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Original Research Article

Nutrient Mining and Potential Low Cost Indicative / Corrective Measures

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Keywords

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A B S T R A C T

The fertility status of Indian soil declined drastically over the year following the era of Green Revolution and is marked by negative balance 10Mt of NPK year^{-1} between nutrient removed by the crops and those added though fertilizer. This gap is likely to increase further with increase in food grain production. Hence to minimize India’s current annual nutrient balance we should increase use of organic manure and bio-fertilizers. The use of higher amount of nutrient is not an key to higher production and productively but proper and balanced use of fertilizer is essential.

Introduction

The global cereal production has doubled in the past 40 years as a result of technological development of the green revolution era, which resulted in increased crop yields mainly due to the introduction of improved crop varieties, greater fertilizer application, development of irrigation facilities and pesticides application [2,3]. This has not only increased per capita food availability, reduced hunger and improved nutrition but also helped in the protection of natural ecosystems from conversion to agriculture lands for increasing food production. The era of green revolution is over, and again a giant leap in agriculture is urgently required to fulfill the requirements of future generations. On the other hand the ill effects of green revolution technologies in the form of soil degradation, water pollution, environmental deterioration, increased pest and disease incidences, decreasing productivity and economic returns are posing threats. The fertility status of Indian soil declined drastically over the year following the era of Green Revolution and is marked by negative balance 10Mt of NPK year^{-1} between nutrient removed by the crops and those added though fertilizer (Tiwari 2008). In 1950-51 only 0.5 kg nutrients ha^{-1} year $^{-1}$ were used to produce 51 Mt of food grains which has arisen to 117 kg ha-^{1} year $^{-1}$ to produce 230 Mt is 2008-09.The soil fertility should be maintained by judicious and integrated use of all possible organic resources in conjugating with minimum chemical fertilizer. Even application of recommended dose of NPK fails to sustained quality and crop productivity (Rao and *et al.*, 2013). A review of current nutrient mining status and potential ameliorative management practices is widely felt to address site specific soil nutrient supply capacities and crop demand challenges.

Inadequate and imbalanced fertilizer use

Has caused wide spared nutrient (mainly N. P. K. S. Zn and B) deficiencies and deterioration in soil health in many parts of India. It has been estimated that at all India level, 63, 42, 13, and 40% soils are deficient in N, P, K and S respectively.

Base on several years of data and analysis of over 250,000 soil samples, 49% of soils have been found to be deficient in Zn, 15% inFe,3% in Cu, 5% in, Mn, 33% in B and 13% in Mo (Singh 2001). Deficiencies of micronutrient and secondary nutrients are increasing under intensive cropping system (Rice-Wheat).

Similarly removal of micronutrient by different crops are also reported by Dr. BP Singh (1991)

A balance sheet of nutrients added and removed from the soil by different crops are also given by Dr Singh as follower

Solution of the problem

It has been proved by many long term experiment that we cannot achieve sustainable agriculture production through only chemical fertilizer but it also not possible to achieve target yield by applying only organic manure. Therefore a more balanced way to get sustainable production may be the Integrated Plant Nutrition System (IPNS) or Integrated Nutrient Management (INM) - It is a system which aims at the maintenance or adjustment of soil fertility and plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of the benefit from all possible sources of plant nutrient in an integral manner.

INM is the necessity of present agriculture because of two main reason firstly increasing the imbalance of major and minor nutrient in most our soil and secondly the fact that neither chemical fertilizer nor organic sources exclusively can achieve the require production in sustainable manure of soil. The importance of IPNS is being magnified because of imbalanced and negative nutrient balance, deterioration in fertilizer use efficiency (Tiwari 2008).

INM refers to the maintenance of soil fertility and of plant nutrient supply at an optimum level for achieving desired productivity though optimization of benefit in an integrated manner. Or An intelligent use of optimum combination of organic, inorganic and biological sources for nutrients in a specific crop rotation or cropping system to achieve and sustain optimum yield without harming soil ecosystem.

Objectives of INM

To maintain fertility and Physico-chemical properties of soil.

To recycle and use of organic wastes.

Encouragement of the judicious use of chemical fertilizers.

Green leaf manures and bio fertilizers for higher productivity.

Creation of positive nutrient balance in soil.

To avoid over exploitation of natural resources.

Maximization of nutrient use efficiency.

Environmentally safe and eco-friendly sustainable agriculture.

To reduce expenditure on cost.

To utilize the potential benefits of green manuring.

To protect soil health.

To meet the social and economic aspirations of the farmer with high productivity and profitability.

Component of INM/ IPNS

Conservation of soil source.

Inorganic Fertilizers

Organic manure/ green manure

Recycling of plant residues / Farm west/ Industrial west

Bio Fertilizer

Conservation of soil resource

Generally INM mean application of combined source of inorganic and organic manure but the soil is important component and due importance should be given for the conservation of nutrients from soil sources. Due to urbanization our fertile soil /our mother earth are being buried. It is good to established smart city and villages and industries for development our countries but fertile soil should be spared for the bread of our future generation. It would be done by following measures

Improvement of Organic Matter content of soil.

Deep summer Plowing

Legumes should be included in cropping system

Use of nutrient responsive varieties.

Use of amendments to neutralize the soil pH

Optimum moisture condition be should be maintained

Leveling and proper drainage system

Weed management.

Integrated Pest & Diseases Management with bio-control agents.

Improvement of Organic Matter content of soil.

Soil organic matter (SOM) is the key attribute of soil physical, chemical and biological properties and largely governs the soil quality.

The productivity is closely linked with SOM status of soil. Organic amendments play an important role in improvement of soil structure and soil organic matter content (Ponnamperuma, 1984, Meelu *et al.*, 1994).

The use and management of crop residues, Farm Yard Manure (FYM), Compost and Green Manure are increasingly important aspect of environmentally sound sustained agriculture (Timsina and commor, 2001).

Deep summer Plowing

Deep summer plowing is very useful for the improvement of soil fertility and soil health.

Table.1 Extents of macronutrient deficiencies in Indian Soil

Nutrient	No. of Samples analyzed	% are of samples bye category		
		Low	Medium	High
N	3,650,004	63	26	11
P	3,650,004	42	38	20
K	3,650,004	13	37	50
S	27,000	40	35	25

Source: Mostra (2002)

Table.2 Potential, on-station and on-farm yields (t ha^{-1}) and yield gapes of rice and wheat at different places in India

Site	Yield of rice as paddy (t ha^{-1})			Yield gap (%)		Yield of what(t ha^{-1})			Yield Gap %	
	Potential (A)	on-Station* (B)	on-farm** (C)	[(A-B)/A] x100	[(A-C)/A] x100	Potential (D)	on-Station* (E)	on-farm** (F)	[(D-E)/D]x 100	[(D-F)] x100
Ludhiana	10.7	5.6	5.6	48	48	7.9	4.7	4.3	41	46
Kernel	10.4	6.8	3.8	35	63	7.3	4.6	3.6	37	51
Kanpur	9.5	4.5	2.8	53	71	7.0	4.6	2.8	35	60
Pantnagar	9.0	5.5	4.2	39	53	6.5	3.9	4.2	40	35
Varanasi	9.2	4.1	3.2	55	65	87.0	3.8	3.2	46	54
Faizabad	9.1	4.2	2.8	54	69	6.7	3.4	2.8	49	5
Dinapur	8.6	3.2	3.1	63	64	5.4	3.8	2.3	31	57
24-Pargans	7.7	4.4	2.8	43	64	5.2	3.0	2.8	43	46

*yield with the recommended level of NPK in the long-term experiments
Source: Ladha *et al.*, (2003)

Table.3 Average Removal of Primary and Secondary Nutrients by Crops

Crops	Economic Yield t/ha	Total nutrients removed kg/ha					
		Primary nutrient			Secondary Nutrient		
		N	P	K	Ca	Mg	S
Rice	30	84	14	89	21	9	9
Wheat	3.0	125	22	92	16	14	14
Maize	5.0	170	35	175	27	39	19
Sugarcane	88.0	180	26	270	132	-	26
Pigeonpea	1.5	85	8	16	23	15	9
Soybean	2.5	125	43	101	35	19	22
Groundnut	2.0	170	30	110	39	20	15
Mustard	1.5	8.	17	71	63	13	26

Source: Nutrient Removal by major crops by Dr. B.P. Singh, Sriram Fertilizers FAI Seminar Held at A.A.I during Aug.9-11, 1991.

Table.4 Micronutrient Removed by Different Crops (g/t dry matter)

Crops	Micronutrient removed					
	Fe	Mn	B	Zn	Cu	Mo
Wheat	232	26	18	21	5	0.87
Jowar	360	27	27	36	8	.98
Hybrid Bajra	264	23	27	22	9	0.84
Groundnut	499	39	44	9	5	1.32
Cotton	106	14	15	16	8	0.77
Potato	160	12	50	9	9	0.80
Guar	71	15	29	15	9	1.14
Mung	170	38	32	13	11	1.05
Cowpea	260	89	53	17	11	1.31

Source: Micronutrients removed by various crops by Dr.B.P Singh, Sriram fertilizers FAI Seminar Held at A.A.I during Aug.9-11, 1991.

Table.5 Balance Sheet of Nutrient (kg/ha) under different Crops

Crops	Nutrient Added			Nutrient Removed			Balance		
	N	P	K	N	P	K	N	P	K
Wheat	120	26	50	176	12.5	204	-56	13.5	-154
Paddy	120	26	25	176	16	189	-56	10	-164
Pigeonea	24	26	50	132	16	73	-108	10	-23

Source: Dr. B.P. Singh, FAI Seminar Held at Alld. Agri.Instt, 9-11th August, 1991.

Table.6 Estimates of Nitrogen Fixed by Some Legumes

Crops	Nitrogen Fixed (kg/ha)	Crop	Nitrogen Fixed (kg/ha)
Alfalifa	100-300	Lentil	35-100
Clover	100-150	Greengram	50-55
Chickpea	26-63	Pigonpea	68-200
Cluster been	37-196	Soybean	49-130
Cowpea	53-85	Peas	46
Groundnut	112-152	Fenugreek	44

Table.7 Residual effect of preceding legume on cereal yield in terms of fertilizers N equivalents

Preceding Legume	Following Cereal	Fertilizers N Equivalents (Kg N/ha)
Berseen	Maize	123
Sweet clover	Maize	83
Chikpea	Maize	60-70
Groundnut	Pearl millet	60
Cowpea	Pearl millet	60
Chikpea	Pearl millet	40
Lentil	Pearl millet	40
Peas	Pearl millet	40
Pignopea	Wheat	40
Lathyrus	Maize	36-48
Pignopea	Pearl millet	30
Greengram	Pearl millet	30
Pignopea	Maize	20-49
Peas	Maize	20-32
Lentil	Maize	18-30

Tabale.8 Removal of plant Nutrients by weeds (kg/ha)

Crop infested with weeds	Average nutrient removal		
	Nitrogen	Phosphorus	Potassium
Rice	22.0	11.3	88.0
Wheat	20.5	1.9	26.4
Maize	39.2	5.3	32.4
Sorghum	37.8	13.4	32.8
Sugarcane	78.0	39.5	188.5
Potato	58.2	11.3	88.0
Peas (vegetable)	28.1	5.5	-
Soybean	46.7	9.2	72.9

Table.9 N- Concentration, N- uptake and N- Use Efficiency (NUE) as influenced by time of nitrogen application for irrigated rice (Mean of 2001-2002)

Treatments	N-content (%)		Total N-uptake (Kg ha^{-1})	Agronomic Efficiency (Kg grain kg^{-1} N applied)	Physiological Efficiency (Kg grain kg^{-1} N uptake)	Nitrogen Utilization Efficiency (Kg N uptake kg^{-1} an applied)
	Grain	straw				
T1 - Control	1.23	0.31	34.03	-	-	-
T2 1/2B+1/4MT+1/4PI	1.35	0.32	61.44	12.91	47.14	27
T3- 1/2B+1/3MT+1/3PI	1.42	0.38	75.20	18.31	44.47	41
T4 - ½ MT ½ PI	1.41	0.42	91.68	24.98	43.33	58
T5-1/3 MT+1/3PI+1/3F	1.43	0.45	93.37	24.95	42.04	59
T6-1/37DAT+1/3MT+1/	1.45	0.47	105.94	28.74	39.97	72
T7- LCC	1.45	0.45	99.38	26.44	40.46	65
CD (P= 0.05)	0.05	0.03	7.05	1.54	2.51	13

B-basal, MT- maximum tillering, PI – Panicle initiation and F- flowering, DAT- days after transplanting, LCC- Leaf colour chart

FUE- in old recommended practice ie 1/2 N as basal + ¼ MT + ¼ at PI stage =41%.

FUE- in new recommended practice ie 1/3 N after 7 days of transplanting + 1/3 at MT + 1/3at PI stage = 72%.

Table.10 Influence of rice straw management practice on yield of rice nutrient status and microbial population in the post-harvest soil (after two years of cropping)

Treatments	Gain yield (t ha^{-1})	Organic carbon (g kg $^{-1}$)	Available N (kg ha $^{-1}$)	Available P (kg ha $^{-1}$)	Available K (kg ha $^{-1}$)	Microbial population (log cfu g^{-1} soil)
T1:Control	2.67	5.2	173.9	11.4	75.4	9.61
T2:RSI+ starter N	2.92	6.2	188.7	12.1	78.8	9.50
T3:RSI+CDM	4.26	6.3	198.3	12.3	80.0	9.88
T4:RSI+EW	4.77	6.2	191.5	12.1	77.5	9.58
T5:RSI+ EW+FYM	3.90	6.8	194.4	12.2	81.9	9.82
T6:RSI+CDM+EW	4.66	5.9	195.5	12.6	82.0	9.92
T7:RSI+FYM	3.12	6.2	192.1	12.1	78.1	9.70
T8:RSI + starter + N+ CDM+ EW+LIME	3.58	5.2	190.7	12.1	78.8	9.79
CD (9=0.05)	0.06	0.9	3.3	0.1	0.7	

RSL- rice straw incorporation, CDM- cellulose decomposing microorganism, EW- earthworms, FYM- Farmyard manure

Table.11 Some Fertilizer Equivalent of Organic Manures and Biofertilizer

Components	**Input level**	**Fertilizer Equivalent of Input in terms on crop yield**
Organic Manures	Per tone	3.6kg N + P_2O_5+K_2O (2:1:1)
Green Manures (Sesbania)	Per tone	4.4 kg N
Green Manures (Sesbania)	45 days crop	50-60 kg N for HYN rice
Cowpea intercropped with castor	Legume buried after 6 weeks	30 kg fertilizer N on castor
Leucania loppings	88kg N in Leucaenia	25kg fertilizer N on sorghum
Rhizobium	Inoculants	19-22 kg N
Azotobacter and Azospirillum	Inoculants	20 kg N
Blue Green Algae	10 kg/ha	20-30 Kg N
Azolla	6-12 t/ha	3- 4kg/t
Sugarcane trash	5 t/ha	12 kg N/t
Rice straw + water hyacinth	5 t/ha	20 kg N/t

Table.12 Effects of continuous application of organics and chemical fertilizers on grain and straw yield (t ha^{-1}) of rice and wheat pooled for years two years (2010-11 and2011-12)

Treatment	**Rice GrainStraw**		**Wheat GrainStraw**	
T1- Control	4.46	2.73	1.22	2.13
T2- 100% NPK to both rice and wheat	6.31	5.41	3.01	5.84
T3- 50%N through FYM plus 50% NPK trough chemical fertilizer to rice and 100%NPK trough chemical fertilizer to wheat	7.26	6.17	3.64	6.05
T4-25%N through FYM plus 75% NPK trough chemical fertilizer to rice and 100%NPK trough chemical fertilizer to wheat	7.31	5.64	2.22	4.17
T5-50%N through FYM plus 50% NPK trough chemical fertilizer to rice and 100%NPK trough chemical fertilizer to wheat	6.28	4.71	2.14	4.69
T6- 25%N through FYM plus 75% NPK trough chemical fertilizer to rice and 100%NPK trough chemical fertilizer to wheat	6.21	4.72	2.34	4.54
T7-50% N through FYM plus 50% NPK trough chemical fertilizer to rice and 100%NPK trough chemical fertilizer to wheat	7.37	6.21	2.77	5.00
T8- 25%N through FYM plus 75% NPK trough chemical fertilizer to rice and 100%NPK trough chemical fertilizer to wheat	6.44	5.67	2.61	4.72
CD (P=0.05)	0.82	.97	0.73	1.45

Table.13 Effects of continuous application of organics and chimerical fertilizers on physicochemical properties of soil after 20 cropping cycle

Treatment Code	pH	Organic Carbon (g kg^{-1})	CEC [cmol(p+) kg^{-1}]	Available nutrient (kg ha^{-1})			
				N	P	K	S
T1	5.5	5.76	10.59	182	17.9	120	10.8
T2	5.2	7.34	13.73	248	66.9	163	20.7
T3	5.7	8.66	14.67	281	75.2	167	22.7
T4	5.6	8.23	13.98	271	70.2	159	20.4
T5	5.6	8.45	13.15	251	65.7	160	20.2
T6	5.5	7.65	13.15	251	65.7	160	20.2
T7	5.6	8.36	13.71	266	62.9	158	19.3
T8	5.5	7.13	12.33	239	70.8	154	18.4
CD (P=0.05)	0.05	0.22	.43	10.7	5.18	7.6	1.88
Initial	5.5	6.0	11.5	675	21.9	221	ND*

*Not Determined

Table.14 Effect of different treatment on microbiological properties of soil after wheat harvest (210-11)

Treatment Code	Microbial biomass carbon (µg g^{-1} soil)	Microbial respiration [µg CO2 g1 soil h^{-1})	Dehydrogennase activity (µg TPE g^{-1} h^{-1})	Urease activity (µg g^{-1} min^{-1})
T_1	173.5	7.1	2.94	2.47
T_2	225.7	13.7	7.14	5.23
T_3	273.2	16.8	12.04	8.64
T_4	262.4	15.4	9.89	7.59
T_5	257.9	16.2	8.46	7.16
T_6	248.1	14.8	7.72	6.83
T_7	261.5	14.0	9.01	7.32
T_8	250.6	13.4	8.80	7.28
CD (P=0.05)	6.5	0.71	0.51	0.34

It breaks the life cycle of causal of organism of many disease and insects.

It destroys weeds and their seeds and bulbs, thus reduces the weed infestation in the next crop.

It improves the water used efficiency.

The nutrients from lower horizon could be utilized by the crops.

Legumes should be included in cropping system

We all are aware the benefits of leguminous crops in soil fertility and health. It fixes the atmospheric Nitrogen, improves the soil health, mines nutrients from lower horizon, and improves the organic matter content of the soil etc. But we have neglected the importance of legumes and most of the formers are adopting Rice-Wheat cropping system. The following table shows the importance of legume cultivation and therefore it should be included in crop rotation for soil health and fertility.

Use of nutrient responsive varieties

Nutrient responsive, deep rooted, low water requiring and high and high yielding variety should be included to reduced the cost of cultivation and conservation of nutrient and water resources.

Use of amendments to neutralize the soil pH

Gypsum, Pyrite, line and organic residues which ever necessary should be apply to neutralize soil pH so that the availability of all nutrients to the plants may be optimum at their requirement.

Optimum moisture condition be should be maintained

The proper moisture content is must for maximum availability of all the nutrients to the plants. Therefore it should be maintain through the crop season for proper utilization of indigenous and edit nutrients from the soil.

Leveling and proper drainage system

Leveling of the land and drainage system improves the nutrient availability fertilizer use efficiency (FUE) and uniform growth and yield of the crop.

Weed management

This is very important component of INM because weeds are responsible to create Competition for nutrients area, and water resources for our crops. This table shows how much nutrients are being lost due to infestation of weed in different crops.

Integrated Pest & Diseases Management with bio-control agents

The agrochemicals are harming soil health and quality of the products therefore efforts should be done for to control insects disease and weeds by bio-control measures.

Inorganic Fertilizers application

Very important entity to fulfill nutrient requirements of plant but some precaution should be maintain while using inorganic fertilizer.

Use balanced fertilizer as per soil analysis.

Slow release urea ie: Sulphur coated, Neem coated and Super granules urea should be applied.

Placement of fertilizer at proper place and time. Adopt method to improve Fertilizer Use Efficiency. (FUE)

The application of fertilizer by the new recommendation practice as reported by S.F.A. Zaidi (2007) improve the fertilize use efficiency as follows.

Organic manure/ green manure

The use and management of recycling of crop residues Farm Yard Manure (FYM), Compost, Vermy composed Green manure and other organic residues should be added replacing 25% to 50% inorganic fertilizer requirements to improve soil fertility, productivity and soil health.

Recycling of plant residues / Farm west/ Industrial west

In recent times, emphasis has been on the increase use of crop residues, green manures as well as other organic manures as a source of soil organic matter and plant nutrient (Sharma 2005).

Rice straw is one of the major sources of organic matter and plant nutrients available to the farmers in significant quantities. The annual availability of rice straw in India is more than 105 Mt (Gour-1992). Further recycling of such residues is necessary for their early decomposition and improvement in soil health.

The incorporation of rice straw with conventional tillage decrees the yield of subsequent crop due to N-immobilization. Recycling of rice straw with different management practices/ amendment are being studied by many research workers.

Rajkhowa D.J. (2012) in his experiment incorporated rice straw (5 t h^{-1}) with 1/3 N as starter, cellulose decomposing microorganisms (CDM), Earthworm culture (EW) EW+FYM, CDM+FYM and starter N+CDM+EW+ lime along with control. Signification improvement in rice productively was recorded when straw was incorporated with CDM and EW. It also significantly improved NPK uptake soil organic carbon and microbial population in the soil.

Bio Fertilizer

Have an important role to play in improving the nutrients supply and their availability in crop production. Many microbial inoculations like N fixing bacteria, Vesicular Arbuscular Mycrorrhizza (VNM), Ectomycorrhiza, Phosphates solubliser and many Plant Growth Promoting Rhizobactria (PGPR) are known to improve the availability and uptake nutrients by plant growth promotion through hormonal action or antibiotic or by decomposition of organic residue.

Effect of INM on soil fertility, productivity and soil health

Upendra Sharma and S.K Subehia (2014) in long tern INM experiment (20th cropping cycles on Rice-Wheat cropping system revels that 50% substitution of NPK through FYM or GM improved the yield nutrient uptake and microbial and enzymatic activities.

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