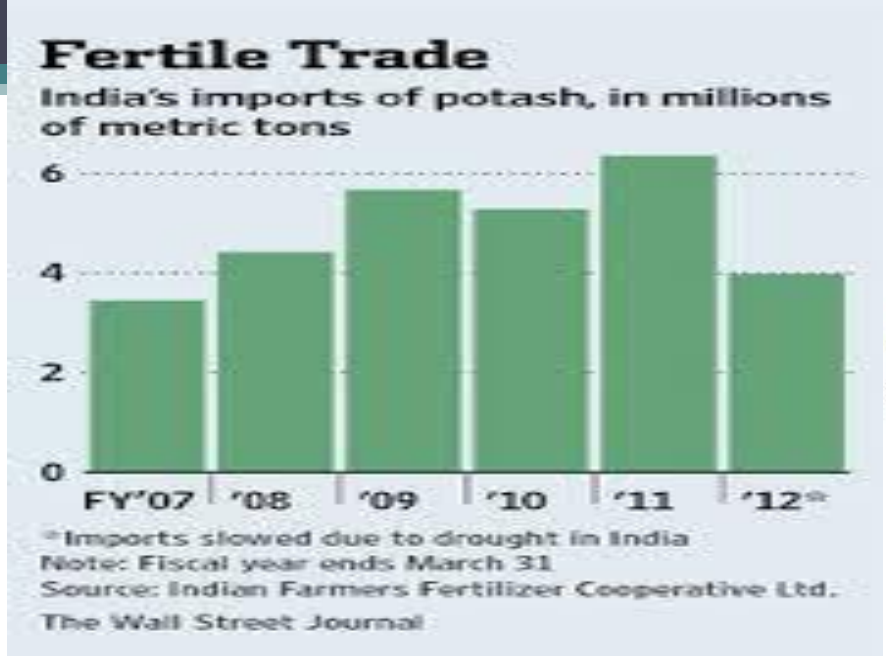
Novel organic matrix based super granular microbial consortium for higher wheat productivity and soil enrichment

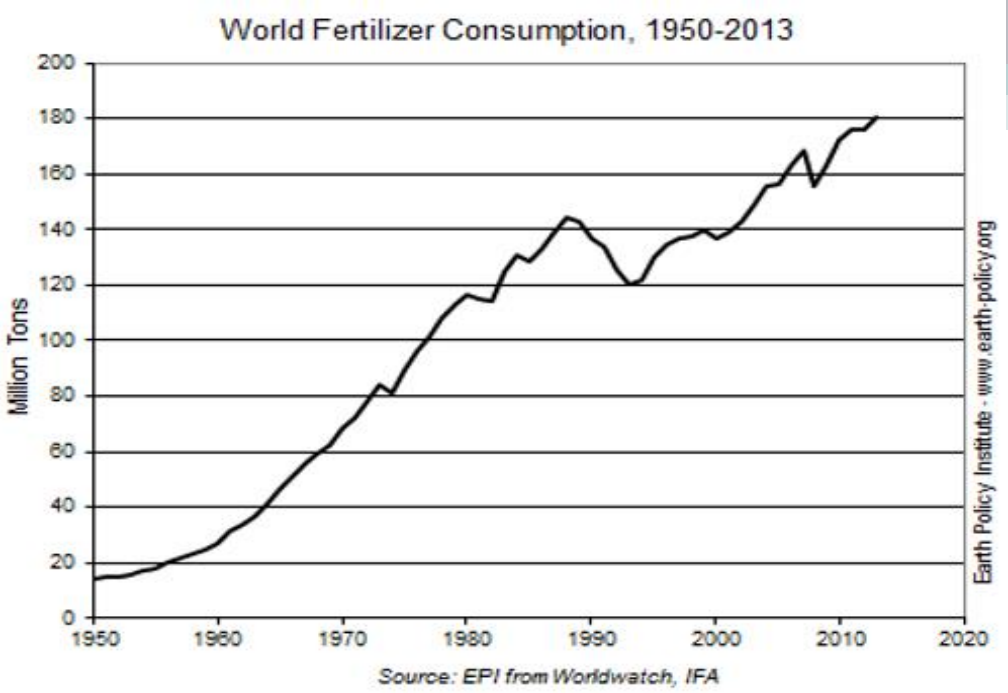
Rana Pratap Singh, Ph.D.
Professor, DES; Dean SMS
Professor- in- Charge, Academic
BBA University (A Central University), Lucknow
www.ranapratap.in

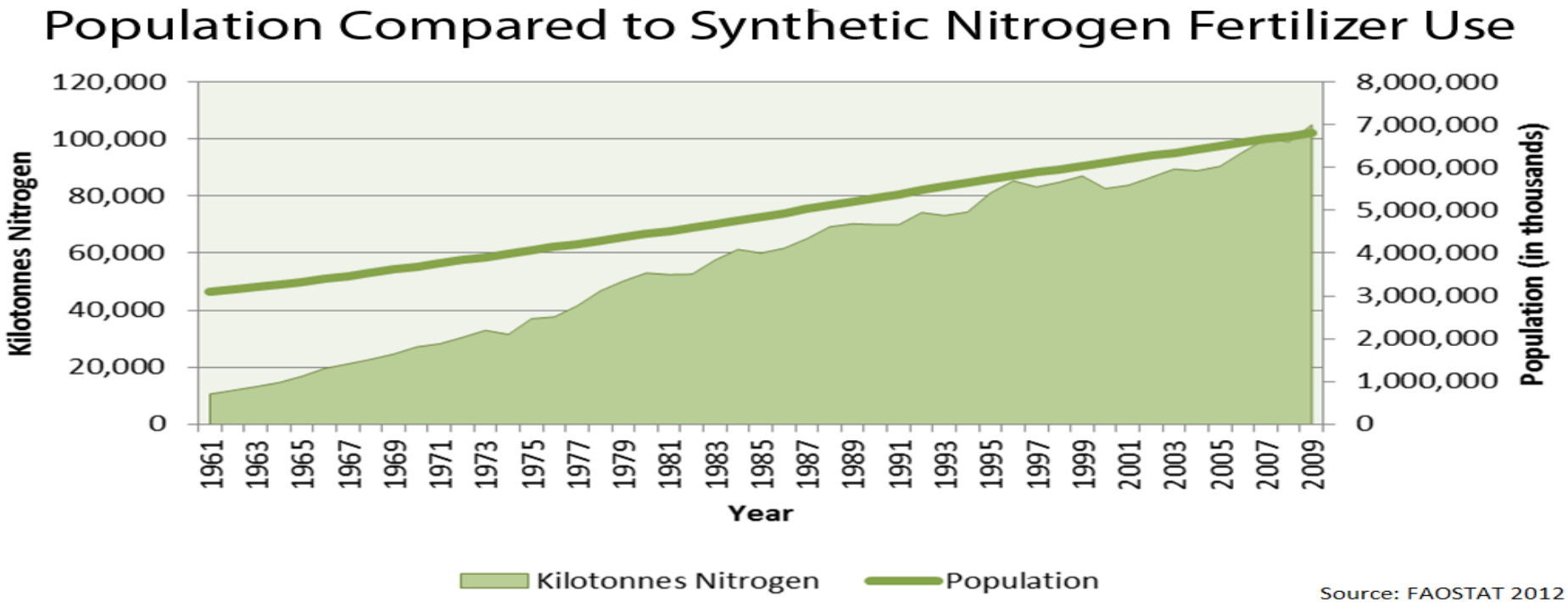
Food and Environment

- We talk about food production
- We talk about food quality
- We talk about food fortification
- We talk about post harvest management
- We talk about food packaging and marketing

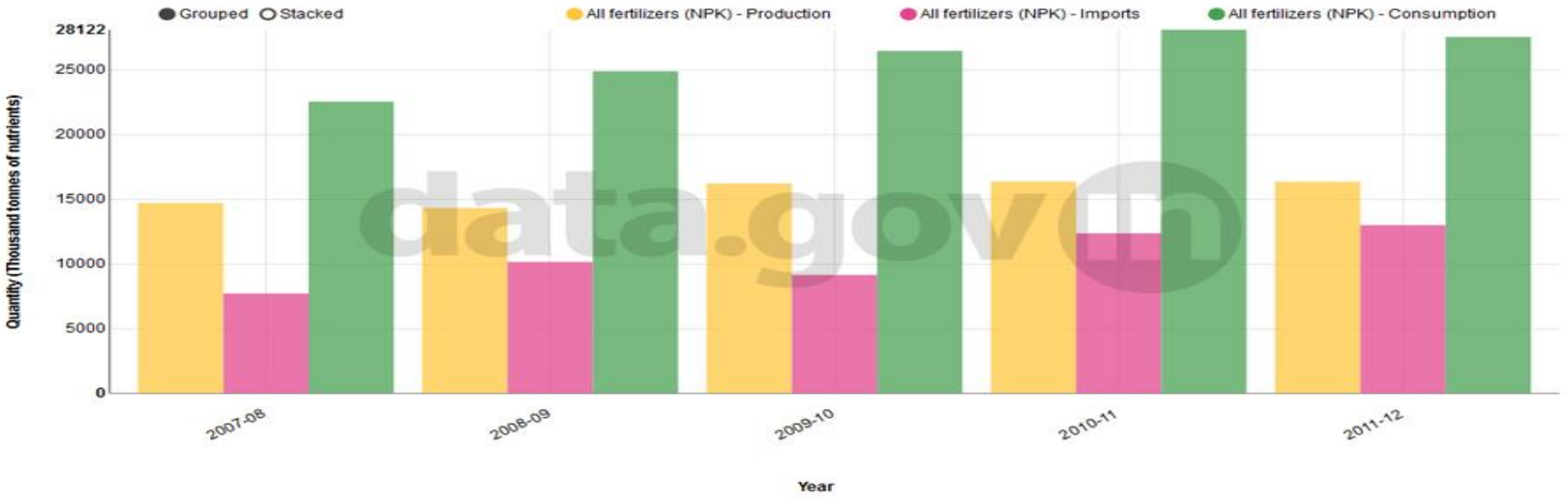
We rarely talk about food environment which determines all the above

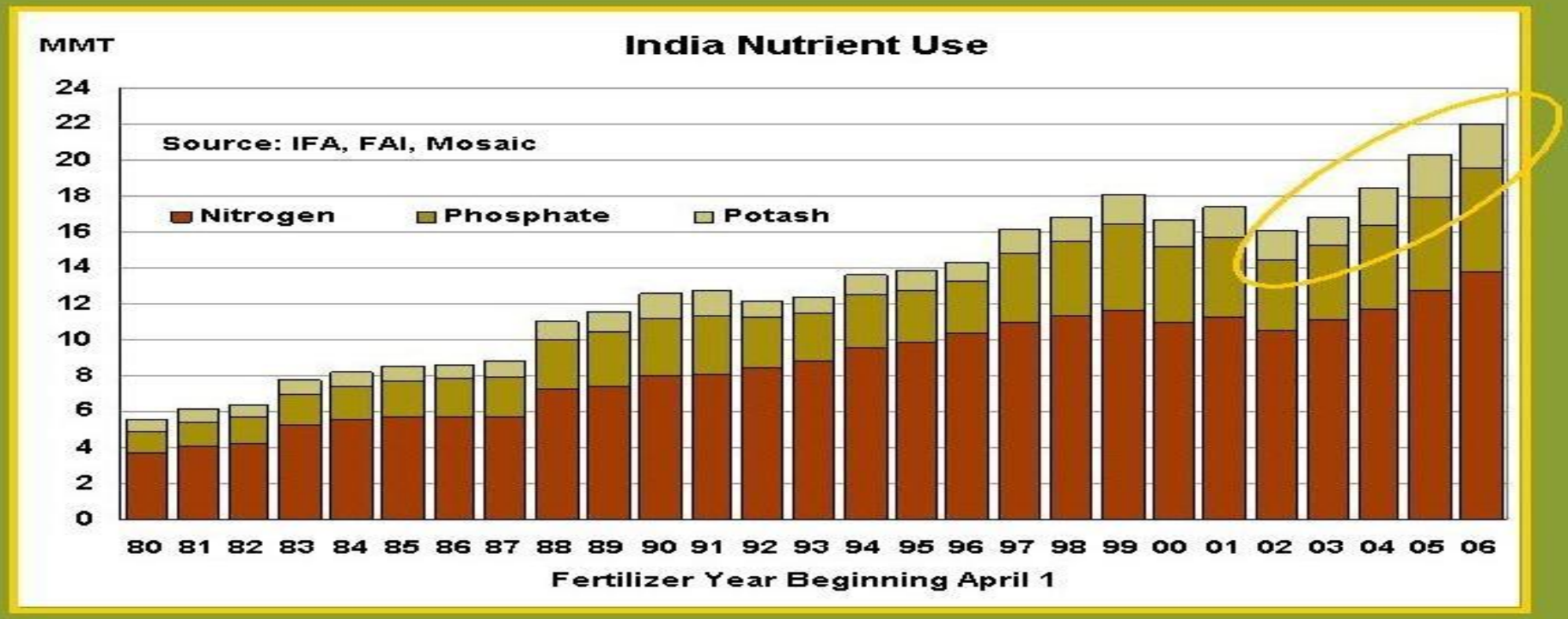






Source: FAOSTAT 2012


Grouped
Stacked
All fertilizers (NPK) - Production
All fertilizers (NPK) - Imports
All fertilizers (NPK) - Consumption
Quantity (Thousand tonnes of nutrients)
28122
25000
20000
15000
10000
5000
0
2007-08
2008-09
2009-10
2010-11
2011-12
Year
data.gov.in


MMT
India Nutrient Use
Source: IFA, FAI, Mosaic
Nitrogen
Phosphate
Potash
24
22
20
18
16
14
12
10
8
6
4
2
0
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06
Fertilizer Year Beginning April 1

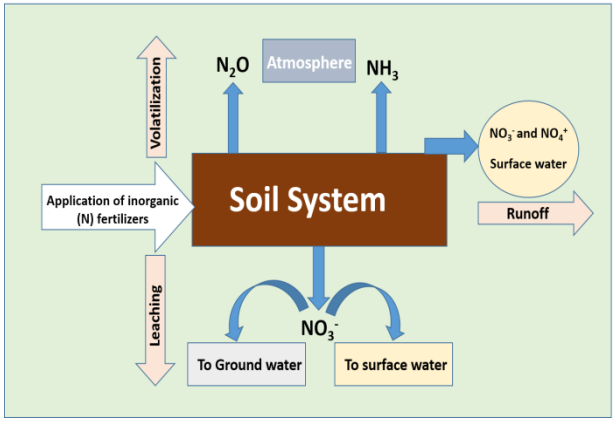
Nitrogen use efficiency (NUE) in different crops at various locations

Plant	Country	% NUE/Absorption
Rice	India	28-34
Rice	Pakistan	49
Flooded rice	Pakistan	38-44*
Wheat	India	57-58
Wheat	Pakistan	24-60*
Spring wheat	Spain	40
Maize	USA	29-45
Maize	USA	23-60*
Cotton	Australia	33
Barley	Finland	28-34
Barley	Finland	14-25
Oat	Spain	37.9
Beet	Spain	12-40*

Source- Adopted from Singh *et al.*, 2006

Environmental and Health related issues of synthetic fertilizers

Environmental degradation due to the application of inorganic fertilizers on crop yield



Environmental degradation due to application of conventional chemical fertilizers and their causative mechanisms

Environmental consequences	Causative Mechanisms
Ground water contamination	Nitrate leaching from soil
Eutrophication	Erosion, surface runoff, and seepage of N from agricultural fields
Acid rain and ammonia re-deposition	Ammonia volatilization
Global warming	Nitrous oxide emissions from soil

Place	Level of NO_3^- (mg l^{-1})		Level of NO_2^-	
	Ground water	Surface Water	Ground water	Surface Water
Lucknow, India	38- 114	34.96- 51.58	0.07- 0.29	0.12-0.26
Karnataka, India	143.66	-	-	-
Rajasthan, India	7.10-82.0	-	-	-
Makurdi, Nigeria	45-148	-	-	-
Rawalpindi, pakistan	45-1125	-	-	-
Assir, audi Arabia	-	-	-	0.07-0.089
North china Plain, Chian	1.2-258	-	-	-
Karnataka, India	6.69-42.45	-	-	-

and nitric
om soil

Contamination of surface and ground water by nitrate and nitrite

Gaseous Nitrogen Loss from the agricultural fields applied soluble chemical fertilizers

Agricultural Field	Emission/ Volatization of Gases	Reference
Wheat and maize	Nitrous oxide	Jiang et al., 2010
Wheat	Nitrous oxide	Chirinda et al., 2010
Corn-Soybeen	NO_X	Woli et al., 2010
Rice	NO_X	Pandey et al., 2008
Wheat	Ammonia and NO_X	Weber et al., 2001
Grass land	Methane and nitrous oxide	Glatzel and Stahr, 2001
Carrot	N_2O and NO	Akiyama et al., 2000
Agricultural Field	Ammonia and NO_X	Kurvits and Marta, 1998
Agricultural soil	NO_X	Marg and vinther , 1996
Agricultural soil	NO	Sullivan et al., 1996

Leaching and emission losses of nitrogen from the agricultural fields under wheat production on application of commercial chemical fertilizers.

Fertilizers used	Leaching and Emission Loses of Nutrients
135 kg N ha^{-1}	NO_3^--N leaching
130 kg N ha^{-1}, 90 kg P_2O_5 ha^{-1}, 36 kg K_2O ha^{-1}	NO^-_3 leaching
270 kg N ha^{-1}, 105 kg P_2O_5 ha^{-1}& 60 kg K_2O ha^{-1}	NO and N_2O emission
Coated urea 75 kg N ha^{-1}-150 kg N ha^{-1}, urea 125 kg N ha^{-1} to 300 kg N ha^{-1}	NH_3 and NO_3^- losses
Urea 250 kg ha^{-1}, superphosphate, 20 kg P ha^{-1}	NO_3^- and NO_2^- leaching

Responsiveness of wheat to the application of different organic/ Bio- fertilizers.

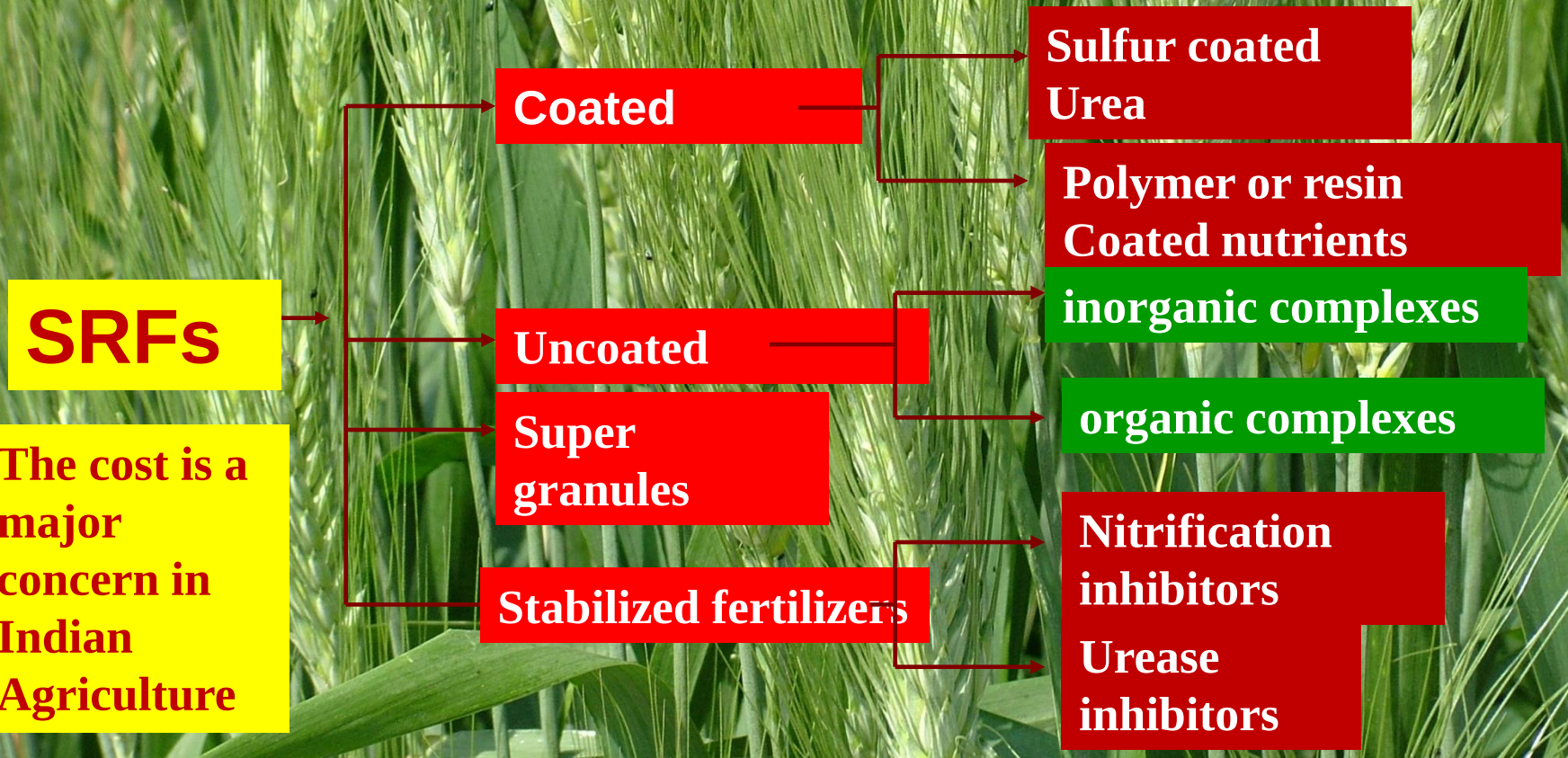
Organic/ Bio-fertilizers	Response observed
Anabaena, Azotobacter, Pseudomonas, Serratia and Mesorhizobium	Enhanced Nitrogen availability: Higher productivity and yield
Integrated nutrient management (organic fertilizers, Urea, SSP, KCL, Nimco)	Higher Growth attributes and yields of wheat
Organic fertilizers, chicken manure, Cerealine i.e. Azospirillum spp.	Higher Wheat yield and yield components

Responsiveness of wheat to the application of different types of the Slow/ Controlled release fertilizers

Slow/ Controlled release fertilizers		Response observed	References
Form	Amount		
Controlled released urea and urea	CRU- 0 to 225 kg N/ha	Dry matter yield, grain or seed yield, seed N concentration	Grant et al. 2012
Controlled release Urea fertilizers	75 -225 kg N/ha	N release, Nitrogen use efficiency, Yield of grain and straw	Yang et al. 2011
Slow release fertilizers: liquid Nitamin (L30), liquid Nitamin (G30), granular Nitamin (N42), Granular Nitrform (NF)	-	N- release in the form of NH_4-N, NO_3-N, soil type, soil temperature	Fan et al. 2010
Controlled release urea	50–60 kg N ha^{-1}	Soil microbial biomass	Lupwayi et al. 2010
Polymer coated Urea	PCU- 0-168 Kg N/ha, Urea- 56 N/ha	Effect of PCU in emergence of all varieties	Ingle et al. 2010
Urea, Coated Urea, Uncoated Urea	Urea - 250 kg N/ha, Coated urea- 75 kg N/ha, uncoated urea – 125 kg N/ha	Increased N content in soil, good crop yield	Wang et al. 2007
Neem coated urea i.e. Neem cake, Nimco, Nimagold	-	Urease activity, Urea transformation in soils and wheat yield	Singh et al. 2006
Green manure Sesbania sesban ,Nitrification inhibitor, Encapsulated calcium carbide (ECC) used	Urea+ Sesbania - 107mg/kg, ECC=10% of N applied	Availability of NH_4^+ and NO_3^- in soil plants have been studied	Patra et al. 2006

Slow release fertilizers (SRFs):

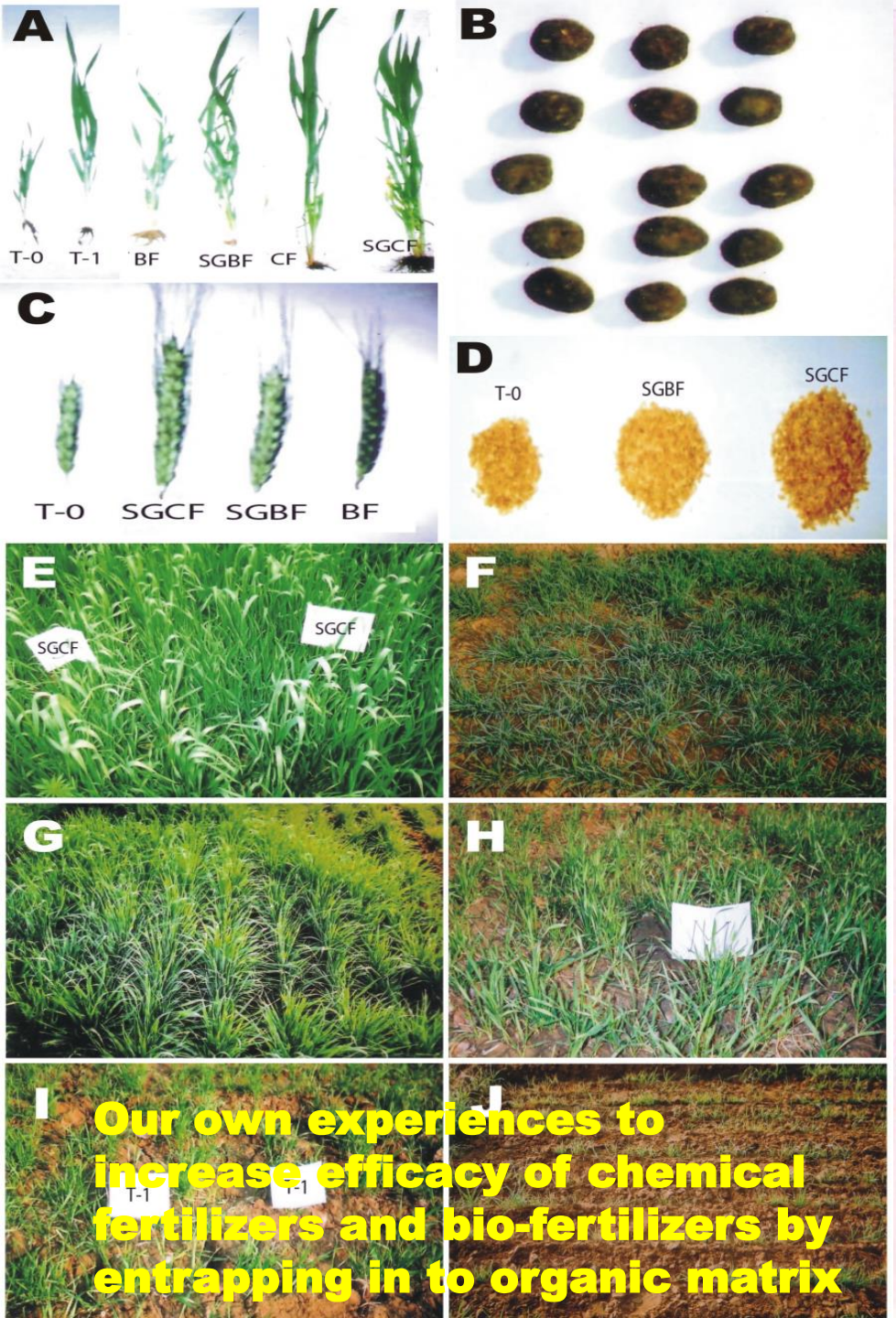
- Provide nutrients for long term
- Increase plant yield
- Restrict loss of fertilizers by leaching/ volatilization
- Saves natural environment and wastage of money



The cost is a major concern in Indian Agriculture

Significance of our Organic Matrix entrapped cost effective and eco friendly fertilizers

Organic entrapment provides a nutritive and porous carrier to microbes for rich growth and slow release of nutrients fixed or solubilized by the microbes. The soluble chemical fertilizers are also entrapped for slow release and longer availability. This interventions can increase the availability of nutrients and minimize the losses due to leaching, volatilization or emissions.

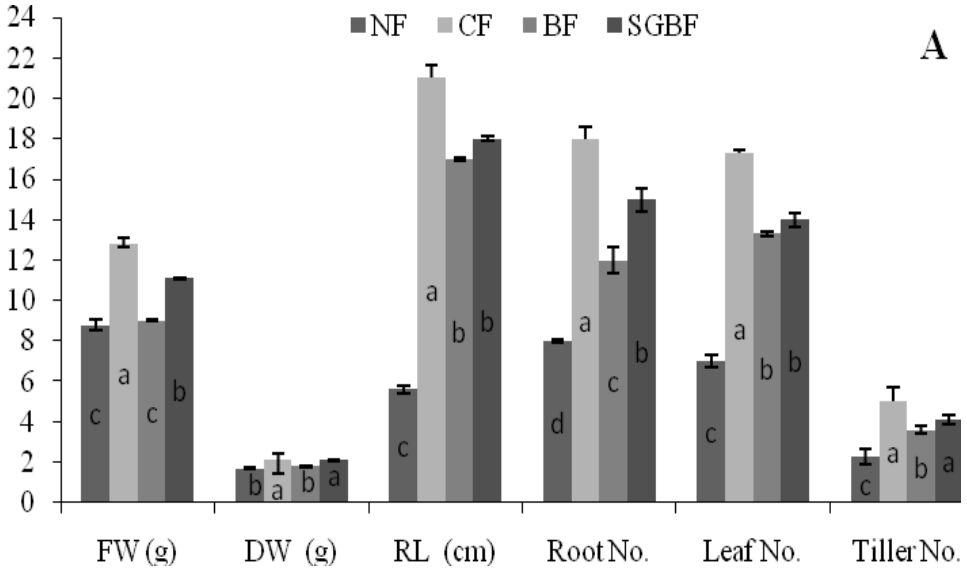

A
T-0
T-1
BF
SGBF
CF
SGCF
B
C
T-0
SGCF
SGBF
BF
D
T-0
SGBF
SGCF
E
SGCF
SGCF
F
G
H
I
T-1
T-1
J
Our own experiences to increase efficacy of chemical fertilizers and bio-fertilizers by entrapping in to organic matrix

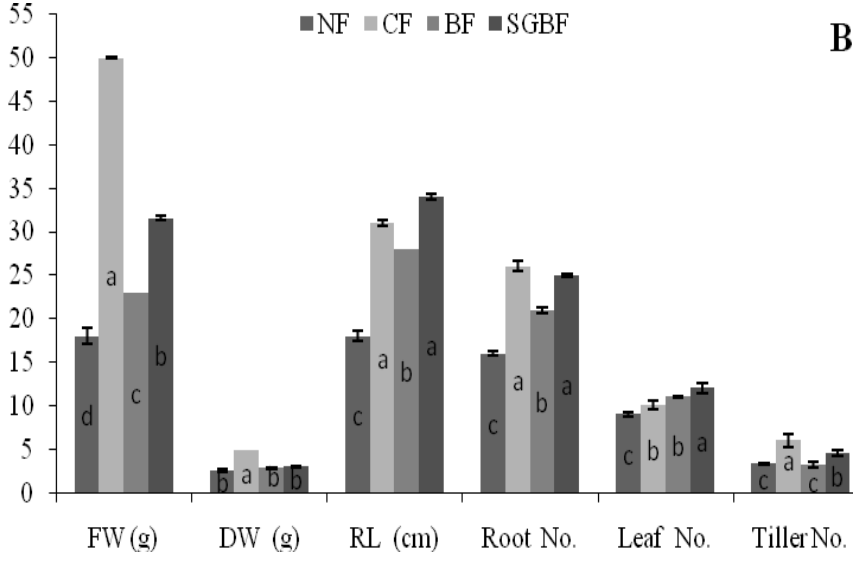

3
4
5
6
7
8
a
b
c
d
9
G
Std.
a
b
c
d
KD
66
45
29
86
49
10

Effect of free urea (FU), biofertilizers (BF) and organic matrix based entrapped biofertilizers (SGBF) on yield of wheat (Triticum aestivum L. cv. WH-711)

Treatments	Seed yield q/ha	Straw yield q/ha
No fertilizer (NF)	10.0d±0.033 (100)	15.0d±0.033 (100)
Chemical fertilizer (CF)	38.0 a ±0.033 (380)	60.0 a ±0.058 (396)
Biofertilizer (BF)	27.0 c ±0.058 (200)	32.0 c ±0.033 (211)
Entrapped biofertilizer (SGBF)	33.0 b ±2.967 (300)	50.0 b ±0.333 (330)

Effect of free urea, biofertilizers and organic matrix based entrapped biofertilizers (SGBF) on growth and productivity at 60 (A) and 120 (B) days old wheat plants





Effect of free urea (FU), biofertilizers (BF) and organic matrix entrapped biofertilizers (SGBF) on soil enzymatic activities in experimental plots before sowing and after harvesting

	Dehydrogenase activity (µg TPF/g soil/24 h)	Alkaline phosphatase activity (µg PNP/g soil/h)
before sowing of wheat crop	13.0	11.0
after sowing of wheat crop		
No fertilizer (NF)	15.0c±0.058 (100)	10.0d±0.058 (100)
Free urea (FU)	18.0d±0.058 (106)	12.0c±0.050 (120)
Biofertilizers (BF)	40.7b±0.033 (268)	20.2b±0.00 (202)
Entrapped biofertilizers (SGBF)	43.7a±0.00 (288)	22.5a±0.033 (225)

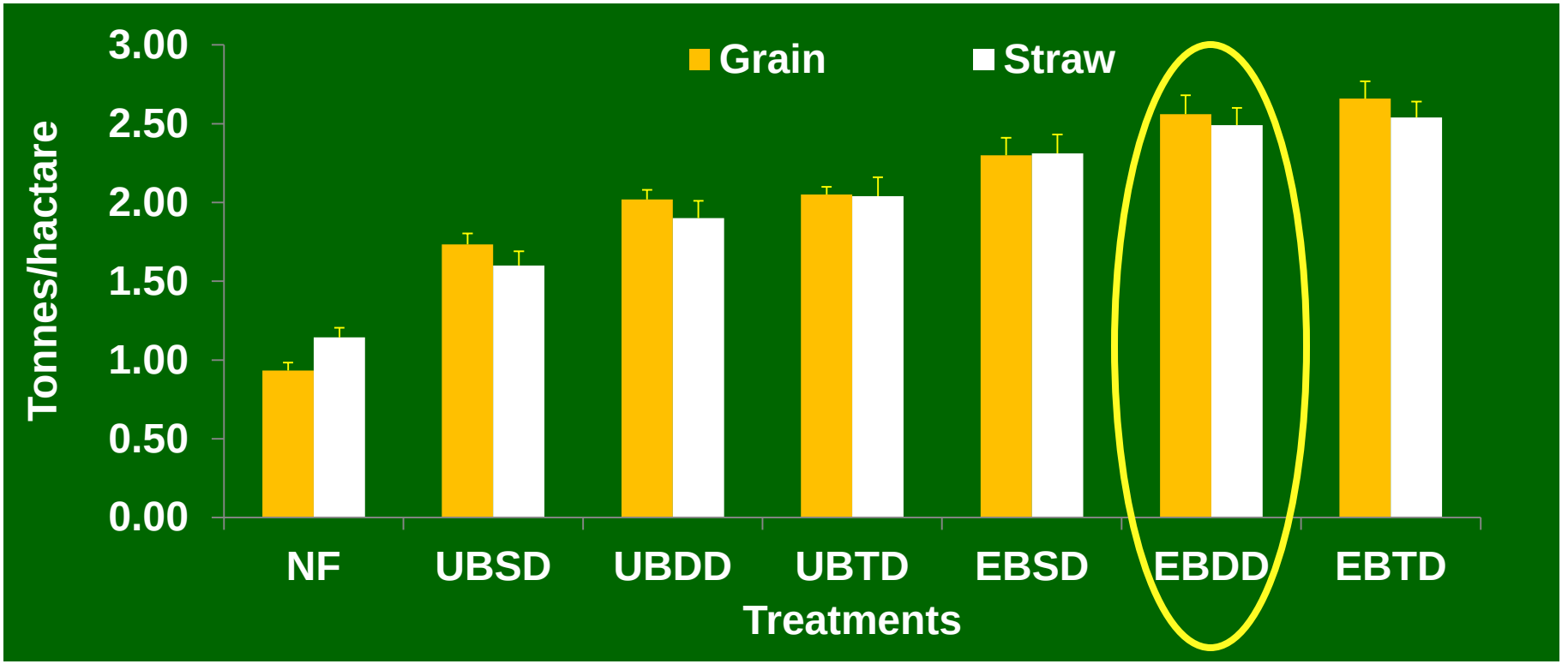
Effect of free urea, biofertilizers and organic matrix based entrapped biofertilizers on microbial properties of soil in experimental plots before sowing and after harvesting

	log No. of Fungal colonies/ g of soil	log No. of Bacterial colonies/ g of soil
Before sowing of wheat crop	1.1	2.1
After sowing of wheat crop		
No fertilizer (NF)	1.2±0.033 (100)	3.2±0.033 (100)
Free urea (FU)	1.3±0.167 (107)	3.4±0.058 (105)
Biofertilizers (BF)	1.4a±0.033 (116)	4.8a±0.058 (140)
Entrapped biofertilizer (SGBF)	1.5a±0.003 (125)	5.1a±0.333 (148)

Cost comparison of entrapped biofertilizers (SGBF) used in wheat crop

	Labour /ha in rupees	Seed Used Kg/ha in rupees	Fertilizer Cost/ Ha in rupees	Other (matrix+ Binder cost) in rupees	Total in rupees	Seed Yield q/ha	Approximate rate/kg in rupees	Cost of produce in rupees	Net loss(-) and gain(+) n rupees
Biofertilizers (BF)	3,000	50.0 (1500)	60.0	-	4,560	27.0	15	40,500	35,940 (+)
Entrapped biofertilizers (SGBF)	5,000	50.0 (1500)	40.0	100	6,640	33.0	15	49,500	42,860 (+)
Free Urea (FU)	3,000	50.0 (1500)	927.0	-	5,427	38.0	15	57,000	51,573 (+)

Effect of doses of conventional and organic matrix entrapped biofertilizers (OMEBs) on grain and straw yield of wheat (*Triticum aestivum* L.) after harvesting



NF= No fertilizers, UBSD= un-entrapped biofertilizers in single dose, UBDD= un-entrapped biofertilizers in double dose, UBTD= un-entrapped biofertilizers in triple dose EBSD= organic matrix entrapped biofertilizers in single dose, EBDD= organic matrix entrapped biofertilizers in double dose, EBTD= organic matrix entrapped biofertilizers in triple dose)


1205
Envirotech
HANDY SAMPLER







Gaseous emission in agricultural crop field wheat (*Triticum aestivum* L.) in 60 Days after sowing (Kumar S. and Singh R.P., unpublished results)

Treatments	SOx	NOx
	µg/m^3	µg/m^3
Control (no fertilizers)	57.05	13.50
Control (outer atmosphere)	69.70	6.4
Free form of Biofertilizers; *Azotobactor chrococum + Bacilus subtilis* (RD)	67.5	39.25
Immobilized form of Biofertilizers (RD)	56.9	35.57
Free form of urea + DAP (RD)	77.95	39.7
Immobilized form of urea + DAP (RD)	69.2	37.65
Free form of urea + DAP (1/2 of RD) + Biofertilizers (RD)	74.5	36.60
Immobilized form of urea + DAP (1/2 of RD) + Biofertilizers (RD)	72.30	34.45

Effect of different doses of un-entrapped and organic matrix entrapped biofertilizers (*Azotobactor chrococum + Bacilus subtilis*) on growth of wheat (*Triticum aestivum* L. cv. PBW-343) roots on 30, 60, 90 and 120 DAS

Parameter	Treatment	30 d	60 d	90 d	120 d
Root Length (cm)	NF	1.47±0.31	3.50±0.40	5.50±0.50	5.73±0.40
	UBSD	4.23± 0.31*	4.47±0.25^{ns}	6.70±0.44*	7.63±1.10**
	UBDD	4.97.0±0.78*	5.87±0.97**	7.50±0.87**	8.87±0.76**
	EBSD	5.37±0.70*	7.30±0.26**	8.57±0.60**	9.43±0.55**
	EBDD	5.77±0.42*	7.57 ±1.44**	8.80±0.36**	9.87±0.25**
Number of roots	NF	2.67±0.58	8.33±1.15	9.33±0.58	11.33±0.58
	UBSD	4.67±0.58 ^{ns}	8.67±0.58 ^{ns}	16.00±2.00**	16.00±2.00**
	UBDD	5.67±1.15*	12.67±1.53**	19.67±1.53**	22.67±0.58**
	EBSD	7.33±1.15**	17.00±1.00**	21.67±1.15**	24.00±2.00**
	EBDD	9.00±2.00**	19.00±1.00**	23.00±1.00**	26.00±1.00**
Fresh wt. of roots (g)	NF	0.12±0.03	0.13±0.02	0.20±0.02	0.24±0.03
	UBSD	0.20±0.02*	0.23±0.02**	0.35±0.06**	0.38±0.11*
	UBDD	0.22±0.03**	0.27±0.03**	0.36±0.03**	0.50±0.03**
	EBSD	0.38±0.05**	0.55±0.05**	0.59±0.04**	0.67±0.02**
	EBDD	0.44±0.05**	0.58±0.03**	0.67±0.03**	0.73±0.04**
Dry wt. of roots (g)	NF	0.02±0.01	0.07±0.01	0.07±0.02	0.08±0.01
	UBSD	0.07±0.03**	0.09±0.02 ^{ns}	0.11±0.01**	0.12±0.01**
	UBDD	0.10±0.01**	0.09±0.01 ^{ns}	0.12±0.01**	0.15±0.02**
	EBSD	0.11±0.01**	0.13=±0.02**	0.12±0.01**	0.13±0.01**

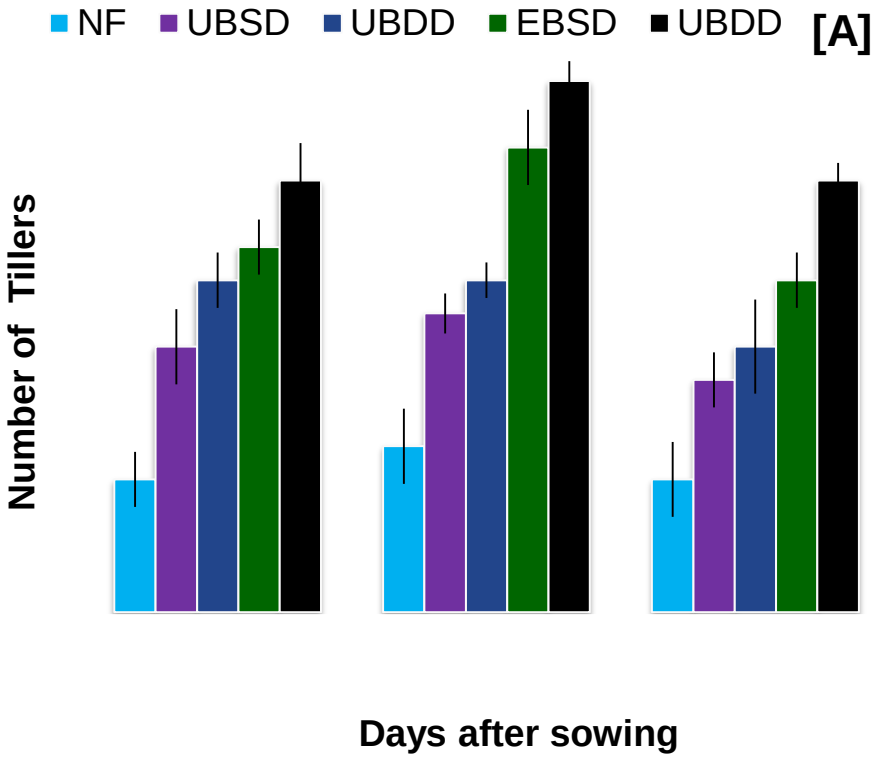
Where: NF=No fertilizer, UBSD= Un-entrapped biofertilizer, single dose (600 g ha^{-1} each), UBDD=Un-entrapped biofertilizer, single dose (1200 g ha^{-1} each) EBSD= Entrapped biofertilizer, single dose (600 g ha^{-1} each EBDD= Entrapped biofertilizer, double dose

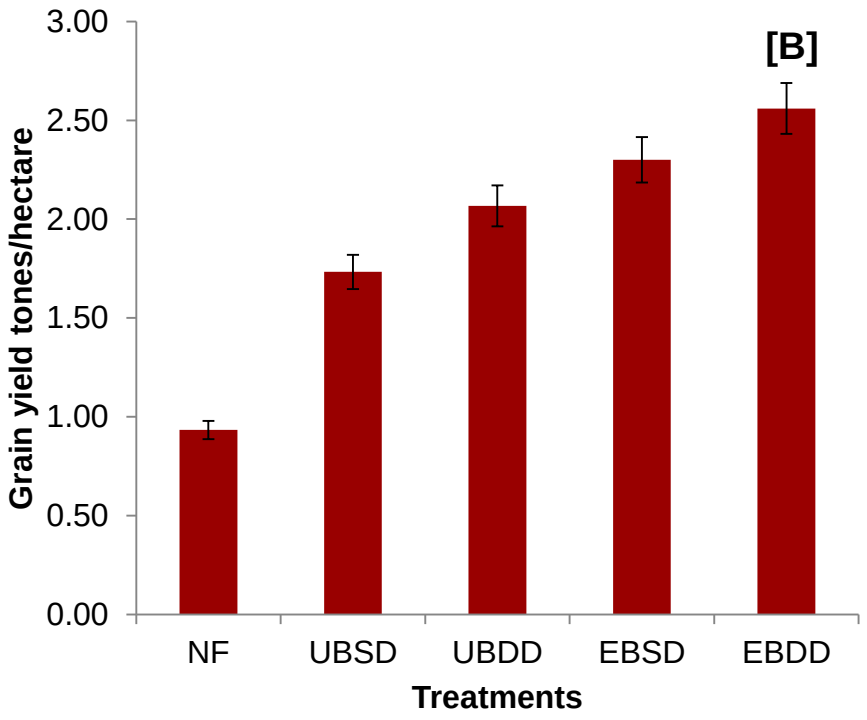
Effect of different doses of un-entrapped and organic matrix entrapped biofertilizers on growth of wheat (*Triticum aestivum* L. cv. PBW-343) shoots on 30, 60, 90 and 120 DAS.

Parameters	Treatment	30 d	60 d	90 d	120 d
Shoot length (cm)	NF	13.27±1.80	24.23±2.50	42.10±2.57	46.20±3.50
	UBSD	15.37±5.15 ^{ns}	35.77±2.71**	51.10±5.09*	54.87±0.92**
	UBDD	16.80±2.84 ^{ns}	37.03±0.51**	53.50±1.44**	56.80±0.79**
	EBSD	18.29±1.69 ^{ns}	38.23±1.33**	55.33±4.58**	59.30±0.75**
	EBDD	19.00±0.56*	46.13±1.97**	58.60±2.58**	61.97±2.04**
Number of leaves	NF	3.00±1.00	5.33±1.15	7.33±1.15	7.00±1.00
	UBSD	5.67±0.58**	9.00±1.00**	10.67±1.53**	9.67±1.15**
	UBDD	6.00±1.00**	12.33±0.58**	13.33±0.58**	11.33±0.58**
	EBSD	6.33±1.15**	14.67±1.53**	15.00±1.00**	14.00±1.00**
	EBDD	7.00±1.0**	16.00±1.00**	17.00±1.00**	15.67±0.58**
Fresh wt of shoot (g)	NF	0.43±0.11	0.69±0.04	1.30±0.50	3.08±0.17
	UBSD	1.08±0.13 ^{ns}	2.61±0.01**	3.07±0.13**	4.40±0.50**
	UBDD	1.79±0.57**	3.12±0.10**	3.52±0.10**	6.25±0.21**
	EBSD	2.69±0.29**	3.06±0.14**	5.25±0.68**	11.25±0.39**
	EBDD	3.86±0.61**	4.07±0.05**	7.70±0.56**	14.32±0.37**
Dry wt. of shoots (g)	NF	0.12±0.03	0.14±0.03	0.36±0.05	0.69±0.04
	UBSD	0.39±0.06**	0.58±0.04**	0.91±0.15**	1.99±0.03**
	UBDD	0.60±0.02**	0.71±0.06**	1.04±0.06**	2.28±0.31**
	EBSD	0.92±0.03**	0.92±0.06**	1.51±0.34**	4.80±0.23**
	EBDD	1.23±0.18**	1.01±0.03**	2.19±0.23**	5.05±0.48**

Where: NF=No fertilizer, UBSD= Un-entrapped biofertilizer, single dose (600 g ha^{-1} each), UBDD=Un-entrapped biofertilizer, single dose (1200 g ha^{-1} each) EBSD= Entrapped biofertilizer, single dose (600 g ha^{-1} each EBDD= Entrapped biofertilizer, double dose

Effect of entrapped and un-entrapped biofertilizers on tiller numbers at 60, 90 and 120 DAS (A) and wheat yield at 120 DAS (B). All the values are means of three replicates with two determinations (n=6) ± S.D. (one way ANOVA).





Increase in Wheat productivity by organic matrix based slow release fertilizers (SRFs) containing chemical N and microbial bio-fertilizers with different binders (our own studies)

SRF type	Organic Matrix used	Binder Used	BioFertilizer / Fertilizers used	Enhanced Growth & yield	% increase in yield over conventional chemical fertilizers	Increased availability of N in soil and plants	Increased soil enrichment
SGBFs	Clay soil, cow dung, rice bran, Neem leaves	Plant gum of Acacia spp (saresh)	Azotobacter chroococcum and B. subtilis	Root length, fresh and dry wt of shoot and root, no. of tillers, grain yield, straw yield	-	Ammonium increased	Enhanced CFU, soil enzymes microbial counts, pH reduction in saline soil, higher soil carbon and soil nitrogen.
ECFBFs	Clay soil, cow dung, Neem leaves	Plant gum of Acacia spp (saresh)	(Urea and DAP)+ Azotobacter chroococcum and B. subtilis	Grain and straw yield	25.68	Nitrate, nitrite and ammonium increased in soil, root and leaves	
EBDD	Clay soil, cow dung,Neem leaves	Plant gum of Acacia spp (saresh)	Azotobacter chroococcum and B. subtilis	Root length, Shoot length, fresh and dry wt of shoot and root, no. of tillers, grain yield, straw yield	-	Nitrate, nitrite and ammonium increased in soil, root and leaves	
ECFs	Clay soil, cow dung,Neem leaves	Plant gum of Acacia spp (saresh)	Urea and DAP	Root length, Shoot length, fresh and dry wt of shoot and root, no. of tillers, grain yield, straw yield	16.75	Nitrate, nitrite and ammonium increased in soil, root and leaves	
OMEU	Clay soil, cow dung, rice bran, Neem leaves	Plant gum of Acacia spp	Urea	Root length, fresh and dry wt of shoot and root, no. of tillers	5.26	Nitrate, nitrite and ammonium increased in	

Cost Rationale of SRFs

- Single basal application reduces operational cost
- Either microbial bio fertilizers or small dose of chemicals are used
- Matrix materials are very low cost(degradable agrowastes)
- Binder is inexpensive(degradable plant product)
- Cost is effective in terms of productivity, enhancement and soil enrichment.

CONCLUSIONS & FUTURE PROSPECTS

Our study demonstrates that organic matrix is a better carrier to enrich soil fertility, crop productivity and cost affectivity in a sustainable manner.

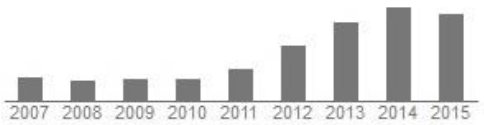
It provides a good home for microbes being rich in organic matter and water holding capacity and can hold nutrients fixed/mobilized by the microbes for longer time to make it available for sustained uptake and assimilation by the plants.

By using local agro-waste materials and cheap natural binders, the cost can be brought down, affordable to the farmers

Our Publications on this work

Google Scholar

Citation indices	All	Since 2010
Citations	2021	1225
h-index	23	20
i10-index	55	45



Research Papers

- Kumar M., Bauddh K., Sainger M., Sainger AP., **Singh R.P. (2015**). Increase in Growth, productivity and nutritional status of Wheat **(***Triticum aestivum* L) and enrichment in soil microbial population applied with biofertilizers entrapped with organic matrix. **Journal of Plant Nutrition, [Impact Factor: ISI=0.536]** 38:260-276 DOI 10.1080/01904167.2014.957391.

- Kumar, S., Bauddh, K., Barman, S.C., **Singh, R.P.** (2014). Amendments of microbial biofertilizers and organic substances reduces requirement of urea and DAP with enhanced nutrient availability and productivity of wheat (*Triticum aestivum* L.). ***Ecological Engineering***, 71, 432-437. **[Impact Factor: ISI=3.136]**

- Kumar, **S,** Bauddh, K. Barman, S.C., **Singh, R.P. (2014):** Organic matrix entrapped bio-fertilizers increase growth, productivity and yield of *Triticum aestivum* L. and mobilization of NO_3^-, NO_2^-, NH_4^+ and PO_4^{-3} from soil to plant leaves. ***Journal of Agricultural Science and Technology,*** 16(2): 315-329 (Impact Factor: **ISI: 0.685)**

Kumar M., Bauddh K., Kumar S. Sainger M., Sainger, P.A. and **Singh R.P.,** (2013). Increase in growth, productivity and nutritional status of wheat (Triticum aestivum L. cv. WH-711) and enrichment in soil fertility applied with organic matrix entrapped urea. ***J. Environ. Biol.*** 34:1-9. **[Impact Factor: ISI=0.55].**

Kumar Sanjeev, Bauddh, K., Barman, S.C., **Singh, R.P.** (**2013**). Evaluation of conventional and organic matrix entrapped urea and di-ammonium phosphate for growth and productivity of *Triticum aestivum L*. and mobilization of NO_3^-, NO_2^-, NH_4^+ and PO_4^{-3} from soil to plant leaves. ***International Journal of Agronomy and Plant Production***, 4(6), 1357-1368. (Impact Factor: **ISI: 0.467; NAAS: 5.5**)

Sharma, P., Singh, G. and **Singh R.P.** (2013). Conservation tillage, optimal water supply enhance microbial enzyme (glucosidase, urease and phoshphatase) activities in field under wheat cultivation during various nitrogen management practices. ***Archives of Agronomy and Soil Science,*** 59; 911-928 **[Impact Factor: ISI=0.515]**DOI:10.1080/0350340.2012.690143.

Chandra, S., Rawat, S.K., Garg, S.K. and ***Singh, R.P***. (2012). Nitrate, nitrite ammonium and phosphate in various drinking and surface water sources of Uttar Pradesh and Madhya Pradesh, India. International Journal of Plant, Animal and Environmental Sciences (IJPAES), 2, 237-240

Sharma, P., Singh, G. and **Singh R.P.** (2011). Conservation tillage, optimal water and organic nutrient supply enhance soil microbial activities during wheat (*Triticum aestivum l.*) cultivation, ***Brazilian Journal of Microbiology*** 42, 531-542. **[Impact Factor: ISI=0.62]**

Research Papers continued

- Rawat, S.K., Singh, R.K. and **Singh, R.P.** (2010). Seasonal variation of nitrate level in ground and surface waters of Lucknow and its remediation using certain aquatic macrophytes. ***International Journal of Lakes and Rivers,*** 3(1) 25-35.
- Rawat, S.K. and **Singh, R.P.** (2009). Levels of nitrate, nitrite and ammonium in drinking and surface water sources in Lucknow (India). ***Pollution Research*** 28, 419-423. **[Impact Factor NAAS=3.3]**

Review Papers

- **Singh, RP** and Jaiwal, PK (1999) Manipulation of ammonia assimilation in improvement of nitrogen use efficiency. ***Curr. Sci***. **77**:325-326. **[Impact Factor: ISI=0.782; NASS=7.2]**

- Sengar, R.S., Pant.RC, **Singh, R.P**. and Srivastava H.S. (1995). Role and regulation of GS-GOGAT enzymes in higher plants. ***Plant Physiol. Biochem***., **22**:89-100. Presently renamed as Journal of Plant Biology, India **[Impact Factor: NAAS=3.6].**

- Srivastava H.S., and **Singh R.P**., (1987).Role and regulation of L-glutamate dehydrogenase in higher plants. ***Phytochemistry.*****26**:597-610 **[Impact Factor: ISI=3.150; NAAS=7.9]**

Review Chapters

- **Singh R.P.,** Sainger M., Bauddh K.,Senger R.S. and Jaiwal P.K. (2010). Sustained nutrient supply reduced nutrient loss and high plant productivity with slow release fertilizers. Senger R.S. and Sharma A.K. (Eds). 2010. Stable Food Production and Sustainable Agriculture. Studium Press (India) Pvt. Ltd. Pp: 62-79.

- **Singh R.P**., Sainger M., Singh D.P. & Jaiwal P.K. (2008). Nitrate and ammonium transporters in plants. *In: Plant Membrane and Vacuolar Transporters* (Eds Jaiwal P. K., Singh R.P. & Dhankhad O.P.) CAB International pp: 83-103.

- Dahiya S. Choudhary, D. Jaiwal R., Dhankher, O.P., **Singh, R.P.** and Jaiwal, P.K. (2008). Elemental biofortification of crop plants. *In: Plant Membrane and Vacuolar Transporters* (Eds Jaiwal P. K., Singh R.P. & Dhankhad O.P.) CAB International pp: 345-371.

- Jaiwal, P.K. and **Singh, R.P.** (2006) Genetic manipulations of nitrogen assimilation to improve nitrogen use efficiency and yield of plants. In Biotechnological Approaches Improve Nitrogen Use Efficiency in Plants (Eds. Singh, R.P . and Jaiwal, P.K.) Studuim Press, LLC, Houston,USA Pp 257-284

Book Chapters continued

- Sharmila P., **Singh, R.P.** and Pardha Sardhi,P,(2006) Nitrogen in interaction with sulfur metaboloism in plants. In. Biotechnological Approaches Improve Nitrogen Use Efficiency in Plants (Eds. Singh, R.P and Jaiwal, P.K.) Studuim Press, LLC, Houston,USA.Pp 241-256

- **Singh R.P**, and Jaiwal P.K, Biotechnological Approaches to improve Nitrogen use efficiency in Plants, Studium press, LLC, Haston, USA

- **Singh, R.P.,**Usha, Shankdhar,N. and Jaiwal, P.K.(2006) Nitrogen utilization in plants under salinity stress. In: *Nitrogen Nutrition and Plant Productivity.* (Eds. Singh, R.P., Shankar N. and Jaiwal, P.K.) Studium Press, LLC, Houstan, USA. Pp 203-276.

Review chapters continued

- Srivastava H.S., Shankar N., Yamaya T. and **Singh R.P**. (2006). Glutamatesynthese, ammonia assimilation and plant productivity. (Eds. Singh, R.P . and Jaiwal, P.K.) Studuim Press, LLC, Houston, USA. Pp 135-166.
- **Singh, R.P.,** Dahiya,S.,Usha, and Jaiwal, P.K.(2004) Slow release fertilizers for sustained nitrogen supply and high plant productivity. In: *Nitrogen Nutrition and Plant Productivity.* (Eds. Singh, R.P., Shankar N. and Jaiwal, P.K.). Studium Press, LLC, Houstan, USA. Pp 329-349.
- Jaiwal,P.K. and **Singh R.P.**(1995). Regulation of nitrogen assimilation by plant Growth hormones. In *Nitrogen Nutrition in Higher Plants* (Eds. Srivastava H.S.and **Singh R.P**.) Associated Publishing Company, New Delhi, pp401-416.

- **Singh R.P**.(1995). Ammonia Assimilation. In *Nitrogen Nutrition in Higher Plants* (Eds. Srivastava H.S.and **Singh R.P**.) Associated Publishing Company, New Delhi, pp189-203.

Books

- *Biotechnological Approaches for Mitigation of Climate Change* (2015) **J**aiwal P.K**., Singh R.P**. and Dhankher O.P. (Ed.) Springer (In Press)
- *Nitrogen Nutrition and Plant Productivity* (2006). **Singh, R. P.,** Shankar, N. and Jaiwal, P.K., Studium Press, LLC, Houstan, USA
- *Molecular Strategies for Improving Nitrogen use effieciency in Plants.* (2006) **Singh, R.,P.,** Shankar,N.and Jaiwal, P.K Studium Press, LLC, Houstan, USA.
- *Nitric Oxide Signaling in Higher Plants* (2005) Jose R. Magalhaes, **Rana P.Singh** and Leonidas P.Passos. Studium Press, LLC, Houstan, USA
- *Nitrogen Nutrition and Plant Growth* (1999) Srivastava, H.S. and **Singh, R.P.** Science Publishers, Enfield, USA/ Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi (Dual Edition)
- *Nitrogen Nutrition in Higher Plants* (1995) Srivastava, H.S. and **Singh, R.P.** Associated Publishing Co. New Delhi



Our Team Members:

Dr. Priti Chaudhary
Dr. Pankaj Sharma
Dr. Manish Sainger
Dr. Manoj Kumar
Dr. Kuldeep Bauddh
Dr. Sanjeev Kumar
Ms. Rose Minz

Acknowledgment:

M.D. University, Rohtak,
BBAU, Lucknow
UGC, New Delhi
CST-UP, Lucknow