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Integrated nutrient management strategies for enhancing Soil quality and Crop productivity

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Abstract

Improving and maintaining soil quality for enhancing and sustaining agricultural productivity is of utmost importance for India's food and nutritional security. Though India is a food surplus nation, at present with about 240 Mt food grain production per annum, it will require about 7-9 Mt additional food grains each year if the trend in rising population persists. This challenge can be met by greater and more efficient use of fertilizer and organic sources. Many factors influence the complex soil chemical, physical and biological processes which govern soil fertility and productivity. Changes in soil fertility caused by imbalanced fertilizer use may take several years to appear. These properties in turn can be influenced by external factors such as global climate change and land use management practices. In this connection, to study the effect of continuous application of plant nutrients in organic, inorganic and integrated nutrient management on crop yield a Permanent Manurial Experiment (PME) in rice based cropping systems has been conducted from 2010 onwards with four treatments *viz.,* control, organics, inorganic fertilization and Integrated Nutrient Management (INM). The results revealed that among the four treatments, INM practices recorded the higher grain yield (5600 kg/ha) followed by inorganic (4700 kg/ha) and organic treatment (3750 kg/ha). Control recorded the lesser grain yield (3200 kg/ha). Over the years due to adoption of soil fertility management practices involving exclusively inorganic fertilizers distortedly, it has become hazardous in the long run depleting the soil fertility, distorting the soil health and declining the quality of the agricultural produces. Total organic farming would not be feasible, viable and profitable under high productive intensive agriculture. Therefore, adoption of integrated plant nutrient supply and management strategies for enhancing soil quality, input use efficiency and crop productivity is extremely important for food and nutritional security in Indian agriculture.

Keywords: crop productivity, food and nutritional security, integrated nutrient management, permanent manurial experiment, soil quality

INTRODUCTION

Improving and maintaining soil quality for enhancing and sustaining agricultural production is of utmost importance for India's food and nutritional security. Though India is a food surplus nation at present with about 240 Mt food grain production per annum, it will require about 7-9 Mt additional food grains each year if the trend in rising population persists. This challenge can be met by greater and efficient use of fertilizers and organic sources (Anand Swarup, 2010). With globalization, Indian agriculture is passing through a critical phase. It is confounded with increasing crop production, sustainability and long-term environmental quality issues. These challenges can be sought out by the long-term experiments which are valuable repositories of information regarding the sustainability of intensive agriculture.

For food security and growth of large rural sector in India, achieving 4% growth in agriculture is essential for food security and incursive growth of large rural sector in India. With shrinking land resource, the desired growth is to come from intensification of agriculture and increase in land productivity. The fertilizers have played a stellar's role in increasing food grain production, contributing about 50% in post-green revolution period and should continue to do so in future as well (Singh, 2010).

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SOIL is known as the "Soul Of Infinite Life", continued maintenance of good soil health is vital to agricultural production. The soil health is continuously deteriorating due to imbalanced fertilizer use coupled with low use of organic manures (Singh, 2010). The wide scale adoption of rice-rice system which is the dominant system followed in the Cauvery Delta Zone of Tamil Nadu, South India has ushered in an increase in agricultural production, but this intensive system over a period of time has set declining in crop productivity as well as deterioration in soil productivity even with optimum use of fertilizers. Many factors influence the complex chemical, physical and biological processes which govern soil fertility and productivity changes in fertility caused by imbalanced fertilizer use, acidification, and alkalinity and declining soil organic matter may take several years to appear. These properties in turn can be influenced by external factors such as global climate change or land use management practices.

In spite increase in fertilizer consumption and low response, the soil health is continuously deteriorating due to imbalanced fertilizer use coupled with low use of organic manures. The soils are not being adequately replenished even for the macronutrients, let alone the secondary and micronutrients. The improper nutrient management has, therefore, led to emergence of multi-nutrient deficiencies. This requires an all round improvement in each component of crop management. Gap between nutrients required by the crops and amounts expected to be made available from soil nutrient supplies has to be bridged through external nutrient application. This can be done through a number of organic, microbial and mineral sources, in an integrated manner.

Importance of Long-term experiments

Long term experiments provide the best possible means of studying changes in soil properties, nutrient dynamics and processes and identifying emerging trends in nutrient imbalances and deficiencies and to formulate the future strategies for maintaining soil health. and growing notion that "certain soil processes are long term in nature and must be studied as such". and growing importance of long-term experiments for addressing current and future agricultural and environmental issues Dawe et al. (2000), Powlson et al. (1998), Swarup (2001) made extensive efforts to review and document available data on

- Yield trend analysis, soil properties and key sustainable indicators such as organic carbon and pH under long-term experiments which cannot be measured from short-term studies

- Identified regional fertility constraints and opportunities to increase agricultural productivity through integrated plant nutrient supply.

These experiments have provided very valuable data relevant for farmers, scientists and policy makers. The results of the experiments at different locations have clearly brought out that

- Yield decline with imbalanced fertilization continued for longer periods. Yield stagnated or declined when input levels were kept constant and / or sub-optimal.

- There are evidences of a downward shift in the entire fertilizer response function at all the levels of fertilizer application which means lesser increases due to application of same dose of plant nutrients. In other words, there is a need for application of heavier doses of fertilizer to obtain the same yields.

- Application of FYM over and above 100% of the recommended NPK invariable sustained high productivity over the years.

- Continuous cropping without adequate inputs decreased indigenous soil N, P and K supply.

- In case of acid soil, application of N-alone aggravates the problem of acidity. Application of lime helped in correcting acidity, but for attaining high yield potential liming has to be accompanied with optimal doze of NPK. Similarly, application of gypsum based on gypsum requirement of soil was extremely important in attaining high yields and maximizing nutrient use efficiency in alkali soils and improving organic carbon status of the soil.

Soil organic carbon and Sustainable Agriculture

India has a long tradition of using organic manures to maintain and improve soil fertility. The rapidly increasing population, shrinking suitable land resources for crop production and increasing concern for declining soil fertility and environmental degradation create an urgency for enhancing and sustaining productivity of land in India. Judicious management of renewable native soil and water resources and accelerated use of inputs like chemical fertilizers and organic and biological resources can meet this challenge. Land clearing or deforestation and cultivation induce a lower equilibrium level of SOC because removal of the harvested material is much faster than incorporation of crop residues into soil. Raising the crop productivity also results in improving the organic carbon content of the soil through greater contribution of root biomass. Continuous cultivation also brings the C / N ratio of the soil in equilibrium with the environment. Dynamic strategies therefore need to be developed for maintaining and enhancing productivity and sustainability in agriculture.

Environmental Consequences of fertilizer use

Fertilizer N, P and K after their application in soil undergo transformation in physical, chemical and biological processes. For example, dynamics of N in the soil-plant atmosphere system includes various soil processes (mineralization, immobilization, urea hydrolysis, nitrification, volatilization, denitrification and N movement in soil), the processes pertaining to above ground plant growth, and nitrogen uptake by crops soil type are most important factors in affecting fertilizer use efficiency and soil productivity.

Phosphorus after its application in soil is either removed by crop or gets immobilized into various insoluble forms (Fe and Al-phosphate and Ca-phosphate in alkaline soils) and gets fixed in soil clays or organic matter. The use efficiency of P does not exceed 20%. Significant amount of P is lost from the soil through surface run off and erosion resulting in eutrophication of water bodies.

Potassium is the most abundant plant nutrient in soil having illitic type of clay mineral. It is more mobile than phosphate and is susceptible to loss by leaching, run off and erosion. The K efficiency is about 70%. Loss of K is a waste but carries no environmental concern.

The major environmental consequences related to fertilizer use (Swarup, 2006) are

- Nitrate pollution of ground water
- Eutrophication
- Ammonia volatilization
- Acid rain
- Green house effect
- Damage to crops and soil organisms and
- Trace element and heavy metal contamination

In this connection, to study the effect of continuous application of plant nutrients in organic, inorganic and integrated nutrient management on crop yield a Permanent Manurial Experiment (PME) in rice based cropping systems has been conducted from 2010 onwards with the following objectives.

Table 1. Initial soil characteristics of the experimental site

BD (Mg m-3)	: 1.34
PD (Mg m-3)	: 2.65
Pore space (%)	: 49.0
pH	: 6.2
EC (d Sm^{-1})	: 0.18
CEC (cmol (p+) kg^{-1})	: 10
OC (%)	: 0.4
Available N (kg ha^{-1})	: 160
Available P (kg ha^{-1})	: 35
Available K (kg ha^{-1})	: 120

Objectives

- To monitor the changes in soil properties as a result of continuous manuring and cropping.
- To study the effect of continuous application of plant nutrients in organic, inorganic and integrated nutrient management on crop yield.

Materials and methods

Permanent Manurial Experiment (PME) was initiated from 2010 onwards at Soil and Water Management Research Institute, Kattuthottam, Thanjavur, South India. The farm is situated in the Cauvery Delta agro-climatic Zone of Tamil Nadu and lies between 79° 12' N latitude and 10° 47′ E longitude at an altitude of 111 m above the mean sea level. The experiment was conducted during both *kuruvai* and *thaladi* seasons. The rice variety ADT 43 and ADT 38 were selected during *kuruvai* and *thaladi* season respectively. The soil is *sandy clay loam* in texture and belongs to *Typic Ustropept* and *Madukkur soil series*. The initial characteristics of the experimental soil are depicted in Table 1.

Treatment Details

The experiment was conducted in a non – replicated design with four treatments in a plot size of 7.5 cents per plot. The details of treatments are as follows

T_1 : Control (without any fertilizer)

T_2 : Organic manuring (Only organics)

T_3 : Inorganic fertilization (Only Inorgancis)

Table 2. Details of analytical methods employed in the soil analysis

S. No	Parameters	Methods	References
a) Physical properties			
1.	Particle size analysis	International pipette method	Piper (1966)
2.	Bulk density	Core method	Gupta and Dakshinamoorthy (1981)
3.	Particle density	Core method	Gupta and Dakshinamoorthy (1981)
4.	Porosity	Core method	Gupta and Dakshinamoorthy (1981)
b) Physico - chemical properties			
1.	Soil reaction	Soil water suspension (1:2.5)	Jackson (1973)
2.	EC	Soil water suspension (1:2.5)	Jackson (1973)
3.	CEC	Neutral normal ammonium acetate	Schollenberger and Dreibelbis (1930)
c) Chemical properties			
1.	Organic carbon	Chromic acid wet digestion	Walkley and Black (1934)
2.	$KMnO_4$ - N	Alkaline permanganate	Subbiah and Asija (1956)
3.	Olsen - P	0.5 M sodium bicarbonate (pH 8.5)	Olsen *et al*. (1954)
4.	NH_4OAc - K	Neutral normal ammonium acetate	Stanford and English (1949)

Table 3. Soil available nutrient status as influenced by different treatments in permanent manurial experiment

Trt.	Treatment details	Soil available nutrient status			
		Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T1	Control	0.40	168	35	169
T2	Organic manuring	0.45	172	39	173
T3	Inorganic fertilization	0.41	173	41	176
T4	Integrated nutrient management	0.43	174	46	180
	Mean	**0.42**	**172**	**40**	**175**

T_4 : Integrated Nutrient Management (Organics, Inorganics and Biofertilizers)

Farm Yard Manure was applied to the organic manuring plot on N equivalent basis and incorporated well. Green manure and Farm Yard Manure were applied to the INM plot and incorporated well and allowed for decomposition. *Azospirillum* and *Phosphobacteria* were appled @ 60 g plot^{-1} mixed with farm yard manure to organic manuring and INM plots. Fertilizers were applied to the inorganic plot as per the DSSIFER recommendation. Other crop management practices were followed as per the crop production guide.

Observation

- Grain and straw yield of the crop
- Analysis of soil for organic carbon and available N, P and K as per the standard procedure

The details of analytical methods employed in the soil analysis were given in the table 2.

RESULTS AND DISCUSSION

Soil nutrient availability (Table 3)

Soil organic carbon content varied from 0.40 to 0.45%. Among the treatments, T2, organic manuring treatment recorded higher organic carbon content (0.45%), followed by T4, Integrated nutrient management (0.43%), inorganic fertilization (0.41%) and T1, control recorded the lower soil organic carbon content of 0.40%. Significant improvement in organic carbon is attributed by the application of organics which stimulated the growth and activity of microorganisms. In INM treatment, in addition to application of organics the organic carbon further enhanced by NPK fertilization resulting in the improvement in the root and shoot growth. Higher production of biomass might have increased the organic carbon content.

Further the results revealed that, integrated nutrient management treatment recorded the higher soil available NPK content followed by inorganic and organic. Control recorded the lower soil available NPK content. This has corroboration with findings of Mishra and Sharma (1997). Higher available N content in integrated nutrient management is due to addition of mineral N along with organics narrowed the C:N ration which enhanced the rate of mineralization and resulting increased N availability. Incorporation of organics along with phosphatic fertilizer increased the available P content by reduction in the fixation of water soluble P, increased mineralization of organic P due to mineralized action and enhanced mobility of P in integrated nutrient management treatment. Similarly, the available K content of the soil is increased in integrated nutrient management treatment. This might be due to the higher amount of K applied, by reduction of K fixation and release of K due to interaction of organics with clay, besides the direct addition of K to available pool of the soil.

Grain and straw yield (Table 4)

The grain yield of rice varied from 3166 to 5600 kg ha^{-1}. Different nutrient management options had a marked influence on the grain yield of rice. Among the treatments, the highest grain yield was recorded under Integrated Nutrient Management treatment (T4) (5600 kg ha^{-1}) followed by inorganic treatment (T3) (4733 kg ha^{-1}), Organic treatment (T2) (3766 kg ha^{-1}), while the lowest yield was recorded under control (T1) (3166 kg ha^{-1}). Significant increase in rice grain yield due to integrated nutrient management was observed by Sudha and Chandini (2002) also. The increase in grain yield with

Table 4. Grain and straw yield of rice as influenced by different treatments in permanent manurial experiment

Trt.	Treatment details	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T1	Control	3166	4000
T2	Organic manuring	3766	5149
T3	Inorganic fertilization	4733	6085
T4	Integrated nutrient management	5600	8350
	Mean	**4316**	**5746**

integrated nutrient management is mainly due to beneficial effect of combined use of organic manure and fertilizers as nutrient availability increased through enhanced microbial activity, conversion from unavailable to available forms and also due to improved physical, chemical and biological conditions.

The straw yield of rice varied from 4000 to 8350 kg ha^{-1}. Among the four treatments Integrated Nutrient Management treatment (T4) recorded the higher straw yield (8350 kg ha^{-1}) followed by inorganic treatment (T3) (6085 kg ha^{-1}), Organic treatment (T2) (5149 kg ha^{-1}) and control recorded lesser straw yield (4000 kg ha^{-1}).

SUMMARY AND CONCLUSION

The need for more food and other agricultural commodities has to be met through higher yields per unit of land, water, energy and time. As farmers continue to achieve higher and higher yields per unit of land ploughed, it is binding upon them to leave the land more fertile and productive than they inherited it, so that future generations can be fed without problem. Fertilizer use which is one of the most important factors for supporting high yield is inadequate, imbalanced, non-integrated and poorly managed. Therefore, adoption of integrated plant nutrient supply and management strategies for enhancing soil quality, input use efficiency and crop productivity is extremely important for food and nutritional security in Indian agriculture.

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