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Growth and yield of over-aged rice (*Oryza sativa*) seedlings under different nitrogen levels in waterlogged situations

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ABSTRACT

Seedlings of three different ages, ie 30, 45 and 60 days old of rice were grown at three different N levels, ie 0, 20 and 40 kg/ ha, for two years in waterlogged condition. Eventhough panicle number showed marginal increase, the panicle growth was superior in older seedlings more so at higher nitrogen level. The panicle length, spikelet number/panicle, panicle weight and number of filled grains/panicle showed significant improvement in older seedlings than younger seedlings of 30 days old. The effect was more pronounced at higher N level. The harvest index was also better in older seedlings at higher N level. In both the years 2007 and 2008 respectively the yield showed closer association with harvest index (r^2 = 0.52, 0.76; n 27) than with total dry matter produced (r^2 = 0.21, 0.56; n 27) suggesting importance of dry matter partitioning efficiency than total dry matter production efficiency for improvement of yield in waterlogged areas.

Key words : Over-aged seedlings, Panicle weight, Waterlogged areas, Yield

Under flood-prone low-lying situation, the yield of rice crop is limited by several constraints, ranging from unfavourable water regime to lack of proper management practices leading to sub-optimal yield. As much as 4 million ha rice growing area is affected by deep water situation. In this type of ecology, unpredictable water regime exposes the crop vulnerable leading to sub-optimal productivity. Under such adverse conditions, in addition to use of suitable cultivars, appropriate management practices have potential to enhance yield under such condition. The use of aged rice seedlings often found better due to better stand and yield (Sharma and Panda 1989, Ghosh 2006). Waterlogging poses two major challenges to rice crop, firstly initial survival of seedlings and good crop stand. The older seedlings manage to give better crop stand mainly due to higher carbohydrate reserves than younger seedlings (Chaturvedi *et al.* 1995, Mallick 1995). Moreover rate of depletion of carbohydrates were found faster in younger rice seedlings than older seedlings providing better chance of survival and improved crop stand (Das *et al.* 2009). Moreover, under excess water situation, tall older seedlings have advantage of height in maintaining partial submergence for longer duration than short younger seedlings. Secondly waterlogging condition also affects grain development and maturity. Even with abundant supply of photosynthates into growing spikelets, grain development and maturity in rice is strongly under hormonal control (Ashikari *et al.* 2005) Preponderance of ethylene due to waterlogged situation is likely to off- balance cross talks among hormones during panicle development and grain-filling stage. Even though N application significantly improved yield of rice crop, but very little information is available regarding effect of applied N on growth and performance of over-aged rice seedlings, particularly in grain development and filling in rice. Therefore in this report yield performance of rice seedlings of different ages were studied and importance of dry matter production and partitioning for yield improvement in waterlogged areas is discussed.

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MATERIALS AND METHODS

The experiments were conducted during monsoon season at experimental Research Farm of Directorate of Water Management, Mendhasal, Bhubaneswar during 2007–08 from June to December under rainfed condition. Seedlings of a local, tall, long duration and photosensitive rice cultivar was grown in nursery for 30, 45 and 60 days. These seedlings of different ages were used for transplanting on 20th and 16th August in 1st and 2nd year respectively. The experiment was conducted under split-plot design with age of seedling as main plot and level of nitrogen (N) as sub-plot with three replications. The nitrogen was given @ 0, 20 and 40kg /ha as mud ball method of application where N0 served as a control treatment. The plot size of experiment was 10m×5m with a depth of 1.5m so as to ensure different levels of applied

Table 1 The monthly rainfall, mean water level in experimental field during 2007–08

Year	June	July	Aug	Sept	Oct	Nov	Dec
			2007				
Rainfall (mm)	263.7	227.7	177	522.9	80.3	0	16
Water level (m)	0.05	0.20	0.25	1.05	0.6	0.2	0.15
			2008				
Rainfall (mm)	286.7	164.9	260.3	502.5	0	0	0
Water level (m)	0.25	0.30	0.40	1.02	0.75	0.25	0.07

fertilizers in different treatments in waterlogged condition. The spacing was maintained at 20cm × 20cm and P, K fertilizers was applied @ 40:40 kg /ha.The entire dosage of P and K was applied during sowing time. The N was applied in three levels, @ 0, 20 and 40kg/ha. The application of N was split in three stages, ie seven days after planting, at maximum tillering stage (58 days after transplanting) and at panicle initiation stage (93 days after transplanting) @10:5:5 and 20:10:10 kg /ha for 20 and 40kg /ha level of N respectively. The crop was harvested in last week of December and yield of both grain and straw was recorded. The depth of water in experimental field was measured with a measuring scale. The data of different growth attributes like panicle number, length of panicle, spikelet number/panicle, number of filled spikelets, weight of 1000 grains were recorded. The total dry matter was recorded after drying samples in hot air oven at 70°C till constant weight and harvest index was calculated following standard formula (Yoshida *et al*. 1976).

The least significant difference of treatment means, correlations and regressions of observations were calculated following Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The water level in the field was 0.3–0.4m at the time of planting and its level increased until September. The water level thereafter declined with recession of rainfall from October up to the time of harvest, ie last week of December. The maximum water level was up to 1.02–1.05m in the month of September with increase in rainfall and thereafter it declined along with recession of rainfall (Table 1). In 2007 in November and 2008 during October, November and December. Eventhough there was no rainfall, the water levels in corresponding months suggested receding water level in the experimental field under rainfed condition. It was evident from data (Tables 2, 3) that N application significantly promoted growth and various yield attributes in seedlings of all the three age groups. However, the effect was more prominent in older seedlings than younger seedlings. Interestingly under given situation of waterlogging, in 2007, the panicle number/unit area did not change significantly in response to increased level of applied N. But in 2008, N application showed significant increase in panicle number at higher N level. The increase was more evident in 45 and 60 days old seedlings at 20 kg N /ha level itself, but in 30 days old seedlings the effect could be seen only at 40 kg N /ha level. Under deep water situation, N application reportedly promoted panicle number in rice seedlings (Randriamiharisoa and Uphoff 2002, Ghosh 2007). However, in our under present experimental condition older seedlings like 45 and 60 days old seedlings were found more responsive than younger seedlings to applied N showing increased panicle number. But age and N in both the years did not show significant interaction suggesting to the fact that there was no synergistic effect of age of seedling and N level for

Table 2 The panicle number, weight of panicle and grain yield of rice seedlings of three different age, 30, 45 and 60d old, at three different levels of nitrogen, ie 0, 20 and 40kg/ha in during 2007–08

Treatments		Panicle number/m^2		Panicle weight (g)		Grain Yield (tonnes/ha)	
Age (d)	N level (kg/ha)	2007	2008	2007	2008	2007	2008
60	40	101.7	100.0	6.06	5.92	2.24	2.14
	20	101.3	100.7	5.71	5.69	1.81	1.80
	0	99.0	97.3	4.73	4.67	1.38	1.37
45	40	100.0	101.3	5.40	5.68	1.39	1.83
	20	98.0	100.0	4.30	4.45	1.28	1.47
	0	92.0	96.0	4.05	4.12	1.15	1.15
30	40	101.0	101.3	5.47	5.12	1.99	1.31
	20	98.7	96.0	4.72	4.30	1.51	1.20
	0	98.0	96.3	3.48	3.41	1.08	1.01
LSD							
Age 5%		NS	ns	0.48	0.20	0.21	0.24
1%		NS	ns	NS	0.34	0.35	0.40
N 5%		NS	2.61	0.79	0.17	0.16	0.23
1%		NS	ns	1.10	0.24	0.23	0.32
A×N 5%		NS	ns	NS	0.33	NS	0.40
1%		NS	ns	NS	0.47	NS	0.56

Table 3 The changes in panicle length, spikelet number/panicle and grain yield of rice seedlings of three different age, 30, 45 and 60d old at three different levels of nitrogen, ie 0, 20 and 40kg/ha during 2007–08

Treatment			Panicle length (cm)		Number of spikelets/ panicle		Number of filled spike lets/panicle		Harvest index	
Age (d)		N level (kg/ha)	2007	2008	2007	2008	2007	2008	2007	2008
60		40	26.1	25.7	281	224	239	177	0.36	0.33
		20	25.5	23.4	250	218	218	153	0.33	0.31
		0	24.2	24.6	201	204	152	119	0.26	0.26
45		40	25.4	25.3	185	242	159	179	0.30	0.27
		20	24.3	24.7	197	236	155	162	0.23	0.24
		0	22.6	19.3	211	145	151	88	0.19	0.19
30		40	25.5	22.8	235	216	183	150	0.28	0.23
		20	24.4	22.1	230	207	179	127	0.25	0.25
		0	23.6	18.7	173	195	123	106	0.24	0.23
LSD										
Age	5%		NS	NS	NS	NS	NS	NS	0.05	0.01
	1%		NS	NS	NS	NS	NS	NS	NS	0.02
N	5%		53	1.5	53	20	24	19	0.04	0.01
	1%		NS	2.1	NS	29	34	27	0.03	0.02
A×N	5%		NS	2.6	NS	35	NS	NS	0.02	0.02
	1%		NS	NS	NS	NS	NS	NS	0.03	0.03

increase in panicle number. But the older seedlings produced heavier panicles in comparison to younger seedlings and trend was persistent in both the years (Table 2). The increased application of N at 20 and 40 kg /ha level increased panicle weight significantly.

The grain yield also showed significant increase at higher N level in all age group seedlings. The effect was clearly evident in 60d old seedlings which at 20kg N level showed up to 30% increase in yield and up to 58% at 40 kg/ha N level compared to treatment without N. The comparative increase in 45d old seedlings was 19 and 40% respectively. Thus it was apparent that panicle weight contributed significantly for higher grain yield apart from panicle number/unit area. The panicle length also significantly increased in older seedlings particularly at higher N level. Similarly, other attributes of yield like, number of spikelets/panicle in general significantly increased with increased N level (Table 2). Similar trend was noted in number of filled grain/panicle also. Increased N level significantly improved number of filled grain/panicle in all the three age group of seedlings (Table 3) But bolder grains, as suggested by higher test weight, in older seedlings (45 and 60d old) might have contributed more to increased yield than 30d old seedlings. Even though number of panicles as well as heavier panicles are critical determinants of yield under excess water situation (Ghosh and Singh 2005), in present investigation, it was noted that under prevalent waterlogged scenario, with marginal increase in panicle number, at higher N level in older seedlings panicle growth played key role, improving yield of the crop. In both the years, harvest index showed closer association with grain yield ($r^2 = 0.52, 0.76$, n 27) than total dry matter ($r^2 = 0.21, 0.56$ at n 27 in 2007 and 2008 respectively) with grain yield. This suggested to the fact that partitioning of dry matter is more importance than total dry matter production to achieve better yield under excess water situation.

Asymmetrical metabolic demand for assimilates among growing spikelets mainly leads to development of partially filled grain (Mohapatra *et al*. 2009). Homogeneity of grain filling could be ensured through exogenous application of plant growth regulators like cytokinins, gibberellins etc. On the other hand, ethylene synthesis inhibitor, 1-aminoethoxyvinyl glycine (AVG) cobalt etc. (Philosoph-Hadas *et al*. 1994, Lynch and Brown 1997), or ethylene action inhibitor like silver (Yu and Yang 1979) improved grain filling of poorly developed basal spikelets. The application of ethylene releasing substances like ACC (1-aminocyclopropane-1-carboxylic acid) CEPA (2-chloroethylphosphonic acid) affected grain-filling of these spikelets. These facts suggested that grain development and grain-filling processes in rice is under hormonal control. In our present study, significant increase in panicle length, number of the spikelets/panicle suggested effective enhancement in sink strength in older seedlings, especially under higher N level. Moreover, better grain-filling as evidenced by higher percentage of filled grain as well as heavier grains suggested that photosynthate mobilization was better in panicles of aged seedlings, particularly 60-day old seedlings and had been promoted by N application.

Therefore, the better panicle development and improved grain-filling and higher test weight of older seedlings at higher N level ensured better yield under waterlogged environment. But how the aged seedlings at higher N level ensured better panicle development either through reduction of endogenous ethylene level (Azuma *et al.* 2007) and maintaining greater metabolic demand in growing panicle, particularly in inferior basal spikelets in waterlogged condition warrants further investigation.

Planting of 60 days old seedlings and use of 40 kg fertilizer N/ha increased the length of panicles, number of spikelets/panicle, mobilization of photosynthate in panicles and thereby grain yield of rice under waterlogged condition. Finding of this study will be helpful in enhancing rice yield in unfavourable, waterlogged and flood-prone situations of eastern India.

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