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Effect of Integrated Nutrient Management on Growth, Physiological, Nutrient Uptake, Root and Yield Parameters of Transplanted Lowland Rice

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Rice is an important cultivated food crop which feeds more than half of the world's population. Even though the area under rice cultivation is large, the productivity is low due to various interaction factors. The imbalance in usage of fertilizers is one of the main factors responsible for the low productivity and also the continuous use of inorganic fertilizers resulted in declining of soil fertility. An integrated nutrient management practices may be necessary to maintain the sustainability in crop production. Field experiment was conducted at wetland farm of Tamil Nadu Agricultural University, Coimbatore during kharif season to study the effect of integrated nutrient management practices on growth, physiological, nutrient uptake, root characters and yield parameters of transplanted lowland rice. The experiment was laid out in randomized block design with three replications and nine treatments. Rice CO(R) 48 was used as a test variety. Dhaincha, vermicompost, farmyard manure were incorporated before transplanting of rice as per treatment schedule. The results revealed growth parameters (Plant height and number of tillers hill^{-1}), physiological parameters (leaf area index and crop growth rate), nutrient uptake (N, P and K uptake), root characters (root length, root volume and root dry weight) and yield parameters (Number of productive tillers m^{-2} and Dry Matter Production) were significantly influenced with

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application of 100 % NPK through inorganic fertilizers + 6.25 t dhaincha which was comparable with 100 per cent NPK through inorganic fertilizers + 5 t vermicompost and 100 per cent NPK through inorganic fertilizers + 12.5t farmyard manure. This was followed by 100 per cent N through dhaincha + balance P & K through inorganic fertilizers.

Keywords: Rice; growth; physiological; nutrient uptake; root and yield.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is an important and extensively cultivated food crop and feeds more than half of the world's population. In Asia alone, more than two billion people obtain 60 to 70 per cent of their energy intake from rice and its derivatives. India has the largest rice area among rice growing countries and it stands second in production next to China. In the World, rice production was 476 million tonnes, while India produces 105 million tonnes of rice over an area of 44 million hectares. In Tamil Nadu, rice occupies an area of 18.49 lakh hectares with an annual production of 57.26 lakh tonnes and productivity of 3094 kg ha^{-1} [1]. The slogan “Rice is life” is most appropriate for India; as this crop plays a vital role in our national food security and is a means of livelihood for millions of rural households. Even though the area under rice cultivation is large, the productivity is low due to various interaction factors. The imbalance in usage of fertilizers is one of the main factors responsible for the low productivity and also the continuous use of inorganic fertilizers resulted in declining of soil fertility [2]. High cost of fertilizer and the low purchasing capacity of the small and marginal peasants of the country, restrict the use of fertilizer inputs [3]. Moreover, Swaminathan [4] opined that the green revolution had gradually turned into a ‘greedy revolution’ as evident in the indiscriminate use of inorganic inputs to attain higher productivity. The increasing demand for rice grain production has to be achieved by using limited available resources in a sustainable manner. In India, about 40 per cent of the total plant nutrients are consumed by rice crop alone. Though the use of fertilizers per unit area of rice is higher, the fertilizer use efficiency is generally low.

To achieve higher and sustainable rice yields, use of organic manures is a must. It is, however, difficult to meet the crop nutrient requirements with bulky organic manure alone and there is a need for integrated application of different sources of nutrients for sustaining the desired crop productivity. Use of organic manure, green manuring, crop residues along with inorganic fertilizers not only reduce the demand for inorganic fertilizers but also increases the efficiency of applied nutrients due to their favourable effect on physical, chemical and biological properties of soil [5]. An integrated nutrient management practices may be necessary to maintain the sustainability in crop production [6].

Green manuring helps to keep soil quality and fertility enhancement as a whole, meeting a part of nutrient need of crops. The pre-season green manuring of *Sesbania aculeata* (Dhaincha) and its in-situ incorporation improves growth and productivity of succeeding cereals, particularly rice. There is ample scope to fit in short duration pulses to a considerable extent in the rice fallows of Tamil Nadu. The beneficial effects of including a pulse crop in rice based cropping system have been well documented [7].

Against the backdrop of diminishing organic and mounting inorganic nutrient source use, the concept and practice of organic farming has assumed center stage in rice farming. Among the organic sources, green manure, farmyard manure and vermicompost a good amount of organic matter and plant nutrients. The effects of integrated use of organic manure and inorganic fertilizers on soil fertility and crop yield were well documented. However, there has been very little research so far on the relative effectiveness of fertilization treatments on root parameters and physiological characteristics of paddy by different agricultural management. The objective of this study was to determine and evaluate the effects of integrated application of inorganic and organic fertilizers on growth, physiological, root characters and nutrient uptake of rice plants under continuously flooded condition. The goal is to supply groundwork and knowledge for establishing appropriate and sustainable paddy nutrient management systems. Possible effect mechanisms were also discussed.

2. MATERIALS AND METHODS

A field experiment was conducted during kharif season at Wetland farm of Tamil Nadu

Agricultural University, Coimbatore. The initial analysis of the soil of the experimental site revealed that the soil was slightly alkaline (pH = 7.85) with low in soluble salts (EC = 0.42dSm^{-1}), medium in organic carbon content (0.58 per cent), low in available N (216 kg ha^{-1}), medium in P_2O_5 (16.2 kg ha^{-1}) and high in K_2O (426 kg ha^{-1}). The irrigation water was found to be neutral in reaction (pH = 7.6) with medium level of the soluble salts (EC = 1.18 dSm^{-1}).

The maximum and minimum temperature ranged from 29.0 to 32.7°C and 19.2 to 23.7°C, respectively. With regard to relative humidity, there was a fluctuation from 77.5 to 94 per cent (07 22 hours) and from 49.6 to 77.3 per cent (14 22 hours). There was a total rainfall of 110 mm was received in 16 rainy days. The evaporation and bright sunshine hour's day^{-1} ranged from 2.8 to 6.6 mm and 3.1 to 7.4 hours, respectively

The study was conducted with nine treatments which are T_1 –100% N through dhaincha + balance P & K through inorganic fertilizers, T_2 – 50% N through dhaincha + balance N, P & K through inorganic fertilizers, T_3 –100% N through vermicompost + balance P & K through inorganic fertilizers, T_4 –50% N through vermicompost + balance N, P & K through inorganic fertilizers, T_5 –100% NPK (150 : 50: 50 kg ha^{-1}) through inorganic fertilizers, T_6 –100% NPK through inorganic fertilizers + 12.5 t farmyard manure, T_7 – 100% NPK through inorganic fertilizers + 6.25 t dhaincha, T_8 – 100% NPK through inorganic fertilizers + 5 t vermicompost, T_9 – Control. The experiment was laid out in RBD with three replications. The test crop were used is medium duration rice variety CO(R) 48.

2.1 Plant Height

Plant height was measured from one hill of each sample unit ground level to the tip of the longest leaf stretched was measured at harvest stages of rice and expressed as cm using large steel scale (Manual method).

2.2 Number of Tillers

Total number of tillers was counted from all the plants of the sample unit at harvest stages and expressed as tillers hill^{-1}.

2.3 Dry Matter Production

From the sampling area in each plot, five plants were removed randomly at harvest stages. These samples were first air dried in shade and then oven dried at 70°C to constant weight and dry weight was recorded and reported as kg ha^{-1}.

2.4 Leaf Area Index

The maximum length and breadth of the 3rd leaf from the top of five tagged plants were measured at flowering stage and the mean value was multiplied with total number of leaves $^{-1}$. The LAI was worked out using the formula suggested by Upendra Rao et al. [2].

$$LAI = \frac{K\ (L\ x\ W)\ x\ Number\ of\ leaves\ per\ hill}{Land\ area\ occupied\ by\ the\ plant}$$

Where,

K- Constant factor (0.73 for *samba* season rice)
L- Maximum length of the 3rd leaf blade from the top (cm)
W - Maximum width of the leaf blade (cm)

2.5 Crop Growth Rate

The Crop growth rate (CGR) indicates an increase in dry matter per unit land area per unit time. It was calculated by using the formula suggested by Watson [8]. It was estimated at active tillering to panicle initiation, panicle initiation to flowering and flowering to harvest stages and expressed in g m^{-2} day^{-1}.

$$CGR = \frac{W2 - W1}{P\ (t2 - t1)}$$

Where,

W_1 and W_2- Whole plant dry weight at time t_1 and t_2 respectively
P- Ground area occupied by the plant (m^2)
t_1 and t_2- Time interval in days

2.6 Root Length

Root length was estimated at harvest stages. For this, five hills were removed from each plot carefully from sampling area, without much loss of roots as far as possible and root length was measured from the base to the tip of the lengthy root and expressed in cm.

2.7 Root Volume

The roots were separated from the plants and washed with water and the root volume was measured by water displacement method [9]. The root volume hill^{-1} was measured and expressed in cubic centimetre (cc).

2.8 Root Dry Matter

After measuring the root volume, the roots were dried in shade and then oven dried at 70°C, till the attainment of constant weight and expressed in g hill^{-1}.

2.9 Plant Analysis

Green manure sample at the time of incorporation and rice plant samples collected at harvest stage for DMP were chopped and ground into fine powder in a Willey mill and used for chemical analysis. For calculating nutrient uptake at harvest, nutrient content of grain and straw was multiplied with respective dry weights.

$$\text{Nutrient uptake} = \frac{\text{Percentage of nutrient x Total dry matter production (kg /ha)}}{100}$$

2.10 Number of Productive Tillers m^{-2}

The ear beating tillers were counted from all the hills from tagged plants and the mean number of productive tillers m^{-2} was calculated.

3. RESULTS AND DISCUSSION

3.1 Growth Characters

3.1.1 Plant height and leaf area index

The treatments imposed had significant influence on the plant height and leaf area index (LAI) of rice at all growth stages (Table 1).

100 per cent NPK through inorganic fertilizers + 6.25 t ha^{-1} dhaincha application recorded maximum plant height of rice at harvest stages (135.5 cm) and Higher leaf area index (5.93) at flowering stage which was comparable with 100 per cent NPK through inorganic fertilizers + 5 t vermicompost (134.9 cm and 5.90) and 100 per cent NPK through inorganic fertilizers + 12.5 t farmyard manure (134.6 and 5.83).

Among the other treatments, 100 per cent N through dhaincha + balance P & K through inorganic fertilizers recorded more plant height (122.3 cm) at harvest stage and higher leaf area index at flowering stage (5.12). Leaf area index was least in control the value of 3.81 at flowering stages of the crop and significantly shorter plants was noticed in control (99.3 cm). This was due to increased availability of nutrients in adequate amount at different growth stages of rice. Increased LAI might be due to increased availability of nutrients from the soil reservoir and also from the added sources of organic manures. Integrated nutrient management would have increased LAI, due to proper decomposition of organic matter and supply of available plant nutrient directly to plants and created favourable soil environment, ultimately increased the nutrient supplying capacity of soil for longer time, which resulted in better growth of the crop [13].

3.2 Yield Parameters

Significant differences were noticed in respect of total number of tillers hill^{-1}, number of productive tillers and DMP at harvest stage.

Application of 100 per cent NPK through inorganic fertilizers + 6.25 t dhaincha attained its statistical supremacy by recording more number of tillers hill^{-1} (10.8), higher number of productive tillers (288m^{-2}) and DMP (13503 kg ha^{-1}) which was on par with 100 per cent NPK through inorganic fertilizers + 5 t vermicompost and 100 per cent NPK through inorganic fertilizers + 12.5 t FYM.

Chart 1. The methods used for plant analysis are furnished in below table

Particulars	Method	Reference
A. Plant analysis		
Total nitrogen	Micro Kjeldahl's method	[10]
Total phosphorus	Triple acid digestion with Vanado molybdate yellow colour method	[11]
Total potassium	Triple acid digestion with flame photometric method	[12]

Table 1. Effect of organic and inorganic sources of nutrients on growth and yield parameters at harvest stage of rice

Treatments	Plant height (cm)	LAI at flowering stage	Total no. of tillers hill^{-1}	No. of productive tillers m^{-2}	DMP (kg ha^{-1})
T_1	122.3	5.12	9.5	235	12501
T_2	111.8	4.59	8.5	196	11483
T_3	112.1	4.61	8.6	204	11622
T_4	111.4	4.54	8.3	190	11314
T_5	111.1	4.50	8.1	187	11012
T_6	134.6	5.83	10.4	274	13384
T_7	135.5	5.93	10.8	288	13503
T_8	134.9	5.90	10.6	285	13437
T_9	99.3	3.81	7.1	166	7688
SEd	4.9	0.21	0.3	9	418
CD (P=0.05)	10.1	0.45	0.8	19	873

Among the other treatments, 100 percent N through dhaincha + balance P & K through inorganic fertilizers recorded significantly higher number of tillers hill^{-1} (9.5), higher number of productive tillers (235m^{-2}) and DMP (12501 kg ha^{-1}).100 per cent RDN through green manure incorporation (*Sesbania acculeata*) might have released the N – NH_4^+ N into the soil solution on decomposition, which is ready usable by rice plants. Lee [14] reported that green manures, particularly the legumes like *Sesbania aculeata* and *Sesbania rostrata* which are comparatively high in N and low in C:N ratio behave almost like chemical fertilizers in respect to the improvement in productive tillers and DMP of rice.

The least number of tillers hill^{-1} (7.1), productive tillers (166 m^{-2}) and DMP (7688 kg ha^{-1}) was registered with the treatment of control. In the present study, the non supply of N through any source resulted in poor performance of rice and noticed by the lowest values of yield parameters in absolute control. When N was not supplied through organic or inorganic source rice has to obviously depend upon initial N, which was not sufficient to produce even reasonable yield [15].

The crop growth rate (CGR) was significantly influenced in rice at active tillering to panicle initiation, panicle initiation to flowering and flowering to harvest phase (Table 2).

Application of 100 per cent NPK through inorganic fertilizers + 6.25 t dhaincha recorded higher crop growth rate (8.87,10.65 and 50.43 g m^{-2} day^{-1} respectively) at active tillering to panicle initiation, panicle initiation to flowering and flowering to harvest phases, which was comparable with 100 per cent NPK through inorganic fertilizers + 5 t vermicompost and 100 per cent NPK through inorganic fertilizers + 12.5 t FYM.

Table 2. Effect of organic and inorganic sources of nutrients on crop growth rate (g m^{-2} day^{-1}) at various growth stages of rice

Treatments	Active tillering to panicle initiation	Panicle initiation to flowering	Flowering to harvest
T_1	8.19	9.79	39.71
T_2	7.50	8.97	36.76
T_3	7.59	9.08	36.89
T_4	7.38	8.83	36.62
T_5	7.17	8.58	36.44
T_6	8.79	10.52	48.24
T_7	8.87	10.62	50.43
T_8	8.83	10.56	49.32
T_9	5.59	6.69	28.53
SEd	0.28	0.32	1.26
CD (P=0.05)	0.58	0.68	2.65

Among the other treatments, application of 100 percent N through dhaincha + balance P & K through inorganic fertilizers significantly recorded highest crop growth rate (8.19, 9.79 and 39.71 g m^{-2} day^{-1}) at active tillering to panicle initiation phase, panicle initiation to flowering, flowering to harvest phases compared to control. The lowest CGR was recorded in control in all the phases of crop growth. Green manure substituted about 100 per cent of N requirement of rice crop. Nazmus Salahin et al. [16] reported that *Sesbania aculeata* was a better green manure than any other green manures. In the present study, green manure application gave higher CGR than other treatments. Green manures have a good potential to maintain soil fertility, supplement nutrient supply to rice crop and could contribute to greater food security [17].

3.3 Root Characters

The development of root system under various organic manure treatments were observed in this study (Table 3). Among the organic treatments, Application of 100 per cent NPK through inorganic fertilizers + 6.25 t dhaincha recorded higher root length (31.5 cm), root volume (29.5 cc $hill^{-1}$) and root dry weight (5.01 g $hill^{-1}$) at harvest phases, which was comparable with 100 per cent NPK through inorganic fertilizers + 5 t vermicompost and 100 per cent NPK through inorganic fertilizers + 12.5 t FYM.

Among the other treatments, application of 100 percent N through dhaincha + balance P & K through inorganic fertilizers significantly recorded highest root length (28.1 cm), root volume (26.8 cc $hill^{-1}$) and root dry weight (4.36 g $hill^{-1}$) at harvest stage compared than all other treatments. The lowest root characters were recorded in control. This might be due higher nutrients supplied through the INM treatment and 100 per cent RDN through green manure application, to the growing tissues which led to the synthesis of more chlorophyll. The INM treatment improved the soil environment which encouraged prolific root characters (root length, root volume and root dry weight) resulting in better absorption of water and nutrients from lower layers and thus resulted in increased growth rate [18].

3.4 Nitrogen Uptake

The uptake of total N varied significantly at harvest stages due to the application of organic and inorganic sources of nutrient management practices (Table 4).

Among the treatments, the highest N uptake (109.5 kg ha^{-1}) was recorded under application of 100 per cent NPK through inorganic fertilizers + 6.25 t dhaincha at harvest stage and it was comparable with 100 per cent NPK through inorganic fertilizers + 5 t vermicompost (109 kg ha^{-1}) and 100 per cent NPK through inorganic fertilizers + 12.5 t FYM (108.7 kg ha^{-1}). Among the other treatments, N uptake was significantly higher with application of 100 per cent N through dhaincha + balance P & K through inorganic fertilizers at harvest stage (100.6 kg ha^{-1}) compared to the other treatments. The lowest N uptake was recorded in control. The reason for increased N uptake may be due to the fact that in lowland rice soils, organic manure and green manure incorporation undergoes decomposition at a steady rate resulting in the release of N – NH_4^+ into soil solution which is readily available to rice plant [19]. The increased available N resulted in better N uptake which in turn improved the vegetative growth as indicated by taller plants, more number of tillers and increased leaf size leading to higher LAI [20].

Table 3. Effect of organic and inorganic sources of nutrients on root characters at harvest stage of Rice

Treatments	Root length (Cm)	Root volume (cc $hill^{-1}$)	Root dry weight (g $hill^{-1}$)
T_1	28.1	26.8	4.36
T_2	26.5	23.1	3.65
T_3	27.8	25.7	4.08
T_4	25.6	22.5	3.15
T_5	24.4	21.0	2.92
T_6	29.9	27.9	4.75
T_7	31.5	29.5	5.01
T_8	30.8	28.6	4.89
T_9	17.9	11.8	2.01
SEd	2.2	2.1	0.31
CD (P=0.05)	4.6	4.3	0.64

Table 4. Effect of organic and inorganic sources of nutrients on nutrient uptake (kg ha^{-1}) at harvest stage of rice

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
T_1	100.6	23.5	164
T_2	91.8	21.1	149
T_3	92.1	21.4	150
T_4	90.9	20.8	148
T_5	90.1	20.5	143
T_6	108.7	25.8	175
T_7	109.5	26.5	180
T_8	109.0	26.2	179
T_9	53.3	16.6	110
SEd	3.8	0.9	6
CD (P=0.05)	8.0	1.9	13

3.5 Phosphorus Uptake

Significant difference in P uptake was observed due to the application of organic and inorganic sources of nutrient management practices (Table 4). The trend noticed in N uptake by the crop at harvest stages was maintained for phosphorus uptake by also.

Similar to the N uptake, higher P uptake (26.5 kg ha^{-1}) was recorded in 100 per cent NPK through inorganic fertilizers + 6.25t dhaincha at harvest stage and it was comparable with 100 per cent NPK through inorganic fertilizers + 5 t vermicompost (26 kg ha^{-1}) and 100 per cent NPK through inorganic fertilizers + 12.5 t FYM (25.8 kg ha^{-1}).

Among the other treatments, significantly highest P uptake was recorded with 100 per cent N through dhaincha + balance P & K through inorganic fertilizers at harvest stages (23.5 kg ha^{-1}) compared to the control. The lowest P uptake (16.6 kgha^{-1}) was recorded in control. Increased P availability might be due to solubilisation of native P by the organic acids produced during organic manure decomposition, thus leading to better utilization of available P.) The organic manure which besides N, might have increased the soil organic P content leading to increased P availability [21] and consequently higher P uptake of rice plants.

3.6 Potassium Uptake

The highest K uptake was registered with the INM practice followed by recommended NPK fertilizers and 100 per cent RDN through green manure in both the years of study at all the growth stages of the crop.

The enhanced K availability irrespective of the season coupled with higher K uptake due to organic manure incorporation could be attributed to higher DMP and K absorption, evidencing the priming effect of K contribution by organic manure [5].

Among the organic manures, *Sesbania aculeata* played a vital role in improving the uptake of NPK followed by poultry manure, vermicompost and FYM irrespective of the season in both the years of investigation. This might be due to the fact that quick release of N from the added green manure with increased availability of P through the mechanism of reduction, chelation and favorable changes in soil pH and K through the priming effect and besides the direct contribution of K by green manure [2]. Higher K uptake in rice might be due to the increase in available K which may contributed to mineralization of organic manures or solubilization of nutrients from native sources during decomposition as reported by Singh et al. [21].

4. CONCLUSION

Addition of organic manures can compensate the detrimental effects on soil health due to injudicious application of chemical fertilizers. Whereas, excessive application of chemical fertilizers suppresses the soil productivity and harm the environment. Incorporation of organic sources into paddy soil could improve growth, physiological, nutrient uptake (N, P and K uptake), root morphological characteristics and root activity of rice plants by increasing root density, root volume and root dry weight as well as yield. It can be concluded that, application of 100 per cent NPK through inorganic fertilizers + 6.25 t dhaincha and 100 per cent N through dhaincha and balance P and K through inorganic fertilizers are the desirable integrated nutrient management practices for western zone of Tamil Nadu.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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