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A review on nursery management for post-planting seedling survival, higher growth and enhanced productivity of rice (*Oryza sativa* L.) in Eastern India

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Abstract

Research on Nursery management in rice carried out in different parts of South East Asia have been reviewed with findings that application of balanced nutrition in the form of inorganics and organics in rice nursery produced healthier seedlings as compared to organic and inorganic alone. Application of nitrogen from recommended dose up to 100 kg ha^{-1} in the nursery along with suitable doses of P_2O_5 and K_2O was beneficial in recording higher growth, yield attributing characters and yield of medium or late duration rice under submergence condition. Application of N at higher dose (basal and top dressing) without P_2O_5 and K_2O was detrimental under flash flood condition. Use of P_2O_5 and K_2O up to 40 kg ha^{-1} along with different doses of N recorded higher growth, yield attributes and yield. The effect of seedling density in nursery under submergence condition was also investigated by several workers. Many of the workers reported that lower seeding (25 to 50 g m^{-2}) was superior in recording the higher seedling growth and better performance during post flood period. The older seedlings up to 45 days old performed better in terms of post flood survival, growth and yield of rice as compared to 25 to 30 days old younger seedlings.

Keywords: Age of seedling, correlation, economics, nutrient management, seedling density and submerged rice

Introduction

Rice is the major staple food for more than half of the world population and 90% of rice is being produced and consumed in Asia (Bhowmick *et al*., 2014) [6]. Rice is grown in diversified ecosystem starting from irrigated plain land to rain-fed upland as well as flood prone low lands. It is the major crop in submergence prone or flood affected low land areas of South and Southeast Asia (Ismail *et al*., 2013) [17]. The flood prone ecosystem includes shallow, flash flood area, medium, deep and very deep water logged areas and tidal wet lands (IRRI, 1984). About 22 million ha of rice land are flood prone in South and Southeast Asia and more than 100 million people primarily depend upon this ecosystem for their livelihood (Hossain and Abedin, 2004) [15]. Nearly 18 million ha area in South and Southeast Asia are not being used because of floods (Singh *et al*., 2004) [39].

Rice is grown in various ecosystems, providing food for millions of subsistence farming families. It is the widely cultivated crop in diverse flood prone areas of Eastern India including Odisha. The productivity of rice in these ecosystems is quite low due to lack of suitable high yielding varieties tolerant to prevailing biotic and abiotic stresses, particularly to the flash flood condition during the initial stages of crop establishment. The major cause of low productivity is poor survival on submergence in transplanted rice. The productivity can be increased by use of suitable tolerant varieties and adapting proper crop management practices both in nursery and transplanted field. Robust seedlings provide enough strength to withstand the damage caused by continuous submergence and also show rapid regeneration after receding of flood water (Ram *et al*., 2009) [31]. Balanced nutrition and optimum seed density in nursery produce robust seedlings (Ella and Ismail, 2006) [11]. Age of seedling at the time of transplanting influences the carbohydrate accumulation in the plant, which affects the survival of rice plant after receding of flood water (Das *et al*., 2005) [10].

Problems and importance of submerged rice in India and Odisha

The flash flood due to continuous rain and over flowing of rivers seriously affects the crop establishment as well as survival, leading to severe yield losses, especially if it occurs during the early vegetative stage and prolongs for more than a week. In eastern India, about 13 million ha of rice lands are prone to floods, causing partial to complete submergence every year (Ram *et al.*, 2009) [31]. 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 t ha^{-1} for favorable rainfed low lands, being much lower than the input intensive irrigated system (Bhowmick *et al*., 2014) [6]. However, these flood prone ecosystem has enormous potential for more food production to meet the ever increasing demands of rice because of the pre-dominance of good soil and fresh water resources (Ismail *et al.*, 2013) [17].

Odisha in eastern India is one of the important states facing the flood like situation every year in the low land rice areas due to heavy rainfall, receiving water from catchment areas of the rivers like Mahanadi, Brahmani, Baitarani, Subarnarekha, Rushikulya *etc.* The over flowing of river and congestion drainage system in the river deltas causes partial to complete submergence of rice crop for a period of 2 days to 2 weeks in 1,21,000 ha of rice area (Singh *et al.*, 2004) [39] leading to poor crop establishment and substantial yield loss. The farmers of this ecosystem are resource poor and face severe economic losses. The submergence or flash flood causes threat to the livelihood of the major section of the farmers.

Nursery management on submerged rice

Seedling health at nursery is extremely important as it affects crop establishment and survival, especially, when submergence occurs at the early stages of crop growth and also under recurrent floods. The beneficial effects of seedling health prior to transplanting seems to be more evident following severe submergence conditions and are directly related to seedling survival and rapid recovery growth after the recession of flood (Ram *et al*., 2009) [31].

Sharma (1995) [37] indicated that water depth after transplanting and initial vigour of plants (height and dry weight) appeared to be the key factors in determining successful crop establishment and yield under flood prone low land conditions.

Nutrient management in the nursery on growth Parameters of rice

Maskina *et al.* (1985) [20] after conducting an experiment to study the effect of organic (Farm yard manure, Green manure, Poultry manure and Azolla) and inorganic nitrogen (0, 60, 120 kg ha^{-1}) sources on the health of rice seedling at Ludhiana reported that application of 120 kg N ha^{-1} proved significantly superior to 60 kg N ha^{-1} in nursery in terms of dry matter, plant height and seedling quality in rice variety *PR-106*. Addition of green manure, poultry manure, azolla and FYM improved the quality of rice seedlings in the order of 76, 54, 21 and 10 percent respectively, over inorganic fertilizer. They also reported that content of N and Zn decreases with age of seedling in treatments receiving inorganic N alone.

Raju *et al*. (1989) [30] studied the effect of nursery fertilization on seedling vigour of rice. They concluded that basal application 100 kg N along with 50 kg ha^{-1} P_2O_5 and K_2O each recorded the highest plant height (36 cm), biomass per plant (980 mg) and root length (21.5 mm). The plant height, biomass plant $^{-1}$ and root length were significantly higher than the control and only P_2O_5 and K_20 application.

Pervin (2005) [27] reported that enriching nursery beds of rice with 60 kg N, 40 kg P_2O_5 and 20 kg $ZnSO_4$ ha^{-1} along with FYM (10 t ha^{-1}) improved seedling vigour relative to the unfertilized control treatment (measured by plant height and shoot biomass) with about 10-30% more shoot carbohydrate concentration before transplanting. Such seedlings exhibited better survival after 10-15 days of complete natural submergence. Such seedlings also recorded higher plant height and biomass after 15 days of recovery period.

Singh *et al.* (2014) [6] observed significantly higher survival rate of 90.8 and 89.9% after de-submergence, when potassium was applied alone (0: 0: 40::N: P_2O_5: K_2O kg ha^{-1}) and when K was applied together with a higher dose of P_2O_5 (0: 60: 40::N: P_2O_5: K_2O kg ha^{-1}) respectively, in the nursery raising of rice variety *Swarna sub1* for submerged condition. Significantly higher seedling height of 17.67 cm at the time of transplanting was recorded with application of 40:40:40:: N:P_20_5:K_2O kg ha^{-1} in the nursery. However, after recovery from submergence, the nursery treatment received K_2O alone (40 kg ha^{-1}) or in combination with P_2O_5 (60 kg ha^{-1}) recorded significantly higher plant height. Application of nutrient at 0:40:40: N:P_2O_5:K_2O kg ha^{-1} in the nursery bed produced the highest dry mater (0.61 mg $plant^{-1}$) in rice plant just before submergence. However, the application of nutrient at 0:60:40:: N:P_2O_5:K_2O kg ha^{-1} recorded the highest dry matter accumulation during post submergence period.

Bhowmick *et al.* (2014) [6] stated that the levels of nutrient management in nursery had significant impact on seedling vigour, post flood survival and subsequent performances of rice variety *Swarna sub1* under submerged condition. Application of nutrient dose of 80:40:40::N:P_2O_5:K_2O kg ha^{-1} in the nursery recorded better seedling vigour in terms of dry matter accumulation (1.11 g $seedling^{-1}$), seedling height (22.23 cm) and root length (16.38 cm) at the time of transplanting as compared to other lower levels of nutrients. This treatment also resulted higher post flood survival (93.8%) and improved crop stand in terms of tillers m^{-2} both at 25 (212.58) and 45 DAT (358.33) as well as plant height (103.97 cm) at harvest.

Sarangi *et al.* (2015) [33] also reported that the application of balanced fertilizer (50:30:15:: N:P_20_5:K_2O kg ha^{-1} + 5 t ha^{-1} FYM) in the rice nursery produced significantly higher seedling biomass at 1st week (0.56 g 10 $seedling^{-1}$) 2nd week (0.81 g 10 $seedling^{-1}$) after sowing and also at the time of uprooting (9.19 g 10 $seedlings^{-1}$) as compared to other lower levels of fertilizers. This treatment also produced significantly higher shoot length (60 cm), root length (15.5 cm), number of green leaves $seedling^{-1}$ (5.2), leaf area $seedling^{-1}$ (58.7 cm^2) and leaf N concentration (1.93%) at the time of uprooting than the other lower levels of N and unbalanced fertilization under rain-fed low land condition.

Bishoyi *et al.* (2016) [7] working on submerged rice in west central table land zone of Odisha, reported that seedling height increased with increase in nitrogen levels and the highest at 100 kg N ha^{-1} at 10 DAS (10.6 cm), 20 DAS (22.5 cm) and at transplanting (30.7 cm). This treatment was statistically at par with the treatment receiving $N:P_2O_5:K_2O$ at 80:40:40 kg ha^{-1} in all the growth stages. The treatment receiving $N:P_2O_5:K_2O$ at 100:40:40 kg ha^{-1} produced significantly higher dry matter at 20 DAS (0.352 g $plant^{-1}$) and at transplanting (1.175 g $plant^{-1}$) than all other treatments. The leaf area $seedling^{-1}$ at transplanting was the highest (24.0 cm^2 $seedling^{-1}$) with the application of $N:P_2O_5:K_2O$ at 100:40:40 kg ha^{-1}, which was at par with the treatment receiving $N:P_2O_5:K_2O$ at 80:40:40 kg ha^{-1}. So far as post flood survival is considered application of $N:P_2O_5:K_2O$ at 80:40:40 kg ha^{-1} recorded significantly higher post submergence survival (94.6%) than that of other levels of nitrogen after 15 days of complete submergence. It was interesting to note that the survival percentage decreased both at lower levels of nitrogen *i.e.* 60 kg ha^{-1} (89.9%) and at higher levels of nitrogen *i.e.* at 100 kg ha^{-1} (90.4%). 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} (1.88 mg g^{-1}) than lower levels of nitrogen application. However, after de-submergence application of $N:P_2O_5:K_2O$ at 80:40:40kg ha^{-1} in the nursery recorded significantly higher value of chlorophyll (1.07 mg g^{-1}) than lower levels of nutrient treatments. The crop growth rate of rice during 75-105 days after transplanting, showed that the treatments receiving $N:P_2O_5:K_2O$ at 80:40:40 kg ha^{-1} in the nursery expressed the highest CGR (9.3 g m^{-2} day^{-1}) which was significantly higher than 60 and 100 kg N ha^{-1} keeping the dose of P_2O_5 & K_2O constant.

Seeding density in nursery on growth parameters of rice

Lal and Roy (1996) [19] studied the effect of seed density (50, 75 and 100 kg/1000 m^{-2}) in nursery on seedling vigour and reported that the lower seed density of 50 kg m^{-2} recorded significantly higher root length (28.2 cm), plant height (32.7 cm) and leaf area $plant^{-1}$ (15.1 cm^2) as compared to higher seed density of 75 and 100 kg/ 1000 m^{-2}. Singh *et al.* (2004) [39] from an experiment confirmed that the lower nursery seed density of 50 g m^{-2} recorded significantly higher survival per cent as compared to higher seed density when 40 days old seedling was submerged for 15 days. Ram *et al*. (2009) [31] reported from an experiment, conducted at BRRI, Bangladesh that a seed density of 75 g m^{-2} in the nursery recorded higher survival rate (up to 23%) after complete submergence for 10 days after transplanting. Naem *et al.* (2010) [24] informed that use of lower seed rate in the nursery produced more vigorous seedlings in terms of seedling height and dry matter accumulation as compared to higher seed rate. Farooq *et al.* (2007) [13] also observed an increasing trend in plant height, and productive tillers $hill^{-1}$ when transplanted with healthy and vigorous seedlings.

Similar result was corroborated by Bhowmick *et al.* (2014) [6] of using lower seeding density (25 g m^{-2}) in the nursery for production of higher seedling height (21.60 cm), root length (16.03 cm), higher dry matter accumulation (1.04 g $seedling^{-1}$) at transplanting. It also produced the higher post flood survival (94.27%) and better crop stand in terms of number of tillers m^{-2} both at 25 (210.92) and 45 DAT (357.08), plant height at harvest (103.96 cm) as compared to higher seeding density (40 g m^{-2}) in rice variety *Swarna sub1* under flood prone low land condition. In a similar experiment Sarangi *et al.* (2015) [33] also proved the beneficial effect of lower seeding density (25 g m^{-2}) in rice nursery recording significantly higher biomass production at 1st week (0.50 g 10 $seedlings^{-1}$), 2nd week (0.80 g 10 $seedlings^{-1}$) and at uprooting (7.25 g 10 $seedlings^{-1}$) as compared to higher seed density (40 g m^{-2}). The lower seed density also recorded significantly higher shoot length (55.2 cm), root length (14.9 cm), number of green leaves $seedling^{-1}$ (4.4), leaf area $seedling^{-1}$ (47.0 cm^2) and leaf nitrogen concentration (1.61%) at uprooting as compared to higher seed density.

Bishoyi *et al.* (2016) [7] from an experiment over two years at College of Agriculture, Chiplima (OUAT) concluded that the use of lower seeding density (40 g m^{-2}) in the nursery produced statistically higher seedling height (29.5 cm), higher dry matter accumulation (1.055 g $seedling^{-1}$) and higher leaf area of 22.9 cm^2 $seedling^{-1}$ at transplanting and also the higher post flood survival (90.9%) after 15 days of complete submergence as compared to higher seeding density (60 g m^{-2}) in rice variety *Swarna sub1* under flood prone low land condition. The lower seeding density of 40 g m^{-2} recorded significantly higher chlorophyll content just before submergence(1.61 mg g^{-1}) as well as just after de-submergence (0.95 mg g^{-1}) in rice leaves than higher seeding density of 60 g m^{-2}. Lower seeding density of 40 g m^{-2} recorded significantly higher CGR than the higher seeding density of 60 g m^{-2} in all the growth stages *i.e.* 45-75 DAT(4.9 g m^{-2} day^{-1}), 75-105 DAT(7.9 g m^{-2} day^{-1}) and 105 DAT- harvest (5.7 g m^{-2} day^{-1}).

Age of seedling on growth parameters of rice

Age of seedling for transplanting in main field plays an important role on survival and further growth under submergence condition. Sharma (1992) [36] reported that the dry matter production and height of seedling increased with increase in age of seedling from 30 days to 60 days but the per cent increase from 45 to 60 days was less as compared to 30 to 45 days. He also indicated that the mean tiller survival during submergence was 56.8, 62.6 and 64.0% in the seedlings at 30, 45 and 60 days, respectively. Similar trend was obtained in dry matter production.

According to Pervin *et al*. (2010) [28] the survival percentage of seedlings increased significantly with the increase of seedling age from 10 to 45 days in four tested varities (var. *FR-13A, BR-11, BRRI dhan 32* and *BR-6110-10-2-1*). The dry matter accumulation in seedlings increased significantly with increase in age, which contributed towards submergence tolerance. More or less similar trend was obtained in seedling height in *FR-13A*. Recovery score was made based on the attributes like tiller number, dry matter accumulation and plant height and better recovery was found at 45 days old seedling in variety *BR-6110-10-2-1*. Similar findings were also reported by Sarkar *et al*. (1999) [34] and Das *et al.* (2005) [10]. Subedi (2013) [42] reported higher dry matter production $seedling^{-1}$ and higher plant height (31.5 cm) in older seedlings (40 days) as compared to younger seedlings (20 days). Bhowmick *et al.* (2014) [6] opined that use of older seedling of 44 days offered better seedling vigour in terms of high dry matter accumulation 0.93 g $seedling^{-1}$, root length (15.72 cm) and shoot length (21.72 cm) at the time of transplanting. Significantly better performance of the seedlings was reflected in main field in terms of their survival (96.69%), plant height (103.68 cm), root length (21.79 cm) and number of tillers m^{-2} (215.5 at 25 and 350.54 at 45 DAT, respectively). In a similar experiment, Sarangi *et al.* (2015) [33] also reported that the dry weight of seedlings increased with age and it was the highest at uprooting at 40 days (7.74 g 10 $seedling^{-1}$) as compared to younger seedlings of 25 day old (3.3 g 10 $seedlings^{-1}$). They also recorded significantly higher shoot length (62.6 cm), root length (16.1 cm), number of green leaves seedlings $^{-1}$ (4.4), leaf area per seedling (41.9 cm^2) at the time of uprooting of seedlings at 40 days than 25 days.

Bishoyi *et al.* (2016) [7] mentioned that use of older seedling of 40 days offered better seedling vigour in terms of higher dry matter accumulation 1.143 g $plant^{-1}$, shoot length (29.8 cm) and leaf area of 22.7 cm^2 $seedling^{-1}$ at the time of transplanting as compared to younger seedlings of 30 days. But the seedlings of 30 days old recorded significantly higher chlorophyll content (1.61 mg g^{-1}) in leaves over the seedlings of 40 days just before submergence. However the older seedlings of 40 days produced significantly higher chlorophyll content (0.94 mg g^{-1}) after de-submergence than that of younger seedlings of 30 days. Significantly better performance of the older seedlings so produced was reflected in main field also in terms of their survival (91.9%), higher CGR of 5.0 g m^{-2} day^{-1} (at 45-75 DAT) and 6.5 g m^{-2} day^{-1} (at 105 DAT-harvesting).

Nutrient management in the nursery on yield attributing characters and yield of rice under submergence

Nutrient management in nursery for raising rice seedlings plays significant role on yield and yield attributing characters. Application of DAP (50 kg P_2O_5 ha^{-1}) to nursery recorded the highest paddy yield (3.28 t ha^{-1}) with a 38% increase over the no fertilizer treatment under water logged condition (Singh, 2004) [39]. The increase in yield was due to production of vigorous seedlings in the nursery which could withstand better excess water stress. Similar findings were also reported by Maskina and Meelu (1984) [21] and Rajgopalan and Krishnarajan (1987) [29]. Pervin (2005) [27] concluded that the seedlings transplanted from the well nourished (60 kg N, 40 kg P_2O_5, 20 kg $ZnSO_4$ and FYM 10 t ha^{-1}) nursery bed produced higher grain yield as well as the yield attributing characters like higher no of effective tillers $hill^{-1}$, number of grains $panicle^{-1}$ and lower spikelet sterility than the control one under 10 to 15 days of complete submergence. Singh *et al.* (2014) [6] reported that application of 40 kg K_2O ha^{-1} in the rice (var. *Swarna sub1*) nursery recorded highest grain yield and yield attributing characters under complete submergence (13 days) condition. However, it was statistically at par with application of 40 kg K_2O along with 60 kg P_2O_5 ha^{-1}. They also reported that application of N alone was detrimental under flash flood condition. Similar findings have also been reported by Cakmak (2005) and Ella and Ismail (2006) [11].

Adhikari *et al.* (2013) from Nepal reported that application of fertilizer at 20:20:0::N:P_2O_5:K_2O kg ha^{-1} along with 6 t ha^{-1} FYM in the nursery bed of rice (var-*Radha-4*) did not show consistent result in recording yield and yield attributing characters over FYM. Top dressing of fertilizer at 20:20:0:: N:P_2O_5:K_2O kg ha^{-1} recorded significantly higher productive tillers m^{-2} (292) and filled grains $panicle^{-1}$ (93). However, these parameters along with grain yield were not statistically significant in the subsequent year, indicating that fertilizer management had little effect on yield and yield attributing characters under rainfed low land condition.

Sumon *et al.* (2013) [43] carried out an experiment to investigate the effect of the nursery nutrient management on performance of rice (var-*BRRI dhan-51*) under 15 days of complete submergence at 10 days after transplanting. They concluded from the experiment that nutrient management in the nursery showed significant differences for 1000-grain weight, grain yield and harvest index except number of total tillers, number of effective tillers, panicle length, number of grains $panicle^{-1}$ and straw yield. Application of 50:40:40::N:P_2O_5:K_2O kg ha^{-1} produced the highest grain yield (5.51 t ha^{-1}) and 25:40:40 kg ha^{-1} produced the lowest grain yield.

Subedi (2013) [42] reported that nursery fertilization at 30 kg N ha^{-1} recorded significantly higher number of effective tillers in main field both in younger (20 days) and older (40days) seedlings raised only from low seeding density (100 g m^{-2}). Higher number of filled grains $panicle^{-1}$, test weight and grain yield were also recorded in the same treatment in rainfed low land rice.

Bhowmick *et al.* (2014) [6] mentioned that the levels of nutrient management in nursery bed had significant impact on yield attributing characters and yield. Application of nutrient at 80:40:40::N:P_2O_5: K_2O kg ha^{-1} in the nursery of rice variety *Swarna sub1* recorded significantly higher panicle length (23.71 cm), panicles m^{-2} (312.67), number of filled grains $panicle^{-1}$ (109.08), 1000 grain weight (19.99 g), grain yield (5.39 t ha^{-1}), straw yield (7.15 t ha^{-1}) and lower sterility (16.51%) as compared to lower levels of nutrient application under flood prone low land situations.

In a similar experiment Sarangi *et al.* (2015) [33] observed that the seedling raised with application of balanced fertilizer (50:30:15::N:P_2O_5: K_2O kg ha^{-1} and 5 t ha^{-1} FYM) in the nursery and when transplanted in the main field produced significantly higher number of tillers $hill^{-1}$ (11.8), panicles $hill^{-1}$ (10.2), grains $panicle^{-1}$ (130.1) in rice variety *Amal–mana* under low land condition. This treatment also recorded significantly higher grain yield (4.57 t ha^{-1}) and straw yield (8.61 t ha^{-1}).

Bishoyi *et al.* (2016) [7] have the opinion that the levels of nutrient management in nursery bed had significant impact on yield attributing characters and yield of rice. Application of nutrient at 80:40:40::N:P_2O_5: K_2O kg ha^{-1} in the nursery of rice variety *Swarna sub1* recorded significantly higher panicle length (22.4 cm), panicles m^{-2} (251.2), number of filled grains $panicle^{-1}$ (106.5), 1000 grain weight (19.35 g), grain yield (4.13 t ha^{-1}), straw yield (5.01 t ha^{-1}), lower sterility (19.8%) and nutrient uptake by grain in the form of N (57.2 kg ha^{-1}), P (14.2 kg ha^{-1}) and K (15.7 kg ha^{-1}) as well as by the straw in the form of N (22.5 kg ha^{-1}), P (6.9 kg ha^{-1}) and K (98.0 kg ha^{-1}) as compared to lower levels of nutrient application(60:40:40::N:P_2O_5: K_2O kg ha^{-1} & farmer's practice of 5 t ha^{-1} FYM) as well as higher levels of nutrient application(100:40:40::N:P_2O_5: K_2O kg ha^{-1}) under flood prone low land situations.

Seeding density in nursery on yield attributing characters and yield of rice under submergence

Number of seedlings raised per unit area is important because it determines the space available and thereby exposure of the seedlings in above ground parts which provide opportunity to grow up seedlings freely. The seedlings raised with lower seed density (50 kg per 1000 m^2) in nursery recorded significantly higher number of grains $panicle^{-1}$ (93.4), grain yield (39.0 q ha^{-1}) and straw yield (52.7 q ha^{-1}) as compared to higher seed density of 75 and 100 kg per 1000 m^2 under normal condition (Lal and Roy, 1996) [19].

The seed density of 50 kg per 1000 m^2 recorded the highest number of productive tillers m^{-2} (185.3).

While conducting an experiment at Rajendranagar, Hyderabad, Padmaja and Reddy (1998) concluded that rice hybrid *APHR-2* transplanted with the seedlings raised in the nursery using a seeding density of 35 g m^{-2} resulted in significantly higher dry matter production (872 g m^{-2}), number of filled grains panicle^{-1} (101), panicle weight (2.47g), 1000 grain weight (20.67 g) and grain yield (4.61 t ha^{-1}) as compared to 20 and 50 g m^{-2} seed density. According to Ram *et al.* (2009) [31] a seeding density of 75 g m^{-2} in the nursery had recorded higher yield to the tune of 4-22% over higher seeding density (150 g m^{-2}) in nursery, when subjected to 10 days of complete submergence at 7 days after transplanting. Pervin (2005) [27] concluded that lower seed density of 50 g m^{-2} in the nursery recorded higher yield as compared to 100 g m^{-2} seed density up to 40% depending on the varieties and submergence duration. The yield attributing characters like number of filled grains pancle^{-1} was also more in lower seed density (50 g m^{-2}). Nursery raising of paddy (var. *BRRI dhan-4*) with 25 g m^{-2} seed density produced significantly the highest number of total tillers hill^{-1} (12.91), number of effective tillers hill^{-1} (9.61), number of grains panicle^{-1} (154.97), grain yield (5.02 t ha^{-1}) and straw yield (5.47 t ha^{-1}) as compared to seed density of 50 and 75 g m^{-2} in the nursery bed (Mustari *et al*., 2013) [23]. Nagata *et al*. (2003) [25] also expressed similar opinion. Naem *et al.* (2010) [24] reported that the seedlings grown with lower seed density and nitrogen fertilization in nursery bed recorded higher yield attributing characters like productive tillers hill^{-1}, 1000 grain weight as well as grain and straw yield as compared to higher seed rate and no nitrogen application. Similar findings were also reported by Mishra and Salokhe (2008) [22].

Bhowmick *et al.* (2014) [6] observed the significant effect of seed density in nursery on yield and yield attributing characters of rice variety *Swarana sub1* under submergence condition. Seedling raised from lower seeding density (25 g m^{-2}), when transplanted in main field recorded significantly higher panicle length (23.99 cm), panicles m^{-2} (312.46), filled grains panicle^{-1} (108.42), 1000-grain weight (19.94 g), grain yield (5.29 t ha^{-1}), straw yield (7.10 t ha^{-1}), harvest index (0.427) and lowest spikelet sterility (16.73%) as compared to higher seeding density (40 g m^{-2}). However, the seed density in nursery did not show any significant effect on the duration of the crop and days to 50% flowering.

Bishoyi *et al.* (2016) [7] reported the significant effect of seed density in nursery on yield and yield attributing characters of rice variety *Swarana sub1* under submergence condition. Seedling raised from lower seeding density (40 g m^{-2}), when transplanted in main field recorded significantly higher panicle length (21.6 cm), panicles m^{-2} (247.6), filled grains panicle^{-1} (104.4), 1000-grian weight (19.26 g), grain yield(3.94 t ha^{-1}), straw yield (4.83 t ha^{-1}) and lowest spikelet sterility (20.6%) as compared to higher seed density (60 g m^{-2}). Significantly higher N (53.1 kg ha^{-1}), P (13.2 kg ha^{-1}) and K (14.4 kg ha^{-1}) uptake by the grain was manifested with lower seeding density of 40 g m^{-2} in the nursery than the higher seeding density of 60 g m^{-2}. The same trend was also noticed by straw and also by grain and straw in total.

Age of seedling on yield attributing characters and yield of rice under submergence

Yield attributing characters and yield of rice under submergence were influenced by the age of seedling at transplanting stage. In general positive relationships were reported up to a certain age of seedlings. Sharma (1992) [36] informed that the rice cultivar *Gayatri* under 10 days of simulated flooding at 30 DAT recorded the highest panicles m^{-2} (125), panicle weight (2.81 g), grain yield (2.25 t ha^{-1}) and straw yield (4.19 t ha^{-1}) when transplanted with 60 days old seedlings. However, the yield attributing characters of rice transplanted with 45 days old seedlings were at par with those of 60 days old seedlings.

Transplanting with 35 days old seedlings proved beneficial when compared with 15, 25 and 45 day old seedlings. Seedlings of 35 days old when transplanted in main field under normal condition recorded the highest number of effective tillers hill^{-1} (16.1), panicle length (25.18 cm), grains panicle^{-1} (171.52), test weight (17.16 g) and grain yield (4.30 t ha^{-1}) in rice variety *BRRI dhan-38* in Bangladesh (Amin and Haque, 2009) [3].

Alam *et al*. (2002) [2] also reported that age of seedlings had significant influence on the effective tillers hill^{-1}, panicle length, grains panicle^{-1}, straw yield *etc*. They observed that 35 days old seedlings produced significant and highest number of effective tillers hill^{-1} (7.6), panicle length (26.77 cm), filled grains panicle^{-1} (104.89), plant height (129.1 cm) and grain yield (4.26 t ha^{-1}) which were at par with 28 days old seedlings in *Aman* rice.

Experiment conducted at Bangladesh Agriculture University by Mustari *et al.* (2013) [23] during *kharif* season revealed that transplanting with 25 days old seedling produced the highest number of tillers hill^{-1} (13.34), effective tillers hill^{-1} (10.0), lowest number of sterile spikelet panicle^{-1}, the highest number of grains panicle^{-1} (148.33), grain (5.07 t ha^{-1}) and straw yield (5.47 t ha^{-1}) as compared to 15, 20, 30 and 35 days old seedling of *BRRI hybrid dhan-4* under normal condition.

Bhagat *et al.* (1991) [5] also reported that 40 days old seedlings produced higher grain yield as compared to 30, 50 and 60 days old seedlings. According to Bhowmick *et al.* (2014) [6] the effect of age of seedling was significantly reflected in main field in recording higher yield attributing characters and yield in rice variety *Swarna sub1* under submergence condition. Transplanting with 44 days old seedlings recorded significantly higher panicle length (22.75 cm), panicles m^{-2} (308.92), filled grains panicle^{-1} (106.83), 1000 grain weight (19.86 g), grain yield (5.23 t ha^{-1}), straw yield (7.02 t ha^{-1}), harvest index (0.427) and lowest sterility (16.93%) as competed to 30 days old seedlings. In a similar experiment Sarangi *et al*. (2015) [33] reported that transplanting with older seedlings (40 days) was always beneficial in recording significantly higher yield and yield attributing characters in rice variety *Amal-mana* under rain-fed low land condition. The older seedlings (40 days) produced significantly higher number of tillers hill^{-1} (11.5), panicles hill^{-1} (9.7), grains panicle^{-1} (121.5), grain yield (4.27 t ha-1) and straw yield (7.83 t ha^{-1}) than the younger seedlings (25 days).

Bishoyi *et al.* (2016) [7] compared the performance of 30 and 40 days old paddy (Var. *Swarna sub1*) seedlings in recording yield and yield attributing characters. They concluded that the older seedlings (40 day old) provided better performance in producing significantly higher panicle length (21.5 cm), productive tillers m^{-2} (248.3), filled grains panicle (105.2), lower spikelet sterility (20.5%), higher grain yield (3.95 t ha^{-1}), straw yield (4.84 t ha^{-1}), and nutrient uptake in the form of N, P and K uptake by grain, straw and also total N (74.5 kg ha^{-1}), P (19.7 kg ha^{-1}) and K (105.0 kg ha^{-1}) uptake than younger seedlings of 30 days under low land rainfed condition.

Agronomic practices on performance of submerged rice

Experiment conducted by Reddy *et al*. (1991) at CRRI, Cuttack revealed that plant height, number of tillers and dry matter production of the rice crop varied considerably with different levels of submergence and rates of phosphorus application (0, 8.7, 17.5, 26.2 and 34.9 kg ha^{-1}). With the application of phosphorus the plants became taller by 5-7 cm, produced more dry matter and more number of tillers both before and after the submergence. The rate of decrease of dry matter production and tiller under submergence was faster in the plots receiving no phosphorus. Application of 34.9 kg P_2O_5 ha^{-1} along with 60 kg ha^{-1} N and 16.7 kg ha^{-1} K_2O recorded significantly higher grain yield (2.5 t ha^{-1}), straw yield (5.33 t ha^{-1}) and panicle weight (2.23 g) over no phosphors application under submerged condition in the semi dwarf rice variety CR-1016. In an experiment conducted at NRRI, Cuttack, Ghosh (2007) concluded that application of 40 kg N (20 kg from urea + 10 kg each from FYM and Sesbania) along with 20 kg P_2O_5 and K_2O each per hectare in direct seeded rice (var. *Gayatri*) produced the highest survival, plant biomass before (252.06 g m^{-2}) and after (225.98 g m^{-2}) 10 days of submergence. It also recorded the highest plant height (144.65 cm) at maturity, panicles m^{-2} (305), panicle weight (4.06 g), grain yield (303 kg ha^{-1}) and N uptake (55.50 kg ha^{-1}) as compared to no nitrogen and application of nitrogen from urea only. He also stated that application of P_2O_5 along with N is beneficial under flood prone situations. According to Choudhary and Pandey (2009) application of 120 kg N ha^{-1} along with 40 kg ha^{-1} P_2O_5 and 20 kg ha^{-1} K_2O recorded significantly higher plant height (111 cm), tillers m^{-2} (288), dry matter accumulation (115 g m^{-2}), leaf area index (4.35), effective panicles m^{-2} (273), grains $panicle^{-1}$ (92), test weight (24.2 g), grain yield (4.4 t ha^{-1}) and straw yield (6.28 t ha^{-1}) in low land transplanted rice as compared to 0, 40 and 80 kg N ha^{-1} application in main field.

Correlation studies

Ella and Ismail (2006) [11] observed significant positive correlation of seedling survival after submergence with stem starch concentration (% of dry weight) before submergence (r= 0.63), root - shoot dry weight ratio (r=0.54) before submergence, chlorophyll concentration after submergence (r=0.76). They also found the significant negative correlation with leaf nitrogen concentration (% dry weight) before submergence (r= -0.65) and negative correlation with leaf stem ratio before submergence (r= -0.49) with the survival of rice plant.

Ella *et al.* (2011) [12] reported that survival was significantly correlated with root dry weight (r=0.43) and root-shoot biomass ratio (r=0.47) before submergence. Leaf and stem dry weight before submergence was poorly correlated with survival. The same tends were observed in the correlation between these parameters measured after de-submergence with survival, for which only root dry weight and root–shoot biomass ratio after de-submergence were positively correlated with survival. They also reported that the survival was negatively correlated with chlorophyll loss during submergence and positively correlated with chlorophyll content after de-submergence.

Sarkar and Bhattacharjee (2011) [35] observed the positive and significant correlation between per cent survival with dry matter accumulation and non-structural carbohydrate content of plant before and after submergence. Bishoyi *et al.* (2016) [7] reported that there was a positive and significant correlation between yield and seedling characters like post submergence survival% (0.96), seedling root length (0.92), leaf area of seedling (0.88), seedling dry weight (0.85) and seedling shoot length at transplanting (0.81) of rice at 1 per cent level of probability.

Economics

Singh (1999) [40] reported that the rice crop grown under 15-30 cm of standing water recorded the highest net return (Rs. 7403 ha^{-1}) and cost: benefit ratio (1:1.62) with less investment (Rs. 11,910 ha^{-1}) when planted with the seedlings raised in the nursery with application of 60 kg N ha^{-1} in the form of farm yard manure. It was economical as compared to other inorganic sources both at 60 kg and 120 kg N ha^{-1}. Adhikari *et al*. (2013) [1] found that raising of rice seedlings with lower seed density (303 g m^{-2}) with top dressing of fertilizer at 20:20:0::N:P_2O_5:K_2O kg ha^{-1} in the nursery bed and transplanting of older (40 days) seedling recorded higher gross return (Rs. 136027 ha^{-1}), net return (Rs. 58013 ha^{-1}) and B:C (1.74).

Sarangi *et al*. (2015) [33] in a similar experiment found that raising of rice (Var.-*Amal mana*) seedlings with lower seed density (25 g m^{-2}) recorded significantly lower cost of cultivation [648 US dollar (USD) ha^{-1}] and significantly higher gross return (1109 USD ha^{-1}), gross margin (461 USD ha^{-1}) and B.C.R (1.72) than higher seed density (40 g m^{-2}). Similarly transplanting with older seedlings (40 days) proved beneficial under rain-fed low land condition in fetching significantly higher gross return (1165 USD ha^{-1}), gross margin (524 USD ha^{-1}), BCR (1.82) but lower cost of cultivation (643 USD ha^{-1}). Seedlings raised with application of balanced fertilizers (50:30:15::N:P_2O_5:K_2O kg ha^{-1}+5 t ha^{-1} FYM) in nursery, when transplanted under rain-fed low land condition fetched significantly higher economic return in terms of gross return (1251 USD ha^{-1}), gross margin (596 USD ha^{-1}) and BCR (1.91) when compared with imbalanced and lower levels of nitrogen application in nursery.

Bishoyi *et al*. (2016) [7] in a similar experiment observed that raising of rice seedlings with lower seed density (40 g m^{-2}) recorded higher gross return (Rs 57053 ha^{-1}), gross margin (Rs 19455 ha^{-1}) and return $rupee^{-1}$ invested (1.52) than higher seed density (60 g m^{-2}). Similarly transplanting with older seedlings (40 days) proved beneficial under rain-fed low land condition in fetching higher gross return (Rs 57304 ha^{-1}), gross margin (Rs 19992 ha^{-1}), return $rupee^{-1}$ invested (1.54) than younger seedlings (30 day). Seedlings raised with application of balanced fertilizers (80:40:40::N:P_2O_5:K_2O kg ha^{-1}) in nursery, when transplanted under rain-fed low condition fetched higher economic return in terms of gross return (Rs 59879 ha^{-1}), gross margin (Rs 22446 ha^{-1}) and return $rupee^{-1}$ invested (1.60) when compared with farmers' practice.

Conclusion

Application of balanced nutrition in the form of inorganic (N, P_2O_5 and K_2O) and organics (FYM, Azolla, Poultry manure *etc.*) in rice nursery produced healthier seedlings as compared to organic and inorganic alone. Many workers have the opinion that application of nitrogen up to 100 kg ha^{-1} in the nursery along with suitable doses of P_2O_5 and K_2O were beneficial in recording higher growth, yield attributing characters and yield of rice under submergence condition. However, few have the opinion that application of N at higher dose without P_2O_5 and K_2O was detrimental under flash flood condition. There are many reports that application of P_2O_5 and K_2O up to 40 kg ha^{-1} along with different doses of N recorded higher growth and yield characters as well as yield. It was found that the older seedlings up to 45 days old performed better in terms of post flood survival, growth and yield of rice as compared to younger seedlings. It became imperative to standardize the nutrition management, seeding density in the nursery to find out the appropriate age of seedling for transplanting for higher survival rate and yield in the submergence and flash flood affected areas.

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