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Effect of nitrogen dose and seeding density in nursery on post flood seedling survival, growth, productivity and economics of rice (*Oryza sativa* L.) under submergence condition of Odisha

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Abstract
A field experiment was conducted at the Instructional Farm of the College of Agriculture, Chiplima, Sambalpur, Odisha for two consecutive years (2019 and 2020) in *kharif* seasons where submergence tolerant rice (Cultivar *'Swarna sub 1'*) was taken as test crop to investigate the effect of nursery management on seedling vigour and post flood survival of rice (*Oryza sativa* L.) as well as to study its subsequent effect on growth and yield under submergence. Application of fertilizers and sowing of the pre germinated seeds were done as per the treatments. The Main field lay out was done as per the nursery lay out. A common Fertilizer dose of $N:P_2O_5:K_2O$ at 80:40:40kg ha^{-1} was applied in the main field. Plants were completely submerged at 10 DAT with a water depth of 1.1 meter for a period of 15 days. From the experimental findings it revealed that application of $N:P_2O_5:K_2O$ at 100:40:40 kg ha^{-1} in the rice nursery produced the highest dry matter production $plant^{-1}$, seedling length and leaf area $seedling^{-1}$ at transplanting in nursery and was comparable with application of $N:P_2O_5:K_2O$ at 80:40:40 kg ha^{-1} (25 kg N ha^{-1} from FYM at 5 t ha^{-1}). The lower seeding density of 40 g m^{-2} and seedlings of 40 days old registered significantly higher dry matter production, seedling length and leaf area $seedling^{-1}$ in nursery than the higher seeding density of 60 g m^{-2} and seedlings of 30 days old respectively. The highest survival of plants after de submergence in the main field was recorded with application of $N:P_2O_5:K_2O$ at 80:40:40 kg ha^{-1} (25 kg N ha^{-1} from FYM at 5 t ha^{-1}) which was significantly higher than all other nutrient treatments. The lower seeding density of 40 g m^{-2} and seedlings of 40 days registered significantly higher post flood survival % than the higher seeding density of 60 g m^{-2} and seedlings of 30 days old, respectively. The chlorophyll content of rice leaves before submergence was significantly higher in the treatment receiving $N:P_2O_5:K_2O$ at 100:40:40 kg ha^{-1} (N_4) than all other nutrient management practices. The lower seeding density of 40 g m^{-2} (D_1) and the seedlings of 30 days (T_1) recorded significantly higher chlorophyll content in rice leaves before submergence as compared to higher seeding density of 60 g m^{-2} (D_2) and older seedlings of 40 days (T_2). Application of $N:P_2O_5:K_2O$ at 80:40:40 kg ha^{-1} (N_2) in the main plot treatment of rice nursery recorded the highest value of chlorophyll after de-submergence which was statistically at par with application of $N:P_2O_5:K_2O$ at 100:40:40 kg ha^{-1} (N_4) and was significantly higher than that of other nutrient management treatments. The lower seeding density of 40 g m^{-2} (D_1) in the nursery resulted significantly higher chlorophyll content in rice leaves just after de-submergence than higher seeding density of 60 g m^{-2} (D_2). The older seedlings of 40 days (T_2) produced significantly higher chlorophyll content of leaves after de-submergence than that of younger seedlings of 30 day (T_1). Application of $N:P_2O_5:K_2O$ at 80:40:40 kg ha^{-1} (N_2) in the main plot treatment of rice nursery recorded significantly higher value of dry matter production m^{-2} than all other nutrient treatments in the main field at 45 DAT, 105 DAT and at harvest. This treatment also recorded significantly higher grain yield, straw yield and return $rupees^{-1}$ invested than all other nutrient treatments. The lower seeding density of 40 g m^{-2} (D_1) in the nursery and older seedlings of 40 days recorded significantly higher dry matter production at 45 DAT, 75 DAT and at harvest as well as significantly higher grain yield, straw yield and return $rupees^{-1}$ invested than higher seeding density of 60 g m^{-2} (D_2) in the nursery and younger seedlings of 30 days, respectively.

Keywords: Rice, submergence, nursery management, nutrient management, age of seedling, seeding density

Introduction
Rice plays a vital role in India's agrarian economy as it is the source of livelihood for a millions of rural households as well as it plays an important role in food security of the nation.

World's rice demand is projected to increase by 38% from the year 2001 to 2025-2030 which is to be produced to keep pace with population growth with less land, water, labor and chemical inputs as well as under different biotic and abiotic stresses. The rice crop in India is currently grown in about 43.4 m ha, with the production of 157.2 m t and productivity of 3.62 t ha^{-1} (FAO 2016) [7]. The rain-fed low land rice occupying a major portion of total rice area has a significant role in total rice production of India. However, rice grown in these areas is very often subjected to partial or complete submergence for a period of one to two week at different stages of growth leading to poor yield of rice. About 13 m ha of rice land prone to floods, partial to complete submergence every year are present in eastern India including Odisha (Ram *et al.* 2009 and Bishoyi *et al.* 2017) [12, 4]. Odisha is one of the eastern states occupying 4.7% of total geographical area of country and about 10.2% of total rice area of the country. About 36% of the rice growing area in this state comes under the purview of rain-fed low lands, which suffer from frequent flash floods due to erratic behavior of the monsoon during *kharif* season causing drastic crop yield reduction. However, these flood prone ecosystems have enormous potential for higher food production to meet the ever increasing demands for rice supply because of predominance of good soils and freshwater resources (Ismail *et al.* 2013) [8]. In west central table land zone, the lowlands adjacent to river banks and natural drainage lines are subjected to partial to complete submergence for a period of 3 to 12 days at the time of heavy rainfall both in catchment and command area of the Hirakud dam, mostly in the month of August causing poor yield to complete damage of rice and heavy economic losses to the poor farmer of the region as well as the state. The average rice productivity of submergence prone areas in eastern India is 0.5 to 0.8 t ha^{-1}, whereas it is about 2.0 tha^{-1}in favorable rain-fed low lands, which is much lower than the input intensive irrigated system (Bhowmick *et al.* 2014) [3]. The low productivity of rice in these areas is mainly due to the use of traditional long duration land races or old varieties and suboptimal agronomic practices in the nursery as well as in the main field, which adversely affects the post flood survival and subsequent stand establishment (Sarangi *et al*. 2015) [15]. The adverse effects of flooding on rice vary by genotypes and of particular importance is the carbohydrate status of the plant before and after submergence, the developmental stage at which flooding occurs, duration and depth of submergence and level of turbidity of flood water The availability of tolerant varieties provide more opportunity for developing and validating proper management options for flood prone condition which could further boost and stabilize the productivity of rice in the submergence prone ecosystem. Proper nursery management is helpful for raising healthy and vigorous seedlings. Apart from having a big impact on survival and recovery after flooding, healthy seedlings can also produce up to 40% more rice even if complete submergence takes place during the vegetative stage (Ella *et al*. 2010) [5]. Practices such as balanced nutrition, optimum seeding density in the nursery, proper seedling age and careful handling at transplanting have been reported to mitigate the adverse effects of floods and other abiotic stresses following transplanting. (Sarangi *et al*. 2015) [15]. Therefore present study was designed to develop the nursery management techniques such as proper nutrient management, seeding density in nursery and suitable age of seedling for transplanting for enhancing the post flood survival of rice seedling and maximizing the productivity of rice in submerged areas.

Materials and Methods

The field experiment was conducted at the Instructional Farm of the College of Agriculture, Chiplima, Sambalpur, Odisha for two consecutive years (2019 and 2020) in *kharif* seasons where submergence tolerant rice (Cultivar *'Swarna sub 1'*) was taken as test crop. The area is situated in the eastern part of the country which falls under the sub-humid climatic condition and it belongs to the West central table land Agroclimatic Zone of Odisha. The experimental site falls under the sub-humid subtropical region with average annual rainfall of 1400 mm, concentrated mostly in the months of June to October. The experimental plot situated at an altitude of 155 m above mean sea level and is intersected by 20º21' N latitude and 80º85' E longitude. The soil at the experimental site is loamy sand. The soil pH of the experimental plot is 6.7. The bulk density and particle density of the soil were 1.55 and 2.44 g cm^{-3}, respectively. The organic carbon (%), available nitrogen (kg ha^{-1}), phosphorus (kg ha^{-1}) and potassium (kg ha^{-1}) status were 0.60, 382, 19.7 and 175.6, respectively. The experiment was laid out in split-plot design with three replications having sixteen treatment combinations. The treatments consist of four nutrient management *viz.* Farmers' practice - 25 kg N ha^{-1} with no P_2O_5 and K_2O (N_1); Recommended fertilizer dose- $N:P_2O_5:K_2O$ at 80:40:40 kg ha^{-1} (N_2); 75% of recommended dose of nitrogen - $N:P_2O_5:K_2O$ at 60:40:40 kg ha^{-1} (N_3) and 125% of recommended N - $N:P_2O_5:K_2O$ at 100:40:40 kg ha^{-1} (N_4) were assigned in the main plot. In each treatment 25 kg N through 5 t ha^{-1} of FYM was applied including in the farmers' practice and remaining N along with full P and K were applied through chemical fertilizer. The combinations of seeding density in nursery and age of seedling at transplanting each at two levels were allotted in sub plots. Four sub plot treatments were the combinations of 40 g m^{-2} seeding density (D_1); 60 g m^{-2} seeding density (D_2); transplanting of 30 days old seedling (T_1) and transplanting of 40 days old seedling (T_2). The size of the individual plot was taken as 2 sq. m (2.0 m x 1.0 m) for the nursery and 20 sq. m(5.0 m x 4.0 m) with net plot area of 11.2 m^2 (3.5 m x 2.8 m) for the main field. Seedlings were raised with staggered wet bed nursery with 15 days interval and transplanted on the same day. Application of fertilizers and sowing of the pre germinated seeds were done as per the treatments. The Main field lay out was done as per the nursery lay out. Two seedlings per hill at a spacing of 20 cm × 15 cm were transplanted. Ten extra rows of '*Swarna'* variety was planted on one side of the experimental plot as sensitive check to determine the time of de-submergence. A common Fertilizer dose of $N:P_2O_5:K_2O$ at 80:40:40kg $ha^{-1}$was applied in the main field. All P & K as basal and N in four equal split *i.e*. at basal, 7 days after de-submergence, maximum tillering stage and PI stage were applied in the experimental plot. Gap filling was done to ensure 100% plant population before submergence. Plants were completely submerged at 10 DAT with a water depth of 1.1 meter for a period of 15 days.

The biometric observation on seedling characters like seedling height, dry matter accumulation and leaf area of seedling were taken. The chlorophyll content of leaves was estimated just before and after submergence. The post survival % was recorded at seven days after de- submergence. The observations on growth and yield parameters like dry matter accumulation, number of panicles m^{-2}, filled grains $panicle^{-1}$, sterility %, 1000 grain weight, grain and straw yield were taken. Economics of rice production in different treatments under submergence condition was also calculated. Data were subjected to analysis of variance (ANOVA) using MS-Excel worksheet.

Results and Discussion

Dry matter

Application of nitrogen at 100 kg ha^{-1} (N_4) in rice nursery registered significantly higher dry matter accumulation seedling-

^{1} at transplanting than all other main plot treatments except the treatment receiving the recommended dose of nutrient (80 kg ha^{-1}), this treatment was statistically at par with the treatment receiving 100 kg nitrogen ha^{-1} in both the years as well as in pooled data. Application of higher dose of nitrogen in the nursery increased the nitrogen availability and uptake by the seedlings which in turn increased the production of photosynthates and also the dry matter accumulation.

Seedlings raised with lower seeding density (40 g m^{-2}) in nursery produced significantly higher dry matter of seedlings at transplanting in both the years of study as well as in pooled data as compared to higher seeding density (60 g m^{-2}) This was mainly because of less plant population in lower seeding density as compared to higher seeding density. The limited plants with same level of growth factors *i.e.* nutrient, space and light utilized the available resources and promoted vigorous and speedy growth of seedlings leading to more dry matter accumulation. The older seedlings (40 days old) recorded significantly higher dry matter than that of younger (30 days) seedlings irrespective of year of study and when pooled over two years. This was simply because of earlier sowing and spending more time in nursery by the older seedlings. Similar results were also reported by (Pervin *et al.* 2010) [11].

Seedling height

The data on seedling height of rice presented in Table 1 revealed that the seedling height of rice varied significantly with nutrient management in nursery irrespective of the years and also in pooled data. The seedling height increased with increase in nitrogen levels up to 100 kg N ha^{-1} in both years and in pooled figures. However, the treatment receiving 80 kg N ha^{-1}(N_2) was second in order and was at par with 100 kg N ha^{-1} (N_4) at transplanting in both the years. But in pooled figure, 100 kg N ha^{-1} (N_4) recorded significantly higher seedling height than all other treatments.

Though seeding density in nursery did not have significant influence on seedling height in the first year of study but lower seeding density of 40 g m^{-2} (D_1) in the nursery was capable of producing significantly higher seedling height than that of higher seeding density of 60 g m^{-2} (D_2) at transplanting in the second year and in the pooled figure of the two years. Lower seeding density in nursery provided more space to the rice seedlings, leading to less intra species competition for light, water and nutrients and supplying more quantity of growth factors leading to more seedling height.

The seedlings of 40 days old (T_2) produced significantly higher seedling height than that of seedlings of 30 days old (T_1) in the nursery at transplanting during both the years and when pooled over two years.

Leaf area of seedling at transplanting

Application of 100 kg N ha^{-1} in the nursery recorded the highest leaf area (Table 1), which was at par with 80 kg N ha^{-1} and significantly higher than all other treatments in both the year of study and in pooled data. The beneficial effect of higher doses of nitrogen in recording higher leaf area could be attributed to the greater availability of N, thereby inducing production of more soft tissues of leaves leading to their elongation (Mengel and Kirkby 1978) [9]. As the level of N supply increased, the extra protein produced presumably enlarged the leaves, which prevailed larger area for photosynthesis and increased the leaf area. This corroborated the findings of (Sarangi *et al*. 2015) [15].

Lower seeding density in the nursery (40 g m^{-2}) and older seedlings (40 days old) recorded significantly higher leaf area seedling^{-1} at transplanting than that of higher seeding density (60 g m^{-2}) and younger seedlings (30 days old), respectively. These findings were valid for both the years and when pooled over two years.

Table 1: Dry matter production, Seedling height and leaf area of seedling at transplanting as influenced by nursery management

Treatments	Dry matter accumulation (g plant^{-1})			Seedling height (cm)			Leaf area (cm^2 seedling^{-1})		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Nutrient Management (N)									
N_1	0.797	0.781	0.789	27.7	26.7	27.2	19.9	18.9	19.4
N_2	1.142	1.107	1.125	29.8	28.8	29.3	23.9	23.0	23.4
N_3	0.934	0.907	0.921	29.0	28.0	28.5	21.2	20.2	20.7
N_4	1.193	1.157	1.175	31.3	30.1	30.7	24.7	23.4	24.0
S. Em (±)	0.035	0.031	0.017	0.66	0.61	0.33	0.86	0.78	0.42
CD (P=0.05)	0.120	0.108	0.052	2.30	2.10	1.01	2.96	2.71	1.28
CV (%)	11.8	11.0	11.7	7.80	7.40	7.86	13.24	12.69	13.16
Seeding density (D)									
D_1	1.070	1.040	1.055	30.0	29.0	29.5	23.5	22.4	22.9
D_2	0.963	0.936	0.950	29.0	27.8	28.4	21.4	20.3	20.8
S. Em (±)	0.020	0.015	0.012	0.43	0.39	0.27	0.22	0.33	0.16
CD (P=0.05)	0.058	0.045	0.035	NS	1.13	0.76	0.63	0.95	0.47
CV (%)	9.6	7.7	8.5	7.08	6.66	6.36	4.74	7.48	5.18
Age of seedling at transplanting (T)									
T_1	0.874	0.850	0.862	28.6	27.5	28.1	21.6	20.6	21.1
T_2	1.160	1.126	1.143	30.4	29.3	29.8	23.2	22.2	22.7
S. Em (±)	0.020	0.015	0.012	0.43	0.39	0.27	0.22	0.33	0.16
CD (P=0.05)	0.058	0.045	0.035	1.24	1.13	0.76	0.63	0.95	0.47
CV (%)	9.6	7.7	8.5	7.08	6.66	6.36	4.74	7.48	5.18

N_1: Farmer's practice - 25 kg N ha^{-1} with no P_2O_5 and K_2O
N_2: Recommended dose of nitrogen with 40 kg each of P_2O_5 and K_2O - N:P_2O_5:K_2O at 80:40:40 kg ha^{-1}
N_3: 75% of recommended nitrogen with 40 kg each of P_2O_5 and K_2O - N:P_2O_5:K_2O at 60:40:40 kg ha^{-1}
N_4: 125% of recommended nitrogen with 40 kg each of P_2O_5 and K_2O - N:P_2O_5:K_2O at 100:40:40 kg ha^{-1}
(In each treatment 25 kg N was applied through 5 t ha^{-1} of FYM including in the farmers' practice)
D_1: 40 g m^{-2} seeding density in nursery, D_2: 60 g m^{-2} seeding density in nursery
T_1: Age of seedling at transplanting (30 days), T_2: Age of seedling at transplanting (40 days)

Post flood survival

Nutrient management in the nursery had considerable influence on post flood survival of rice (Table 2). Farmers' practice (5 t ha^{-1} FYM) recorded significantly lower survival than that of the treatments receiving nitrogen at different levels (N_2, N_3 and N_4) during post flood period. This might be due to production of weaker seedlings due to imbalanced fertilization. However, application of balanced fertilizer in the form of 40 kg P_2O_5 and 40 kg K_2O ha^{-1} along with different levels of nitrogen, where 25 kg of recommended N was applied from 5 t ha^{-1} FYM registered higher survival rate as compared to 5 t ha^{-1} alone after 15 days of submergence. This was because of combined application of balanced chemical fertilizers along with FYM supplied the nutrient to the rice seedlings in a balanced and sustained manner which increased seedling vigour in the form of dry matter, seedling height and leaf area at transplanting (Table 1). These robust seedlings were capable of sustaining the ravages of flood due to more carbohydrate content at the time of flooding and also having quick regeneration ability as explained by (Bhowmick *et al* 2014) [3]. During the first year the survival was the highest with application of 80 kg N ha^{-1} which was significantly higher than that of all other nutrient treatments except 60 kg N ha^{-1}. In the second year of study the treatment received 80 kg N ha^{-1} was also recorded highest survival rate, which was at par with the treatment received 100 kg N ha^{-1}. However, on analysis of pooled data, it was found that application of 80 kg N ha^{-1} was significantly higher than that of all other nutrient treatments. It was interesting to note that the survival % decreased both at lower level of nitrogen *i.e.* 60 kg ha^{-1} (N_3) and at higher level of nitrogen *i.e.* at 100 kg ha^{-1} (N_4). Seedlings fertilized with 100 kg N ha^{-1} recorded lower survival rate as compared to 80 kg N ha^{-1} might be due to application of excess nitrogen beyond 80 kg N ha^{-1} increased the nitrogen content in plant tissue rather than carbohydrate content, which made the plant susceptible to flooding as explained by Ella and Ismail (2006) [6]. Similar findings were also reported by (Ravi Kumar *et al*. 2012 and Bhowmick *et al.* 2014) [13, 3].

In the sub plots, the lower seeding density (D_1) and older seedlings (T_2) registered significantly higher survival percent than the higher seedling density (D_2) and younger seedlings (T_1), respectively during both the years and when pooled over two years. The beneficial effect of lower seeding density was due to production of healthy and robust seedlings owing to availability of wider space and greater accessibility to the growth factors. Similarly, the older plants having more mature tissue and sachharides content survived under submergence avoiding the damage from flood (Ram *et al.* 2009) [12].

Table 2 : Effect of nutrient management, seeding density in nursery and age of seedling on post flood survival of rice

Treatments	Survival %		
	2019	2020	Pooled
Nutrient Management (N)			
N_1	9.116 (83.6)*	9.10 (82.5)	9.136 (83.0)
N_2	9.782 (95.2)	9.724 (94.1)	9.753 (94.6)
N_3	9.536 (90.5)	9.472 (89.2)	9.504 (89.9)
N_4	9.459 (89.0)	9.605 (91.8)	9.532 (90.4)
S. Em (±)	0.074	0.056	0.035
CD (P=0.05)	0.255	0.195	0.108
CV (%)	2.692	2.06	2.551
Seeding density (D)			
D_1	9.562 (91.0)	9.555 (90.9)	9.558 (90.9)
D_2	9.409 (88.1)	9.398 (87.9)	9.404 (88.0)
S. Em (±)	0.036	0.029	0.023
CD (P=0.05)	0.104	0.086	0.066
CV (%)	1.849	1.51	1.689
Age of seedling at transplanting (T)			
T_1	9.402 (88.0)	9.392 (87.8)	9.397 (87.9)
T_2	9.569 (91.2)	9.561 (91.0)	9.565 (91.9)
S. Em (±)	0.036	0.029	0.023
CD (P=0.05)	0.104	0.086	0.066
CV (%)	1.849	1.51	1.689

* Figures in the parentheses are the original values (X). The data transformed to SQRT(X + 0.5)

N_1: Farmer's practice - 25 kg N ha^{-1} with no P_2O_5 and K_2O

N_2: Recommended dose of nitrogen with 40 kg each of P_2O_5 and K_2O - N:P_2O_5:K_2O at 80:40:40 kg ha^{-1}

N_3: 75% of recommended nitrogen with 40 kg each of P_2O_5 and K_2O - N:P_2O_5:K_2O at 60:40:40 kg ha^{-1}

N_4: 125% of recommended nitrogen with 40 kg each of P_2O_5 and K_2O - N:P_2O_5:K_2O at 100:40:40 kg ha^{-1}

(In each treatment 25 kg N was applied through 5 t ha^{-1} of FYM including in the farmers' practice)

D_1: 40 g m^{-2} seeding density in nursery, D_2: 60 g m^{-2} seeding density in nursery

T_1: Age of seedling at transplanting (30 days), T_2: Age of seedling at transplanting (40 days)

Total chlorophyll content of leaves

a) **Total chlorophyll content of leaves before submergence:** The results revealed that the total chlorophyll content of rice leaves just before submergence was the highest in the main plot treatment receiving the highest level of nitrogen application (100 kg ha^{-1}) (Table 3) which was significantly higher than all other lower levels of nitrogen in both the years and when pooled over two years. This was simply because of higher availability and uptake of nitrogen owing to production of more chlorophyll in leaves as nitrogen is one of the important element for chlorophyll production.

Use of lower seeding density (40 g m^{-2}) in the nursery registered significantly higher chlorophyll content of leaves (Table 3) as compared to higher seeding density (60 g m^{-2}) in both the years and when pooled over two years. This was because of less intra-plant competition between the seedlings due to wider spacing of seedlings in the nursery. Similarly, the age of seedling also had significant impact on chlorophyll content of leaves just before submergence. The younger seedlings (30 days) recorded significantly higher chlorophyll content in leaves as compared to older seedlings (40 days). This was because of more soft tissues on the leaves of the younger seedlings.

b) Total chlorophyll content of leaves after de-submergence: Nursery nutrient management had a significant impact on total chlorophyll content (Table 3) of leaves just after de-submergence in the main field. The treatment receiving fertilizers N : P_2O_5 : K_2O at 80 : 40 : 40 kg ha^{-1}, where 25 kg of recommended N was applied from 5 t FYM recorded significantly higher chlorophyll content than all other nutrient treatments except the treatment which received N : P_2O_5 : K_2O at 100 : 40 : 40 kg ha^{-1} (N_4). Similar trend was obtained during second year of study and when pooled over two years. The value was the highest in the treatment N_2 because the rate of depletion of chlorophyll during the submergence was the lowest in N_2 (Difference in the chlorophyll content of leaves just before and just after submergence). There was a good negative correlation between the rate of depletion of chlorophyll and the survival percentage (Table 2) as explained by (Ella *et al*. 2011) [6]. They explained that the survival percent was negatively correlated with chlorophyll loss during submergence but positively correlated with the chlorophyll content of leaves after submergence. Similar findings were also reported by (Sarkar and Bhattacharjee 2012) [16].

Among the sub plot treatments the lower seeding density of 40 g m^{-2} (D_2) registered significantly higher chlorophyll content (Table 3) as compared to higher seedling density of 60 g m^{-2} (D_2) due to more initial chlorophyll content and lower chlorophyll loss during submergence. Similarly the older seedlings of 40 days (T_2) registered more chlorophyll content as compared to younger seedlings (30 days) at just after de-submergence due to slower rate of chlorophyll loss in older seedlings during submergence which showed the positive correlation with survival rate as explained by (Ella *et al*. 2011) [6].

Table 3: Total chlorophyll content of leaves before submergence and after de-submergence as influenced by nutrient management, seeding density and age of seedling of rice

Treatments	Total chlorophyll content of leaves before submergence (mg g^{-1})			Total chlorophyll content of leaves after de-submergence (mg g^{-1})		
	2019	2020	Pooled	2019	2020	Pooled
Nutrient Management (N)						
N_1	1.38	1.40	1.39	0.70	0.69	0.69
N_2	1.55	1.58	1.56	1.08	1.06	1.07
N_3	1.44	1.46	1.45	0.88	0.86	0.87
N_4	1.85	1.90	1.88	1.06	1.04	1.05
S. Em (±)	0.04	0.04	0.02	0.02	0.02	0.01
CD (P=0.05)	0.12	0.14	0.06	0.08	0.08	0.04
CV (%)	7.95	8.90	8.80	8.27	8.58	8.63
Seeding density (D)						
D_1	1.59	1.62	1.61	0.96	0.93	0.95
D_2	1.52	1.55	1.53	0.90	0.89	0.89
S. Em (±)	0.02	0.02	0.02	0.01	0.01	0.01
CD (P=0.05)	0.07	0.07	0.05	0.04	0.04	0.03
CV (%)	7.07	7.36	7.11	7.75	7.03	7.25
Age of seedling at transplanting (T)						
T_1	1.59	1.62	1.61	0.91	0.89	0.90
T_2	1.52	1.55	1.53	0.95	0.93	0.94
S. Em (±)	0.02	0.02	0.02	0.01	0.01	0.01
CD (P=0.05)	0.07	0.07	0.05	NS	NS	0.03
CV (%)	7.07	7.36	7.11	7.75	7.03	7.25

N_1: Farmer's practice - 25 kg N ha^{-1} with no P_2O_5 and K_2O
N_2: Recommended dose of nitrogen with 40 kg each of P_2O_5 and K_2O -N:P_2O_5:K_2O at 80:40:40 kg ha^{-1}
N_3: 75% of recommended nitrogen with 40 kg each of P_2O_5 and K_2O - N:P_2O_5:K_2O at 60:40:40 kg ha^{-1}
N_4: 125% of recommended nitrogen with 40 kg each of P_2O_5 and K_2O - N:P_2O_5:K_2O at 100:40:40 kg ha^{-1}
(In each treatment 25 kg N was applied through 5 t ha^{-1} of FYM including in the farmers' practice)
D_1: 40 g m^{-2} seeding density in nursery, D_2: 60 g m^{-2} seeding density in nursery
T_1: Age of seedling at transplanting (30 days), T_2: Age of seedling at transplanting (40 days)

Dry matter accumulation in rice

From the Table 4 it was observed that application of 80 kg N ha^{-1} (N_2) in the main plot of nursery produced significantly higher dry matter of rice m^{-2} than that of farmers' practice of 25 kg N through FYM at 5 t ha^{-1} (N_1) and application of nitrogen at 60 kg ha^{-1} (N_3) at 45 DAT in both the years. On perusal of pooled data at 45 DAT, it was clear that application of 80 kg N ha^{-1} (N_2) was the best in recording significantly higher dry matter than that of all other treatments. The treatment receiving 100 kg N ha^{-1} (N_4) in the main plot was second in order at 45 DAT in both the years as well as in pooled data. The nutrient management in the nursery had significant influence on dry matter production of rice at 75 DAT. Application of nitrogen at 80 kg ha^{-1} (N_2) produced significantly higher dry matter than that of farmers' practice (N_1) in both years of study and also in pooled data over the years. This treatment (N_2) was at par with the treatments receiving 60 kg N ha^{-1} (N_3) and 100 kg N ha^{-1} (N_4) in both the years and in pooled data. On analysis of pooled data (Table 4) at 105 DAT and at harvest, it was noticed that application of nitrogen at 80 kg ha^{-1} (N_2) registered significantly higher dry matter production than that of all other treatments, followed by the treatments receiving 100 kg N ha^{-1} (N_4). However, the treatment producing the highest dry matter was at par with the treatment receiving 100 kg N ha^{-1} (N_4) in the first year and second year of study at 105 DAT and at harvest. The treatment farmers' practice (N_1) recorded the lowest dry matter irrespective of stages of growth and year of study. Application of nutrients N : P_2O_5 : K_2O at 80 : 40 : 40 kg ha^{-1}(where 25 kg of recommended N was substituted with 5 t FYM ha^{-1}) was the best in recording significantly higher dry matter production m^{-2} than all other treatments at 45 DAT, 105 DAT and at harvest in pooled data and higher dry matter production than all other treatments during other stages of growth and years of study. This might be because of application of proportionate fertilizer and FYM which supplied the nutrient in a balanced and sustained manner, owing to production of vigorous seedlings. These vigorous seedlings recorded more survival per cent during post flood period and continued to grow in the same pace as it was in nursery leading to production of more dry matter as compared to lower level of nitrogen. These findings were in accordance with the findings of (Singh *et al*. 2014) [17].

Seedlings raised with lower seeding density of 40 g m^{-2} (D_1) in the nursery recorded significantly higher dry matter production during post flood period as compared to higher seeding density (D_2) of 60 g m^{-2} during all the stages of growth and years of study. The beneficial effect of lower seeding density were most likely due to lower seedling competition for nutrient, light and space resulting in more vigorous seedling (Adhikari *et al*. 2013) [1] leading to higher post flood survival and dry matter production.

Transplanting with older seedlings (40 days old) proved beneficial in recording significantly higher dry matter (Table 4) production during post flood period as compared to younger seedlings (30 days old) at 45 DAT, 75 DAT and at Harvest. This was because the older seedlings recovered faster from the transplanting and submergence shock, possibly due to higher carbohydrate content (Adhikari *et al.* 2013) [1].

Table 4: Dry matter accumulation of rice in main field at different stages of observation as influenced by nursery management

Treatments	Dry matter accumulation (g m^{-2})											
	45 DAT			75 DAT			105 DAT			At Harvesting		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Nutrient Management (N)												
N_1	53.1	54.4	53.8	182.3	186.4	184.4	392.4	360.8	376.6	500.3	487.9	494.1
N_2	84.6	86.8	85.7	226.3	231.4	228.8	512.4	501.3	506.8	708.5	668.6	688.6
N_3	65.9	67.7	66.8	217.6	222.0	219.8	438.5	431.0	434.7	635.0	623.2	629.1
N_4	78.3	80.2	79.3	215.7	220.6	218.2	475.8	467.4	471.6	652.8	640.0	646.4
S. Em (±)	2.39	2.35	1.27	6.51	5.34	4.42	14.16	15.31	10.03	17.28	16.13	8.89
CD (P=0.05)	8.27	8.13	3.91	22.51	18.46	13.63	48.99	52.99	30.92	59.81	55.81	27.40
CV (%)	11.75	11.26	12.32	10.71	8.59	14.40	10.78	12.05	15.54	9.59	9.24	10.03
Seeding density (D)												
D_1	73.8	75.7	74.8	220.7	225.4	223.1	473.6	453.0	463.3	649.6	623.8	636.7
D_2	67.1	68.9	68.0	200.2	204.8	202.5	436.0	427.3	431.6	598.6	586.1	592.4
S. Em (±)	1.43	1.08	0.88	2.49	3.23	1.98	5.96	6.14	4.01	11.07	9.21	6.93
CD (P=0.05)	4.17	3.15	2.49	7.27	9.42	5.63	17.39	17.92	11.40	32.31	26.88	19.70
CV (%)	9.94	7.32	8.51	5.80	7.35	6.45	6.42	6.83	6.21	8.69	7.46	7.81
Age of seedling at transplanting (T)												
T_1	67.4	69.1	68.2	199.5	203.8	201.6	451.9	444.0	448.0	593.0	580.4	586.7
T_2	73.6	75.5	74.5	221.4	226.5	224.0	457.6	436.3	447.0	655.2	629.5	642.3
S. Em (±)	1.43	1.08	0.88	2.49	3.23	1.98	5.96	6.14	4.01	11.07	9.21	6.93
CD (P=0.05)	4.17	3.15	2.49	7.27	9.42	5.63	NS	NS	NS	32.31	26.88	19.70
CV (%)	9.94	7.32	8.51	5.80	7.35	6.45	6.42	6.83	6.21	8.69	7.46	7.81

N_1: Farmer's practice - 25 kg N ha^{-1} with no P_2O_5 and K_2O

N_2: Recommended dose of nitrogen with 40 kg each of P_2O_5 and K_2O -N:P_2O_5:K_2O at 80:40:40 kg ha^{-1}

N_3: 75% of recommended nitrogen with 40 kg each of P_2O_5 and K_2O - N:P_2O_5:K_2O at 60:40:40 kg ha^{-1}

N_4: 125% of recommended nitrogen with 40 kg each of P_2O_5 and K_2O - N:P_2O_5:K_2O at 100:40:40 kg ha^{-1}

D_1: 40 g m^{-2} seeding density in nursery, D_2: 60 g m^{-2} seeding density in nursery

T_1: Age of seedling at transplanting (30 days), T_2: Age of seedling at transplanting (40 days)

Grain yield

The data on grain yield of rice presented in Table 5 expressed that it varied significantly among the different main plot treatments during both years of study. The main plot treatment which received 80:40:40::N:P_2O_5:K_2O kg ha^{-1} (N_2) registered the highest grain yield, which was significantly higher than that of farmers' practice of 25 kg N through FYM at 5 t ha^{-1} (N_1) and the treatments of 60:40:40::N:P_2O_5:K_2O kg ha^{-1} (N_3) and was at par with 100:40:40::N:P_2O_5:K_2O kg ha^{-1} (N_4) in both the years of study. Where as in pooled data the treatment 80:40:40:N:P_2O_5:K_2O kg ha^{-1} (N_2) produced the highest grain yield and which was significantly higher than all other nutrient treatments. This was mainly because application of balanced fertilizers in the form of N, P_2O_5 and K_2O and FYM in the rice nursery produced the healthier and more vigorous seedlings measured in terms dry matter accumulations, Plant height and leaf area $seedling^{-1}$ at the time of transplanting as explained by (Ram *et al*. 2009) [12] and (Bhowmick *et al*. 2014) [3]. These seedlings having higher vigour, established faster after transplanting and showed higher survival rate during post submergence period as evident from Table 2. (Ros *et al.* 2003) [14]. The treatment receiving 80 kg N ha^{-1} in (N_2) in the nursery recorded the highest survival even higher than application of 100 kg nitrogen ha^{-1} (N_4). This was mainly due to higher N content of leaves with higher dose of nitrogen beyond a certain limit (80 kg N ha^{-1}). This was inconformity with the findings of Ella and Ismail (2006) [6] who explained that high N content of leaves at the time of transplanting reduced survival rate and recovery. The treatment N_2 having higher survival rate produced more number of tillers per unit area and also recorded the highest number of panicles m^{-2} which was an important criteria determining the grain yield of rice. Seedlings raised with balanced fertilization in nursery also showed better growth trends during post submergence period and have recorded higher dry matter accumulation during pre-anthesis period. The rice plants which recorded higher values of growth attributes during pre-anthesis period also promoted the production of higher yield attributing characters and ultimately the grain yield. Similar observations were reported by several workers (Adhikar *et al*. 2013, Singh *et al*. 2015 and Bhowmick *et al*. 2014) [1, 15, 3].

Among the sub plot treatments the seeding density in the nursery did not have significant effect on grain yield of rice during first and second year of study. However, seedlings raised with seeding density of 40 g m^{-2}(D_1) in the nursery, when transplanted produced higher grain yield than that of higher seeding density of 60 g^{-2} (D_2) during both the years under submerged condition. But the seeding density had significant impact on grain yield of rice in pooled data. Significant higher grain yield was obtained in the sub plot treatment with lower seeding density of 40 g m^{-2}(D_1) as compared to higher seeding density of 60 g m^{-2}(D_2). Lower seeding density of 40 g m^{-2}(D_1) was found to be better in recording higher grain yield of rice as compared to higher seeding density of 60 g m^{-2} (D_2) in the nursery This is because seedlings grown with wider spacing were healthier and more vigorous and capable of higher post flood survival as well as higher growth and yield parameters resulting in production of higher grain yield as compared to higher seeding density. This was in accordance with the findings of and (Adhikari *et al*. 2013) [1].

Older seedlings had a highly significant and positive effect on grain yield in both the years and in pooled data. The older seedlings increased grain yield by 5.2% and 4.3% in the first and second, respectively. These results were in agreement with (Bhagat *et al*. 1991) [2] who found that 40 days old seedlings produced higher grain yield as compared to 30, 50 and 60 days old seedlings. It must be noted in the present experiment that the sowing of seeds for older seedlings was done 10 days ahead (but transplanted at the same time as young seedlings) availing more favourable environment for growth and produced more vigorous seedlings. These seedlings also registered higher post flood survival rate, higher values of growth and yield attributing characters and ultimately the grain yield of rice. Similar opinions were put forward by (Mustari *et al*. 2013 and Sumon *et al*. 2013) [10, 19].

Straw yield

It was observed that the straw yield of rice varied significantly among the main plot treatments in the nursery during both the years and when pooled over the years. Application of 80:40:40::N:P_2O_5:K_2O kg ha^{-1} (N_2) in the nursery produced significantly higher straw yield than that of all other treatments except the treatments receiving100:40:40::N:P_2O_5:K_2O kg ha^{-1} (N_4) in both the year of study. This treatment (N_2) also produced the highest straw yield and was statistical at par with the treatments receiving100:40:40::N:P_2O_5:K_2O kg ha^{-1} (N_4) in both the year of study. On perusal of pooled data over two years. It was observed that the main plot treatment received 80:40:40::N:P_2O_5:K_2O kg ha^{-1} (N_2) produced the significantly higher straw yield than that of other treatments.

With regards to seeding density and age of seedlings both showed significant influence on straw yield of rice under 15 days of submergence. Lower seeding density (40 g m^{-2}) produced 4% higher straw yield as compared to younger seedlings in both the years. Similarly the older seedlings produced 4.6% and 4.59% higher straw yield in the first and second, respectively as compared to that of younger seedlings (30 days). Similar findings have also been reported by (Singh *et al*. 2014 and Sarangi *et al*. 2015) [17, 15].

Return rupees-1 invested

It was indicated that among the nutrient management treatments, application of 80:40:40::N:P_2O_5:K_2O kg ha^{-1} (N_2) in the nursery recorded the highest value of return rupees-1 invested ratio followed by the treatment receiving100:40:40::N:P_2O_5:K_2O kg ha^{-1} (N_4). Farmers' practice of 25 kg N through FYM at 5 t ha^{-1} (N_1) recorded the lowest value. Similar findings were observed in both the years and in mean data, which was linked with the higher grain and straw yield and comparatively lower cost of production Similar monetary benefit was also reported by (Sarangi *et al*. 2015) [15]. Among the sub plot treatments, the lower seeding density of 40 g m^{-2} (D_1) in nursery and transplanting of seedlings of 40 days (T_2) recorded higher return rupees-1 invested than that of higher seeding density of 60 g m^{-2}(D_2) and seedlings of 30 days (T_1), respectively during both the years of study and also in mean data.

Table 5: Yield and economics of rice as influenced by nursery management

Treatments	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Return rupees-1 invested		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Mean
Nutrient Management (N)									
N_1	3.53	3.38	3.46	4.45	4.29	4.37	1.39	1.32	1.36
N_2	4.21	4.05	4.13	5.07	4.96	5.01	1.63	1.57	1.60
N_3	3.90	3.81	3.85	4.77	4.65	4.71	1.51	1.47	1.49
N_4	4.06	3.92	3.99	4.90	4.78	4.84	1.57	1.52	1.54
S. Em (±)	0.08	0.06	0.04	0.08	0.08	0.05	-	-	-
CD (P=0.05)	0.28	0.22	0.13	0.28	0.29	0.16	-	-	-
CV (%)	11.61	11.93	13.26	8.58	9.06	10.03	-	-	-
Seeding density (D)									
D_1	4.00	3.87	3.94	4.89	4.77	4.83	1.54	1.49	1.52
D_2	3.84	3.72	3.78	4.70	4.58	4.64	1.50	1.45	1.48
S. Em (±)	0.06	0.05	0.04	0.06	0.06	0.04	-	-	-
CD (P=0.05)	NS	NS	0.10	0.18	0.17	0.12	-	-	-
CV (%)	7.19	6.69	6.52	6.40	6.17	6.01	-	-	-
Age of seedling at transplanting (T)									
T_1	3.82	3.71	3.77	4.69	4.57	4.63	1.48	1.44	1.46
T_2	4.02	3.87	3.95	4.91	4.78	4.84	1.56	1.51	1.54
S. Em (±)	0.06	0.05	0.04	0.06	0.06	0.04	-	-	-
CD (P=0.05)	0.17	0.15	0.10	0.18	0.17	0.12	-	-	-
CV (%)	7.19	6.69	6.52	6.40	6.17	6.01	-	-	-

N_1: Farmer's practice - 25 kg N ha^{-1} with no P_2O_5 and K_2O

N_2: Recommended dose of nitrogen with 40 kg each of P_2O_5 and K_2O -N:P_2O_5:K_2O at 80:40:40 kg ha^{-1}

N_3: 75% of recommended nitrogen with 40 kg each of P_2O_5 and K_2O - N:P_2O_5:K_2O at 60:40:40 kg ha^{-1}

N_4: 125% of recommended nitrogen with 40 kg each of P_2O_5 and K_2O - N:P_2O_5:K_2O at 100:40:40 kg ha^{-1}

1. D_1 : 40 g m^{-2} seeding density in nursery, D_2 : 60 g m^{-2} seeding density in nursery

T_1: Age of seedling at transplanting (30 days), T_2: Age of seedling at transplanting (40 days)

Conclusion

Application of $N:P_2O_5:K_2O$ at 80:40:40 kg ha^{-1} where 25 kg N applied through FYM @ 5 t ha^{-1}, seeding density of 40 g m^{-2} in the nursery and transplanting of 40 days old seedlings resulted comparable growth parameters of seedling at transplanting. Such practices significantly increased the post flood survival of rice leading to record significantly higher growth parameters, grain yield and return $rupees^{-1}$ invested of rice in flood prone low land condition. These practices can effectively be implemented in other states of India as well Bangladesh and in the regions having similar ecologies.

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