Evaluation of soil fertility and partial nutrient balances for improved fertilizer recommendations under intensive agriculture in India

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This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Changing scene of Indian agriculture

Parameters	1950-51	2007-08
Gross Area Under food Grains (million ha)	97.3	124.4
Gross Irrigated Area Under food Grains (million ha)	18.3	56.6
Per Capita Gross Sown Area (ha person $^{-1}$)	0.34	0.16
Cropping Intensity (%)	112	135
Fertilizer consumption (million tones)	.07	23.02
Food Grain production (million tones)	50.8	230.7

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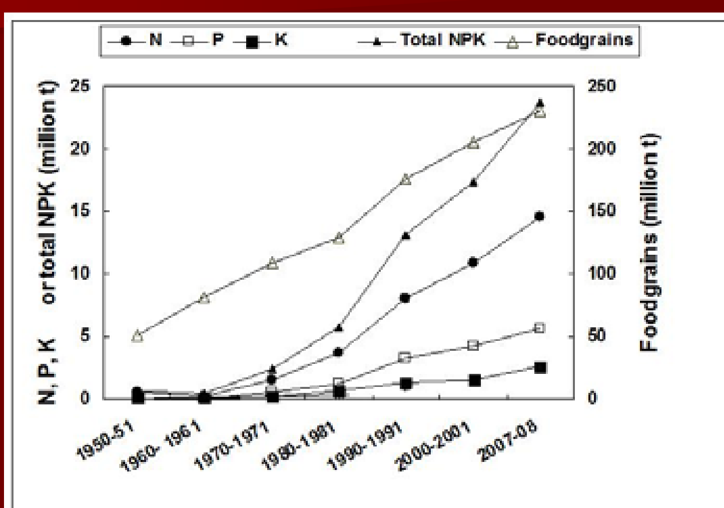
Structure of Presentation

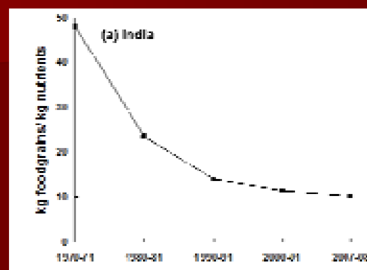
- Trends in fertilizer use and crop response
- Soil fertility evaluation approaches
- Fertilizer recommendation philosophies
- Partial nutrient balances
- Balanced fertilization and FUE

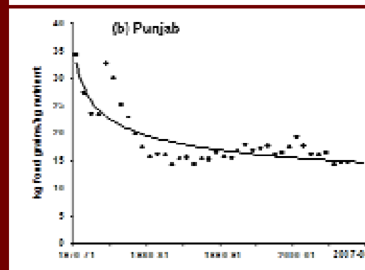
Trends in fertilizer N, P and K consumption and food grain production in India

(1950-51 to 2007-08)

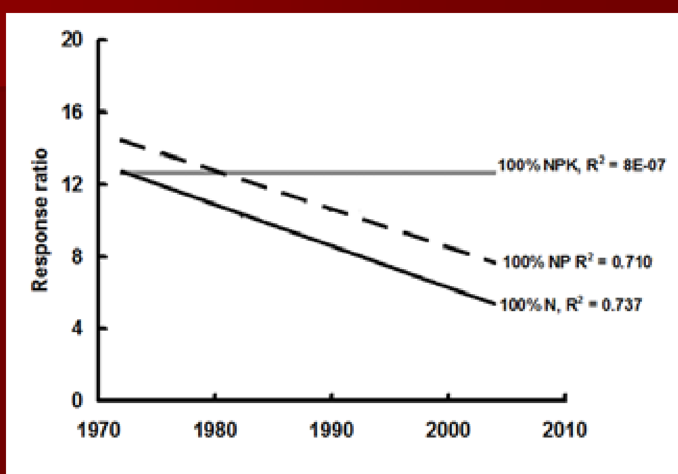


Partial factor productivity of fertilizer NPK for food grains production in India and Punjab





Nutrient response ratios in cereals



Drawn from long-term fertilizer experiments data averaged over 1972-2003 and several locations of rice, wheat, maize and finger millet.

Inefficient use of fertilizers is

- Uneconomical
- Unecological

Which may lead to:

- Environmental pollution
- Groundwater contamination
- Soil health problems

Soil fertility evaluation

1. ***Soil testing***
2. ***Plant analysis***

1) <u>Soil testing</u>

- To estimate the nutrient–supplying power of a soil by biological or chemical methods
- Soils classified into low, medium and high

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2) Plant Analysis

- Valuable supplement to soil testing.
- Useful in confirming nutrient deficiencies, toxicities or imbalances

Limitations:

- Does not consider nutrient balances and interactions
- Requires different critical values for different tissue ages

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Soil Test Interpretation and Fertilizer Recommendations Approaches

- **Generalized Fertilizer recommendation (GRD)**
- **Soil Test based fertilizer recommendation (STRD)**
- **Critical Value or sufficiency approach**
- **Fertilizer recommendation for targeted yields**
- **Build-up and maintenance concept**
- **Response surfaces and mechanistic modeling**

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Generalized or state level blanket fertilizer recommendation

- It is most commonly advocated and followed method
- Ideally suited to soils of medium fertility

Limitations:

- Due to variation in soil fertility it does not ensure economy and efficiency of applied fertilizer
- Wastage in high fertility and sub-optimal use in low fertility soils

Soil Test Based fertilizer recommendations

Fertilizer recommendation is based on soil which is considered as medium.

Fertilizer dose

- ✓ increase by 25% for **low soils**
- ✓ decreased by 25% for **high soils**

Limitations

- Same dose for extremely low and moderately low soil
- Same dose for extremely high and moderately high soils
- Only single nutrient is considered
- Interaction with other nutrients and soil properties are ignored

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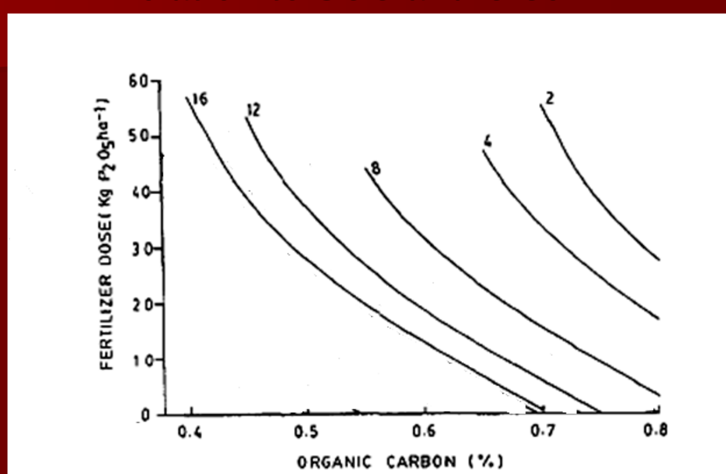
Solution

- **Fertilizer recommendation should be based on actual soil test value instead of soil fertility class**
- **Interaction effect should be considered, e. g. response to P depends both on P status and organic carbon status of soil**

Fertilizer P requirement for 5 t/ha wheat yield in relation to SOC and Olsen P



Values at the top of the curves indicate Olsen P (mg kg^{-1}).

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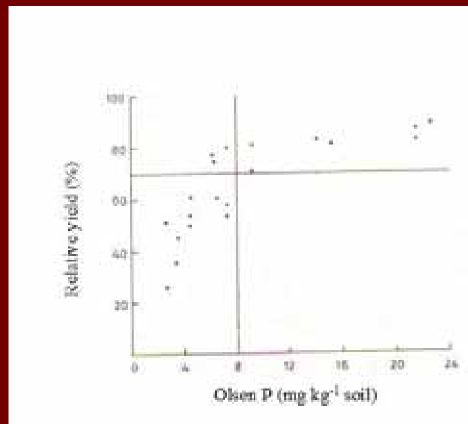
Critical Value Approach

- Applied to differentiate responsive from non-responsive soils
- Maximum data points should fall in 1st and 3rd quadrant



Critical limits of available K in soils for different crops and soils

Crop	Soils Type	Critical Limit (mg kg^{-1})
Rice	Medium Black	100
	Red	75
	Alluvial	190
	Laterite	80
Wheat	Alluvial	100
	Calcarious	60
Sorghum	Vertisol	335

Based on data from different regions of India

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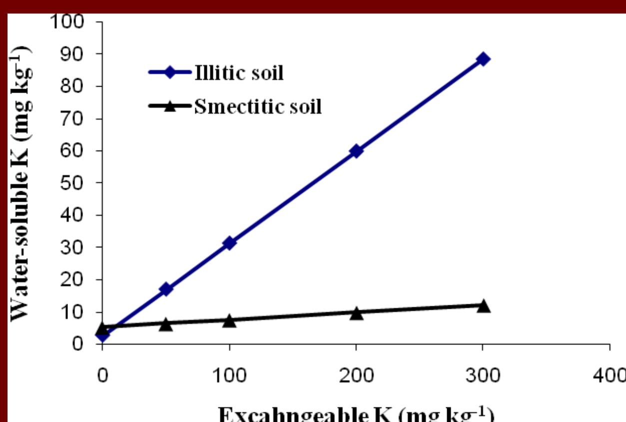
Fertilizer recommendations for K

- Extraction with NH_4OAc is adopted in Soil Testing labs. and a value of 55 mg K kg^{-1} is used to differentiate responsive from non-responsive soils.
- The glaring discrepancy in K availability by adopting uniform critical values for all soils could be seen by comparing the illite rich mineral soils with smectite dominant soils

Soil	NH_4OAc-K (mg K kg^{-1})	Response to K
Illite rich mineral soil	60	Non-responsive
Smectite dominant soils	300	Responsive

Relationship between exchangeable and water soluble K for illitic and smectitic soils



(Sekhon et al. 1992)

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Relationship between exchangeable and water soluble K

Soil	Relationship	Solution K (mg Kg^{-1})	Exch. K (mg Kg^{-1})
Illitic	Y=2.59 + 0.286X	12.0	33
Smectitic	Y=5.14 + 0.023X	12.0	300

Y = Solution K ; X = Exchangeable K

Site-specific nutrient management

- Feeding crops with nutrients as and when needed
- The application and management of nutrients are dynamically adjusted to crop needs of the location and season

Example:

- Use of leaf colour chart (LCC) or Chlorophyll meter
- Target yield concept

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Target yield concept

- **It not only prescribes the optimum dose of nutrient but also predicts the level of yield that a farmer can expect**

Fertilizer dose is obtained by computing three basic parameters:

- NR- nutrient requirement per unit of economic yield
- CS- contribution from soil available pool
- CF- fractional recovery of applied fertilizer nutrient

Limitations:

- Problems in estimating contribution of nutrient from soil available pool (CS)
- CS is influenced by soil type, texture, rooting depth and nutrient release characteristics of the soil
- Heavily biased towards high fertility of native and applied nutrients
- Difficult to estimate the contribution of non-exchangeable K towards plant uptake

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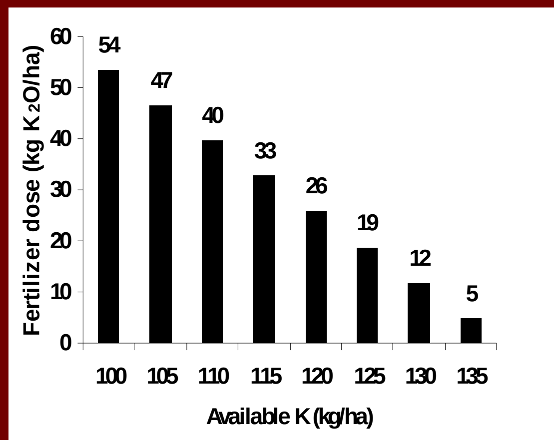
Soil test based fertilizer K recommendations for target yield of rice (7 t/ha) in alluvial soils of Punjab



Imbalanced fertilization and nutrient balances

1. The present NPK use ratio of 6.8:2.8:1 in India is typically unfavourable to K compared to the generally proclaimed ideal ratio of 4:2:1
2. Punjab having highest productivity of wheat (4.52 t ha^{-1}) & paddy (5.8 t ha^{-1}), has highest imbalanced use of NPK (33.7:9.2:1.0) and substantial mining of K from soils

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3. Ratio of 4:2:1 could be satisfactory for cereals but for other crops like legumes the ratio could vary from 1:1:1 to 2:1:2

4. Imbalanced use of NPK is main cause for declining crop response ratios

Total K loss from Punjab soils

Description	Years				
	1960-61	1970-71	1980-81	1994-95	2006-07
Addition thro' fertilizer ($X10^3$ tonnes)	Nil	7	29	14	43
Total K removal ($X10^3$ tonnes)	159	305	495	820	825
Net loss ($X10^3$ tonnes)	159	299	466	806	782
Loss (kg/ha/crop)	44	67	82	122	118

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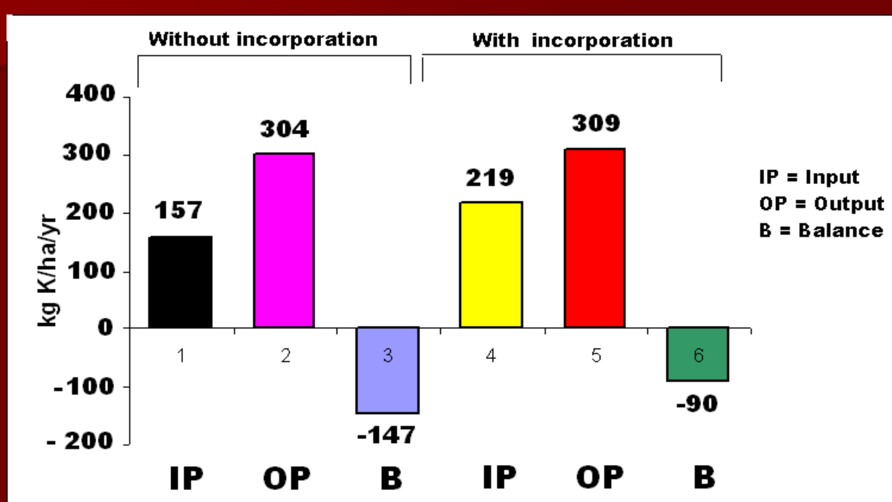
K removed (kg ha^{-1}) by maize-wheat sequence (1970-71 to1983-84)

Treatment	Removed	Applied	ΔE-K	ΔNE-K	Total E-K + NE- K	Release from NE-K	Unaccou-nted
Control	**803**	**0**	**-51**	**-597**	**-648**	**752**	**155**
N100	**1392**	**0**	**-72**	**-1110**	**-1182**	**1320**	**210**
N100 P22	**1766**	**0**	**-78**	**-1483**	**-1561**	**1689**	**205**
N100 P22 K41	**2323**	**1097**	**+6**	**-1101**	**-1095**	**1250**	**149**

Adapted from Singh and Brar (1986)

Annual K balance in long term rice-wheat cropping system at Ludhiana (India) during 1988- 2000

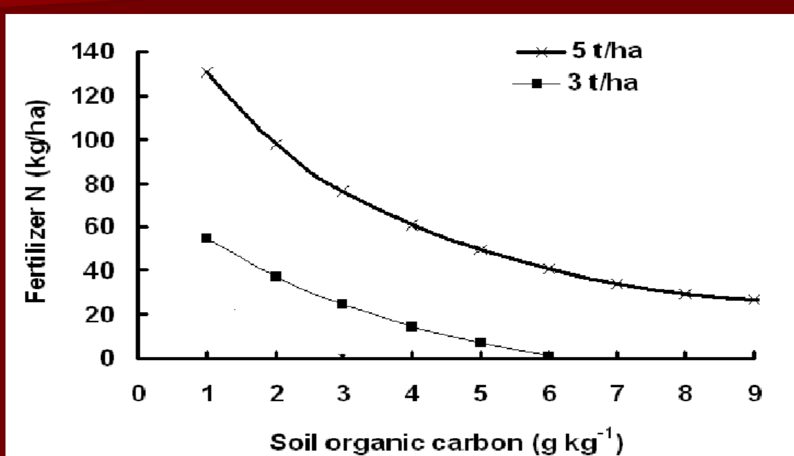


Yadvinder-Singh et al. (2004)

Balanced Fertilization and fertilizer Use Efficiency

Crop	Soil type/ Location	N use efficiency (%)			P use efficiency (%)	
		N	NP	NPK	NP	NPK
Maize	Inceptisol/ Ludhiana	16.7	23.5	36.4	10.3	21.4
Wheat		32.0	50.6	63.1	20.6	30.7
Maize	Alfisol/ Palampur	6.4	34.7	52.6	21.8	35.6
Wheat		1.9	35.6	50.6	10.7	15.2

Fertilizer N use efficiency could be improved if the fertilizer N rate is adjusted for the actual SOC concentration instead of fertility classes



Source: Benbi and Chand (2007)

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Conclusions

- The fertilizer consumption in India increased dramatically but the response has declined
- While there is a wide-scale adoption of blanket fertilizer recommendation there is a need for site-specific nutrient management for balanced fertilization
- Need to monitor soil fertility and emerging nutrient deficiencies

- Soil test methods should be augmented with other chemical and biological fractions for better interpretations
- Fertilizer adjustment for K, needs to consider non-exchangeable K along with exchangeable or water soluble K
- Different critical levels for available K should be used for soils with different mineralogical composition

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Thanks