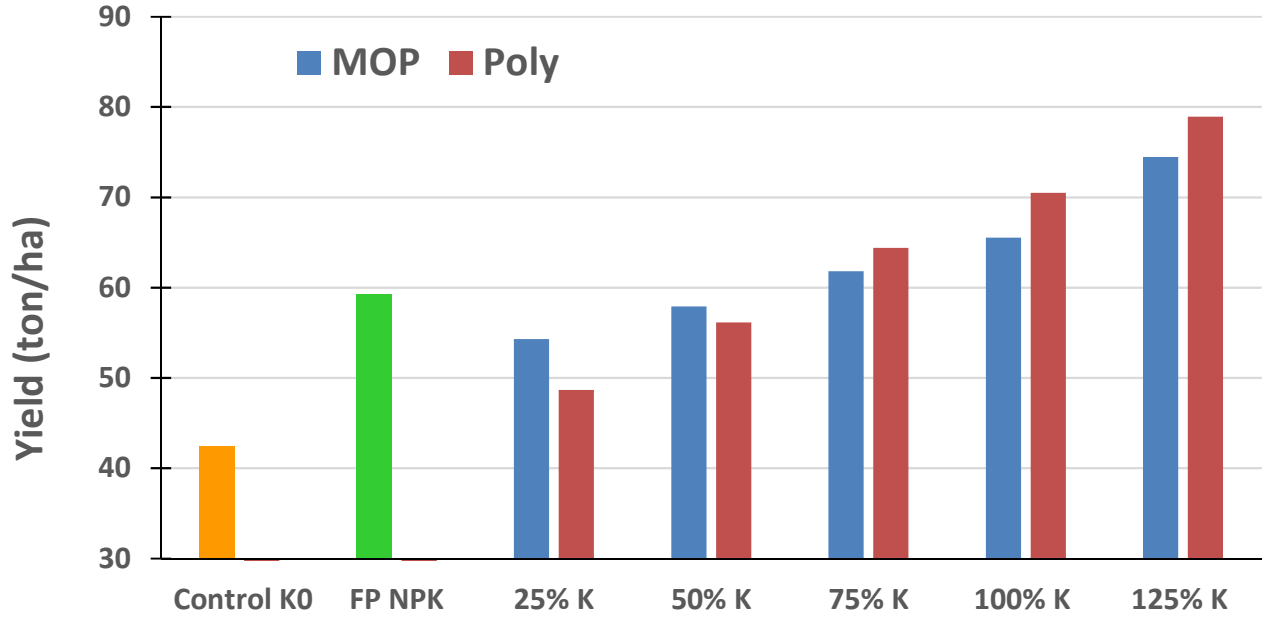




❶ Onion – TNAU

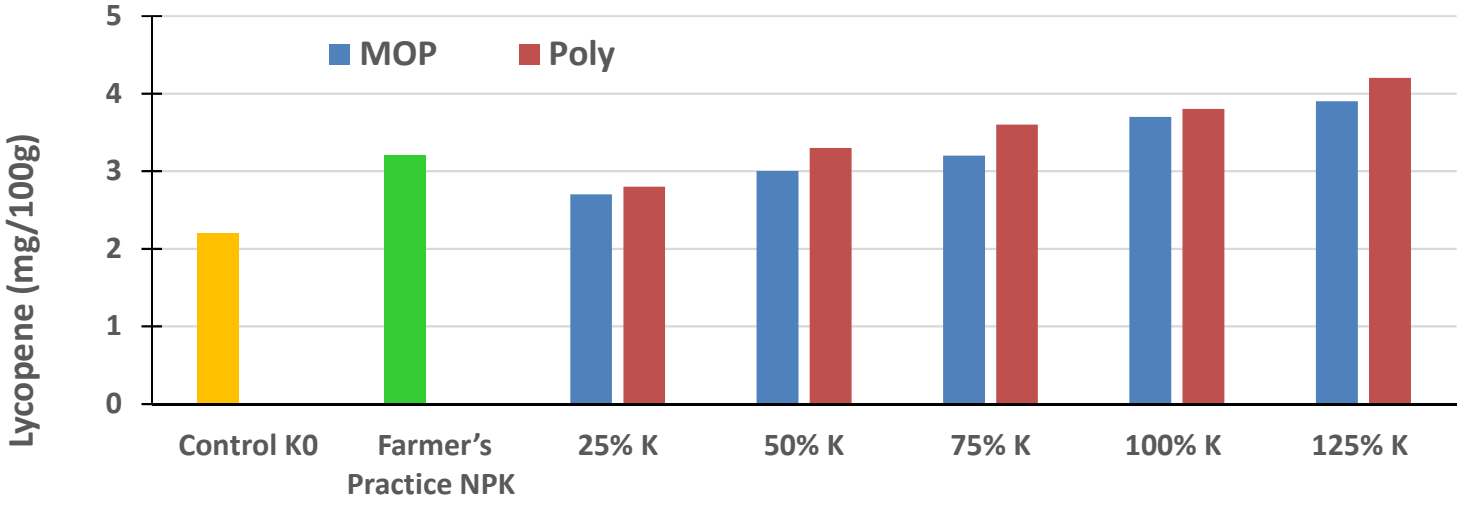

R1T1
R1T2
R1T3
R1T4
R1T5
R1T6
Control K0
FP
25% K Poly
50% K Poly
75% K Poly
100% K Poly
R1T7
R1T8
R1T9
R1T10
R1T11
R1T12
125% K Poly
25% K MOP
50% K MOP
75% K MOP
100% K MOP
125% K MOP

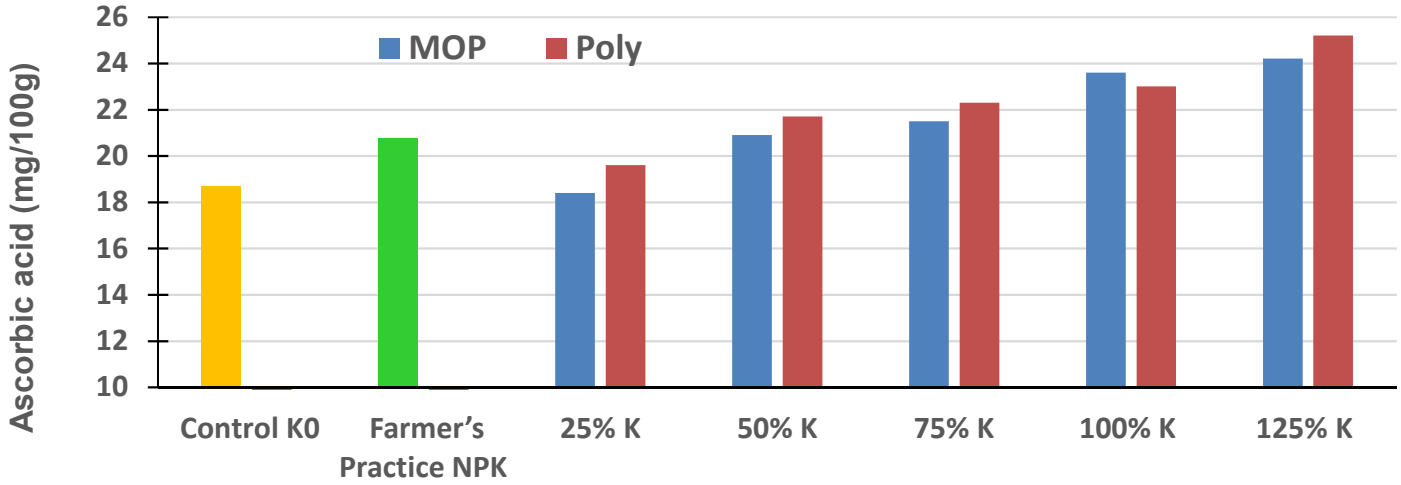
Polyhalite Effect on Tomato yield – TNAU Madurai, 2018-19



Kg K_2O/ha	0	250	66	132	198	264	330

Polyhalite Effect on Tomato Quality – TNAU, Madurai, 2018-19

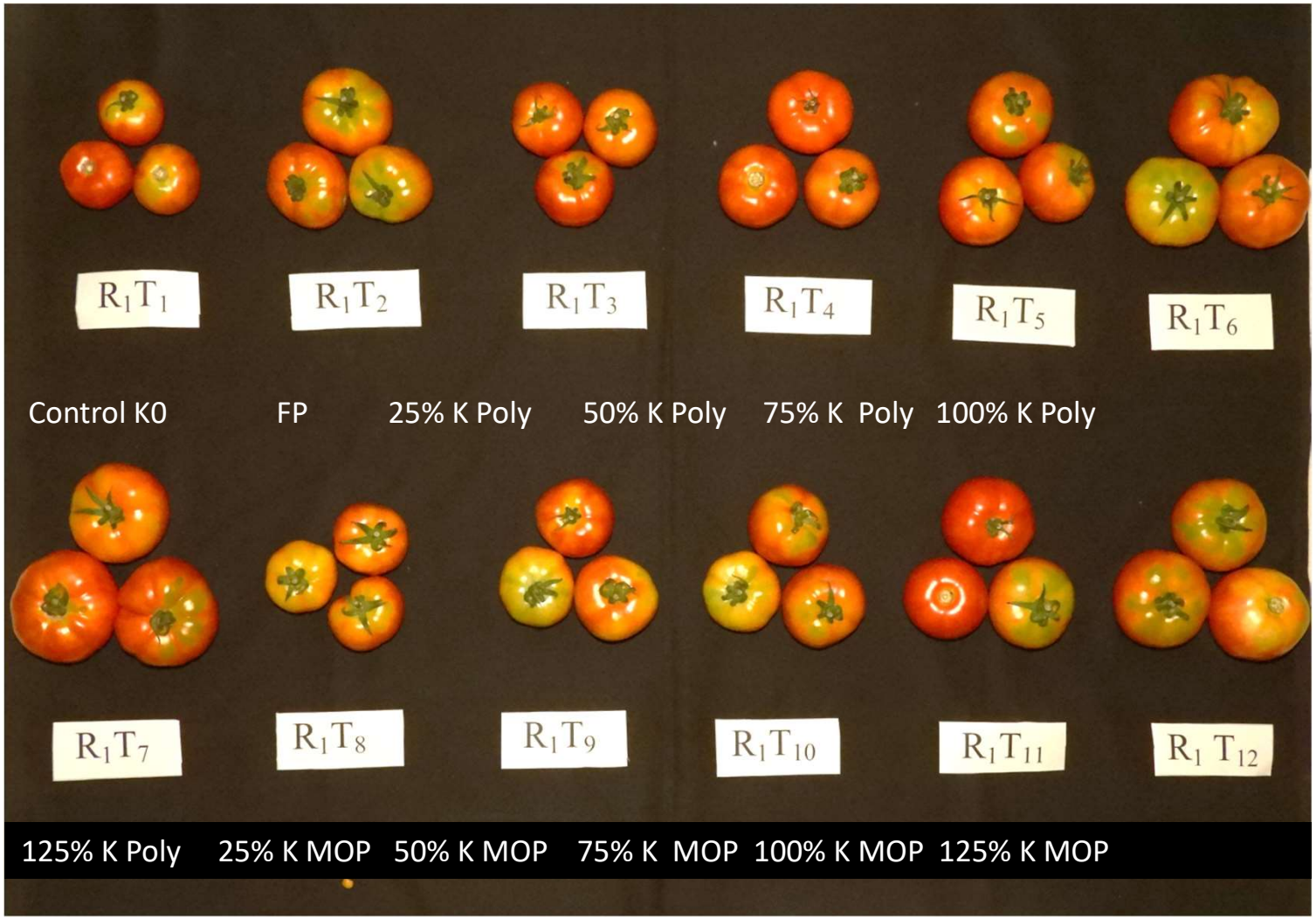




Kg K_2O/ha	0	250	66	132	198	264	330

❶ Tomato – TNAU

❶ Tomato – TNAU



Polyhalite on Cassava – CTCRI, Trivandrum Kerala, 2018-19

- **Treatments:**

1. POP (Package of Practices) for cassava (NPK 100:50:100 kg ha^{-1}+FYM @12.5 t ha^{-1})
2. Soil test based recommendation of NPK and FYM (STBF)
3. POP + lime @full LR* + Polysulphate 1.5-2 ton/ha (LF+PS)
4. POP + lime@1/2 LR + Polysulphate 1.5-2 ton/ha (1/2 L+PS)
5. POP + Dolomite @full LR + Polysulphate 1.5-2 ton/ha (DF+PS)
6. POP + Dolomite @1/2 LR + Polysulphate 1.5-2 ton/ha (1/2D+PS)
7. POP + Polysulphate 1.5-2 ton/ha (PS)
8. POP + lime @1/2 LR + dolomite @ 1/2 LR + Polysulphate 1.5-2 ton/ha (1/2L+1/2D+PS)
9. POP + lime @1/2 LR + dolomite@ 1/2 LR (1/2L+1/2D)

* LR: Lime Requirement

❷ Cassava - CTRI

❷ Cassava Yield and Quality- CTRI

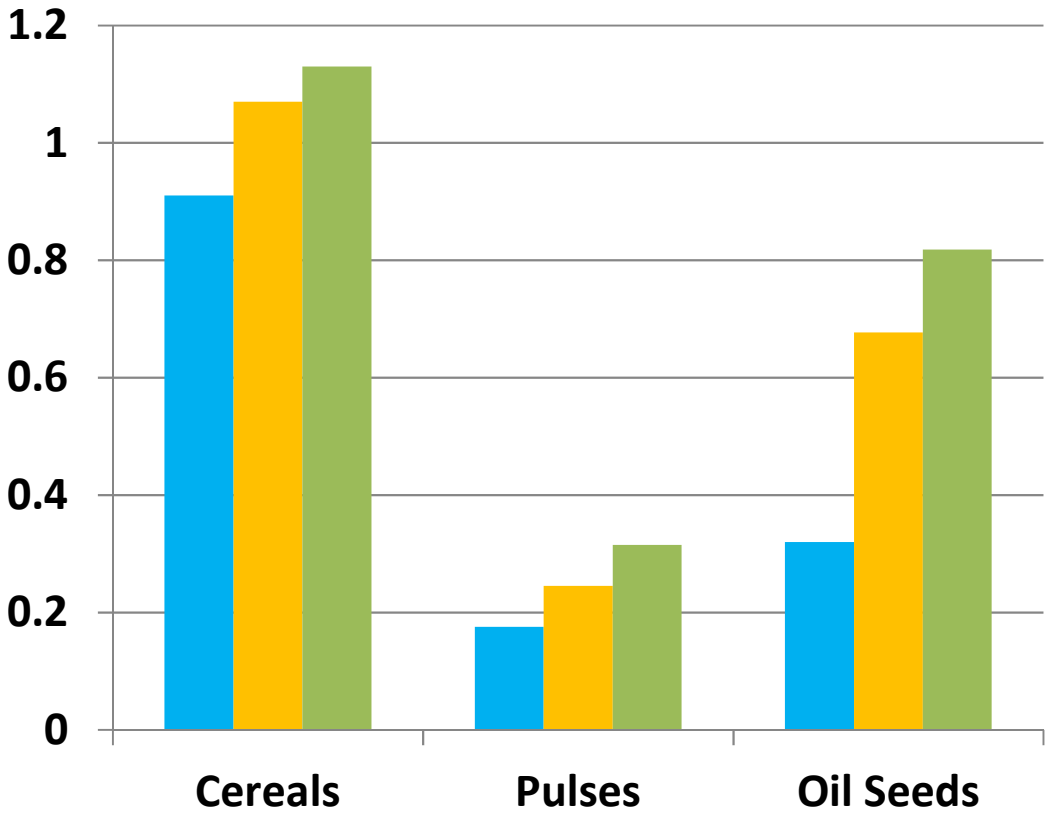
Treatment	Description	Yield (t ha^{-1})	Cyanogenic glucosides (ppm)	Starch (%FW basis)
T1	PoP	30.1	134.37	23.52
T2	STBF	29.9	63.65	18.30
T3	PoP + L + PS	35.5	71.15	21.02
T4	**PoP + 1/2L + PS**	**41.0**	**57.58**	**15.81**
T5	**PoP + DF + PS**	**46.5**	**73.97**	**20.44**
T6	PoP +1/2D + PS	21.3	59.44	17.18
T7	**PoP + PS**	**50.5**	**113.80**	**22.87**
T8	PoP + 1/2L + 1/2D + PS	25.2	43.72	17.34
T9	PoP + 1/2L + 1/2D	24.0	152.55	12.84
	CD(0.05)	*12.37*	*13.693*	*3.202*

L: Lime
D: Dolomite

❷ Cassava - CTRI

- **Conclusions and Future Requirements**

Projected Requirements of S in India (million t)



Total demand for S in India is projected at 1.99 in 2025 and at 2.26 million t in 2030

Source: DOS, Govt of India 2015

Conclusions

- Deficiency of S is fast emerging in Indian Soils.
- More deficiency of S in southern India as compared to others.
- There is negative balance of about 0.4 million t S in Indian soils.
- S application at 30-45 kg/ha to different crops improve crop yield of about 10-40% and quality, particularly oil content in oil seed crops.
- Among the different sources, Gypsum seems to be the cheapest source.
- Polyhalite was found superior or equally effective source of S, Ca, Mg and K in most of the crops tested.

Future Thrust

- More field studies need to be conducted for establishing S fertilizer recommendations for different set of crops in different areas.
- Extension and promotion efforts need to be strengthened to promote S use in crops other than oil seeds, as well.
- As Polyhalite is equally effective source of S and other nutrients, more research efforts need to be carried out for more crops in different regions.

Thank You !