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Efficient and effective nutrient management strategies for wheat

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ABSTRACT

Use of chemical fertilizers proved a boon for achieving higher wheat productivity and self sufficiency in food grain production of India. However, continuous increase in consumption (0.07 mt in 1951-52 to 20.0 mt in 2006-07) of fertilizers and imbalanced fertilizers' nutrients use especially in northern states (NPK 16:5:1) are posing serious threat to production sustainability of the crop. Burning of wheat and rice straw in northern states of India is causing not only huge losses of nutrients but also environmental pollution. To overcome these problems combined use of rural and urban wastes, crops residues, biofertilizers, geen manuring, organic manuring and vermi-composting complemented with chemical fertilizers may prove excellent for nutrients management for better wheat productivity, sustainability and solution of environmental problems. Harnessing each and every percent beneficial effect from each of these natural resources may only guarantee the filling up of ever increasing food bowl of India and healthy environment for the generations to come. India has been bestowed with huge human (>1000m) and animal population (> 500m) as well as crops residues resource (> 400 mt annually) which can generate more than 17 mt of major (NPK) nutrients and hence, judicious and combined use of these natural and renewable resources may reduce the dependency on chemical fertilizers on one hand and help in solving the environmental pollution problem on the other hand.

Key words: Nutrient management, Chemical fertilizers, Crop residues, Organic manures, Biofertilizers, Green manures, Press mud

Keeping the fields fallow or growing of legumes or use of animals dung as manure were the only means to sustain soil fertility up to the end of 18th century but with the advent of manufacturing of single super phosphate (SSP) by Lawes and Gilbert in the middle of nineteenth century in England and synthesis of Ammonia by German Chemist Fritz Haber in 1918 brought about new dawn in the era of soil fertility. This led to the use of chemical fertilizers for improving soil fertility and achieving higher productivity. The use of chemical fertilizers, though proved a boon for achieving higher crop productivity and food security to starving human population through out the world but soon it was realized that continuous use of high doses of chemical fertilizers alone created an imbalance in soil fertility and plant nutrient supply system. To overcome this problem a new approach was conceived for maintaining the soil fertility and improving the productivity of crops to achieve food security and balanced human nutrition for ever increasing human population. This new approach was termed as Integrated Nutrient Management. It is an approach that seeks to both increase agricultural production and safeguard the environment for future generations. It is a strategy that incorporates both organic and inorganic plant nutrients to attain higher crop productivity, prevent soil degradation, and thereby help meet future food supply needs. It relies on nutrient application and conservation, new technologies to increase nutrient availability to plants, and the dissemination of knowledge between farmers and researchers

The concept of Integrated Nutrient Management (INM) takes into consideration the nutrient cycle involving soils, crops and live stock, nutrient deficiencies, organic recycling, conjunctive use of organic manures and mineral fertilizers and biological nitrogen fixing potential. The primary goal of integrated nutrient management is to combine old and new methods of nutrient management into ecologically sound and economically viable farming systems that utilize available organic and inorganic sources of nutrients in a judicious and efficient way. Integrated nutrient management optimizes all aspects of nutrient cycling. It attempts to achieve tight nutrient cycling with synchrony between nutrient demand by the crop and nutrient release in the soil, while minimizing losses through leaching, runoff, volatilization and immobilization.

The term Integrated Plant Nutrient Supply System (IPNS) is also synonymously used for integrated nutrient management. The basic concept underlying IPNS is the maintenance or adjustment of soil fertility/productivity and of optimum plant nutrient supply for sustaining the desired level of crop productivity through optimization of the benefits from all possible sources of plant nutrients including locally available ones in an integrated manner while ensuring environmental quality. In practical term, a system of crop nutrition in which plant nutrient needs are met through a pre-planned integrated use of mineral fertilizers; organic manures/fertilizers (e.g. green manures, recyclable wastes, crop residues, FYM etc); and bio-fertilizers. The appropriate combination of different sources of nutrients varies according to the system of land use and ecological, social and economic conditions at the local level.

CHEMICAL FERTILIZERS

The progress made in the food grain production in India after independence may be broadly divided in to two distinct parts i.e. pre-green revolution and post-green revolution era. In pre-green revolution era, food grain production increased from 52 million tones (mt) in 1951-52 to 72.3 mt in 1965-66 (Table 1) mainly due to increase in area under cultivation (97.3 to 114.1 million hectare (mha) i.e. 17.3% increase), increase in irrigation potential (18 to 24 mha i.e.33% increase) and increased fertilizer use (0.07 to 0.78 mt i.e. 11 fold increase).Only Ammonium Sulphate and Single Super Phosphate fertilizers were manufactured in India in 1950s but later on started the production of Urea, Calcium Ammonium Nitrate and Ammonium Phosphate in 1959 to 1961. The total production of Nitrogenous and Phosphate fertilizers was only 0.36 mt in 1965-66. Considerable efforts were made to popularize the fertilizers use during this era but tall and less fertilizer responsive varieties wheat were the major constraints. They could take only 30- 40 Kg N and at higher doses they lodged. Single crop in a year and regular application of Farm Yard Manures (FYM) by majority of farmers at that time further added to less response of applied doses of N, P and K fertilizers during this period. Nevertheless, the agronomic efficiency of the applied nutrients was worked out to be 28.6 kg grain per kg of plant nutrient applied (Prasad 2000). Import of short statured (dwarf), fertilizer responsive wheat varieties from Mexico led to green revolution era set in. New agronomic package of practices for these varieties was developed in which one of the major recommendations was application of higher doses of balanced NPK fertilizers. It has been observed that increase in food grain production in India due to fertilizers has been 50-60%. Thus in realization of full potential of high yielding varieties of wheat fertilizers have played a key role.

Table 1 Food grain production, Irrigated area, HYV area and Fertilizer consumption of India

Particulars	Pre-green revolution		Post-green revolution					
	1951-52	1965-66	1970-71	1980-81	1990-91	2000-01	2006-07	2010-11*
Food grain production (mt)	52.0	72.3	108.4	129.6	176.4	196.8	211.8	240.0
Area under food grain (mha)	97.3	114.1	124.3	126.7	127.8	121.1	124.7	124.0
Irrigated area (mha)	18.3	24.0	30.1	37.6	44.5	51.6	52.1	52.1
HYV area (mha)	-	-	15.4	43.1	60.0	80.7	90.1	95.0
Fertilizer consumption (mt) $N+P_2O_5+K_2O$	0.07	0.78	2.3	5.7	12.5	18.0	21.0	25.0

(Source: Anonymous, 2006) *Expected

It is evident from Table 2 that five Northern states were in the same rank in the productivity of wheat and rice as well as fertilizer consumption. These data bring out clearly the importance of fertilizers in food grain production. It has been estimated that in India, the total food grain demand by 2010 will be around 240 mt for which the fertilizers requirement will be around 25 mt per annum. Imbalance use of N, P and K fertilizers is also posing great threat to soil fertility in India. The ratio of N, P and K fertilizers consumption is 5:2:1 in India on average basis but it is too wide in Northern states i.e. 16:5:1.

Table 2 Fertilizer consumption and productivity of wheat in Northern states (2005-06)

State	Fertilizer consumption		Wheat Productivity	
	(Kg/ha)	Rank	(t/ha)	Rank
Punjab	210.1	1	4.2	1
Haryana	166.7	2	3.9	2
U. P.	140.4	3	2.6	3
J & K	81.3	4	1.8	5
H. P.	48.8	5	1.9	4

(Source: Anonymous, 2006)

The other major problem associated with chemical fertilizers is their use efficiency which is quite low in Nitrogenous, Phosphatic and micronutrients. Only less than one third of applied nutrients are taken up by the crops and rest are either lost in the environment or fixed in the soil.

ORGANIC MANURES

The annual potential of organic sources in the country generated through human beings, animals and crop residues is about 17 mt of N, P_2O_5 and K_2O. The major share is of animal dung which has a potential of 7 mt of N, P_2O_5 and K_2O. This dung is used to make organic manures like FYM, vermi-compost, etc. These organic sources constitute an important component of INM system (Singh 2005). Studies conducted on farmers fields under All India Coordinated Agronomic Research Project have shown that residual effect of 12 t FYM/ha applied in rice and 60kg N/ha in wheat produced higher grain yield of wheat as compared to the treatment where no FYM was applied to rice and 60kgN to wheat (Table 3). Experiments carried out at Ludhiana showed that application of 12 t FYM/ha in combination with 80 kg N /ha produced same rice yield as with 120 kg N /ha. In the following wheat crop a significant residual effect equivalent to 30 kg N and 30 kg P_2O /ha was obtained due to FYM application in rice at Kaul, Haryana. Rice responded significantly up to 120 Kg N /ha on FYM applied plots as compared to 180 Kg N /ha on without FYM amended plots.

Table 3 Residual effect of organic manure on wheat yields (t/ha)

Fertilizer treatment		Bhagalpur, alluvial soils (mean of 87 trials)	Manipur, red and yellow soils (mean of 96 trials)	Ludhiana, loamy sand alluvial soil (mean of 5 trials)
Rice	wheat			
*F_0N_0	F_0N_0	1.57	0.57	1.3
F_0N_{120}	F_0N_{60}	2.75	1.04	2.8
*$F_{12}N_{60}$	F_0N_{60}	2.95	1.33	3.9

(Source: Singh, 2005) *F_0- No FYM, *F_{12}- 12tons FYM/ha

In several studies it has been found that combined application of organic manures and chemical fertilizers generally produced higher crop yields than when each was applied alone. This increase in crop productivity may be due to many components present in the organic manures and their effects on soil physical and biological properties and partly to synergism.

GREEN MANURES

Green manures (GM) constitute a valuable potential source of N & organic matter. *Sesbania aculeata* is a versatile flood tolerant green manure and highly adapted to varying soil and climatic conditions. *Crotalaria juncea* and *Tephrosia purpurea* are important drought tolerant legumes. The amount of N accumulated in 45-60 days old GM crops can reach up to more than 200 kg /ha; generally it is around 100 kg /ha which corresponds to the average amount of mineral fertilizer N applied to most of agricultural crops in Asia. Green manuring is better suited to rice based cropping systems. Integrated use of green manure and chemical fertilizers can save 25-35 % of N fertilizers in wheat. Green manuring also increase the availability of several other plant nutrients through its favourable effects on chemical, physical and biological properties of soil (Singh 2005).

BIOFERTILIZERS

Azotobactor and, *Azospirillum* are important bio fertilizers for wheat. They can save 10-20 kg N /ha in wheat. Several studies from various locations have found that *Azospirillum* in wheat can give 5 - 33.9 % increase in grain yield over control (Table 4). *Azotobactor* application in wheat and rice has been reported to increase grain yield from 2 - 23 % over uninoculated control. Phosphate Solubilizing Bacteria (PSB) has also been reported to increase the grain yield wheat significantly when applied with rock Phosphate @ 100 Kg P_2O_5 /ha (Subba Roa 1988).

Table 4 Effect of *Azospirillum* on wheat

Location	Initial N level(kg /ha)	Grain yield (q /ha)		% increase over corresponding control
		Un-Inocultd.	Inoculated	
Delhi	0	27.63	29.21	5.7
	40	39.19	41.90	6.9
Karnal	0	17.24	17.93	4.0
	40	29.30	31.33	6.0
	80	35.25	35.94	2.0
Hisar	0	37.78	38.96	3.1
	40	45.39	45.76	0. 8
	80	49.38	57.53	16.5
	120	49.47	62.88	27.1
Hyderabad	0	14.40	12.23	0.0
	40	14.95	16.30	9.0
	80	18.12	19.66	8.5
Solan	0	30.34	37.14	22.4
	40	33.56	35.70	6.6
Shilong	0	13.79	14.59	5.0
	30	16.5	22.20	33.9
	60	17.53	19.00	8.4

(Source: Subba Roa, 1988)

CROP RESIDUES

The residues of rice, wheat, sorghum, maize, gram, arhar, mung bean, groundnut, rapeseed and mustard, sugarcane trash, potato, soybean, cotton, jute and coconut contribute substantially towards the total amount of about 400 mt of crop residues available in the country. It has been estimated that only one-third of the residues potential is available for utilization in agricultural production and of the nutrients taken up by the cereal crops about 25% of N and P, 50% of S and 75% of K is retained in the residues making them valuable nutrient sources. A sizable quantity of crop residues is left in the field in the areas where mechanical harvesting is done. The residues of rice and wheat are burnt in situ causing loss of nutrients and organic matter. The burning of residues results in complete loss of nutrients like C, N and S and partial loss of P, K and Mo to the atmosphere. In Punjab alone, about 81% of rice and about 48% of wheat residues (17 mt) are being burnt annually causing a loss of about 0.351 mt nutrients costing about 233 crores (Sidhu et al., 2003). The major disadvantage with incorporation of cereal straw having wider C:N ratio, is the immobilization of inorganic N and crop growth may be adversely affected due to deficiency of N. Residue characteristics, soil type and management practices affect the decomposition of applied crop residues in soil. Under optimum temperature and moisture conditions, the period of immobilization can last as long as 4 to 6 weeks (Singh, 2005). Kharub *et al.* (2004) from Karnal reported that there was no significant adverse effect of rice residues incorporation before wheat on the productivity of wheat in a five year study (Table 5).

Table 5 Wheat productivity as affected by rice residue management practices (mean of 5years)

Residue management option	Wheat yield (t/ha)
Straw removal	5.15
Straw removal + GM	5.29
Burning	5.37
Straw incorporation	5.19
Straw incorporation + GM	5.28

Leguminous green manures with narrow C:N ratio can be advantageously utilized for lowering down the ratio of cereal residues. In a long term experiment, Meelu et al. (1994) reported that incorporation of sesbania green manure along with wheat or rice straw not only counteracted the adverse effect of the residues of rice but also improved the organic matter content and physical properties of soil. Low temperature and short interval between harvesting of rice and sowing of wheat make the recycling of rice straw in wheat more difficult than that of wheat straw in rice. At Palampur, lower yields of wheat were obtained from incorporation of rice straw at 30 days before sowing of wheat during first three years of study and in later years, straw incorporation gave no adverse effect on grain yield of wheat. At Ludhiana, allowing 40 days interval for decomposition of rice straw before sowing of wheat showed no adverse effect on wheat with recommended N level (Singh, 2005).

OTHER NON-CONVENTIONAL SOURCES

Other non-conventional sources include agro-industrial waste products such as pressmud, oil cakes, distillery waste water, paper mill sludge, dairy waste water and coir waste. Among these sources pressmud is very important and it is a potential source of organic manure produced by sugarcane industries. It contains 1-2.5 % N, 0.25-0.6 % P and 0.40-0.85 % K on dry weight basis. Pressmud obtained from sulphitation is acidic in nature and can be applied on alkaline soils, whereas pressmud obtained from carbonation process contains lime which is useful for acidic soils. In a long term experiment in Ludhiana, application of 200 kg N /ha through pressmud in wheat substituted for 50 kg N/ha during the first three years and up to 100 kg N / ha in the later years of the study. Pressmud application also showed significant residual effect on the succeeding crops and physical properties of soil (Singh 2005).

Table 6 Influence of pressmud application on yield of wheat and soil pH

Pressmud dose (t /ha)	Yield (t /ha)	Soil pH after harvest of crop
0	1.35	4.3
1	1.53	5.4
2	2.24	6.1
4	2.18	6.2
5	2.07	6.2
6	2.13	6.3
8	2.18	6.5
10	2.36	6.8
CD (0.05)	0.53	-

(Source: Gupta *et al.* 2003)

CONCLUSION

Although organics are essential components of any viable nutrients management strategy yet bulk of the nutrients supplies will have to come from the chemical fertilizers in the irrigated agriculture for high crop productivity because of high pressure on the agricultural land. However, on thirsty and hungry soils of the dry area lands, organics including crop residues and FYM shall have to play a major role because of their beneficial effects in terms of improving soil structure, conserving soil moisture through enhanced aggregation, mulching and moderating the extremities in soil temperature. Bio chemical processes of mineralization, mobilization and transformation and transport of nutrients are the added advantages associated with them and hence, judicious and combined use of these natural and renewable resources may reduce the dependency on chemical fertilizers on one hand and help in solving the environmental pollution problem on the other hand.

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