

Growth and yield of rice as influenced by climate smart nitrogen and water management approaches

ABSTRACT

Achieving sustainability of the rice production in the irrigated areas in eastern India in general and Odisha in particular, under progressive climate change and variability necessitates the adoption of practices and technologies that increase food production, adaptation and mitigation in a feasible way. A field experiment was carried out for two consecutive years during 2020-21 and 2021-22 with *kharif* rice in the research farm of OUAT, Bhubaneswar. The experiment was carried out in a strip plot design having 16 treatments and 4 replications. All the growth attributes like plant height, tillers/hill, LAI and dry matter production were superior under 3DADPW and STBNR treated plot in water and nitrogen management approaches, respectively. Amongst the water management approaches in rice, 3DADPW resulted in higher grain yield (5.28 t/ha) followed by soil saturation. Similarly, INM practices produced higher grain yield (5.45 t/ha) as compared to other N-management options and was followed by STBNR.

Key words: 3DADPW, AWD, RTNM, STBNR, INM, LAI

1. INTRODUCTION

Rice has been cultivated in four major ecosystems in India viz., irrigated, rainfed lowland, rainfed upland and deep water system. More than half of rice growing area (55 %) is under rainfed ecosystem. In India, it is a staple food for over two thirds of the population and is cultivated over an area of 45.1 Mha with a production of 110.15 MT while in Odisha area is 4.31 Mha and production is 8.04 MT (Anon., 2021). The good yield of rice plant cannot be achieved without having better growth of crop plants at critical stages like tillering, panicle initiation which in turn helps the plant to be productive. The better growth of plant is directly related to the uptake of the nutrient which in turn helps in more dry matter accumulation and thus increasing the yield. Indiscriminate use of external inputs in the input intensive cereal production system has also gradually led to the deterioration of agri-environment and natural resources (Erenstein *et al.*, 2012). Rice being a high duty crop with the least water use efficiency requires alternate methods of irrigation to curtail water requirement without reduction in yield. The AWD is able to increase grain yield in the range of 6-15%, water productivity by 27-51% and reduce irrigation water applied by 23-43% as compared to conventional irrigation practices (Yang *et al.*, 2017). In rice only 30 to 40% of the applied N is recovered by the crop resulting in large losses of reactive N, which not only negatively affects yield but also, pollute the environment. Site-specific, demand-driven, balanced and efficient use of fertilizer N in conjunction with organic manures, bio-fertilizers, *etc* on the principle of integrated nutrient supply system is a right prescription to increase the NUE, minimize the use of synthetic fertilizers, facilitate carbon sequestration, minimize the pool of excessive N in soil and thus reduces nitrous oxide emissions and increases yield. Under progressive climate change scenario, it is the need of the hour for the adoption of climate smart practices and technologies that increase food production, adaptation and mitigation in a feasible way.

2. MATERIALS AND METHODS

2.1 Location of Experimental site

Field experiment was carried out for two consecutive years during 2020-21 and 2021-22 starting with *kharif* rice in the research farm of OUAT, Bhubaneswar (20°15'N latitude, 85°52'E longitude with an elevation of 25.9 m above MSL). The station falls under the East and South Eastern

Coastal Plains Agro-climatic Zone (AZ 63) of Odisha as per NARP classification and Agro Ecological Sub Region (AESR) 18.4 of NBSS & LUP classification with moisture deficit index (MDI) value of -0 to -20 and length of growing period (LGP) of 180 to 210 days. The climate of Bhubaneswar is characterized by hot, moist and sub-humid with hot summer and mild winter. The rainfall is monsoonal with unimodal distribution. The soil of the experimental site was sandy loam in texture.

2.2 Details of Experiment

The experiment was carried out in a strip plot design having 16 treatments and 4 replications. The nitrogen management approaches comprised of organics (N_1), INM (N_2), STBNR (N_3) and RTNM (N_4), respectively. The organic treatment (N_1) composed of Green manure + $1/3^{\text{rd}}$ N each by FYM and NOC (Neem oil cake). Similarly, INM (N_2) treatment comprised of Green manure + 75% STBNR. Organic manures such as dhanicha, farmyard manure, neem oil cake and poultry manure were analysed for NPK contents and then calculated equivalent to recommended dose of nitrogen of rice and sweet corn based on their N contents. All the organic manures were applied in line at sowing. *Dhaincha* was sown @ 25 kg seeds/ha as per the treatment specifications and was incorporated in the field at 42 DAS. In STBNR approach 100 kg N/ha was applied for rice as soil N content was low. In case of STBNR and INM approach nitrogen was applied in 3 splits *i.e.*, 25% at transplanting, 50% at active tillering and 25% at panicle initiation (PI) stage in the form of neem coated urea (NCU). Again in RTNM approach, nitrogen was applied based on the SPAD readings *i.e.*, 20 kg/ha as basal and @ 20 kg N/ha each, when the SPAD reading falls to 35.

The water management approaches for rice crop, W_1 : Continuous shallow submergence, W_2 : 3 DADPW, W_3 : Soil saturation throughout and W_4 : Alternate Wetting and Drying (AWD). In case of shallow submergence water level was maintained at 5 cm depth up to dough stage and thereafter excess water was drained out of experimental plot automatically by maintaining the height of the sluice height. Water was drained out 10 days before harvesting to facilitate easy harvesting. For 3Days after the disappearance of ponded water (DADPW), irrigation was applied three days after disappearance of ponded water to a shallow depth of 5 cm each time. In soil saturation throughout, the soil was kept as close to saturation as possible, thereby reducing the hydraulic head of the ponded water. In practice, a shallow irrigation was given to attain about 2 cm depth of ponded water. Whenever, water falls below 2 cm marked peg, once again irrigation was given, so that the soil was brought back always to above the saturation level. Irrigations were applied at 5-7 days interval depending on rainfall received. Again for alternate wetting and drying (AWD), a field water tube called '*panipipe*' was used which is typically 30 cm long with an inner diameter of 15 cm, inserted into the soil to a depth of 15-20 cm and soil was removed from inside the tube. The section of the *panipipe* below the soil surface is perforated to allow water to enter the pipe. It is helpful to assess the water level in the soil by simply measuring the depth of water in the pipe. Irrigation was applied to a shallow depth of 5 cm above the soil surface when water level inside the pipe falls to 15 cm below the soil surface.

Seedlings of prativa variety (125 days duration) were raised in wet bed method on a well puddled and levelled seed bed. The seeds were treated with Vitavax power (carboxin 37.5% + thiram 37.5%) @ 2.5 g/kg seed against seed borne diseases. Optimum soil moisture was maintained in the nursery for healthy growth of seedlings. Seedlings of 25-30 days were planted in the main field @ 2/hill at a spacing of 20 cm x 10 cm.

2.3 Details observations on plant height, tillers/plant, leaf area index (LAI), dry matter production and yield

2.3.1. Plant height: Plant height of 10 randomly selected plants in each plot was measured from the base of the plant to the tip of the topmost fully opened leaf/panicle at 30, 60, 90 DAT and at harvest and was expressed in centimeter (cm).

2.3.2. Tillers per hill: Number of tillers per hill was counted from 10 randomly selected hills in each plot at 30, 60, 90 DAT and at harvest and averaged to compute tillers/hill.

2.3.3. Leaf area index (LAI): Leaves of the hills uprooted for recording dry weight at different stages were detached for sun drying, oven drying and recording dry weight. The Specific Leaf Area *i.e.*, leaf area to leaf weight (cm²/g) was worked out at each stage and the same was multiplied by the leaf dry weight at each stage to obtain the leaf area/hill. Ground area occupied by each hill was taken as 20 cm x 10 cm. The LAI was worked out by using the following formula given by Watson (1952).

$$LAI = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Ground area (cm}^2\text{)}} = \frac{\text{Total leaf area of the hill (cm}^2\text{)}}{\text{Land area occupied by the hill (cm}^2\text{)}}$$

2.3.4. Dry matter accumulation: Dry weight of plant was recorded at 30, 60, 90 DAT and at harvest. The above ground plant parts of three sample hills from the destructive sampling area were cut close to the ground. Their dry weight was taken separately with help of electronic balance after sun drying followed by oven drying at 70°C till a constant weight was obtained and was expressed in g/hill.

2.3.5. Grain and straw yield: The crop was harvested plot wise leaving border and sampling areas. Threshing was done after sun drying for 3-4 days by a power operated thresher and grain and straw yields were separately recorded in kg/plot and converted to t/ha.

2.3.6. Harvest index: Harvest index was computed by using the following expression (Donald, 1962).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (t/ha)}}{\text{Biological yield (t/ha)}} \times 100$$

2.4 Statistical analysis

Data collected on various characters of rice, were analyzed statistically by following standard analysis of variance technique (ANOVA) for strip-plot design (Gomez and Gomez, 1984). The treatment variations were tested for significance by 'F' test. The standard error of mean SE (m)± and critical difference (CD) at 5% probability level were calculated to interpret the results.

Table 1. Initial soil physic-chemical characteristics of the experimental site

I. Physical characteristic		
Bulk density (Mg/m ³)	1.31	Core method (Black, 1965)
II. Chemical properties		
pH ((1:2.5:: soil:water))	6.1	Glass electrode pH meter (Jackson, 1973)
EC (dS/m) at 25°C	0.51	Digital Electrical Conductivity meter (Jackson, 1973)
Organic carbon (%)	0.39	Modified Walkley and Black (Jackson, 1973)
Available N (kg/ha)	183.1 (Low)	Alkaline potassium permanganate (Subbiah and Asija, 1956)
Available P (kg/ha)	11.8 (Medium)	Bray's method (Jackson, 1973)
Available K (kg/ha)	181.0 (Medium)	Ammonium acetate extraction method (Jackson, 1973)

3. RESULTS AND DISCUSSION

3.1. Plant height

Data pertaining to plant height (Table 2.) indicate progressive increase in height till harvest, although the increase was at a diminishing rate after 90 DAT. In general, the plants were taller during 2020- 21 than 2021-22. The average plant height at 30, 60, 90 DAT and at harvest were 36.4, 90.4,

111.8 and 113.3 cm, respectively. Water management approaches failed to express significant variation in case of plant height in both the years of experimentation, except at 60 DAT and harvest, where 3DADPW recorded higher plant height as compared to other treatments.

Among the different nitrogen management approaches, application of nitrogen based on soil test value along with green manuring (INM) recorded significantly higher plant height in all the stages (38.4, 94.8, 115.1, 115.4 cm at 30, 60, 90 DAT and at harvest, respectively) and it was followed by STBNR and RTNM treated plot. The lowest plant height was observed in organic (*i.e.* 1/3rd of N through FYM, 1/3rd through NOC and GM) treated plot.

Rapid growth rate under INM practice could be attributed to adequate nutrient supply to the crops due to rapid mineralisation of N from green manure and absorption by the crop that enhances various metabolic processes increasing net photosynthesis and better mobilisation of synthesized carbohydrate to amino acids and proteins. This in turn stimulated the rapid cell division and cell elongation, thus allowed the plants to grow faster (Kumari *et al.*, 2014).

3.2 Tillers/hill

The tillers per hill increased up to 60 DAT in both the years and declined thereafter (Table. 3). On an average, the crop produced 10.7, 15.9, and 15.1 tillers per hill at 30, 60 and 90 DAT, respectively. Among the water management approaches, 3 DADPW (W2) resulted in significantly higher number of tillers per hill (11.2, 16.7 and 15.6 at 30, 60 and 90 DAT) and it was on par with soil saturation (W3). The treatment received under INM recorded highest number of tillers per hill *i.e.* 12.1, 17.8 and 16.8 at 30, 60 and 90 DAT followed by inorganic practice. The organic sources of nitrogen produced the minimum number of tillers at all the stages.

3.3 Leaf area index (LAI)

LAI increased progressively up to 60 DAT in both the years while the value decreased as it headed towards maturity (Table 4.). The average LAI values at 30, 60 and 90 DAT were 1.28, 4.41 and 2.60, respectively. LAI followed the same trend as that of number of tillers per hill under water management approaches. Similarly, among the four nitrogen management options the leaf area index was found to be highest in INM treated plot at all the growth stages in both the years followed by STBNR, RTNM and organic treated plot, respectively.

3.4 Dry matter accumulation (g/hill)

The dry matter production has followed an increasing trend throughout the crop growth period with the average of 5.1, 14.1 and 34.8 g/hill at 30, 60 and 90 DAT, respectively (Table 5.).

Although the water management approaches did not have any significant impact on dry matter production at 30 DAT, but higher dry matter production was recorded under 3DADPW at 60 and 90 DAT followed by soil saturation. Nitrogen management approaches significantly influenced the dry matter production at all the stages in both the years. Among the nitrogen management options, INM treated plot resulted in the highest dry matter accumulation at all the stages, with an average of 5.7, 16.1 and 37.7g/hill at 30, 60 and 90 DAT, respectively, which were 1.7, 1.8 and 1.8 per cent higher than STBNR treated plot and 21.2, 25.7 and 14.9 per cent higher than RTNM treated plot as well as 32.5, 36.4 and 18.5 per cent higher than organic treated plot at respective stages.

More number of tillers, higher LAI and dry matter production were recorded under 3DADPW followed by soil saturation, might be due adequate availability of nutrients which enhanced the root activity. This finding is in conformity with Harishankar *et al.* (2016). The INM practice availability of nitrogen due to slow release of N from organic source, closely matching the N supply with rice N demand that increased the rate of leaf expansion leading to better interception of solar radiation by the canopy, enhanced photosynthesis, nitrogen metabolism, transformation of carbohydrates and oxidationreduction process in plants thereby producing more tillers, LAI and other growth attributes. Singh (2013) also reported higher chlorophyll content, tiller number, LAI as well as dry matter production of hybrid rice with 75% RDF + green manuring.

3.5 Grain yield, straw yield and harvest index

Among the water management approaches, 3 DADPW resulted in significantly higher grain yield (5.28 t/ha) followed by soil saturation throughout (5.15 t/ha) (Table 6.). While maximum straw yield was recorded under soil saturation and it was on par with 3DADPW. Similarly, In case of nitrogen management approaches, INM practice produced the maximum grain yield (5.45 t/ha), which was, on an average, 9.2, 11.9 and 13.5 per cent more than the STBNR, RTNM and organic practice, respectively. Similarly, the straw yield followed the same trend as that of grain yield under nitrogen management approaches. While, different nitrogen and water management approaches did not have any significant impact on harvest index of rice.

Higher grain yield under 3DADPW might be due to rotational irrigation practices which might have resulted in reduced nutrient loss and better uptake of nutrients leading to better yield attributing characters. The findings are in conformity with Sandhu and Mahal (2014), Nayak *et al.* (2017). Green manure crop *dhaincha* was a succulent herbage with high above and underground biomass having low C:N (18:1). On decomposition, N is released to the soil synchronizing with the demand that resulted in better yield attributes and yield. Due to deep root system, green manuring crops also increase P and K availability in plough layer of paddy soil, which is favourable to promote N absorption. In addition to the macro-nutrients (N, P and K), green manuring plants also contain micro- and secondary nutrients (Ca, Mg, Si, Zn, etc.), which promote and maintain the sustainable nutrients supply to the soil. Combining green manuring with N enhanced the photosynthetic rate, stomatal conductance of rice, effective translocation of assimilates to sink leading to increase in the dry matter accumulation as well as yield attributes. Mankotia (2007) and Mohanty *et al.* (2013) reported better performance of rice crop in INM comprising of green manuring resulting in higher grain and straw yields and harvest index.

4. CONCLUSION

Rotational irrigation to rice at 3DADPW resulted in higher grain yield (5.28 t/ha) followed by soil saturation. Similarly, INM practices produced higher rice grain yield (5.45 t/ha) as compared to other N-management options followed by STBNR. Integrated nutrient management approach comprised of 75% STBNR (inorganic) *i.e.*, 75 kg N/ha + green manuring with *dhaincha* along with irrigation at 3DADPW during *kharif* in rice is the optimal combination for better growth and higher yield.

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Table 2. Effect of climate smart nitrogen and water management approaches on plant height (cm) of rice at different stages

Particular	30 DAT			60 DAT			90 DAT			Harvest		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Water management												
W ₁	38.2	34.6	36.4	93.2	86.7	89.9	114.8	110.1	112.5	115.8	112.2	114.0
W ₂	38.2	34.5	36.3	96.1	88.5	92.3	113.8	110.6	112.2	115.9	112.7	114.3
W ₃	38.1	35.6	36.8	93.0	88.1	90.6	114.0	110.1	112.0	114.0	112.1	113.0
W ₄	37.8	34.4	36.1	91.2	86.3	88.7	112.8	108.6	110.7	113.2	110.5	111.8
SEm (±)	0.65	0.30	0.36	1.18	0.88	0.74	1.63	0.76	0.90	0.93	0.80	0.61
CD (0.05)	NS	NS	NS	3.8	NS	2.2	NS	NS	NS	NS	NS	1.8
Nitrogen management												
Organic	36.7	33.6	35.2	90.4	84.8	87.6	110.2	106.0	108.1	111.3	107.9	109.6
INM	40.3	36.6	38.4	98.3	91.4	94.8	117.5	112.7	115.1	115.9	114.8	115.4
STBNR	38.2	34.9	36.5	94.1	87.4	90.7	115.6	111.7	113.7	117.7	113.8	115.7
RTNM	37.1	34.1	35.6	90.7	85.9	88.3	112.1	108.9	110.5	113.9	110.9	112.4
SEm (±)	0.72	0.49	0.44	1.83	1.13	1.08	1.65	0.85	0.93	1.30	0.89	0.79
CD (0.05)	2.3	1.6	1.3	5.9	3.6	3.2	5.3	2.7	2.8	4.2	2.8	2.3

Table 3. Effect of climate smart nitrogen and water management approaches on tillers/hill of rice at different stages

Particular	30 DAT			60 DAT			90 DAT		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Water management									
W ₁	10.8	10.2	10.5	16.0	15.7	15.9	15.5	14.9	15.2
W ₂	11.5	10.9	11.2	16.8	16.5	16.7	16.0	15.3	15.6
W ₃	11.5	10.8	11.1	16.6	16.3	16.4	15.6	14.9	15.3
W ₄	10.4	9.7	10.1	14.6	14.3	14.4	14.4	13.8	14.1
SEm (±)	0.35	0.33	0.24	0.54	0.53	0.38	0.39	0.38	0.27
CD (0.05)	NS	NS	0.7	1.7	NS	1.1	1.3	1.2	0.8
Nitrogen management									
Organic	9.7	9.2	9.4	13.4	13.1	13.3	13.5	13.0	13.2
INM	12.5	11.8	12.1	18.0	17.6	17.8	17.1	16.4	16.8
STBNR	11.8	11.1	11.4	17.2	16.8	17.0	16.3	15.6	15.9
RTNM	10.2	9.6	9.9	15.5	15.2	15.4	14.6	14.0	14.3
SEm (±)	0.34	0.32	0.24	0.45	0.44	0.32	0.30	0.29	0.21
CD (0.05)	1.1	1.0	0.7	1.4	1.4	0.9	1.0	0.9	0.6

Table 4. Effect of climate smart nitrogen and water management approaches on leaf area index of rice at different stages

Particular	30 DAT			60 DAT			90 DAT		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Water management									
W ₁	1.34	1.24	1.29	4.40	4.23	4.31	2.69	2.53	2.61
W ₂	1.37	1.27	1.32	4.73	4.53	4.65	2.76	2.58	2.66
W ₃	1.32	1.23	1.28	4.58	4.39	4.48	2.71	2.54	2.62
W ₄	1.26	1.21	1.23	4.30	4.12	4.21	2.58	2.45	2.52
SEm (±)	0.036	0.021	0.021	0.206	0.198	0.143	0.061	0.057	0.042
CD (0.05)	NS	NS	NS	NS	NS	0.42	0.20	NS	0.13
Nitrogen management									
Organic	1.13	1.05	1.09	3.86	3.58	3.72	2.58	2.42	2.50
INM	1.47	1.37	1.42	5.05	5.00	5.03	2.80	2.63	2.71
STBNR	1.35	1.28	1.32	5.02	4.67	4.84	2.73	2.56	2.65
RTNM	1.33	1.24	1.28	4.09	4.05	4.07	2.64	2.48	2.56
SEm (±)	0.044	0.030	0.027	0.240	0.181	0.150	0.041	0.039	0.028
CD (0.05)	0.14	0.10	0.08	0.77	0.58	0.45	0.13	0.12	0.08

Table 5. Effect of climate smart nitrogen and water management approaches on dry matter production (g/hill) of rice at different stages

Particular	30 DAT			60 DAT			90 DAT		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Water management									
W ₁	5.1	4.8	4.9	14.1	13.6	13.9	35.4	34.2	34.8
W ₂	5.6	5.4	5.5	15.6	14.8	15.2	36.0	35.3	35.6
W ₃	5.4	5.1	5.2	14.6	14.1	14.4	36.4	34.4	35.4
W ₄	4.9	4.5	4.7	13.3	12.9	13.1	34.2	32.8	33.5
SEm (±)	0.19	0.21	0.14	0.55	0.75	0.47	1.01	0.97	0.70
CD (0.05)	NS	NS	NS	1.8	NS	1.4	NS	NS	2.0
Nitrogen management									
Organic	4.4	4.1	4.3	12.3	11.4	11.8	32.6	31.0	31.8
INM	5.9	5.6	5.7	16.3	15.9	16.1	38.4	36.9	37.7
STBNR	5.8	5.4	5.6	16.2	15.4	15.8	37.3	36.7	37.0
RTNM	4.9	4.6	4.7	12.8	12.8	12.8	33.6	32.0	32.8
SEm (±)	0.34	0.32	0.23	1.07	1.06	0.75	0.84	1.18	0.72
CD (0.05)	1.1	1.0	0.7	3.4	3.4	2.2	2.7	3.8	2.1

Table 6. Effect of climate smart nitrogen and water management approaches on grain yield, straw yield and harvest index of rice at harvest

Particular	Grain yield (t/ha)			Straw yield (t/ha)			HI (%)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Water management									
W ₁	5.02	4.76	4.89	7.10	7.24	7.17	41.38	39.85	40.62
W ₂	5.42	5.15	5.28	7.53	6.74	7.13	41.92	43.46	42.69
W ₃	5.42	4.88	5.15	7.93	6.69	7.31	40.68	42.32	41.50
W ₄	4.91	4.67	4.79	7.38	6.61	7.00	39.97	41.60	40.79
SEm (±)	0.155	0.135	0.103	0.183	0.378	0.210	0.700	0.839	0.546
CD (0.05)	0.50	0.43	0.31	0.58	1.22	0.62	NS	NS	NS
Nitrogen management									
Organic	4.94	4.67	4.80	6.94	6.58	6.76	41.68	41.72	41.70
INM	5.73	5.17	5.45	8.09	7.52	7.80	41.54	41.11	41.32
STBNR	5.09	4.88	4.99	7.48	6.63	7.05	40.45	42.44	41.44
RTNM	5.01	4.74	4.87	7.43	6.56	6.99	40.29	41.97	41.13
SEm (±)	0.108	0.097	0.072	0.204	0.236	0.156	0.857	0.735	0.565
CD (0.05)	0.35	0.31	0.22	0.65	0.76	0.46	NS	NS	NS