Biological Forum – An International Journal **14(4a): 802-809(2022)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Integrated Nutrient Management Combined with Starter Applied Residue Incorporation Enhances the Growth and Yield of Transplanted *kharif* Rice (*Oryza sativa* L.)

Priyanka Nayak[1], Rabindra Kumar Paikaray[2], Bama Shankar Rath[2], Sanat Kumar Dwibedi[3], Rajendra Kumar Panda[4], Shivasankar Acharya[5] and Sabyasachi Sahoo[1]*

[1]Ph.D. Scholar, Department of Agronomy,
College of Agriculture, OUAT, Bhubaneswar (Odisha), India.
[2]Professor, Department of Agronomy,
College of Agriculture, OUAT, Bhubaneswar (Odisha), India.
[3]Assistant Professor, Department of Agronomy,
College of Agriculture, OUAT, Bhubaneswar (Odisha), India.
[4]Assistant Professor, Department of Plant Physiology,
College of Agriculture, OUAT, Bhubaneswar (Odisha), India.
[5]Assistant Professor-cum-Junior Scientist, Department of Agronomy,
Bihar Agricultural College, BAU, Sabour, Bhagalpur (Bihar) India

(Corresponding author: Sabyasachi Sahoo)*
(Received 14 August 2022, Accepted 10 October, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Field experiment was conducted during *kharif* seasons of 2020 and 2021 at Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India, to evaluate the effect of different rice residue and nitrogen management practices on growth, yield components and yield of *kharif* rice, which was carried out in a split plot design, having six main plot treatments, consisting of rice residue management options *viz*., rice residue removal, *in-situ* burning of rice residues, *in-situ* incorporation of rice residues, *in-situ* incorporation of rice residues + 20 kg N ha^{-1} as starter, *in-situ* incorporation of rice residues + 20 kg N ha^{-1} + 20 kg P_2O_5 ha^{-1} as starter and *in-situ* incorporation of rice residues+ waste decomposer; and four sub-plot treatments consisting soil test-based N, leaf colour chart based N, chlorophyll meter based N and integrated nitrogen management based N (75% N through inorganic + 25% N through FYM). The results of the experiment revealed highest growth parameters *viz*., plant height (126.9 cm), tillers m^{-2} (283.5), LAI (4.53), dry matter (1002.4 g m^{-2}) recorded with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1}, whereas, among the N management options, INM based N application resulted in highest plant height at harvest (128.0 cm), tillers m^{-2} (285.6), LAI at 60 DAT (4.53) and dry weight (966.1 g m^{-2}). Among the growth attributing parameters, the highest number of panicles m^{-2} (271) was recorded with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1}, whereas, the highest grains panicle^{-1} (125.0) and 1000-grain weight (23.64 g) were with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1}. Similarly, INM based N management resulted in highest number of panicles m^{-2} (274) and grains panicle^{-1} (123.4). The interaction effect of residue and nitrogen management revealed highest grain yield (5833 kg ha^{-1}) and straw yield (7227 kg ha^{-1}) recorded with INM based N application combined with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1}. Thus, *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1} as starter is an optimum and sustainable approach to enhance the growth and yield of *kharif* rice.

Keywords: *Kharif* rice, Residue incorporation, Nitrogen management, Growth, Yield.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important cereal food crop of India, occupying about 22% of gross cropped area, contributing 40% of total food grain production of the country. India is the second largest producer of rice in the world, next to China, with an area of 46.38 Mha, production of 130.29 Mt and productivity of 2.81 t ha^{-1}, which far below the world average (Agricultural statistics at a glance, 2022). India produces approximately 500 Mt of crop residues per year, while only Punjab state produces 23 Mt and 17 Mt of paddy and wheat straw, respectively, of which more than 80% of paddy residues are burnt in fields (Kumar *et al.*, 2015). Crop residues have long been recognized as an important source of plant nutrients, which, besides supplying plant nutrients to the current crop, leave substantial residual effect on succeeding crops in the system and also favourably influence the physical, chemical and biological properties of soil. In India, with intensive cropping involving high yielding varieties of crops and increased productivity, crop residue surpluses have been building up continuously and there is lack of awareness among the farmers in many areas about the potential benefits of crop residues and as a result could not able to manage crop residues properly. Generally, after harvest, crop residues are completely removed for alternative uses such as animal feed, fuel or sometimes burnt to facilitate smooth tillage operations for the next crop. Open field burning of rice straw and other crop residues emit gases such as CO_2, N_2O, CH_4, CO, non-methane hydrocarbons, SO_2, particulate matter (Gadde *et al.,* 2009). Apart from greenhouse effect, burning causes almost complete loss of N, 25 % loss of P, 20 % loss of K and 5 to 60% loss of S (Dobermann and Fairhurst 2002). Therefore, burning of crop residues should be avoided and alternate measures of disposal of residues should be found out. A potential solution to the problem of rice straw burning would be its recycling in soil, which can improve soil organic matter, so that the succeeding crops can benefit from this (Kumar and Goh 2000; Samra and Kumar 2003). Recycling of rice straw with high C:N ratio (60-70%), however, could accelerate immobilization of N causing N-deficiency to the following crop (Singh *et al*., 2001). To overcome the problem of net N-immobilization due to straw addition, application of N could be done in the form of inorganic N so that the succeeding crop will not suffer from N-deficiency (Pathak and Sarkar 1994). In this regard, there is an urgent need of *in-situ* management of rice residues, which otherwise would be burnt in the field due to lack of knowledge about its value for improving soil health.

Nitrogen, the key element that governs the crop yield to a larger extent, plays a key role in plant physiological processes and influences sink size, thereby increasing the grain yield of rice (Somasundaram *et al.,* 2002). Nitrogen management in rice is the most important operation as it is required in larger amount and leads to nitrate pollution in surface of puddled rice fields along with ground water in the agricultural areas (Xue *et al.*, 2007). Effective management of fertilizers, particularly N remains a major challenge to researchers and producers. Hence, adoption of wise-management practices by timely application based on the crop requirement is need of the hour, to answer the 4-R stewardship of N application. Leaf greenness and/or leaf N content are closely related to photosynthetic rates and biomass production, and is a sensitive indicator of changes in crop N demand during the growing season. Chlorophyll meter (SPAD), leaf colour chart and green seekers are such devices which can be effective in optimization and recommendation of precise application of nitrogen. Hence, the present experiment was undertaken to evaluate the effect of different rice residue and nitrogen management practices on growth, yield components and yield of *kharif* rice.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* seasons of 2020 and 2021 at Agronomy Main Research Farm, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India, having a latitude and the longitude of 20º15′ N and 85º52′E, respectively, with an altitude of 25.9 m above the mean sea level. The station comes under the East and South Eastern Coastal Plain Agro-Climatic Zone of Odisha. The climate of Bhubaneswar is characterized by hot, moist and sub-humid with hot summer and mild winter. The rainfall is monsoonal and unimodal. Soil of the experimental site was sandy loam in texture, with pH 5.67 and EC 0.11 ds m^{-1}, low in organic carbon (0.48 %), low in available nitrogen (228.0 kg ha^{-1}), medium in available phosphorus (20.4 kg ha^{-1}) and medium in available potassium (146.5 kg ha^{-1}). Hasanta rice variety was taken for this experimental work. The experiment was carried out in a split plot design having three replications. The main plot included six treatments consisting of rice residue management viz., C_1:Rice residue removal, C_2: *In-situ* burning of rice residues, C_3: *In-situ* incorporation of rice residues, C_4: C_3+ 20 kg N ha^{-1} as starter, C_5: C_3 + 20 kg N ha^{-1} + 20 kg P_2O_5 ha^{-1} as starter, C_6: C_3 + waste decomposer (500 L ha^{-1}), whereas in sub-plot, there were four treatments consisting of nitrogen management approaches comprising of N_1: Soil test-based nitrogen, N_2: Leaf colour chart (LCC) based N management, N_3: Chlorophyll (SPAD) meter based N management, N_4: Integrated nitrogen management (INM) based N (75% N through inorganic source + 25% N through FYM).

The experimental plot was ploughed twice during April-May and before transplanting in the main field, about 5 t ha^{-1} crop residue of previous rice crop were taken and incorporated in the soil of main-plots of C_3, C_4, C_5 and C_6, by chopping into small pieces. In the main plot C_1, residues were removed by cutting the plant above ground after maturity, whereas, entire amount of residues were burnt in the soil for the main plot C_2. 20 kg N ha^{-1} was applied to main plot C_4, while 20kg N ha^{-1} and 20kg P_2O_5 ha^{-1} were applied to the C_5. In the month June, the nursery bed was raised by wet bed nursery method. In the sub-plot, nitrogen management practices like soil test based nitrogen management, leaf colour chart (LCC), chlorophyll meter / SPAD meter and INM (inorganic N: organic N::75:25 %). The organic source was supplied through FYM. The experiment started by growing of rice under puddled condition in *kharif* seasons of 2020 and 2021.

Complete dose of P_2O_5 was applied during transplanting, whereas, K_2O was applied in two splits, i.e., during transplanting and at panicle initiation (PI) stage, while N was supplied at three splits i.e., ¼ at basal, ½ at tillering and ¼ at PI, which were supplied through urea, DAP and MOP and standard package of practices were followed to manage the pest and diseases and weeds in order to keep the crop healthy. The optimum soil moisture was maintained throughout the experimentation, as and when required. Observations of SPAD meter and leaf colour chart were recorded from upper fully expanded leaves, at 10 days interval, from 20 DAT to flowering. Leaf Area Index (LAI) was recorded at 60 DAT, whereas, plant height, number of tillers m^2 and dry matter were recorded at harvest. Ten hills were collected at physiological maturity from net plot area for measuring yield components viz., panicles m^{-2}, grains panicle^{-1} and 1000-grain weight. The crop was harvested, plot wise, leaving border and sampling areas. Threshing was done after sun drying for 3-4 days by a pedal thresher and grain yield and straw yield were recorded from the net plot area and were expressed in kg ha^{-1}, whereas the harvest index was expressed in percentage. Statistical analysis for all the compiled biometric data recorded at pre and post-harvest studies were done, following the analysis of variance technique for split-plot design by applying the F-test at 0.05% level of probability, as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

A. Growth attributes

Crop growth and development of rice was measured in terms of plant height at harvest, tiller m^{-2} at 90 DAT, LAI at 60 DAT and dry matter at harvest and are shown in Table 1. Among the residue management treatments, the highest plant height at harvest (126.9 cm) was recorded with C_5, i.e., *in-situ* incorporation of rice residues along with starter application of N and P_2O_5, which, however, was found at par with *in-situ* incorporation of rice residues along with starter application of N only, but differed significantly with other residue management options. Among the nitrogen management options, N_4, i.e., INM based N application resulted in highest plant height at harvest (128.0 cm), differing significantly with all other treatments.

Number of tillers m^{-2} at 90 DAT was found significantly higher values (283.5) with C_5, i.e., *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1}, which was statistically at par with treatment C_4 (*in-situ* incorporation of rice residues along with 20 kg N ha^{-1}), whereas, INM based N management option resulted in the maximum number of tillers m^{-2} (285.6). The highest LAI at 60 DAT (4.53) was recorded with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1}, which was significantly superior to all other treatments, whereas, among the sub-plot treatments, INM based N management resulted in the maximum LAI (4.29), differing significantly with all other nitrogen management treatments. The plant dry weight was increased with the advancement in crop stage, reached maximum at the time of harvest. The higher plant dry weight (1002.4 g m^{-2}) was recorded with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1}, which was significantly superior to other residue management treatments, whereas, INM approach resulted in the maximum plant dry weight (966.1 g m^{-2}), among the sub plot treatment options.

The increase in growth parameters like plant height, dry matter and LAI with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1} as starter and INM was might be due to adequate nutrient supply to the plant which resulted in rapid growth and establishment of root and various metabolic processes related to growth and development. The favourable effect of INM based N management through both inorganic and organic sources on higher crop growth and yield was also reported by Kumar *et al.* (2008); Sabina *et al.* (2014); Hussain *et al.* (2012).

Table 1: Growth attributes of rice as influenced by residue and nitrogen management options (Pooled data).

Treatments	Plant height at harvest (cm)	Tillers m^{-2} at 90 DAT	LAI at 60 DAT	Dry matter at harvest (g m^{-2})
Residue Management				
C_1: Rice residue removal	113.1	258.7	4.00	772.2
C_2: *In-situ* burning of residues	111.5	269.5	3.94	800.7
C_3: *In-situ* incorporation of residues	119.9	276.8	4.07	819.9
C_4: C_3+ 20 kg N ha^{-1} as starter	123.9	281.3	4.29	981.6
C_5: C_3 + 20 kg N ha^{-1} + 20 kg P_2O_5 ha^{-1} as starter	126.9	283.5	4.53	1002.4
C_6: C_3 + waste decomposer (500 L ha^{-1})	122.0	272.9	4.18	957.7
SEm (±)	1.03	1.94	0.01	10.8
CD (P=0.05)	3.00	5.70	0.03	32.0
Nitrogen Management				
N_1: Soil test based N	122.9	267.1	4.21	829.9
N_2: LCC based N	116.1	268.8	4.12	870.5
N_3: SPAD based N	111.2	273.6	4.04	889.9
N_4: INM based N (Inorganic N: Organic N::75:25)	128.0	285.6	4.29	966.1
SEm (±)	0.77	1.27	0.01	8.26
CD (P=0.05)	2.2	3.6	0.02	23.3

B. Yield attributes

In the first year of experimentation, significantly highest number of panicles m^{-2} (270) was recorded with *in-situ* incorporation of rice residues along with 20 kg Nha^{-1}, whereas, during the second year, highest number of panicles m^{-2} (275) was recorded with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1} (Table 2). The pooled data of both the years revealed highest number of panicles m^{-2} (271) recorded with C_4, i.e., *in-situ* incorporation of rice residues along with 20 kg N ha^{-1}, which was statistically at par with the treatments likeC_5, C_6 and C_3, having values of 270, 266 and 264, respectively. Among the main plot treatments, number of grains panicle^{-1} of rice was significantly highest with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1}, whereas, among the sub plot treatments, INM resulted maximum number of grains panicle^{-1} of rice, during both the years of study. The pooled data also revealed the highest number of grains panicle^{-1} (125.0) with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1}, among residue management options and INM based N application, among nitrogen management options (123.4). With respect to 1000-grain weight of rice, significant difference was observed due to residue and nitrogen treatment combinations. In both the year of study, highest 1000-grain weight was observed with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1}. The pooled data revealed that highest 1000-grain weight (23.64g) observed with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1} which was at par with C_6 (*in-situ* incorporation of rice residues along with waste decomposer @ 500 L ha^{-1}), whereas, among the nitrogen management treatments, SPAD based nitrogen management recorded highest 1000-grain weight (23.63 g), which was statistically at par with LCC based N-management option (23.43g). The highest yield attributes due to *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1} as starter and INM was might be due to regular supply of macro and micronutrients to the crop throughout the life cycle of the crop along with translocation of nutrients as well as photosynthesis from source to sink, as earlier reported by Gupta *et al.* (2006); Suresh *et al.* (2013); Yang *et al.* (2004).

Table 2: Yield attributes of rice as influenced by residue and nitrogen management options.

Treatments	Panicles m^{-2}			Grains panicle^{-1}			1000-grain weight (g)		
	2020	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
Residue Management									
C_1: Rice residue removal	245	249	247	99.6	102.3	100.9	23.01	23.45	23.23
C_2: *In-situ* burning of residues	253	255	254	103.5	97.5	100.5	23.03	23.59	23.31
C_3: *In-situ* incorporation of residues	263	265	264	106.9	103.8	105.3	22.98	23.33	23.15
C_4: C_3+ 20 kg N ha^{-1} as starter	270	273	271	109.4	112.3	110.8	22.98	23.31	23.14
C_5: C_3 + 20 kg N ha^{-1} + 20 kg P_2O_5 ha^{-1} as starter	266	275	270	124.7	125.3	125.0	23.30	23.98	23.64
C_6: C_3 + waste decomposer (500 L ha^{-1})	256	261	258	113.3	115.1	114.2	23.21	23.84	23.53
SEm (±)	4.00	2.91	2.47	3.25	2.28	1.98	0.13	0.09	0.08
CD (P=0.05)	12.6	9.2	7.3	10.2	7.2	5.9	0.4	0.1	0.2
Nitrogen Management									
N_1: Soil test based N	255	254	254	97.4	95.2	96.3	23.04	23.35	23.20
N_2: LCC based N	253	258	256	108.3	105.9	107.1	23.22	23.64	23.43
N_3: SPAD based N	255	264	259	112.0	109.9	110.9	23.38	23.89	23.63
N_4: INM based N (Inorganic N: Organic N::75:25)	272	275	274	120.4	126.4	123.4	22.69	23.44	23.07
SEm (±)	1.74	1.72	1.23	2.51	2.14	1.65	0.11	0.29	0.09
CD (P=0.05)	5.0	4.9	3.5	7.2	6.1	4.6	0.3	0.4	0.2

C. Grain yield of rice

Grain yield of rice was significantly influenced by the interaction effect of residue and nitrogen management in both the years of experimentation (Table 3). In the year, 2020, the highest grain yield of rice (5548 kg ha^{-1}) was obtained with the treatment combination of C_5 and N_4, i.e., INM with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1} and was found at par with treatment combinations of INM based N application along with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} (5487 kg ha^{-1}), whereas, during the year 2021, treatment combinations like INM based N application with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1} recorded the highest (6118 kg ha^{-1}) grain yield of rice, being at par with C_4N_4, C_5N_4 and C_6N_4 combinations. The pooled data of the interaction effect of residue and nitrogen management revealed significant influence with the highest grain yield recorded for the treatment combinations of C_5 and N_4, i.e., INM based N application along with *in-situ* incorporation of rice residues combined with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1} (5833 kg ha^{-1}), which however, did not differ significantly with the treatment combinations of C_4 and N_4, having value of 5731 kg ha^{-1}.

Table 3: Grain yield of rice as influenced by interaction effect of residue and nitrogen management.

Treatments	Grain yield (kg ha^{-1})									
	N_1: Soil test based N	**N_2: LCC based N**	**N_3: SPAD based N**	**N_4: INM based N**	**Mean**		**C**	**N**	**C within N**	**N within C**
1st year (2020)										
C_1: Rice residue removal	3800	3929	3830	4168	**3932**	SEm (±)	62.0	47.5	118.2	116.3
C_2: *In-situ* burning of residues	3905	3986	3925	4356	**4043**	CD (P=0.05)	195.4	136.2	459.4	333.5
C_3: *In-situ* incorporation of residues	3856	4122	4039	4409	**4107**					
C_4: C_3+ 20 kg N ha^{-1} as starter	4217	4338	4659	5487	**4675**					
C_5: C_3 + 20 kg N ha^{-1} + 20 kg P_2O_5 ha^{-1} as starter	4458	4558	4679	5548	**4811**					
C_6: C_3 + waste decomposer (500 L ha^{-1})	4192	4281	4545	5020	**4509**					
Mean	**4071**	**4202**	**4279**	**4831**						
2nd year (2021)										
C_1: Rice residue removal	3944	4087	4020	4371	**4106**	SEm (±)	114.9	73.9	194.3	180.9
C_2: *In-situ* burning of residues	3983	4199	4105	5616	**4476**	CD (P=0.05)	361.9	211.9	736.1	518.9
C_3: *In-situ* incorporation of residues	4167	4450	4195	5669	**4620**					
C_4: C_3+ 20 kg N ha^{-1} as starter	5236	5683	5886	5975	**5695**					
C_5: C_3 + 20 kg N ha^{-1} + 20 kg P_2O_5 ha^{-1} as starter	5344	5779	5906	6118	**5786**					
C_6: C_3 + waste decomposer (500 L ha^{-1})	5171	5576	5656	5860	**5566**					
Mean	**4641**	**4962**	**4961**	**5601**						
Pooled										
C_1: Rice residue removal	3872	4008	3925	4270	**4019**	SEm (±)	65.3	43.9	113.7	107.6
C_2: *In-situ* burning of residues	3944	4093	4015	4986	**4259**	CD (P=0.05)	192.5	123.8	325.5	303.2
C_3: *In-situ* incorporation of residues	4012	4286	4117	5039	**4364**					
C_4: C_3+ 20 kg N ha^{-1} as starter	4727	5011	5273	5731	**5185**					
C_5: C_3 + 20 kg N ha^{-1} + 20 kg P_2O_5 ha^{-1} as starter	4901	5168	5292	5833	**5299**					
C_6: C_3 + waste decomposer (500 L ha^{-1})	4682	4929	5100	5440	**5038**					
Mean	**4356**	**4582**	**4620**	**5216**						

D. Straw yield and harvest index

Like grain yield, straw yield of rice was also significantly influenced by the interaction effect of residue and nitrogen management, in both the years of experimentation (Table 4). During the year 2020, the highest straw yield of rice (7306 kg ha^{-1}) was obtained with the treatment combinations of C_5 and N_4, i.e., INM and *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1}, being at par with treatment combinations of C_4 and N_4, i.e., INM based N application along with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} (6903 kg ha^{-1}). However, the straw yield of rice during 2021 was highest (7736 kg ha^{-1}) for the treatment combinations of C_5 and N_2, i.e., LCC based N application along with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1}, which was found at par with treatmentcombinations of C_5 and N_4, i.e., INM with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1} (7148ha^{-1}). The pooled data of the interaction effect of residue and nitrogen management revealed significant influence, with the highest value of straw yield recorded with the treatment combinations of C_5 and N_4, i.e., INM based N application combined with *in-situ* incorporation of rice residues along with 20 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1} (7227 kg ha^{-1}), which was found at par with the treatment combinations of C_6 and N_4, i.e., INM based N application along with *in-situ* incorporation of rice residues applied with waste decomposer, having value of 7081 kg ha^{-1}. Higher yield of crops with incorporation of residue along with waste decomposer was earlier reported by Kumari *et al*. (2022).

Harvest index of rice as influenced by rice residue incorporation and nitrogen management was found to be non-significant for both the years as well as pooled data. However, the highest harvest index of rice was noticed for INM based N application along with *in-situ* incorporation of rice residues applied with waste decomposer, having value of 45.9%.

Grain and straw yield of a crop are the functions of growth and yield parameters. The starter application of

N and P_2O_5 along with the residue helped in preventing the immobilization of nutrients by the microorganisms, thereby resulting in quicker decomposition, which improved the fertility status of the soil through improvement in soil physical, chemical and biological parameters, which contributed towards increase in grain and straw yields (Zhang *et al.*, 2015; Wang *et al.*, 2015). Several earlier research findings also revealed that INM fertilization by replacing a substantial part (25 to 50%) of the N through different organic amendments improved the grain yield of rice (Srinivasarao *et al.*, 2014; Mitran and Mani 2017) by facilitating the translocation of nutrients to the economic part of the crop (Yang *et al.*, 2004).

Table 4: Straw yield of rice as influenced by interaction effect of residue and nitrogen management.

Straw yield (kg ha^{-1})										
Treatments	**N_1: Soil test based N**	**N_2: LCC based N**	**N_3: SPAD based N**	**N_4: INM based N**	**Mean**		**C**	**N**	**C within N**	**N within C**
1st year (2020)										
C_1: Rice residue removal	4321	4677	4529	4916	**4611**	SEm (±)	126.6	102.6	251.7	251.2
C_2: *In-situ* burning of residues	4603	4689	4841	5139	**4818**	CD (P=0.05)	398.9	294.1	985.2	720.4
C_3: *In-situ* incorporation of residues	4743	4841	5043	5632	**5065**					
C_4: C_3+ 20 kg N ha^{-1} as starter	4482	5203	5481	6903	**5517**					
C_5: C_3 + 20 kg N ha^{-1} + 20 kg P_2O_5 ha^{-1} as starter	4696	5799	6095	7306	**5974**					
C_6: C_3 + waste decomposer (500 L ha^{-1})	4552	5047	5394	6016	**5252**					
Mean	**4566**	**5043**	**5230**	**5985**						
2nd year (2021)										
C_1: Rice residue removal	4759	4856	4788	5368	**4943**	SEm (±)	61.4	77.6	175.7	190.1
C_2: *In-situ* burning of residues	4694	4991	5094	5664	**5111**	CD (P=0.05)	193.4	222.5	720.8	545.1
C_3: *In-situ* incorporation of residues	4886	5187	5286	6035	**5349**					
C_4: C_3+ 20 kg N ha^{-1} as starter	6427	6616	6985	7128	**6789**					
C_5: C_3 + 20 kg N ha^{-1} + 20 kg P_2O_5 ha^{-1} as starter	6355	7736	6985	7148	**7056**					
C_6: C_3 + waste decomposer (500 L ha^{-1})	6065	6616	6721	8147	**6887**					
Mean	**5531**	**6000**	**5976**	**6582**						
Pooled										
C_1: Rice residue removal	4540	4767	4658	5142	**4777**	SEm (±)	70.3	64.3	153.5	157.5
C_2: *In-situ* burning of residues	4649	4840	4968	5402	**4965**	CD (P=0.05)	207.5	181.3	436.8	444.0
C_3: *In-situ* incorporation of residues	4815	5014	5165	5834	**5207**					
C_4: C_3+ 20 kg N ha^{-1} as starter	5454	5909	6233	7015	**6153**					
C_5: C_3 + 20 kg N ha^{-1} + 20 kg P_2O_5 ha^{-1} as starter	5525	6767	6540	7227	**6515**					
C_6: C_3 + waste decomposer (500 L ha^{-1})	5308	5831	6057	7081	**6070**					
Mean	**5049**	**5521**	**5603**	**6284**						

Table 5: Harvest Index rice as influenced by interaction effect of residue and nitrogen management.

Harvest Index (%)										
Treatments	**N_1: Soil test based N**	**N_2: LCC based N**	**N_3: SPAD based N**	**N_4: INM based N**	**Mean**		**C**	**N**	**C within N**	**N within C**
1st year (2020)										
C_1: Rice residue removal	46.8	45.9	45.8	45.9	**46.1**	SEm (±)	0.59	0.58	1.3	1.4
C_2: *In-situ* burning of residues	45.9	46.1	44.7	45.9	**45.6**	CD (P=0.05)	NS	NS	NS	NS
C_3: *In-situ* incorporation of residues	44.8	46.0	44.5	44.2	**44.9**					
C_4: C_3+ 20 kg N ha^{-1} as starter	48.5	45.5	46.0	44.3	**46.1**					
C_5: C_3 + 20 kg N ha^{-1} + 20 kg P_2O_5 ha^{-1} as starter	48.7	44.0	43.5	43.2	**44.8**					
C_6: C_3 + waste decomposer (500 L ha^{-1})	47.9	46.0	45.7	45.7	**46.3**					
Mean	**47.1**	**45.6**	**45.0**	**44.9**						
2nd year (2021)										
C_1: Rice residue removal	45.3	45.7	45.6	44.8	**45.4**	SEm (±)	0.67	0.54	1.32	1.31
C_2: *In-situ* burning of residues	46.1	45.7	44.6	49.7	**46.5**	CD (P=0.05)	NS	NS	NS	NS
C_3: *In-situ* incorporation of	46.1	46.2	44.3	48.5	**46.3**					

residues										
C_4: C_3+ 20 kg N ha^{-1} as starter	44.9	46.1	45.7	45.6	**45.6**					
C_5: C_3 + 20 kg N ha^{-1} + 20 kg P_2O_5 ha^{-1} as starter	45.6	42.7	45.8	46.1	**45.0**					
C_6: C_3 + waste decomposer (500 L ha^{-1})	46.0	45.7	45.7	41.9	**44.8**					
Mean	**45.7**	**45.4**	**45.3**	**46.1**						
Pooled										
C_1: Rice residue removal	46.0	45.8	45.7	45.4	**45.7**	SEm (±)	0.45	0.39	0.95	0.96
C_2: *In-situ* burning of residues	46.0	45.9	44.6	47.8	**46.1**	CD (P=0.05)	NS	NS	NS	NS
C_3: *In-situ* incorporation of residues	45.5	46.1	44.4	46.3	**45.6**					
C_4: C_3+ 20 kg N ha^{-1} as starter	46.7	45.8	45.8	45.0	**45.8**					
C_5: C_3 + 20 kg N ha^{-1} + 20 kg P_2O_5 ha^{-1} as starter	47.2	43.4	44.6	44.6	**44.9**					
C_6: C_3 + waste decomposer (500 L ha^{-1})	47.0	45.9	45.7	43.8	**45.6**					
Mean	**46.4**	**45.5**	**45.1**	**45.5**						

CONCLUSIONS

It can be concluded from the investigation thatincorporation of rice residuesintegrated with starter application of 20 kg each of N and P_2O_5 ha^{-1}, along with integrated nitrogen management based nitrogen application in rice can enhance the growth and yield attributes, thereby increasing the grain and straw yield of rice under Odisha condition.

FUTURE SCOPE

This work can be used as reliable reference for future research on residue incorporation and nitrogen management. Similar studies may be conducted in different agro-climatic zones of the country to determine the validity of the treatments. Quantification of doses of nitrogen application may be done according to the real time N management practices by taking different varieties of rice.

Acknowledgement. I gratefully record my indebtedness to my advisor and all the faculty members of Department of Agronomy, College of Agriculture, OUAT, Bhubaneswar, Odisha, for valuable suggestions and constant guidance throughout the course of this doctoral research work.
Conflict of Interest. None.

REFERENCES

Agricultural statistics at a glance (2022). Government of India, Ministry of Agriculture & Farmers Welfare, Department of Agriculture & Farmers Welfare, Economics and Statistics Division.

Dobermann, A. and Fairhurst, T. H. (2002). Rice straw management. *Better Crops International*, *16*(1), 7-11.

Gadde, B., Menke, C. and Wassmann, R. (2009). Rice straw as a renewable energy source in India, Thailand, and the Philippines: Overall potential and limitations for energy contribution and greenhouse gas mitigation. *Biomass and Bioenergy*, *33*(11), 1532-1546.

Gomez, K. A. and Gomez A. A. (1984). Statistical procedures for agricultural research, 2nd Ed. John Willey and Sons, New York, USA.

Gupta, V., Sharma, R. S. and Vishvakarma, S. K. (2006). Long term effect of integrated nutrient management on yield sustainability and soil fertility of rice (*Oryza sativa*) -Wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy*, *51*(3), 160-164.

Hussain, A., Bhat, M. A. and Gaine, M. A. (2012). Effect of number and age of seedling on growth, yield, nutrient uptake and economics of rice under system of rice intensification in temperate condition. *Indian Journal of Agronomy*, *57*(2), 133-137.

Kumar, K. and Goh, K. M. (2000). Crop residues and management practices: Effects on soil quality, soil nitrogen dynamics, crop yield, and nitrogen recovery. *Advances in Agronomy, 68*, 197–319.

Kumar, B., Gupta, R. K. and Bhandari, A. L. (2008). Soil fertility changes after long term application of organic manures and crop residues under rice-wheat system. *Journal of the Indian Society of Soil Science, 56*, 80-85.

Kumar, P., Kumar, S. and Joshi, L. (2015). Socioeconomic and environmental implications of agricultural residue burning: A case study of Punjab, India. *Nature*, pp. 144.

Kumari, P. M., Prathibhasree, S., Mrudhula K. A. and Mohana R. P. (2022). Effect of Rice Crop Residue Management Techniques and Nitrogen Levels on Growth and Yield of Succeeding Sorghum. *Biological Forum – An International Journal*, *14*(3), 1469-1472.

Mitran, T. and Mani, P. K. (2017). Effect of organic amendments on rice yield trend, phosphorus use efficiency, uptake and apparent balance in soil under long-term rice-wheat rotation. *Journal of Plant Nutrition*, *40*, 1312-1322.

Pathak, H. and Sarkar, M. C. (1994). Nitrogen supplying capacity of an Ustochrept amended with manures, urea and their combinations. *Journal of the Indian Society of Soil Science*, *42*(2), 261-267.

Samra, J. S. and Kumar, K. (2003). Managing crop residues in the rice-wheat system of the Indo-Gangetic Plain. In: Improving the productivity and sustainability of rice-wheat systems: issues and impacts. Proceedings of an international symposium, held at the 2001. Annual Meetings of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Charlotte, NC, USA, 22 October 2001. *American Society of Agronomy*, pp. 173-195.

Singh, B., Bronson, K. F., Singh, Y., Khera, T. S. and Pasuquin, E. (2001). Nitrogen balance as affected by rice straw management in a rice-wheat rotation in northwest India. *Nutrient Cycling in Agroecosystems*, *59*, 227-237.

Somasundaram, E., Velayuthan, Poonguzhalan, R. and Sathiyavelu, A. (2002). Effect of nitrogen levels on growth and yield of rice under sodic soil conditions. *Madras Agricultural Journal*, *89*(7-9), 506-508

Srinivasarao, C., Ramachandrappa, B. K., Jakkula, V. S., Kundu, S., Venkateswarlu, B., Pharande, A. L., Manideep, V. R., Naik, R. P. and Venkanna, K. (2014). Nutrient balance after thirteen years of organic and chemical nutrient management and yield sustainability of groundnut-finger millet rotationin rainfed alfisols of semi-arid India. *Journal of Indian Society of Soil Science*, *62*, 235-247.

Suresh, K., Ramasubba Reddy, G., Hemlatha, S., Narasa Reddy, S., Sreenivasa Raju, A. and Madhulety, T.Y. (2013). Integrated Nutrient Management in rice: A Critical Review. *International Journal of Applied Biology and Pharmaceutical Tech*nology, *4*(2), 47-53.

Sabina, A., Basumatary, A., Das, K. N., Medhi, B. K. and Srivastava, A. K. (2014). Effect of integrated nutrient management on yield, nutrient uptake and soil fertility in autumn rice on Inceptisol of Assam. *Annals of Plant and Soil Research*, *16*(3), 192-197.

Wang, C., Gu, F., Chen, J., Yang, H., Jiang, J., Du, T. and Zhang, J. (2015). Assessing the response of yield and comprehensive fruit quality of tomato grown in greenhouse to deficit irrigation and nitrogen application strategies. *Agricultural Water Management*, *161*, 9-19.

Xue, G., Chang, J., Hua and Chang, J. (2007). Much improved water use efficiency of rice under non-flooded mulching cultivation. *Integrated Plant Biology*, *49*, 1527-1534.

Yang, C. M., Yang, L., Yang, Y. and Ouyang, Z. (2004). Rice root growth and nutrient uptake as influenced by organic manure in continuously and alternately flooded paddy soils. *Agricultural Water Management*, *70*(1), 67-81.

Zhang, P., Wei, T., Li, Y. L., Wang, K., Jia, Z. K., Han, Q. F. and Ren, X. L. (2015). Effects of straw incorporation on the stratification of the soil organic C, total N and C:N ratio in a semiarid region of China. *Soil & Tillage Research*, *153*, 28–35.

How to cite this article: Priyanka Nayak, Rabindra Kumar Paikaray, Bama Shankar Rath, Sanat Kumar Dwibedi, Rajendra Kumar Panda, Shivasankar Acharya and Sabyasachi Sahoo (2022). Integrated Nutrient Management Combined with Starter Applied Residue Incorporation Enhances the Growth and Yield of Transplanted *kharif* Rice (*Oryza sativa* L.). *Biological Forum – An International Journal*, *14*(4a): 802-809.