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Integrated nutrient management practices on dry matter production, yield and NPK content of transplanted rice

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Abstract
A field investigation was carried out during *kharif* seasons of 2016 and 2017 at research farm of College of Agriculture, Central Agricultural University, Imphal, to study the influence of integrated nutrient management on dry matter production, yield and NPK content of transplanted rice. The treatments were laid out in a randomized block design and replicated thrice using the rice variety (CAU-R1). Among the different treatments, higher dry matter production and N content in rice were found significantly in T_8 (100% RDN from urea + 10 tonnes *Azolla* ha^{-1}) on 30th, 60th and 90th DAT. At harvest, significantly higher content of N in grain was observed in T_{10} (75% RDN from urea + 25% RDN from FYM + 10 tonnes *Azolla* ha^{-1}) while treatments T_8 and T_{10} showed the similar effect in straw N content. However, statistically higher P concentration was recorded in T_{11} (50% RDN from urea + 50% RDN from FYM + 10 tonnes *Azolla* ha^{-1}) throughout the growing period and also in grain and straw at harvest time. T_{12} (25% RDN from urea + 75% RDN from FYM + 10 tonnes *Azolla* ha^{-1}) noted the highest K concentration in grain followed by T_{11} while K content in straw was highest in both the treatments T_{11} andT_{12}. In contrary to P content, the K content recorded in grain was low under different treatments. Critical analysis of the pooled data showed that soil treated with 75% RDN from urea + 25% RDN from FYM + 10 tonnes *Azolla* ha^{-1}(T_{10}) yielded significantly higher grain and straw yield of rice.

Keywords: Integrated nutrient management, dry matter production, NPK content, yield, rice

Introduction
Rice (*Oryza sativa* L.) is one of the most popular field crop among other cereals in the world, being cultivated in different agro-ecosystems and serves as the staple food for world's half population (FAO, 2004) [5]. More than 759.6 Mt of rice was produced globally in 2017 (FAO, 2018) [6]. India is the world's second largest rice producer (131 million tonnes) after China, with an area of 44 million hectares. The rice productivity in India was 2.98 t ha^{-1}, while the world average is 4.25 t ha^{-1} (IRRI, 2011). The ever-increasing need for food to satisfy the growing population, rice production must be increased significantly. The increasing demand for rice grain production has to be achieved by using an integration of organic and inorganic fertilizer to maintain the sustainability in crop production. Therefore, more efforts are needed to identify the improved nutrient management strategy for a particular target environment. Appropriate combinations of organic and inorganic nutrient sources enhance the use efficiency of nutrients and ultimately increased the growth and yield attributes of rice. Hence, the present study was initiated to study the integrated nutrient management practices on dry matter production, yield and NPK content of rice.

Materials and Methods
Field experiments were conducted during *kharif* seasons of 2016 and 2017 at the research farm of College of Agriculture, Central Agricultural University, Imphal. The soil of the experimental site (24^{o}48'44.50''N latitude and 93^{o}53'29.98''E longitude) was clayey in texture having pH 5.4, organic carbon 1.84%, EC 0.19 dSm^{-1}, CEC 15.25 [cmol(p+)]kg^{-1}, available N 290.68 kg ha^{-1}, available P_2O_5 17.20 kg ha^{-1}and available K_2O 240.45 kg ha^{-1}. Rice variety 'CAU-R1' was used as test variety. The experiment was laid out in a randomized block design with three replications and unit plot size being 4m × 4m.

The treatments includes: T_1 = Control, T_2 = 100% RDN from urea, T_3 = 100% RDN from FYM, T_4 = 20 tonnes *Azolla* ha^{-1}, T_5 = 75% RDN from urea + 25% RDN from FYM, T_6 = 50% RDN from urea + 50% RDN from FYM, T_7 = 25% RDN from urea + 75% RDN from FYM, T_8 = 100% RDN from urea + 10 tonnes *Azolla* ha^{-1}, T_9 = 100% RDN from FYM + 10 tonnes *Azolla* ha^{-1}, T_{10} = 75% RDN from urea + 25% RDN from FYM + 10 tonnes *Azolla* ha^{-1}, T_{11} = 50% RDN from urea + 50% RDN from FYM + 10 tonnes *Azolla* ha^{-1} and T_{12} = 25% RDN from urea + 75% RDN from FYM + 10 tonnes *Azolla* ha^{-1}.

The recommended dose of nitrogen (RDN) i.e. 60 kg N ha^{-1} was applied as urea and FYM on equivalent nitrogen basis. The total N content of FYM was 0.54%. A constant dose of 40 kg P_2O_5 ha^{-1} through SSP and 30 kg K_2O ha^{-1} through MOP were applied in all the treatments. Half dose of N, full dose of P_2O_5 and two-third of K_2Owere applied as basal dressing before transplanting. The remaining half dose of N was applied at tillering and panicle initiation stages equally and the remaining one-third of K_2O was applied at panicle initiation stage. FYM containing equivalent dose of nitrogen was incorporated in the plots as per treatments 15 days prior to transplanting of rice seedlings. *Azolla* was collected from the surrounding area and intercropped with the rice seven days after transplanting on fresh weight basis. After twenty days of inoculation water was drained out from the field and it was left to decompose. Twenty five days old seedlings were transplanted in the experimental plots maintaining two seedlings per hill and plant spacing of 20cm × 10cm.

Plant samples were periodically collected randomly at 30^{th}, 60^{th} and 90^{th}days after transplanting (DAT) for study of dry matter yield and nutrients content. Grain and straw yield were recorded at the time of harvest.

Samples were washed properly, then, dried at $65^{0}C$ for 72 hours, powdered and kept for analysis. Total N content was estimated using the modified micro kjeldahl method as described by Jackson (1973) [10]. Di-acid (HNO3: HClO4) extracts of plant samples were subjected to analysis of P using the vanadomolybdate phosphoric acid yellow colour (Ammonium molybdate + ammonium metavanadate) method and total potassium was determined flame photometrically from the same extract (Jackson, 1973) [10].

Result and Discussion

Dry matter production

Results pertaining to both the consecutive years and pooled mean values (Table 1) revealed that irrespective of different treatments, dry matter yield of paddy increased with advancement of crop growth upto 90 DAT. The results were supported by Singh and Mandal (1997) [22]; Shah and Kumar (2014) [19] and Jeyajothi and Durairaj (2016) [11]. In general comparatively higher dry matter yield of paddy was observed in soils amended with inorganic or organic sources of nitrogen applied either singly or in combination over control at different growth stages (Bar *et al*., 2004; Shah and Kumar, 2014 and Sahu *et al.*, 2015) [4, 19, 17]. The dry matter yield was mainly dependent on mineral –N status throughout the growing stage, and therefore, on mineralization of organic N forms, rice crop produced a good amount of dry matter yield. Enhanced agronomic effectiveness of inorganic and organic N sources was reflected in increased dry matter yield of paddy. The dry matter yield was found in soil treated with 100% RDN from urea + 10 tonnes *Azolla* ha^{-1} (T_8) which was at par with treatments 100% RDN from urea (T_2) and 75% RDN from urea + 25% RDN from FYM + 10 tonnes *Azolla* ha^{-1} (T_{10}) on 30, 60 and 90 DAT. However, on 90 DAT, these treatments remained at par again with 75% RDN from urea + 25% RDN from FYM (T_5) and 50% RDN from urea + 50% RDN from FYM (T_6) amended soil followed by soil treated with 50% RDN from urea + 50% RDN from FYM + 10 tonnes *Azolla* ha^{-1} (T_{11}) showing similarity effects with the remaining N treatments except soil incorporated with 20 tonnes *Azolla* ha^{-1} (T_4). Higher dry matter production might be due to increased availability of major nutrients through chemical fertilizer and mineralized nutrient from organic sources throughout the cropping period (Jeyajothi and Durairaj, 2016) [11]. This leads to enhancement of proficient growth and development of rice through highest uptake and utilization of the nutrients.

Table 1: Effect of Integrated nutrient management on dry matter production, grain and straw yield of Rice

Treatments	Dry matter production (kg ha^{-1})									Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	30^{th} DAT			60^{th} DAT			90^{th} DAT								
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	1771.00	1743.00	1757.00	5400.50	5243.00	5321.75	7605.50	7360.50	7483.00	3539.58	3233.00	3386.29	4395.33	4202.67	4299.00
T_2	2513.00	2460.50	2486.75	6940.50	7010.50	6975.50	10318.00	10206.00	10262.00	4922.02	4832.00	4877.01	6425.00	6476.00	6450.50
T_3	1914.50	1946.00	1930.25	6062.00	5855.50	5958.75	8988.00	9037.00	9012.50	4332.00	4211.98	4271.99	5317.37	5407.69	5362.53
T_4	1960.00	1953.00	1956.50	6034.00	5943.00	5988.50	8911.00	8911.00	8911.00	4102.67	3913.17	4007.92	5293.45	5224.27	5258.86
T_5	2317.00	2387.00	2352.00	6818.00	6905.50	6861.75	10157.00	10122.00	10139.50	5142.67	5069.54	5106.10	6216.67	6520.00	6368.33
T_6	2215.50	2373.00	2294.25	6692.00	6692.00	6692.00	10083.50	10031.00	10057.25	4911.00	4462.53	4686.76	6214.58	5946.00	6080.29
T_7	2093.00	2093.00	2093.00	6594.00	6482.00	6538.00	9996.00	9828.00	9912.00	4848.00	4563.37	4705.68	5731.25	5900.00	5815.63
T_8	2565.50	2548.00	2556.75	6993.00	7073.50	7033.25	10377.50	10335.50	10356.50	5024.33	4948.79	4986.56	6491.67	6392.00	6441.83
T_9	1953.00	1998.50	1975.75	6412.00	6464.50	6438.25	9688.00	9786.00	9737.00	4473.00	4423.28	4448.14	5579.27	5596.21	5587.74
T_{10}	2436.00	2530.50	2483.25	6874.00	7028.00	6951.00	10223.50	10265.50	10244.50	5294.00	5436.10	5365.05	6541.67	6583.00	6562.33
T_{11}	2177.00	2215.50	2196.25	6594.00	6580.00	6587.00	9996.00	9947.00	9971.50	5223.33	5079.01	5151.17	6275.00	6476.00	6375.50
T_{12}	2149.00	2215.50	2182.25	6492.50	6492.50	6492.50	9740.50	9828.00	9784.25	4850.00	4727.67	4788.83	5920.83	6258.00	6089.42
SEd(±)	61.69	62.04	43.34	118.94	118.34	82.67	239.47	238.30	154.51	141.36	122.12	95.97	198.82	271.96	161.81
CD(p=0.05)	127.93	128.66	86.86	246.67	245.42	165.67	496.64	494.21	309.65	293.17	253.26	192.32	412.32	564.00	324.27

Grain and straw yield

Significantly higher grain and straw yield of paddy were found in soil treated with inorganic and organic sources of nitrogen and their combinations over untreated control (Table 2). Similar reports on higher yield due to application of inorganic and organic N sources applied either singly or in combination were reported earlier by Husan *et al*. (2014); Islam *et al.* (2014); Sohel *et al*. (2016) and Kumar *et al*. (2018) [8, 9, 23, 12]. Pooled mean values showed that soil treated with 75% RDN from urea + 25% RDN from FYM + 10 tonnes *Azolla* ha^{-1}(T_{10}) yielded significantly higher grain and straw yield followed by 50% RDN from urea + 50% RDN from FYM + 10 tonnes *Azolla* ha^{-1} (T_{11}) showing parity with T_8 and T_5 on grain yield. However, T_{10} remained at par with 100% RDN from urea (T_2), 75% RDN from urea + 25% RDN from FYM (T_5)and 50% RDN from urea + 50% RDN from FYM + 10 tonnes *Azolla* ha^{-1} (T_{11}) on straw yield. Comparing between the sole application of inorganic and organic sources of N, significantly higher amount of grain and straw yield were observed in inorganic N treated soil (T_2) than organic sources (T_3 and T_4).The increased grain and straw yield due to combined application of organic manures and urea was mainly attributed to overall improvement in soil fertility including N supply (Azam, 1990) [2]. Crop yield depend mainly on the availability of NH_4^+-N in submerged condition. Organic manures alone or with urea N supply NH_4^+-N to the plant through continuous mineralization of organic N increasing N supply and ultimately giving higher grain and straw yield. This revealed the production efficiency of organic sources of nutrients due to improved soil fertility levels (Satish *et al.*, 2011 and Aditya and Kushwaha, 2018) [18, 1]. Application of urea N produced higher yield than organic manures alone might be due to inability of organic N sources to release nutrients at peak requirement of the crop.

Table 2: Effect of Integrated nutrient management on N content (%) in rice

	30 DAT			60 DAT			90 DAT			Grain			Straw		
Treatments	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	0.98	0.96	0.97	1.08	1.05	1.07	1.06	1.02	1.04	1.02	1.02	1.02	0.38	0.37	0.38
T_2	1.32	1.29	1.31	1.89	1.81	1.85	1.51	1.50	1.51	1.44	1.42	1.43	0.65	0.64	0.65
T_3	1.13	1.13	1.13	1.25	1.28	1.27	1.18	1.20	1.19	1.29	1.30	1.30	0.56	0.57	0.57
T_4	1.10	1.08	1.09	1.17	1.22	1.20	1.13	1.16	1.15	1.25	1.27	1.26	0.54	0.55	0.55
T_5	1.28	1.27	1.28	1.59	1.60	1.60	1.48	1.50	1.49	1.44	1.37	1.41	0.63	0.63	0.63
T_6	1.22	1.23	1.23	1.50	1.55	1.53	1.27	1.28	1.28	1.37	1.37	1.37	0.61	0.61	0.61
T_7	1.17	1.16	1.17	1.37	1.37	1.37	1.24	1.26	1.25	1.35	1.34	1.35	0.60	0.61	0.61
T_8	1.36	1.32	1.34	2.03	1.87	1.95	1.58	1.57	1.58	1.45	1.44	1.45	0.68	0.67	0.68
T_9	1.14	1.15	1.15	1.29	1.31	1.30	1.21	1.23	1.22	1.31	1.32	1.32	0.56	0.58	0.57
T_{10}	1.32	1.35	1.34	1.97	1.87	1.92	1.58	1.54	1.56	1.48	1.46	1.47	0.66	0.67	0.67
T_{11}	1.23	1.25	1.24	1.60	1.62	1.61	1.48	1.48	1.48	1.39	1.40	1.40	0.62	0.63	0.63
T_{12}	1.18	1.16	1.17	1.39	1.42	1.41	1.29	1.29	1.29	1.37	1.35	1.36	0.61	0.62	0.62
SEd(±)	0.03	0.03	0.02	0.04	0.03	0.05	0.03	0.03	0.02	0.03	0.03	0.02	0.01	0.01	0.01
CD(p=0.05)	0.05	0.05	0.04	0.07	0.07	0.10	0.06	0.06	0.04	0.06	0.06	0.04	0.03	0.03	0.02

Nitrogen content

N content in the plant in both the years of the experiment and pooled data followed similar pattern. N content was increased on 60 day followed by a declining trend on 90 DAT. The periodical declining trend of N content in plants with rice crop stage advancement was in agreement with Shinde *et al.* (2017) [21] and Meetei *et al.* (2019) [15]. It was attributed to dilution factor. Regardless of different sampling days, application of either inorganic, organic or their combinations significantly increased the N concentration over the untreated control under different sampling days. Grain and straw also observed the significantly higher N content with N treatments than control. The finding was also given by Nongmeikapam and Devi, 2018 [16] and Meetei *et al.*, 2019 [15]. The pooled data revealed that statistically higher N content was observed in T_8 on 30, 60 and 90 DAT which was at par with T_2 and T_{10} and only with T_{10} on 90 DAT. At harvest significantly higher content of N in grain was observed in T_{10} showing parity to T_8 and T_2. Similar effect of treatments T_8 and T_{10} in straw N content was also recorded. The improvement in N content in organic treatment along with inorganic source might be slow release of nutrients to the soil along with inorganic source and made it available throughout the growing period (Helgason *et al.*, 2007; Baitilwake *et al.*, 2012 and Meetei *et al.*, 2019) [7, 3, 15].

Phosphorus content

A decreasing trend in P content (Table 3) in rice with increased in crop growth in both the years as well as in pooled. P content decline with crop growth advancement was also observed by Liu and Zhu (1996) [14]; Latha *et al.* (2019) [13] and Meetei *et al.* (2019) [15]. The decrease in P content with the advancement of crop growth might be due to three reasons: dilution effect, caused by higher dry matter production, low P status of soil or fixation of applied P (Meetei *et al.*, 2019) [15]. Significantly higher P accumulation was recorded in all N treatments than control. Similar finding on higher concentration of P in rice crop was earlier given by Shinde *et al.* (2017) [21]; Latha *et al.* (2019) [13] and Meetei *et al.* (2019) [15]. The increased P content might be due to gradual release of nutrients from organic sources thereby increasing soil nutrients along with inorganic source and made available during the growing season. Decline in P content with advancement of crop growth was found in all the treatments. Comparing among the different treatments, significantly higher P concentration was recorded in T_{11} throughout the growing periods and also in grain and straw at harvest time. It was also observed that $T_{11,}$ T_6 and T_{10} remained statistically at par on P content in grain of rice.

Table 3: Effect of Integrated nutrient management on P content (%) in rice

	30 DAT			60 DAT			90 DAT			Grain			Straw		
Treatments	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	0.11	0.09	0.10	0.06	0.05	0.06	0.03	0.03	0.03	0.23	0.20	0.22	0.07	0.05	0.06
T_2	0.23	0.22	0.23	0.15	0.13	0.14	0.10	0.09	0.10	0.27	0.25	0.26	0.12	0.11	0.12
T_3	0.16	0.17	0.17	0.11	0.11	0.11	0.06	0.07	0.07	0.26	0.26	0.26	0.11	0.11	0.11
T_4	0.14	0.16	0.15	0.10	0.08	0.09	0.06	0.06	0.06	0.25	0.24	0.25	0.11	0.09	0.10
T_5	0.23	0.20	0.22	0.15	0.13	0.14	0.09	0.10	0.10	0.34	0.30	0.32	0.15	0.14	0.15
T_6	0.26	0.24	0.25	0.20	0.16	0.18	0.13	0.13	0.13	0.37	0.32	0.35	0.17	0.18	0.18
T_7	0.20	0.22	0.21	0.16	0.14	0.15	0.14	0.12	0.13	0.33	0.30	0.32	0.15	0.14	0.15

T_8	0.26	0.22	0.24	0.16	0.16	0.16	0.13	0.12	0.13	0.30	0.31	0.31	0.17	0.17	0.17
T_9	0.18	0.19	0.19	0.13	0.12	0.13	0.08	0.08	0.08	0.28	0.29	0.29	0.13	0.13	0.13
T_{10}	0.27	0.25	0.26	0.21	0.18	0.20	0.17	0.15	0.16	0.39	0.35	0.37	0.18	0.19	0.19
T_{11}	0.29	0.26	0.28	0.24	0.24	0.24	0.19	0.21	0.20	0.42	0.36	0.39	0.21	0.21	0.21
T_{12}	0.21	0.25	0.23	0.21	0.23	0.22	0.16	0.17	0.17	0.35	0.32	0.34	0.18	0.17	0.18
SE(d)±	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.003	0.003	0.01
CD(p=0.05)	0.02	0.02	0.04	0.01	0.02	0.03	0.01	0.01	0.02	0.01	0.01	0.04	0.01	0.01	0.02

Table 4: Effect of INM on K content (%) in rice at different growth stages

	30 DAT			**60 DAT**			**90 DAT**			**Grain**				**Straw**	
Treatments	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
T_1	1.31	1.28	1.30	1.28	1.25	1.27	1.17	1.15	1.16	0.27	0.24	0.26	1.06	1.03	1.05
T_2	1.60	1.60	1.60	1.43	1.36	1.40	1.25	1.22	1.24	0.33	0.33	0.33	1.21	1.23	1.22
T_3	1.59	1.60	1.60	1.44	1.40	1.42	1.26	1.25	1.26	0.34	0.33	0.34	1.23	1.25	1.24
T_4	1.59	1.60	1.60	1.43	1.38	1.41	1.24	1.23	1.24	0.34	0.34	0.34	1.21	1.24	1.23
T_5	1.63	1.65	1.64	1.45	1.45	1.45	1.35	1.28	1.32	0.36	0.37	0.37	1.25	1.25	1.25
T_6	1.65	1.66	1.66	1.48	1.48	1.48	1.32	1.31	1.32	0.38	0.38	0.38	1.30	1.26	1.28
T_7	1.66	1.76	1.71	1.51	1.52	1.52	1.32	1.33	1.33	0.39	0.40	0.40	1.28	1.28	1.28
T_8	1.63	1.65	1.64	1.45	1.43	1.44	1.31	1.27	1.29	0.35	0.33	0.34	1.25	1.24	1.25
T_9	1.60	1.61	1.61	1.42	1.41	1.42	1.28	1.26	1.27	0.33	0.35	0.34	1.25	1.25	1.25
T_{10}	1.90	1.72	1.81	1.51	1.47	1.49	1.37	1.30	1.34	0.38	0.38	0.38	1.28	1.30	1.29
T_{11}	1.90	1.92	1.91	1.53	1.50	1.52	1.42	1.38	1.40	0.39	0.40	0.40	1.32	1.31	1.32
T_{12}	1.92	1.91	1.92	1.51	1.52	1.52	1.38	1.36	1.37	0.42	0.43	0.43	1.30	1.33	1.32
SE(d)±	0.04	0.04	0.05	0.03	0.03	0.03	0.03	0.03	0.02	0.01	0.01	0.01	0.02	0.02	0.02
CD(p=0.05)	0.07	0.07	0.10	0.07	0.07	0.05	0.06	0.06	0.04	0.03	0.03	0.02	0.05	0.05	0.05

Potassium content

With advancement of crop growth, a progressive declined in K concentration was observed in rice in both the years. The result was also supported by Shahi *et al*. (2017) [20]; Latha *et al*. (2019) [13] and Meetei *et al*. (2019) [15]. The decline in K content might be due to dilution effect, caused by higher dry matter production, low K status of soil and fixation of applied K (Shahi *et al*., 2017) [20]. Application of either inorganic, organic or their combinations found the significantly higher K content in rice over control. This might be due to slow release of nutrients from organic sources thereby increasing K in soil along with inorganic source during the growing stage and made it available throughout the growing period (Baitilwake *et al.*, 2012 and Meetei *et al.*, 2019) [3, 15]. Comparing the different treatments, significantly higher K content was recorded in T_{12} on 30 DAT; T_{12}, T_{11} and T_7 on 60 and T_{11} on 90 DAT. However, at the time of harvest, T_{12} noted the highest K concentration in grain followed by T_{11} and T_7 while K content in straw was highest in both the treatments T_{11} andT_{12} showing parity with T_5, T_6 and T_{10}. In contrary to P content, the K content recorded in grain was low under different treatments.

Conclusion

From the experimental results, it can be concluded that that integrated nutrient management practices significantly increased higher dry matter production grain yield and NPK content in rice. 75% RDN from urea + 25% RDN from FYM + 10 tonnes *Azolla* ha^{-1} could be considered as a better option for achieving higher productivity of rice under transplanted condition.

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