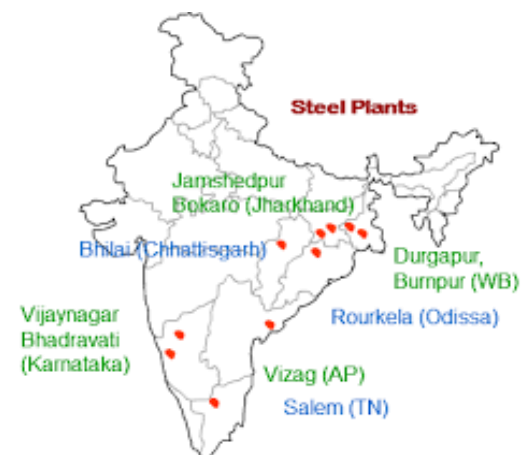


Steel slag utilization in agriculture as fertilizer: Waste to wealth opportunity



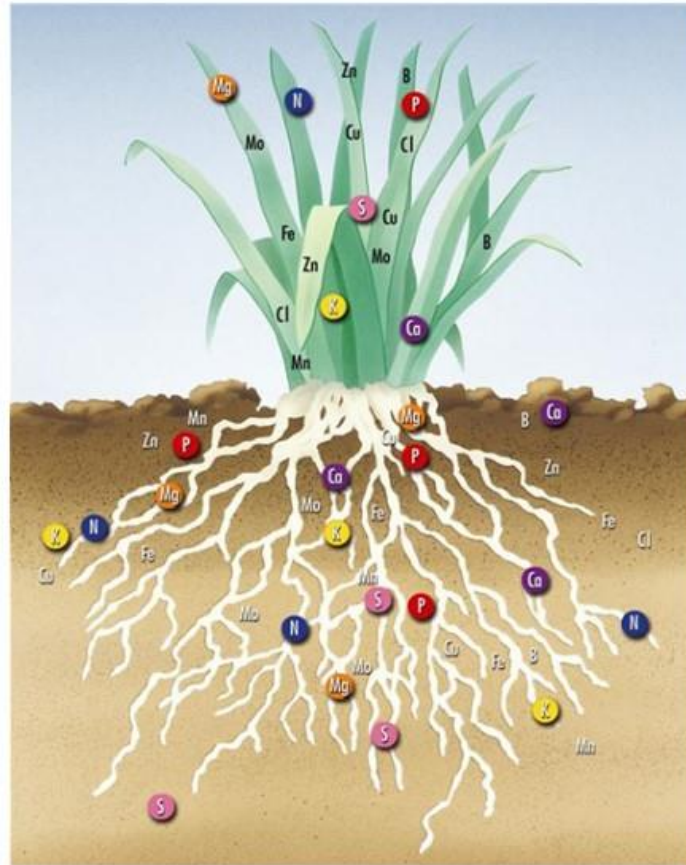
National Conference on Steel in Infrastructure 16.3.24



Bhupinder Singh

**Division of Environment Science,
ICAR-Indian Agricultural Research Institute, New Delhi -110 012
bhupindersinghiari@yahoo.com**

Sustaining agricultural productivity under changing environment



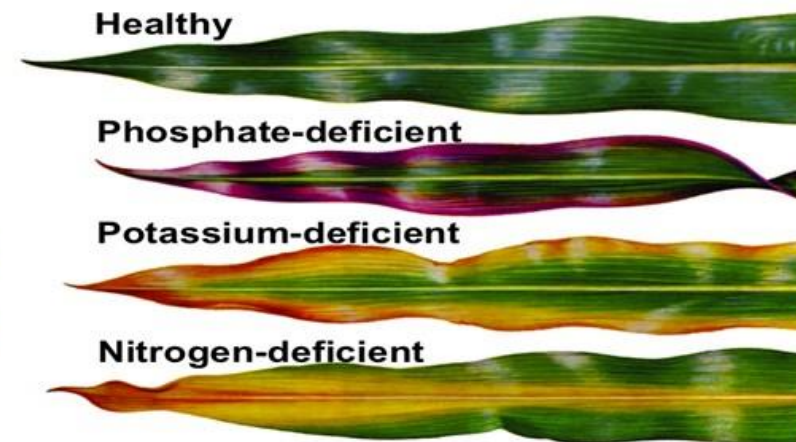
**Better
plant
health**

**Better
plant
health**

**Greater
uptake of
elements**

□ Plant health regulates the demand and consequent uptake of nutrients.

□ Unfavorable condition of soil, plant and environment (abiotic and biotic stress) restrict availability and uptake.

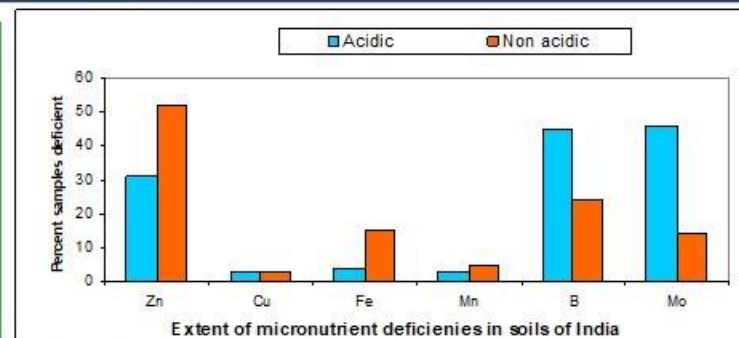


Challenges in Mineral Nutrition

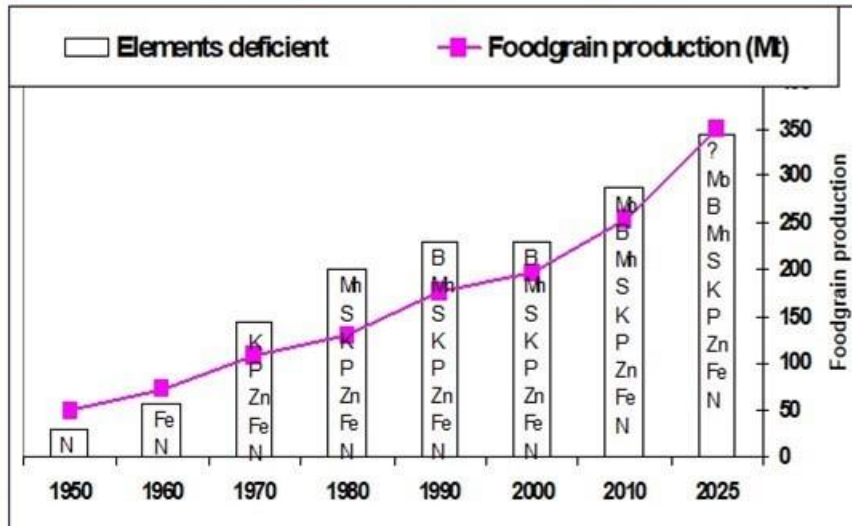
Challenges arise

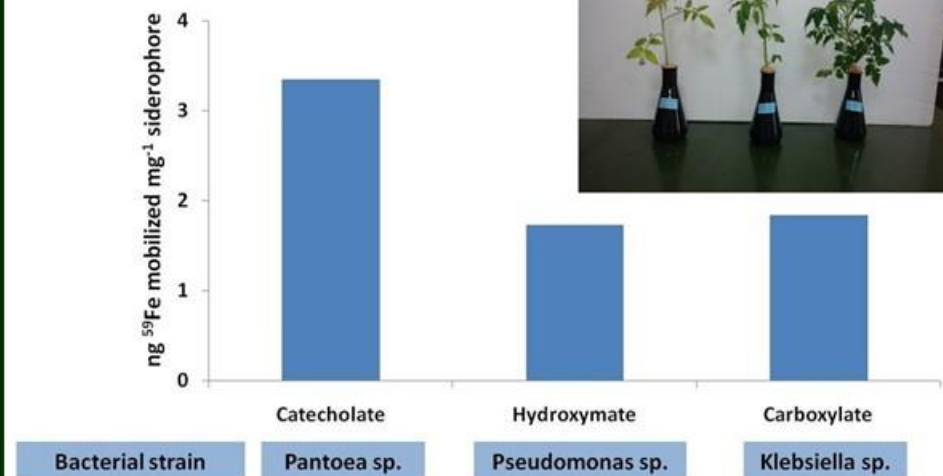
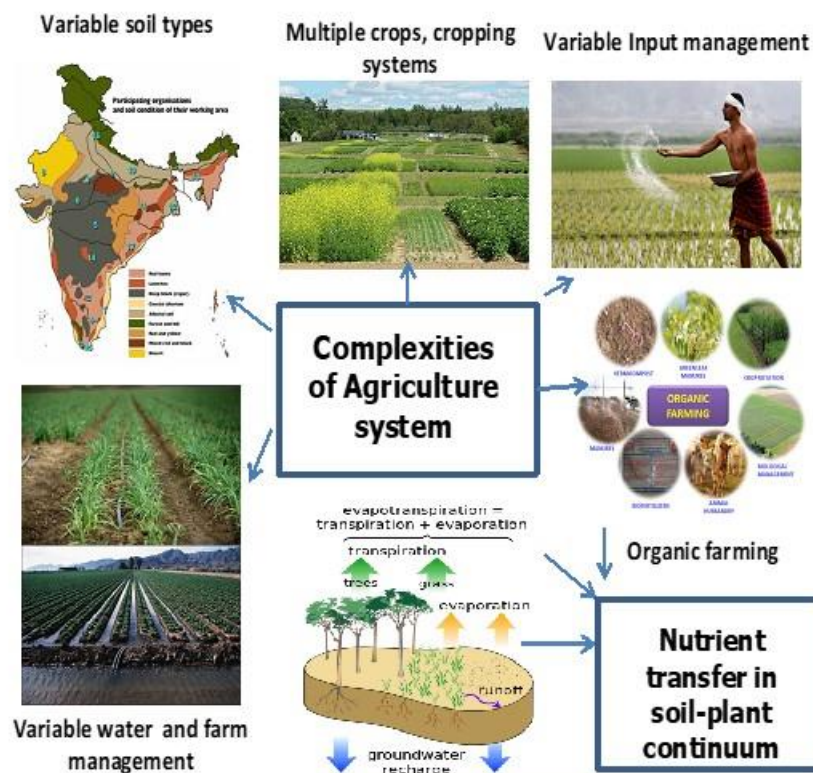
- Soils
- Crops
- Abiotic stress

- ❖ Deficiency
- ❖ Toxicity
- ❖ imbalance
- ❖ malnutrition



Crops	Severity of defi.	Critical conc. (mg Zn/kg dm)	(Whole Plant)
Sorghum	Deficiency	8	(do)
Maize	Deficiency	< 20-22	(do)
Rice	Deficiency	<10-15	(do)
Wheat	No response to Zn	>20	(do)
	Latent	12-20	(do)
	Moderate	8-12	(do)
	Acute	< 8	(do)

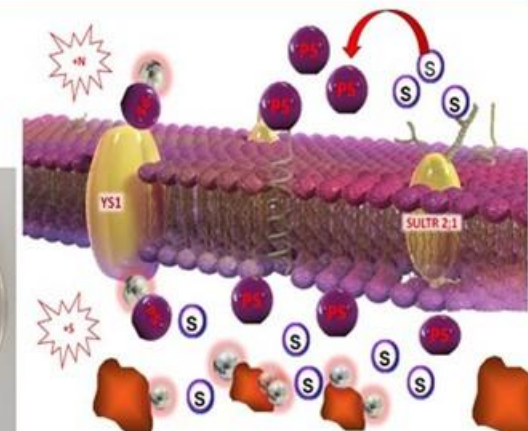
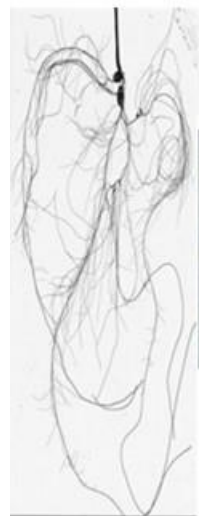




Micronutrient mobilization by siderophores

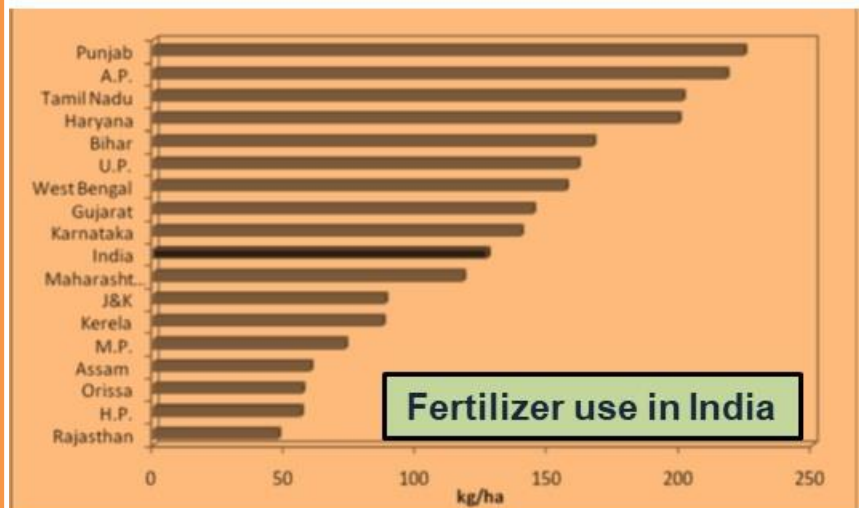
PLANT DOES NOT CARE FOR THE SOURCE

Root characteristics and nutrient acquisition



Challenges and opportunities

- ❖ India has become the second largest producer of Steel (~102 MT) in the world and plans are afoot to achieve an annual production capacity of 300 MT by 2030.
- ❖ Huge quantities of blast furnace (BF) and other steel slags are generated.
- ❖ Steel industry is searching for effective disposal of this by-product
- ❖ Steel slag has a pH of ~11.0 and is rich in lime (CaO), magnesium (MgO), phosphate (P_2O_5), silica (SiO_2), ferrous (FeO / Fe_2O_3) and Mn.



Fertilizer use in India

India should cut urea consumption to half by 2022

Degraded soils and soil acidity

Total cultivable land: 157 Mha

49 Mha is acidic (8% of total geographical area in India) and limits crop production.

Soil acidity varies from <3.4 to 5.5

11% of earth's vegetated surface has been degraded so badly it will be very expensive or impossible to fix.

Liming solutions for acidic soils

Application of liming materials

CaO (71% Ca)

Ca(OH)₂ (54 % Ca)

CaCO₃ (40% Ca)

CaSiO₃ (23% Ca)

Ca.Mg(CO₃)₂ (21.7%)

pH of soil-buffer suspension (soil taken from the field)	Lime required to bring pH down to indicated level (Calcium carbonate) in tonnes per acre		
	pH 6.0	pH 6.4	pH 6.8
5.8	4.8	5.7	6.5
5.7	5.2	6.2	7.1
5.6	5.6	6.7	7.7
5.5	6.0	7.2	8.3
5.4	6.5	7.7	8.9
5.3	6.9	8.2	9.4
5.2	7.4	8.4	10.0
5.1	7.8	9.1	10.6
5.0	8.2	9.6	11.2
4.9	8.6	10.1	11.8
4.8	9.1	10.6	12.4

Steel slag : An opportunity for green economy

initial pH	sandy loam	silt loam	silty clay loam
4.8	2.5	4.0	6.0
5.0	2.25	3.6	5.40
5.5	1.5	2.4	3.6
6.0	0.75	1.2	1.8

Slag requirement (tons/acre) to attain pH 6.5 varies in different textured soils; CaO content 45-48%.

Average cost of liming material: INR 2500-3800 per ton.

@ ~2 ton acre⁻¹ or 5 ton ha⁻¹ cost works out to be ~INR 15000 ha⁻¹.

Volume shall be ~100 Million ton lime material or ~ INR 300 billion.

ICAR-IARI, Ministry of Steel and Steel Industry Collaboration



Brainstorming meeting to prepare a roadmap for the

Development of Steel Slag Based Cost Effective Eco-friendly Fertilizers for Sustainable Agriculture and Inclusive Growth

Leadership of Ms Ruchika Chaudhary Govil, JS

Inked in July, 2021 to work on "Development of steel slag based cost effective eco-friendly fertilizers for sustainable agriculture and inclusive growth" in the presence of Ms Rasika Chaube, Additional Secretary, MoS; Mr Mukesh Kumar, Director SRTMI; The Director IARI and Senior Functionaries of Tata Steel Limited; JSW Steel Limited and SAIL.



सत्यमेव जयते

Ministry of Steel
Government of India

Development of LD slag based value added fertilizers/ amendments

- ❖ Soil health
- ❖ Acid soil reclamation
- ❖ Source of plant nutrients
- ❖ Slag based value added products
- ❖ Short term and long term implications



भारत
ICAR

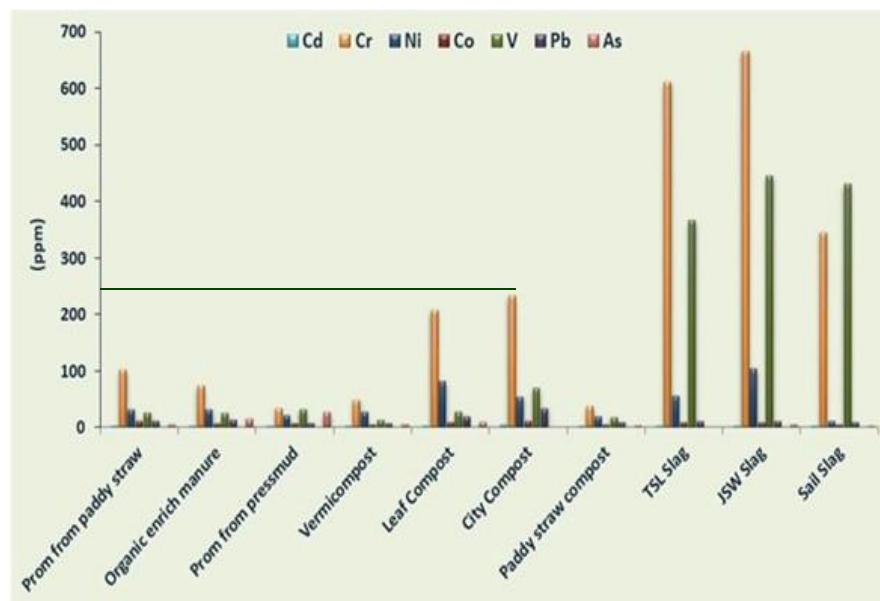
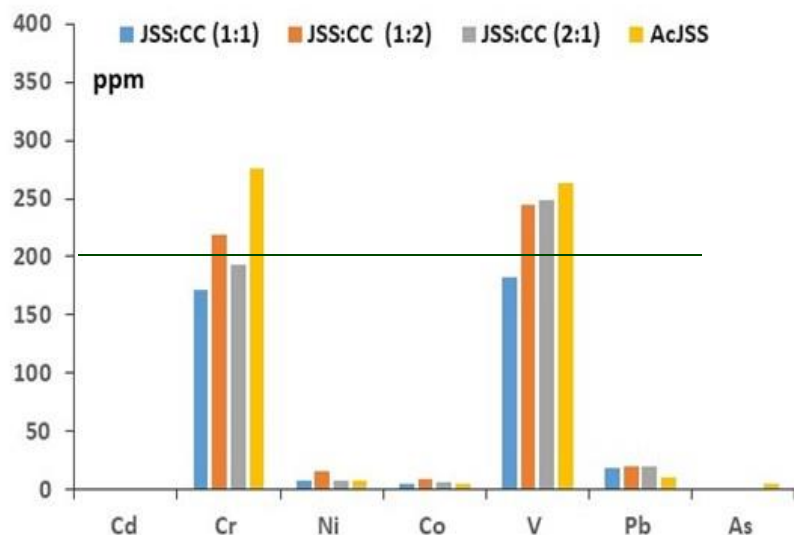
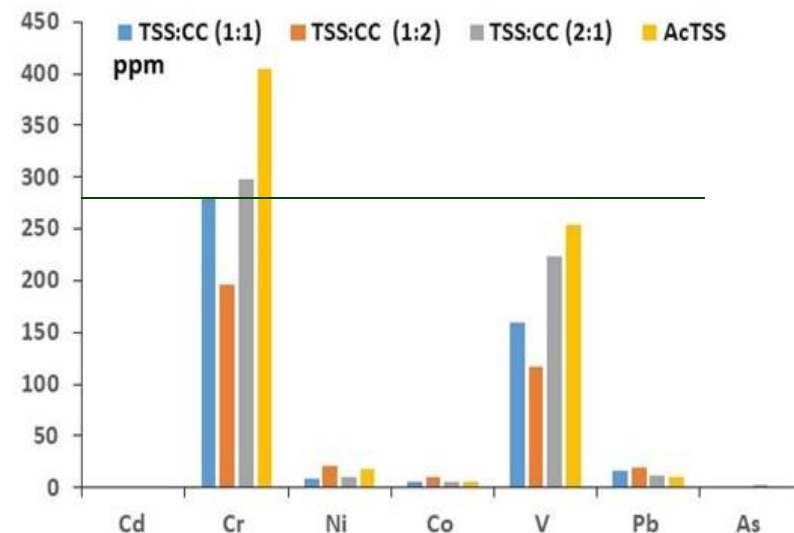
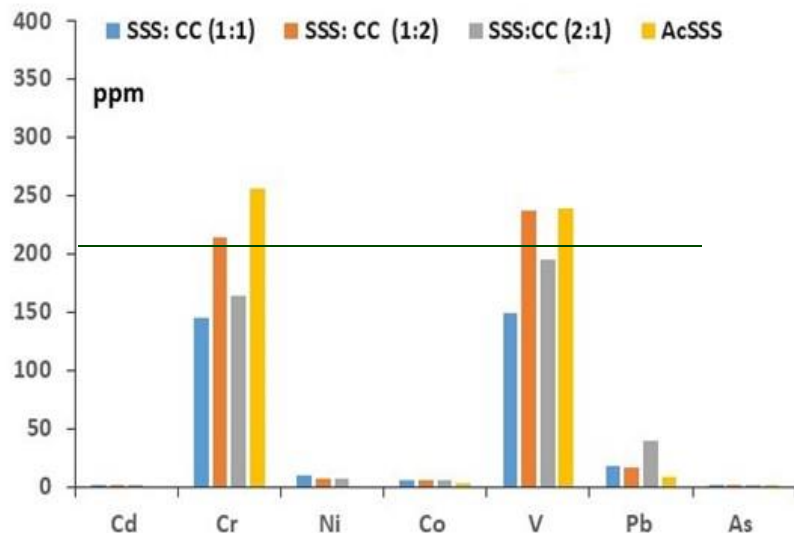


Salient developments: Value addition of steel slag for agri-applications

- ❖ Total of 51 organically/inorganically amended steel slag based nutrient rich value added products (SSBVAPs) have been developed for normal/acidic/degraded soil.
- ❖ Product performance evaluated over 31 trials in 12 crops across eight locations covering cereal/ vegetable/ oil seed/ pulse/ tuber/medicinal and aromatic plants in terms of grain-produce yield and heavy metal uptake-accumulation.
- ❖ Soil physico-chemical attributes, nutrients/heavy metals assessed.
- ❖ Total chromium concentration of the final products maintained between <150 ppm Cr as against 700-1000 ppm Cr in raw slag.
- ❖ Thirteen promising products identified for normal/ acidic/ degraded soil; economic of production and utilization assessed.



Use of city waste based compost as it is available in bulk



Steel Slag based value added product (SSBVAP-1)

Mineral nutrients

T-N (%): 0.44 ± 0.01
A-P (ppm): 82.58 ± 51.09
A-K (ppm): 6720.03 ± 76.74
S (%): 0.8
A-Ca (ppm): 2864.16 ± 245.31
Mg (%): nd
Fe (ppm): 4.01 ± 0.54
Zn (ppm): 0.05 ± 0.01
Cu (ppm): 25.04 ± 1.61
B (ppm): 17.66 ± 0.97
Mo (ppm): 175.56 ± 40.98
Mn (ppm): 0
Co (ppm): 3.95 ± 0.06
Si (%): 11.2

Heavy metals (ppm)

Pb: 7.96 ± 1.56
Cd: 0.27 ± 0.05
Cr: 176.09 ± 11.83
Ni: 9.82 ± 0.07

Shelf life: One Year at RT;
Moisture Content: 4-6%

**Development of Steel Slag Based
Cost Effective Eco-Friendly
Fertilizers for Sustainable
Agriculture and Inclusive Growth**

**Product 1
PRSS**

Microorganisms	
<i>Streptomyces variabilis</i>	
<i>Streptomyces sampsonii</i>	
<i>Nocardiopsis dassonvillei</i>	
<i>Streptomyces albiaxialis</i>	
<i>Lactococcus lactis</i>	
<i>Mixta intestinalis</i>	
<i>Pantoea agglomerans</i>	
<i>Enterobacter asburiae</i>	
<i>Pseudomonas plaeoglossidae</i>	
<i>P-Solubilizer</i>	
<i>P sol and auxin producer</i>	

Product Composition

SS: 29.4 %
OA1: 41.2 %
OA2: 29.4 %

* Contains microbial consortia capable of surviving in pH 5-10; produce cellulase, amylase, protease, P-K solubilizer, siderophore producer, Auxin

Permissible limits of hazardous and other impurities

Elements/Parameters	Unit	Specs for material putting into soil	
		IS(Awasthi) 2000 Specs	EU 2002
Pb	ppm	250 - 500	300
Cu	ppm	130 - 270	140
Cr	ppm	-	150
Cd	ppm	3 - 6	3
As	ppm	-	10 - 20
Ni	ppm	75 - 100	75
Zn	ppm	300 - 600	300

Availability of Amendments (mt/annum)

OA1: 38.7

OA2: 312.6

Nutrient contribution of Amendment (ppm)

OA1: N (411); P (11); K (107); S (47); Fe (18); Zn (4); Si (8.5%)

OA2: N (147); P (242); K (66); Fe (45); Zn (3); Si (10.0%)

Crop response to SSBVAP application

Center	% change in grain/produce yield over 80% / 100% RDF		
	Wheat	Lemongrass	Withania
New Delhi	13.1/2.3	-	-
Hisar	12.35/AP	-	-
Pant Nagar	13.2/AP	-	-
Agra	-	43.5/AP	76.5/59.6
Range of dosage (t/ha)	1-4	1-1.5	1-2
Recommended dose (t/ha)	2	1.5	2

Suitable for wheat, withania, lemongrass applied @2 t/ha with 80% RDF

Steel Slag based value added product (SSBVAP-2)

Mineral nutrients

T-N (%) : 0.48 ± 0.03
 A-P (ppm): 64.70 ± 60.37
 A-K (ppm): 6393.53 ± 441.87
 S (%): 0.6
 A-Ca (ppm): 2851.23 ± 75.98
 Mg (ppm): nd
 Fe (ppm): 3.59 ± 0.08
 Zn (ppm): 0.04 ± 0.01
 Cu (ppm): 13.02 ± 1.72
 B (ppm): 14.66 ± 1.27
 Mo (ppm): 174.83 ± 52.23
 Mn (ppm): 1478.60 ± 37.82
 Co (ppm): 2.31 ± 0.56
 Si (%): 21.0

Heavy metal content (ppm)

Pb: 5.59 ± 1.42
 Cd: 0.19 ± 0.09
 Cr: 158.07 ± 24.13
 Ni: 15.41 ± 6.54

Shelf life: One Year at RT;
 Moisture Content: 4-6%



Development of Steel Slag Based
 Cost Effective Eco-Friendly
 Fertilizers for Sustainable
 Agriculture and Inclusive Growth



**Product 2
KRSS**

Product Composition

SS: 29.4 %
 OA1: 41.2 %
 OA3: 29.4 %

Microorganisms
<i>Streptomyces variabilis</i>
<i>Streptomyces sampsonii</i>
<i>Nocardiopsis dassonvillei</i>
<i>Streptomyces albiavialis</i>
<i>Lactococcus lactis</i>
<i>Mixta intestinalis</i>
<i>Pantoea agglomerans</i>
<i>Enterobacter asburiae</i>
<i>Pseudomonas plaeoglossidae</i>
<i>P-Solubilizer</i>
<i>P sol and auxin producer</i>

*Contains microbial consortia capable of surviving in pH 5-10; produce cellulose, amylase, protease, P-K solubilizer, siderophore producer, Auxin



Permissible limits of hazardous and other impurities

Elements/Parameters	Unit	Specs for material putting into soil	
		IS(Awasthi) 2000 Specs	EU 2002
Pb	ppm	250 - 500	300
Cu	ppm	130 - 270	140
Cr	ppm	-	150
Cd	ppm	3 - 6	3
As	ppm	-	10 - 20
Ni	ppm	75 - 100	75
Zn	ppm	300 - 600	300

Availability of Raw materials (mt/annum)

OA1: 38.7

OA3: 634.0

Nutrient contribution of Amendment (ppm)

OA1: N (411); P (11); K (107); S (47); Fe (18); Zn (4); Si (8.5%)

OA3: N (73); P (2); K (72); S (8); Fe (7) ; Zn (0), Si (30.3%)

Crop response to SSBVAP application

Center	% change in grain/produce yield over 80% / 100% RDF				
	Wheat	Brinjal	Rice	Lemongrass	Withania
New Delhi	14.2/2.1	43.5/31.7	-	-	-
Hisar	14.37/AP	-	-	-	-
Pant Nagar	-	-	11.5/AP	-	-
Agra	-	-	-	18.2/-25.8	67.05/50.95
Range of dosage (t/ha)	1-4	3	1-2	1-1.5	1-2
Recommended dose (t/ha)	2	3	2	1.5	2

Suitable for wheat; brinjal; rice; withania; lemongrass @2 t/ha with 80% RDF

Steel Slag based value added product (SSBVAP-3)

Mineral nutrients

T-N (%) : 0.40 ± 0.04
A-P (ppm): 56.75 ± 22.03
A-K (ppm): 5225.00 ± 1225.26
S (%): 0.61
A-Ca (ppm): 2591.53 ± 212.81
Mg (ppm): nd
Fe (ppm): 4.17 ± 0.23
Zn (ppm): 0.05 ± 0.01
Cu (ppm): 20.11 ± 0.13
B (ppm): 14.91 ± 0.93
Mo (ppm): 182.78 ± 55.53
Mn: 783.12 ± 37.05
Co (ppm): 3.78 ± 0.49
Si (%): 15.3

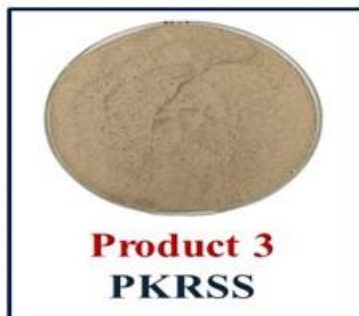
Heavy metal content (ppm)

Pb: 6.79 ± 1.12
Cd: 0.18 ± 0.03
Cr: 173.13 ± 26.51
Ni: 13.18 ± 5.67

Shelf life: One Year at RT;
Moisture Content: 4-6 %



Development of Steel Slag Based
Cost Effective Eco-Friendly
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Agriculture and Inclusive Growth



**Product 3
PKRSS**

Product Composition

SS: 29.4%
OA1: 41.2%
OA2: 14.7%
OA3: 14.7%

Microorganisms
<i>Streptomyces variabilis</i>
<i>Streptomyces sampsonii</i>
<i>Nocardiopsis dassonvillei</i>
<i>Streptomyces albiaxialis</i>
<i>Lactococcus lactis</i>
<i>Mixta intestinalis</i>
<i>Pantoea agglomerans</i>
<i>Enterobacter asburiae</i>
<i>Pseudomonas plaeglossidae</i>
<i>P-Solubilizer</i>
<i>P sol and auxin producer</i>

*Contains consortia capable of surviving in pH 5-10; produce cellulose, amylase, protease, P-K solubilizer, siderophore producer, Auxin



Permissible limits of hazardous and other impurities

Elements/Parameters	Unit	Specs for material putting into soil	
		IS(Awasthi) 2000 Specs	EU 2002
Pb	ppm	250 - 500	300
Cu	ppm	130 - 270	140
Cr	ppm	-	150
Cd	ppm	3 - 6	3
As	ppm	-	10 - 20
Ni	ppm	75 - 100	75
Zn	ppm	300 - 600	300

Availability of Raw materials (mt/annum)

OA1: 38.7
OA2: 312.6
OA3: 634.0

Nutrient contribution of Amendment (ppm)

OA1: N (411); P (11); K (107); S (47); Fe (18); Zn (4); Si (8.5%);
OA2: N (147); P (242); K (66); Fe (45); Zn (3), Si (10.0%)
OA3: N (73); P (2); K (72); S (8); Fe (7); Zn (0), Si (30.3%)

Crop response to SSBVAP application

Center	% change in grain/produce yield over 80% / 100% RDF					
	Wheat	Brinjal	Brassica	Rice	Lemongrass	Withania
New Delhi	-	78.6/34.4	8.6/3.3	-	-	-
Pant Nagar	17.9/4.3	-	-	11.5/AP	-	-
Agra	-	-	-	-	36.2/14.5	98.4/79.3
Dose (t/ha)	1-2	3	2-4	1-2	1-1.5	1-2
Recommended dose (t/ha)	2	3	2	2	1.5	2

Suitable for wheat; Brinjal; brassica, rice; withania; lemongrass @2 t/ha with 80% RDF

Steel Slag based value added product (SSBVAP-4)

Mineral nutrients

T-N (%) : 0.40 ± 0.01
 A-P (ppm): 60.13 ± 49.32
 A-K (ppm): 4173.66 ± 2587.79
 S (%): 6.2
 T-Ca; A-Ca (ppm):
 2715.22 ± 868.24
 Mg (ppm): nd
 Fe (ppm): 4.21 ± 0.02
 Zn (ppm): 0.04 ± 0.00
 Cu (ppm): 15.55 ± 1.46
 B (ppm): 17.88 ± 3.42
 Mo (ppm): 173.22 ± 43.53
 Mn (ppm): 1069.78 ± 384.55
 Co (ppm): 3.76 ± 0.13
 Si (%): 11.1

Heavy metal content (ppm)

Pb: 5.92 ± 0.34
 Cd: 0.10 ± 0.01
 Cr: 170.42 ± 36.13
 Ni: 13.75 ± 4.65

Shelf life: One
 Year at RT;
 Moisture
 Content: 4-6 %



Development of Steel Slag Based
 Cost Effective Eco-Friendly
 Fertilizers for Sustainable
 Agriculture and Inclusive Growth



**Product 4
SRSS**

Product Composition

SS: 29.4 %
 OA1: 41.2 %
 OA4: 29.4 %

Microorganisms
<i>Streptomyces variabilis</i>
<i>Streptomyces sampsonii</i>
<i>Nocardopsis dassonvillei</i>
<i>Streptomyces albiacialis</i>
<i>Lactococcus lactis</i>
<i>Mixta intestinalis</i>
<i>Pantoea agglomerans</i>
<i>Enterobacter asburiae</i>
<i>Pseudomonas plaeglossidae</i>
P-Solubilizer
P sol and auxin producer

*Contains microbial consortia capable of surviving in pH 5-10; produce cellulase, amylase, protease, P-K solubilizer, siderophore producer, Auxin



Permissible limits of hazardous and other impurities

Elements/Parameters	Unit	Specs for material putting into soil	
		IS(Awasthi) 2000 Specs	EU 2002
Pb	ppm	250 - 500	300
Cu	ppm	130 - 270	140
Cr	ppm	-	150
Cd	ppm	3 - 6	3
As	ppm	-	10 - 20
Ni	ppm	75 - 100	75
Zn	ppm	300 - 600	300

Availability of Raw materials (mt/annum)

OA1: 38.7

OA4: 6-7

Nutrient contribution of Amendment (ppm)

OA1: N (411); P (11); K (107); S (47); Fe (18); Zn (4); Si (8.5%)

OA4: N (126); P (1); K (89); S (2080); Fe (28); Zn (1); Si (8.9%)

Crop response to SSBVAP application

Center	% change in grain/produce yield over 80% / 100% RDF					
	Wheat	Brinjal	Chickpea	Rice	Lemongrass	Withania
New Delhi	19.4/7.9	70.7/15.6	-	-	-	-
Hisar	13.90/4.24	-	-	-	-	-
Dharwad	-	-	10.0/6.2	7.3/AP	-	-
Cuttack	-	-	-	14.8/1.44	-	-
Agra	-	-	-	-	43.2/10.1	131.4/109.15
Range of dosage (t/ha)	1-4	3	1-2	1-2	1-1.5	1-2
Recommended dose (t/ha)	2	3	2	2	1.5	2

suitable for wheat; brinjal; chickpea; rice; withania; lemongrass @2 t/ha with 80% RDF

Steel Slag based value added product (SSBVAP-5)

Mineral nutrients

T-N (%): 0.27 ± 0.02
A-P (ppm): 70.19 ± 5.24
A-K (ppm): 1495.28 ± 300.21
S (%): 5.27
A-Ca (ppm): 2523.81 ± 84.67
Mg (ppm): nd
Fe (ppm): 3.84 ± 0.22
Zn(ppm): 0.04 ± 0.00
Cu (ppm): 23.10 ± 2.51
B(ppm): 14.07 ± 0.33
Mo (ppm) 202.34 ± 7.68
Mn (ppm): 1145.32 ± 558.73
Co (ppm): 3.90 ± 0.25
Si (%): 12.0

Heavy metal content (ppm)

Pb: 4.58 ± 1.15
Cd: 0.19 ± 0.03
Cr: 133.55 ± 1.56
Ni: 17.19 ± 1.25

Shelf life: One Year at RT;
Moisture Content: 4-6 %



Development of Steel Slag Based
Cost Effective Eco-Friendly
Fertilizers for Sustainable
Agriculture and Inclusive Growth



**Product 5
PSRSS**

Product Composition

SS: 22.7%
OA1: 31.8%
OA2: 22.7%
OA4: 22.7%

Microorganisms
<i>Streptomyces variabilis</i>
<i>Streptomyces sampsonii</i>
<i>Nocardopsis dassonvillei</i>
<i>Streptomyces albiacialis</i>
<i>Lactococcus lactis</i>
<i>Mixta intestinalis</i>
<i>Pantoea agglomerans</i>
<i>Enterobacter asburiae</i>
<i>Pseudomonas plaecoglossidae</i>
<i>P-Solubilizer</i>
<i>P sol and auxin producer</i>

*Contains microbial consortia capable of surviving in pH 5-10; produce cellulase, amylase, protease, P-K solubilizer, siderophore producer, Auxin



Permissible limits of hazardous and other impurities

Elements/Parameters	Unit	Specs for material putting into soil	
		IS(Awasthi) 2000 Specs	EU 2002
Pb	ppm	250 - 500	300
Cu	ppm	130 - 270	140
Cr	ppm	-	150
Cd	ppm	3 - 6	3
As	ppm	-	10 - 20
Ni	ppm	75 - 100	75
Zn	ppm	300 - 600	300

Availability of Raw materials (mt/annum)

OA1: 38.7

OA2: 312.6

OA4: 6-7

Nutrient contribution of Amendment (ppm)

OA1: N (411); P (11); K (107); S (47); Fe (18) ; Zn (4); Si (8.5%)

OA3: N (73); P (2); K (72); S (8); Fe (7) ; Zn (0), Si (30.3%)

OA4: N (126); P (1); K (89); S (2080); Fe (28) ; Zn (1); Si (8.9%)

Crop response to SSBVAP application

Center	% change in grain/produce yield over 80% / 100% RDF					
	Wheat	Brinjal	Chickpea	Rice	Lemongrass	Withania
New Delhi	27.7/11.2	145.3/65.2	-	-	-	-
Hisar	10.32/AP	-	-	-	-	-
Pant Nagar	8.1/AP	-	-	12.2/AP	-	-
Dharwad	-	-	10.0/3.90	-	-	-
Agra	-	-	-	-	30.2/AP	110.6/90.4
Dose (t/ha)	1-4	3	1-2	1-2	1-1.5	1-2
Recommended dose (t/ha)	2	3	2	2	1.5	2

Suitable for wheat; brinjal; chickpea, rice; withania; lemongrass @2 t/ha with 80% RDF

Steel Slag based value added product (SSBVAP-6)

Mineral nutrients

T-N (%): 0.26 ± 0.02
 A-P (ppm): 46.37 ± 21.55
 A-K (ppm): 1854.21 ± 802.01
 S (%): 5.5
 A-Ca (ppm): 2665.18 ± 55.44
 Mg (ppm): nd
 Fe (ppm): 3.84 ± 0.08
 Zn (ppm): 0.04 ± 0.01
 Cu (ppm): 15.18 ± 0.64
 B (ppm): 13.90 ± 0.46
 Mo (ppm): 179.95 ± 68.19
 Mn (ppm): 1263.23 ± 72.12
 Co (ppm): 2.90 ± 0.12
 Si (%): 18.1

Heavy metal content (ppm)

Pb: 4.62 ± 0.02
 Cd: 0.06 ± 0.01
 Cr: 133.33 ± 14.46
 Ni: 9.50 ± 0.91

Shelf life: One Year at RT;
 Moisture Content: 4-6 %



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**Product 6
KSRSS**

Product Composition

SS: 22.7 %
 OA1: 31.8%
 OA3: 22.7%
 OA4: 22.7%

Microorganisms
<i>Streptomyces variabilis</i>
<i>Streptomyces sampsonii</i>
<i>Nocardiopsis dassonvillei</i>
<i>Streptomyces albiaxialis</i>
<i>Lactococcus lactis</i>
<i>Mixta intestinalis</i>
<i>Pantoea agglomerans</i>
<i>Enterobacter asburiae</i>
<i>Pseudomonas plaeoglossidae</i>
<i>P-Solubilizer</i>
<i>P sol and auxin producer</i>

*Contains microbial consortia capable of surviving in pH 5-10; produce cellulose, amylase, protease, P-K solubilizer, siderophore producer, Auxin



Permissible limits of hazardous and other impurities

Elements/Parameters	Unit	Specs for material putting into soil	
		IS(Awasthi) 2000 Specs	EU 2002
Pb	ppm	250 - 500	300
Cu	ppm	130 - 270	140
Cr	ppm	-	150
Cd	ppm	3 - 6	3
As	ppm	-	10 - 20
Ni	ppm	75 - 100	75
Zn	ppm	300 - 600	300

Availability of Raw materials (Mt/annum)

OA1: 38.7

OA3: 634.0

OA4: 6-7

Nutrient contribution of Amendment (ppm)

OA1: N (411); P (11); K (107); S (47); Fe (18); Zn (4); Si (8.5%)

OA3: N (73); P (2); K (72); S (8); Fe (7) ; Zn (0), Si (30.3%)

OA4: N (126); P (1); K (89); S (2080); Fe (28) ; Zn (1); Si (8.9%)

Crop response to SSBVAP application

Center	% change in grain/produce yield over 80% / 100% RDF				
	Wheat	Soybean	Chickpea	Lemongrass	Withania
New Delhi	16.5/5.5	-	-	-	-
Pant Nagar	8.3/AP	-	-	-	-
Dharwad	-	9.70/AP-	10.0/5.7	-	-
Agra	-	-	-	54.3/AP	34.6/21.6
Range of dosage (t/ha)	1-4	1-1.5	1-2	1-1.5	1-2
Recommended dose (t/ha)	2	1	2	1.5	2

Suitable for wheat; soybean; chickpea; withania; lemongrass @1.5- 2 t/ha with 80% RDF

Steel Slag based value added product (SSBVAP-7)

Mineral nutrients

T-N (%) : 0.26 ± 0.08
A-P (ppm): 54.33 ± 46.20
A-K (ppm): 2490.81 ± 1244.78
S (%): 0.21
A-Ca (ppm): 2142.00 ± 517.11
Mg (ppm): nd
Fe (ppm): 3.74 ± 0.38
Zn (ppm): 0.04 ± 0.01
Cu (ppm): 24.00 ± 2.73
B (ppm): 13.29 ± 0.47
Mo (ppm): 210.87 ± 24.47
Mn (ppm): 1178.07 ± 483.12
Co (ppm): 3.29 ± 0.59
Si (%): 17.6

Heavy metal content (ppm)

Pb: 5.50 ± 2.35
Cd: 0.17 ± 0.00
Cr: 154.53 ± 32.87
Ni: 15.84 ± 6.46

Shelf life: One Year at RT;
Moisture Content: 4-6 %



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Product 7
*PKRSS

Product Composition

SS: 22.7%
OA1: 31.8%
OA2: 22.7%
OA3: 22.7%

Shelf life: One Year at RT; Moisture Content: 4-6%



Permissible limits of hazardous and other impurities

Elements/Parameters	Unit	Specs for material putting into soil	
		IS(Awasthi) 2000 Specs	EU 2002
Pb	ppm	250 - 500	300
Cu	ppm	130 - 270	140
Cr	ppm	-	150
Cd	ppm	3 - 6	3
As	ppm	-	10 - 20
Ni	ppm	75 - 100	75
Zn	ppm	300 - 600	300

Microorganisms

Streptomyces variabilis
Streptomyces sampsonii
Nocardiopsis dassonvillei
Streptomyces albiaxialis
Lactococcus lactis
Mixta intestinalis
Pantoea agglomerans
Enterobacter asburiae
Pseudomonas plaeglossidae
P-Solubilizer
P sol and auxin producer

*Contains microbial consortia capable of surviving in pH 5-10; produce cellulase, amylase, protease, P-K solubilizer, siderophore producer, Auxin

Availability of Raw materials (mt/annum)

OA1: 38.7

OA2: 312.6

OA3: 634.0

Nutrient contribution of Amendment (ppm)

OA1: N (411); P (11); K (107); S (47); Fe (18) ; Zn (4); Si (8.5%)

OA2: N (147); P (242); K (66); S (0); Fe (45) ; Zn (3), Si (10.0%)

OA3: N (73); P (2); K (72); S (8); Fe (7); Si (30.3%)

Crop response to SSBVAP application

Center	% change in grain/produce yield over 80% / 100% RDF						
	Wheat	Brinjal	Soybean	Brassica	Rice	Lemongrass	Withania
New Delhi	27.7/14.8	115.7/43.5	-	13.1/8.0	-	-	-
Pant Nagar	-	-	-	-	12.2/AP	-	-
Dharwad	-	-	9.39/AP	-	6.28/AP	-	-
Agra	-	-	-	-	-	8.4/AP	63.3/47.6
Dose (t/ha)	1-4	3	1-1.5	2-4	1-2	1-1.5	1-2
Recommended dose (t/ha)	2	3	1	2	2	1.5	2

Suitable for wheat; brinjal; soybean, brassica, rice; withania; lemongrass @2 t/ha with 80% RDF

Steel Slag based value added product (SSBVAP-8)

Mineral nutrients

T-N (%) : 0.20 ± 0.00
 A-P (ppm): 67.42 ± 13.31
 A-K (ppm): 1507.31 ± 255.82
 S (%) : 4.9
 A-Ca (ppm): 2441.89 ± 128.52
 Mg (ppm): nd
 Fe (ppm): 3.51 ± 0.06
 Zn (ppm): 0.04 ± 0.01
 Cu (ppm): 16.78 ± 5.49
 B (ppm): 10.37 ± 1.61
 Mo (ppm): 180.50 ± 38.83
 Mn (ppm): 1193.25 ± 275.74
 Co(ppm): 3.32 ± 0.07
 Si (%) : 18.2

Heavy metal content (ppm)

Pb: 5.52 ± 0.50
 Cd: 0.15 ± 0.04
 Cr: 115.85 ± 10.27
 Ni: 12.20 ± 0.18

Shelf life: One Year at RT;
 Moisture Content: 4-6%



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**Product 8
PKSRSS**

Product Composition

SS: 24.5%
 OA1: 20.0%
 OA2: 18.5%
 OA3: 18.5%
 OA4: 18.5%

Microorganisms
<i>Streptomyces variabilis</i>
<i>Streptomyces sampsonii</i>
<i>Nocardiopsis dassonvillei</i>
<i>Streptomyces albiacialis</i>
<i>Lactococcus lactis</i>
<i>Mixta intestinalis</i>
<i>Pantoea agglomerans</i>
<i>Enterobacter asburiae</i>
<i>Pseudomonas plaeglossidae</i>
<i>P-Solubilizer</i>
<i>P sol and auxin producer</i>

*Contains microbial consortia capable of surviving in pH 6-10; produce cellulase, amylase, protease, P-K solubilizer, siderophore producer, Auxin



Permissible limits of hazardous and other impurities

Elements/Parameters	Unit	Specs for material putting into soil	
		IS(Awasthi) 2000 Specs	EU 2002
Pb	ppm	250 - 500	300
Cu	ppm	130 - 270	140
Cr	ppm	-	150
Cd	ppm	3 - 6	3
As	ppm	-	10 - 20
Ni	ppm	75 - 100	75
Zn	ppm	300 - 600	300

Availability of Raw materials (mt/annum)

OA1: 38.7
 OA2: 312.6
 OA3: 634.0
 OA4: 6-7

Nutrient contribution of Amendment (ppm)

OA1: N (411); P (11); K (107); S (47); Fe (18) ; Zn (4); Si (8.5%)
 OA2: N (147); P (242); K (66); S (0); Fe (45) ; Zn (3), Si (10.0%)
 OA3: N (73); P (2); K (72); S (8); Fe (7) ; Zn (0), Si (30.3%)
 OA4: N (126); P (1); K (89); S (2080); Fe (28) ; Zn (1); Si (8.9%)

Crop response to SSBVAP application

Center	% change in grain/produce yield over 80% / 100% RDF					
	Brinjal	Soybean	Brassica	Rice	Lemongrass	Withania
New Delhi	67.9/38.8	-	10.8/5.6	-	-	-
Dharwad	-	14.76/AP	-	-	-	-
Cuttack	-	-	-	11.7/AP	-	-
Agra	-	-	-	-	37.6/AP	121.8/100.5
Dose (t/ha)	3	1-1.5	2-4	1-1.5	1-1.5	1-2
Recommended dose (t/ha)	3	1	2	1.5	1.5	2

Suitable for brinjal; soybean, brassica, rice; withania; lemongrass @1.5-2 t/ha with 80% RDF

Steel Slag based value added product (SSBVAP-9)

Mineral nutrients

T-N (%) : 0.23
 A-P (ppm): 82.10 ± 7.66
 A-K (ppm): 5437.86 ± 473.36
 S (%): 0.1-0.5
 A-Ca (ppm): 2697.03 ± 60.53
 Mg (ppm): nd
 Fe (ppm): 4.23 ± 0.08
 Zn (ppm): 0.36 ± 0.00
 Cu (ppm): 22.94 ± 0.69
 B (ppm): 18.88 ± 0.78
 Mo (ppm): 198.64 ± 0.49
 Co (ppm): 7.75 ± 0.34
 Mn (ppm): 954.41 ± 1.88
 Si (%): 10.5

Heavy metal content (ppm)

Pb: 4.59 ± 0.45
 Cd: 0.17 ± 0.02
 Cr: 120.43 ± 3.20
 Ni: 13.94 ± 0.44

Shelf life: One Year at RT;
 Moisture Content: 4-6%

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**Product 9
SiP-1**

MICROORGANISMS

Trichoderma sp.

Penicillium sp

Cheatomium sp.

Bacillus sp.

Pseudomonas sp.

*Contains microbial consortia capable of survive in pH 6-10; cellulose degrader, P-Solubiliser, silica solubiliser

Product Composition

SS: 29.41%

OA6: 58.82%

OA8: 11.77%

Permissible limits of hazardous and other impurities

Elements/Parameters	Unit	Specs for material putting into soil	
		IS(Awasthi) 2000 Specs	EU 2002
Pb	ppm	250 - 500	300
Cu	ppm	130 - 270	140
Cr	ppm	-	150
Cd	ppm	3 - 6	3
As	ppm	-	10 - 20
Ni	ppm	75 - 100	75
Zn	ppm	300 - 600	300

Availability of Raw materials

OA6: 2.7 mt (2020); 5.6 mt (2030)

OA8: 40 billion litre pa

Nutrient contribution of Amendment (ppm)

OA6: TN (1.1%); P₂O₅ (10.11%); K₂O (1.2%); TOC (13.2%), EC dS/m (3.2); pH (6.8)

Bulk density g/cm³ (1.4)

OA8: N (12000-15000); P (2200); K (80); Mg (95.3); Mn (256); Zn (2.5); pH (8.1)

Bulk density g/cm³ (0.6), particle size (96 %)

Crop response to SSBVAP application

Center	% change in grain/produce yield over 80% / 100% RDF			
	Chickpea	Rice	Lemongrass	Withania
Dharwad	2.89/AP	-	-	-
Cuttack	-	10.56/AP	-	-
Agra	-	-	33.3/16.7	25.0/AP
Range of dosage (t/ha)	1-2	1-1.5	1-1.5	1-2
Recommended dose (t/ha)	2	1.5	1.5	2

Suitable for chickpea, rice; withania; lemongrass @1.5-2 t/ha with 80% RDF

Steel Slag based value added product (SSBVAP-10)

Mineral nutrients

T-N (%) : 0.54
 A-P (ppm): 23.49 ± 1.57
 A-K (ppm): 7071.46 ± 5214.74
 S (%) : 0.24
 A-Ca (ppm): 3129.67 ± 889.09
 Mg (ppm): nd
 Fe (ppm): 3.61 ± 0.53
 Zn (ppm): 0.11 ± 0.01
 Cu (ppm): 21.28 ± 2.89
 B (ppm): 13.6 ± 0.42
 Mo (ppm): 89.07 ± 108.10
 Mn (ppm): 435.72 ± 14.33
 Co (ppm): 4.37 ± 0.70
 Si (%) : 6.0

Heavy metal content (ppm)

Pb: 5.23 ± 1.53
 Cd: 0.26 ± 0.02
 Cr: 57.60 ± 11.65
 Ni: 13.70 ± 0.35

Shelf life: One Year
 at RT; Moisture
 Content: 4-6%



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Product Composition
 SS: 29.4%
 OA7: 58.8%
 OA8: 11.8%

MICROORGANISMS

Trichoderma sp.

Penicillium sp

Cheatomium sp.

Bacillus sp.

Pseudomonas sp.

*Contains microbial
 consortia capable of
 survive in pH 6-10;
 cellulose degrader,
 P-Solubiliser, silica
 solubiliser



Permissible limits of hazardous and other impurities

Elements/Parameters	Unit	Specs for material putting into soil	
		IS(Awasthi) 2000 Specs	EU 2002
Pb	ppm	250 - 500	300
Cu	ppm	130 - 270	140
Cr	ppm	-	150
Cd	ppm	3 - 6	3
As	ppm	-	10 - 20
Ni	ppm	75 - 100	75
Zn	ppm	300 - 600	300

Availability of Raw materials

OA7: 12-14 mt pa

OA8: 40 billion litre pa

Nutrient contribution of Amendment (ppm)

OA7: N (1.4%); P₂O₅ (9.38%); K₂O (1.4%); OC (13.81), EC ds/m (3.5); pH (7.6)

OA8: N (12000-15000); P (2200); K (80); Mg (95.3); Mn(256); Zn (2.5); pH (8.1)

Bulk density g/cm³ (0.6), particle size (96 %)

Crop response to SSBVAP

Center	% change in grain/produce yield over 80% / 100% RDF			
	Chickpea	Rice	Lemongrass	Withania
Dharwad	3.03/AP	-	-	-
Cuttack	-	16.92/3.30	-	-
Agra	-	-	62.7/42.4	28.2/2.5
Dose (t/ha)	1-2	1-1.5	1-1.5	1-2
Recommended dose (t/ha)	2	1.5	1.5	2

Suitable for chickpea, rice; withania; lemongrass @1.5-2 t/ha with 80% RDF

Steel Slag based value added product (SSBVAP-11)



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**Product 11
ASSS-1**

Product Composition

SS: 25 %
OA1: 40 %
OA9: 35 %

**Increases yield by
15-20% @2.5t/ha
application rate.
Saves 20% NPK
fertilizers and on LR**

**Suitable for
cultivation of tuber,
cereal and vegetable
crops in acidic soils**

**Shelf life: One Year
at RT; Moisture
Content: 4-6%**



Crop response to SSBVAP application

Center	% change in grain/produce yield over 80% / 100% RDF				
	Pea	French bean	Rice	Green gram	Potato
Wellington	-	-	-	-	106.3/60.7
Cuttack	-	-	16/1.7	33.7/6.9	-
Meghalaya	42.6/31.7	31/20.9	-	-	-
Range of dosage (t/ha)	2.5-5	2.5-5	2.5-5	2.5-5	2.5-5
Recommended dose (t/ha)	2.5	2.5	2.5	2.5	2.5

Heavy metal accumulation (ppm) in shoot and produce in response to SSBVAP application

HM	Plant part	Rice	Green gram
Cr	Shoot	5.88	3.46
	Produce	0.52	0.72
Cd	Shoot	4.24	3.67
	Produce	0.45	0.36
Pb	Shoot	3.50	3.64
	Produce	0.93	0.73

Tissue	Limit to HM Content (ppm)			
	Cd	Cr	Pb	Ni
Plant	1.5	20	2.5	1.5

Suitable for Potato, Pea, frenchbean, rice, green gram @2.5 t/ha

Steel Slag based value added product (SSBVAP-12)



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भारतीय कृषि
अनुसंधान संस्थान
ICAR



Product 12
ASSS-2

**Increases yield by
15-20% @2.5t/ha
application rate.
Saves 20% NPK
fertilizers and on LR**

**Suitable for
cultivation of cereals
and vegetables in
acidic soils**

Product Composition

SS: 30.0 %
OA1: 35.0 %
OA10: 35.0%

**Shelf life: One Year
at RT; Moisture
Content: 4-6%**



Crop response to SSBVAP application

Center	% change in grain/produce yield over 80% / 100% RDF				
	Wheat	Pea	French bean	Rice	Green gram
Wellington	63.2/9.92	-	-	-	
Cuttack	-	-	-	17.2/2.7	43.8/15.05
Meghalaya	-	49.5/34.5	34.8/24.5	-	
Range of dosage (t/ha)	2.5-5	2.5-5	2.5-5	2.5-5	2.5-5
Recommended dose (t/ha)	2.5	2.5	2.5	2.5	2.5

Soil physico-chemical attributes as affected by SSBVAP application in rice-green gram cycle.

	Rice-Green gram
pH	7.23 (6.72)
EC (dS/m)	0.26 (0.24)
OC (%)	0.61 (0.57)
Cd (mg/kg)	0.61 (0.54)
Pb (mg/kg)	52.6 (54.3)
Cr (mg/kg)	9.07 (8.94)

Matrix	Limit to HM content (ppm)			
	Cd	Cr	Pb	Ni
Soil	3-6	150	250-500	75-150

Suitable for wheat, french bean, rice, pea, green gram @2.5t/ha



Steel Slag based value added product (SSBVAP-13)



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**Product 13
HMCSS1**

**Increases yield by
10-15% @2.5t/ha
application rate.
Saves 20% NPK
fertilizers and on LR**

**Suitable for
cultivation of cereals
on degraded soils
Reduces uptake of
HM by plant**

Product Composition

SS: 29.4 %
OA1: 41.2 %
OA3: 29.4 %

**Shelf life: One Year
at RT; Moisture
Content: 4-6%**



Crop response to SSBVAP application on As contaminated soil

Treatments	Plant height (cm)	No. of panicles/pl ant	Grain yield (t/ha)
Control	84.97	4.0c	5.3b
Product 12	89.33	6.0a	6.0a
Product 13	87.80	5.8b	5.9a
CD (0.01)	NS	0.3	0.4

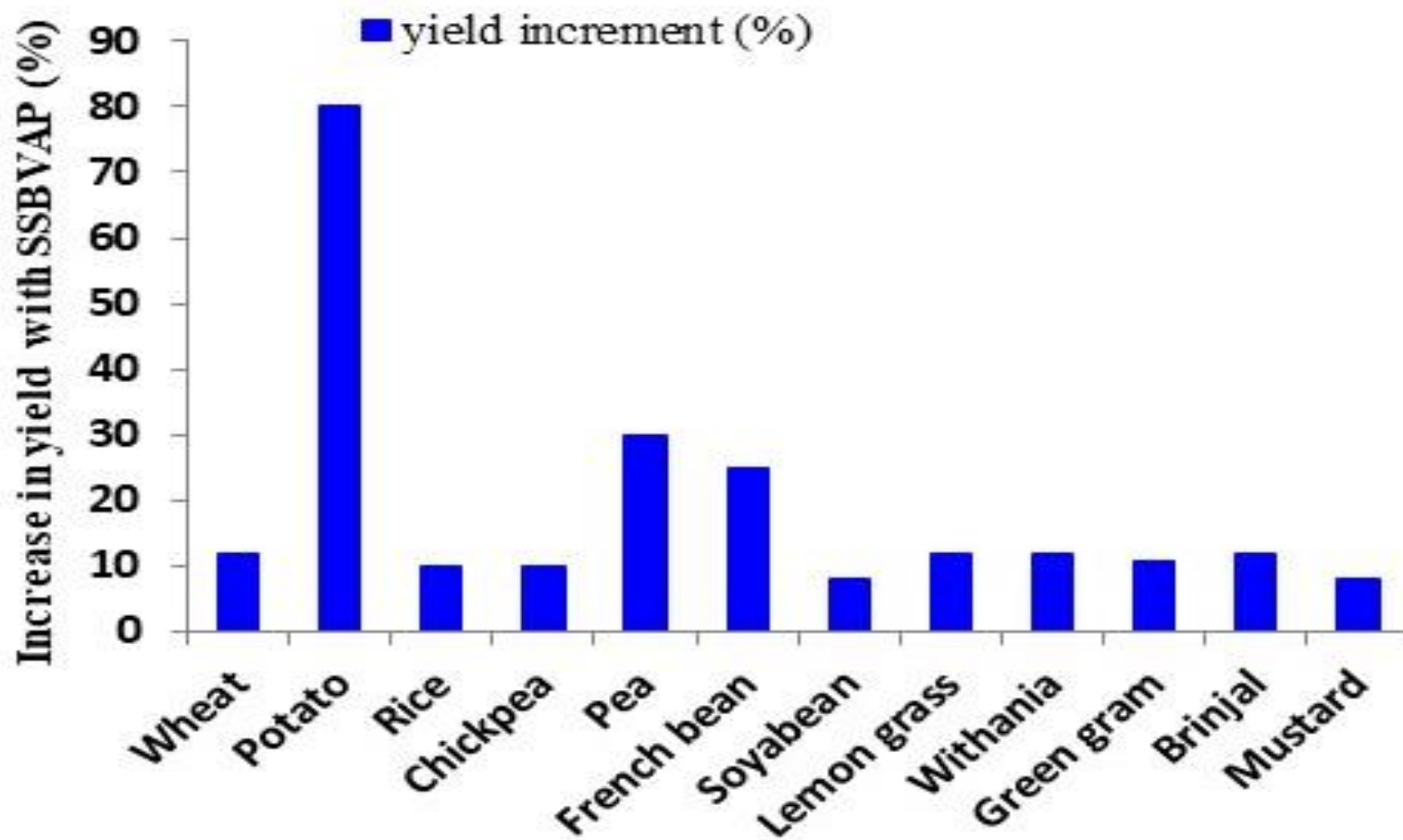
As contaminated soil contained more than 13 mg/kg As as against 3mg/kg in normal soil

Percent reduction of As compared to control

Root: Product 13 (74%) > Product 12 (17%)
Shoot: Product 13 (21.9%) > Product 12 (21.1%)
Grain: Product 13 (43%) > Product 12 (22.9%)

Suitable for rice cultivation on HM contaminated soils. Reduces uptake of HM by plant. Rate of application @5t/ha.

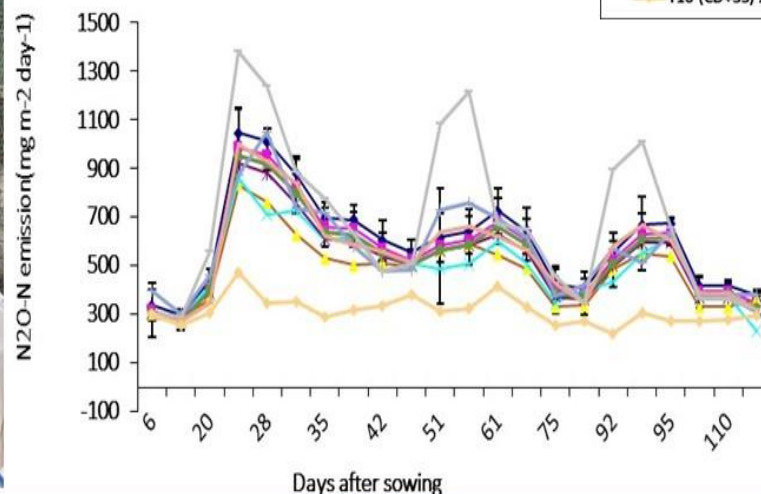
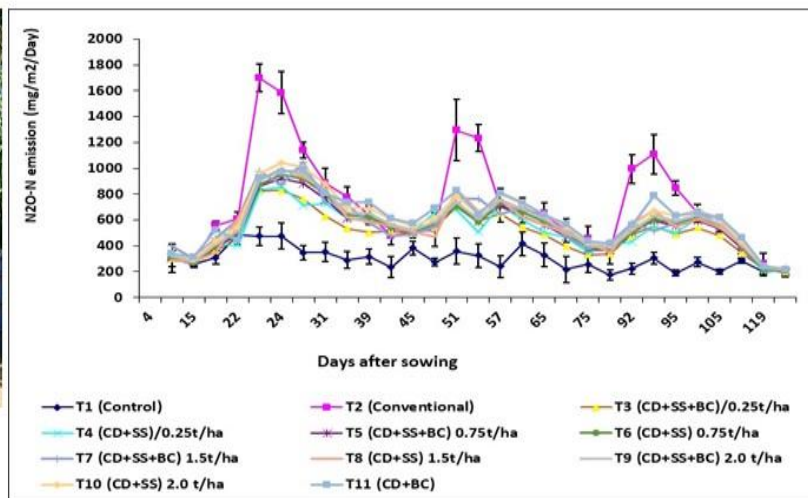
Mean increase in economic yield (%) in response to application of steel slag based value added product



Suitability of crops across SSBVAP's

[illegible]

Effect of bio-augmented and amended LD slag on GHGs (N_2O emission) in wheat cv HD-2967



➡ Mean N_2O flux ranged from 300 to 719.3 $mg/m^2/Day$.

N_2O emission was reduced by applying a higher dose of bioaugmented and organically amended LD slag.

Availability of resources used for amendment of Steel slag

S No	Amendment	Availability in India (mt/annum)	S No	Amendment	Availability in India (mt/ annum)
1	OA1	140.2	6	OA6	2.9
2	OA2	312.7	7	OA7	1.1
3	OA3	634.0	8	OA8	1587 million L
4	OA4	6.0-7.0	9	OA9	4.0
5	OA5	Biome	10	OA10	2.25

Potential utilization of steel slag through fertilizers/ amendments

Steel slag utilization in Agriculture: A modest beginning

S No	Crop	Total area under cultivation (mha)	Estimated area under SSBVAP (mha @15%)	Total utilization of SSSBVAP based on application rate @ 1t/ha (Mt)	Total utilization of SSBVAP based on application rate @ 2t/ha (Mt)	Utilization of slag based on slag content in SSBVAP i.e. 40% (Mt)
1	Rice	43.0	6.45	6.45	12.9	2.58-5.16
2	Wheat	30.0	4.5	4.5	9.0	1.8-3.6
3	Soybean	12.0	1.8	1.8	3.6	0.72-1.44
4	Mustard	8.7	1.3	1.3	2.61	0.522-1.044
5	Potato	2.0	0.3	0.3	0.6	0.12-0.24
	Total	98.7	14.81	14.81	29.61	5.74-11.48

*SS génération in India ~12-16 million tonnes per annum

Economics of production of Steel Slag based value added products (SSBVAP's)

Code	Product profile	Input Cost		Manpower Cost (in Rs)	Other costs (in Rs/t product)	Total cost (in Rs/t product)
		Cost of amendment (in Rs/t product)	Steel slag @1Rs/kg used @ 20-35 % (in Rs/t prod.)			
P-1	SS+OA ₁ +OA ₂ +OA ₅	1709	313	400	200	2622
P-2	SS+OA ₁ +OA ₃ +OA ₅	2322	313	400	200	3235
P-3	SS+OA ₁ +OA ₂ +OA ₃ +OA ₅	2343	313	400	200	3256
P-4	SS+OA ₁ +OA ₄ +OA ₅	1710	333	400	200	2643
P-5	SS+OA ₁ +OA ₂ +OA ₄ +OA ₅	1767	250	400	200	2617
P-6	SS+OA ₁ +OA ₃ +OA ₄ +OA ₅	2257	250	400	200	3107
P-7	SS+OA ₁ +OA ₂ +OA ₃ +OA ₅	2257	238	400	200	3095
P-8	SS+OA ₁ +OA ₂ +OA ₃ +OA ₄ +OA ₅	2213	200	400	200	3013
P-9	SS+OA ₇ +OA ₈ +OA ₅	1500	294	400	200	2394
P-10	SS+OA ₇ +OA ₈ +OA ₅	1500	294	400	200	2394
P-11	SS+OA ₁ +OA ₉	5482	250	400	200	6332
P-12	SS+OA ₁ +OA ₁₀	3281	300	400	200	4181
P-13	SS+OA ₁ +OA ₉ +OA ₁₀	4409	300	400	200	5309

Conclusion

- ❖ Steel slag alone application is not sustainable.
- ❖ SSBVAP's have lower than permissible heavy metals for on- farm application.
- ❖ Don't cause a accumulation of heavy metals over multiple cropping seasons.
- ❖ Produce raised on SSBVAP's does not show any phyto-toxicity.
- ❖ Mean dose of SSBVAP application is 1.5-2 t/ha across crops on normal soils and @2.5t/ha on acidic soils; increases yield by 7-15% at 80% RDF in comparison to the yield obtained at 100% RDF.
- ❖ Average cost of production of SSBVAP is around Rs 2500-3000/ton.
- ❖ Savings on account of 20% RDF also -P/-K application as per product.

Snapshot of the field visit by the experts and stakeholders



VISIT TO CCSHAU, HISAR DATE: 20.03.23 CROP: WHEAT



VISIT TO GBPUAT, PANTNAGAR

Farmers field, Cuttack



12 Sept, 23



14 Aug, 23



12 Sept 23



12 Sept, 23



SNBVAP-10 Date: 22 September, 23

Thank You



Ministry of Steel
Government of India

