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Effect of integrated nutrient management on grain yield, straw yield and harvest index of transplanted rice

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Abstract
The field experiments were conducted to evaluate the effect of inorganic fertilizers along with organic manures at the Experimental Farm, Department of Agronomy, Annamalai University, Tamil Nadu. The treatments were tested in Split- plot Design and replicated thrice. It was observed that the grain yield, straw yield and harvest index of rice crop influenced by combined application of inorganic fertilizers and organic manures. The application of 150% of recommended NPK + 75% of recommended dose of Vermicompost @ 3.75 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT recorded higher grain, straw yield and harvest index. This was on par with 125% of recommended NPK + 75% of recommended dose of Vermicompost @ 3.75 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT.

Keywords: grain yield, straw yield, harvest index, INM

Introduction

Rice, one of the predominant member of the graminea family is the world's most important food commodity for more than half of the world population. Globally, it plays a vital role in food as well as nutritional security for several billions of human beings and thus the slogan "Rice is Life" coined by IRRI during 2004 seems to be the most appropriate (Chandrasekaran *et al.*, 2007) [10].

In India, rice cultivated in an area of 44.0 million ha^{-1} with a production of 116.8 million tonnes and the average productivity of 2.93 t ha^{-1}. However, considering the current population growth rate of 1.5 per cent the projected demand for rice for the exploding, population the total rice requirement by 2025 would be around 300 million tonnes (Panda, 2010) [16].

Although sixteen numbers of nutrients constituted of macro, secondary and micronutrients are required for optimal growth and establishment of crop plants, the major nutrient elements *viz.*, nitrogen, phosphorus and potassium are essentially needed for varied metabolic process of crop plants, while nitrogen is the key nutrition synthesis of ATP. It is the prime component of chlorophyll, proteins and enzymes and it also assists the plants in synthesis and utilization of carbohydrates (Mengel and Kirkby, 2001; Sara *et al*., 2013) [14, 18]. Phosphorus being a constituent of nucleotides such as in ADP and ATP energy bonds, it involved in many processes such as mitotic activities, tissue growth and development (Bhattacharyya and Jain, 2000) [5]. The crop plants could not achieve its maximum yield potentials without supply of adequate phosphorus (Alam *et al*., 2009; Murtaza *et al*., 2014) [2, 15]. It also play a crucial role in root proliferation, consistent grain filling and quality.

Similarly, potassium is essential for the maintenance of electrical potential across cellular membranes and cellular turgor, which permits cell expansion and enlargement, opening and closing of stomata and pollen tube development. Further, it is also an activator of many enzymes and it also involved in translocation of nitrate and sucrose (Britto and Kronzucker, 2008) [9].

The farmyard manure (FYM) is the only available bulky organic manure which is being utilized for crop production by the farmers for the past several decades. It is a mixture of cattle dung, urine, litter or bedding material, portion of fodder not consumed by cattle and domestic wastes. Application of farmyard manure improves the soil fertility (Gora *et al*., 2017) [11]. Its incorporation, significantly improves soil physico-chemical characteristics, prevents soil erosion improves soil organic carbon content, enhances microbial activity, neutralizers soil pH, minimizes the electrical conductivity and furthermore the decomposed FYM, act as an 'chelate', which would retains the nutrient elements within its biomass and release them as and when the crop require. However, is becoming scarcely available, due to drastically dwindling cattle population. However, its timely inavailability escarted cost factor, the cumbersome and the extended time involvement for its transportation limits its usage.

Vermicompost is the decomposed product of organic solid wastes by earthworms gut and egested as casts (Janagan *et al.*, 2003) [13]. It contains most of the macro and micronutrients that too in easily available forms facilitating enhanced crop uptake growth and productivity as well as maintaining up of soil health (Marinari *et al.*, 2008).

Pressmud is an one of the most valuable organic by-product obtaining from the sugar industry, before crystallization of sugar from sugar juice (Agarwal *et al.*, 2014).

Biofertilizers are eco-friendly, cost effective organic agro inputs which are essential nutritional supplement for crop plants in conjunction with wide range of beneficial enzymes and growth hormone (Bloemberg *et al.*, 2000; Amudha *et al*., 2014) [3].

From ancient times, seaweeds is also considered to be source of food, fodder, medicine and an nutrients supplementing bio-inoculant. The commercial product of seaweed liquid fertilizer (SLF) is available which would enhance the productivity of crop plants as an supplemental nutrition supply (Bokil *et al.*, 1974 and Bai *et al.*, 2007) [8, 4].

Materials and Methods

The field experiment was conducted to study the effect of INM on rice at Experimental Farm, Department of Agronomy, Annamalai University with rice var. CO-51. The research comprised of

A. Main: Plot (NPK doses)

M_1: 100% of recommended NPK
M_2: 125% of recommended NPK
M_3: 150% of recommended NPK

B. Sub: Plot (Organic inputs levels)

S_1: 100% of recommended dose of FYM @ 12.5 t ha^{-1}

S_2: 75% of recommended dose of FYM @ 9.5 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT.

S_3: 50% of recommended dose of FYM @ 6.25 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT.

S_4: 75% of recommended dose of Vermicompost @ 3.75 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT.

S_5: 50% of recommended dose of Vermicompost @ 2.50 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT.

S_6: 75% of recommended dose of fortified pressmud @ 3.75 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT.

S_7: 50% of recommended dose of fortified pressmud @ 2.5 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT.

Results and Discussion

Grain yield (Table 1)

Grain yield of rice was significantly influenced by the integrated application of nutrients through inorganic fertilizers and organic manures in the experiment.

Among the different levels of inorganic fertilizers, application of 150% of recommended NPK (M_3) recorded highest grain yield of 6688 kg ha^{-1} in experiment. Application of 100% of recommended NPK (M_1) registered lower grain yield of 5958 kg ha^{-1} in experiment.

The effects between the inorganic fertilizer levels and organic manure sources, application of 75% of recommended dose of Vermicompost @ 3.75 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (S_4) appear its dominance by producing the highest grain yield of 6901 kg ha^{-1} in experiment. This was statistically on par with the application 75% of recommended dose of FYM @ 9.5 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (S_2). The lowest grain yield of 6617 kg ha^{-1} in experiment was recorded with the application of 50% of recommended dose of fortified pressmud @ 2.5 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (S_7).

Similarly, application of 150% of recommended NPK + 75% of recommended dose of Vermicompost @ 3.75 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (M_3S_4) excelled all other treatments and registered the highest grain yield of 7252 kg ha^{-1} in experiment, respectively. The lowest grain yield of 5578 kg ha^{-1} in experiment was recorded in the combined application of 100% of recommended NPK + 50% of recommended dose of fortified pressmud @ 2.5 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (M_1S_7).

Straw yield (Table 2)

Integrated nutrient management practices exerted marked influenced on straw yield of rice at harvest stage.

Among the different levels of inorganic fertilizers, application of 150% NPK (M_3) recorded highest straw yield of 7807 in experiment at harvesting stage. Application of 100% of recommended NPK (M_1) registered lowest straw yield of 7400 kg ha^{-1} experiment at harvesting stage.

Significant impact on straw yield of growth were documented with the application of different levels of manures and other organic inputs in both the years of experimentation. Application of 75% of recommended dose of vermicompost @ 3.75 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (S_4) significantly registered highest straw yield of 7678 kg ha^{-1} experiment at harvest stage. The lowest straw yield of 7565 kg ha^{-1} was resulted with application of 50% of recommended dose of fortified pressmud @ 2.5 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (S_7) in experiment at harvest stage.

Similarly, application of 150% of recommended NPK + 75% of recommended dose of Vermicompost @ 3.75 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (M_3S_4) excelled all other treatments and registered the highest grain yield of 7896 kg ha^{-1} in experiment. The lowest grain yield of 7385 kg ha^{-1} in experiment were recorded in the combined application of 100% of recommended NPK + 50% of recommended dose of fortified pressmud @ 2.5 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (M_1S_7).

Harvest index (Table 3)

Integrated nutrient management practices exerted marked influenced on harvest index of rice at harvest stage.

Among the different levels of inorganic fertilizers, application of 150% of recommended NPK (M_3) recorded highest harvest index of 46.1 in experiment at harvesting stage, respectively. Application of 100% of recommended NPK (M_1) registered lowest harvest index of in 44.5 experiment at harvesting stage.

Similarly, application of 150% of recommended NPK + 75% of recommended dose of Vermicompost @ 3.75 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (M_3S_4) excelled all other treatments and registered the highest harvest index of 47.3 in experiment. The lowest harvest index of 46.2 in experiment were recorded in the combined application of 100% of recommended NPK + 50% of recommended dose of fortified pressmud @ 2.5 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (M_1S_7).

Among the main plot treatments, application of 150% of recommended NPK (M_3) showed a significant influence on grain and straw yield. This might be due to application of 150% of recommended NPK in the crop and it has enhanced crop grain and straw yield production. This result is in conformity with the reports of (Sarker *et al*. 2008).

With respect to subplot treatments, a positive response of growth parameters was noticed to different organic manures combination of nutrients, irrespective of the different combination of nutrients. The response was observed upto 75% of recommended dose of Vermicompost @ 3.75 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (S_4) has significantly increased grain and straw yield.

The increased in grain and straw yield of rice with combined application of inorganic, organic and biofertilizers sources of plant nutrient was attributed to significant improvement in growth and yield characters. The efficient supply of nutrient delayed the senescence and increased the life cycle of the plant, which resulted in higher economic yield. Judicious use of organic and inorganic fertilizer enabled the rice plant to assimilate sufficient photosynthates resulting in increased dry matter production and these together produced more productive tillers, panicle and number of filled grains leading to higher grain yield, these results in accordance with (Hossaen *et al*., 2011) [12].

Among the various treatment combinations, 100% of recommended NPK + 75% of recommended dose of Vermicompost @ 3.75 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (M_3S_4). Which efficiently increased the grain yield when compared to other treatment combinations. The above treatment also recorded higher straw yield due to higher LAI and DMP. These results are in conformity with the findings of Singh *et al*. (2005) [21].

Within in the plant treatments, application of 150% of recommended NPK (M_3) showed a significant ascendancy on harvest index. It is due to the application of 150% of recommended NPK in the crop plant and it enhanced into the crop yield attributes. This results are ascertained with the (Rao *et al.*, 2020).

With respect to sub plot treatments incorporation of 75% of recommended dose of vermicompost @ 3.75 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (S_4) significantly registered higher harvest index of 47.3%. The lowest harvest index of 43.9% experiment at harvest stage was resulted with the incorporation of 50% of recommended dose of fortified pressmud @ 2.5 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (S_7) treatment (Biramo, 2018) [6].

The increased in harvest index percentage depends on the developmental stages of the crop (grain and straw yield). Application of integrated nutrient management in a efficient amount leads towards the higher yield and it proportionally increased harvest index percentage with reflect on economics as well. These reuslts are in conformity with the findings of Singh *et al.* (2018).

Among the various treatment combinations, 150% of recommended NPK + 75% of recommended dose of Vermicompost @ 3.75 t ha^{-1} + Azophos @ 10 kg ha^{-1} + *in situ* application of Azolla @ 10 kg ha^{-1} on 10 DAT + foliar application of seaweed extract @ 2.0% on 15 and 30 DAT (M_3S_4). Which efficiently increased the harvest index percentage when compared to other treatment combinations. The above treatment also recorded higher harvest index percentage due to higher grain and straw yield. These results are in conformity with the findings of Tomar *et al*. (2015).

Table 1: Effect of NPK doses and the levels of manures and other inputs on grain yield (kg ha^{-1})

Treatments	Grain yield (kg ha^{-1})			
	M_1	M_2	M_3	Mean
S_1	6053	6564	6788	6468
S_2	6242	6655	6956	6617
S_3	5555	6057	6427	6013
S_4	6556	6895	7252	6901
S_5	5765	6292	6477	6178
S_6	5962	6459	6690	6370
S_7	5578	6034	6226	5946
Mean	5958	6422	6688	–
	SEd		CD (P=0.05)	
M	287.4		604.7	
S	251.1		527.3	
M × S	214.8		452.0	
S at M	215.6		453.8	

Table 2: Effect of NPK doses and the levels of manures and other organic inputs on straw yield (kg ha^{-1})

Treatments	Straw yield (kg ha^{-1})			
	M_1	M_2	M_3	Mean
S_1	7402	7406	7920	7576
S_2	7420	7653	7987	7686
S_3	7204	7370	7615	7396
S_4	7530	7609	7896	7678
S_5	7466	7501	7808	7591
S_6	7398	7608	7604	7536
S_7	7385	7489	7823	7565
Mean	7400	7519	7807	–
	SEd		CD (P=0.05)	
M	95.6		201.3	
S	70.7		148.7	
M × S	86.6		182.2	
S at M	86.9		183.0	

Table 3: Effect of NPK doses and the levels of manures and other organic inputs on harvest index (%)

Treatments	Harvest index (%)			
	M_1	M_2	M_3	Mean
S_1	44.9	46.9	46.2	45.9
S_2	45.6	46.5	46.6	46.2
S_3	43.5	45.1	45.7	44.7
S_4	46.5	47.5	47.9	47.3
S_5	43.2	45.6	45.3	44.8
S_6	44.7	45.9	46.8	45.8
S_7	43.1	44.6	44.3	43.9
Mean	44.5	46.0	46.1	–
	SEd		CD (P=0.05)	
M	0.59		1.24	
S	0.69		1.45	
M × S	0.87		1.85	
S at M	0.88		1.87	

Conclusion
On the basis of experiment finding the conclusions that INM proved its superiority in increasing the grain yield, straw yield and harvest index percentage under sustainable crop productivity.

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