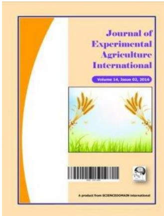

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Effect of Plant Spacing on Growth and Yield of Rice (*Oryza sativa* L.) under Submerged Condition

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Authors' contributions

This work was carried out in collaboration among all authors. Author BV designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors LKR and MS managed the analyses of the study. Author MS managed the literature searches. All authors read and approved the final manuscript.

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Short Research Article

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ABSTRACT

The experiment was conducted to find out the effect of plant spacing on the performance of rice variety IR-64 and IR64-Sub1 under conventional and Submerged condition at the National Rice Research Institute (NRRI), Cuttack, Odisha during the Rabi season of 2018. Different planting densities were maintained using different spacing's. These include (S_1) 15 cm × 10 cm, (S_2) 15 cm × 20 cm. The experiment was laid out in a randomized complete block design with 3 replications spacing of 15 cm × 10 cm with produced the highest grain yield of 350 gm^{-2} in submerged condition on IR64-Sub1 rice cultivar, which was significantly higher than the yield with recommended density (15 cm × 10 cm with IR64 Sub1). This yield was increased due to higher number of panicles m^{-2}. This result suggests that higher planting density (15 cm×10 cm) rather than increased number of seedling $hill^{-1}$ is necessary for getting higher yield of IR-64Sub1 rice cultivar in continuous submerged condition (where V_1=IR 64, V_2=IR-64 Sub1, S_1=15 cm×10 cm, S_2=20 cm×15 cm).

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Keywords: Rice; submergence; planting density; spacing; number of tillers.

1. INTRODUCTION

Rice is India's pre-eminent crop, covering about one-fourth of the total cropped area and providing food to about half of the Indian population. Rice is mostly grown under submerged soil conditions and requires much more water compared to other crops. Plant spacing has an important role on growth and yield of rice [1]. Optimum plant density ensures the plant to grow properly with the aerial and underground parts by utilizing more solar radiation and soil nutrients [2]. The maximum benefit can be derived from a rice field, if the crop is properly spaced between rows and within rows. [3] stated that optimum spacing gave a maximum number of total tillers m^{-2}, maximum number of fertile tillers m^{-2} which was dependent on temperature, moisture and other soil factors. Chowdhury et al. [4] reported that optimum number of seedlings $hill^{-1}$ may affect the rice plant to grow properly both in its aerial and underground parts by utilizing maximum radiant energy, nutrient, space and water and also can reduce seedling cost. On the other hand, close spacing plant has more survival rate in submerged condition as compare to wider spacing plant and per square meter has maximum plant population in close spacing plant. Submergence tolerance variety are maximum survival rate in close spacing. In susceptible rice cultivars, submergence causes degradation of chlorophyll, resulting in strong reduction of photosynthesis and enzymatic activity [5]. After de-submergence, tissue injuries which developed underwater can be intensified as the floodwater recedes and shoots become re-exposed to the atmosphere [6]. Submergence-tolerant species are able to alleviate adverse impacts of submergence and de submergence by changing the morphology and anatomy of shoots and roots, adjusting metabolic pathways or regulating antioxidant defense mechanisms. Cell elongation also requires synthesis of new cell walls, and hence the availability of energy and carbohydrate. Low land rice cultivars, which respond to submergence by elongation growth, have lower survival. Some of the acclimatory responses of terrestrial plants to submergence can be attributed to two contrasting strategies of flood tolerance: the “escape” and “quiescence” strategies [7]. Plants with escape strategy respond to submergence by enhancing shoot elongation to regain contact with the atmosphere, whereas those with the quiescence strategy conserve energy and carbohydrate by restraining growth. The costly escape strategy is advantageous in shallow floodwater, in which elongation growth allows plants to re-establish air contact; failure to do so results in accelerated depletion of carbohydrate reserves. The quiescence strategy, on the other hand, can save energy and resource during submergence, which could positively affect the survival rate and generation of new tissues after de-submergence. Alam [3] reported that highest number of total tillers and number of effective tillers were obtained from two seedlings $hill^{-1}$ in optimum spacing for rice.

1.1 Objective

To study the growth and yield of rice under submerged condition.

2. MATERIALS AND METHODS

A field experiment was conducted Rabi season 2018 at the National Rice Research Institute of CPD, Cuttack, Odisha. The experiment site lies 85°.94E, 20°.44N elevation 24 m above the MSL. subtropical, monsoon climate from February to May. The soil was sandy clay loam pH(5.8), EC ($0.53dSm^{-1}$), SOC (0.43%), Available nitrogen (172.48 kg/ha), NO_3-N (29.72 mg/kg), NH_4^{+}-N (7.6 mg/kg), Available phosphorus (55.85 kg/ha), Available potassium (129 kg/ha), MBC(433.61 mg/kg),CEC(16.82Cmol/kg). The experiment was arranged in a factorial randomized block design with three Replication with two Indica rice (*Oryza sativa* L.) cultivars IR-64 (V_1) and IR-64 Sub1(V_2) having submergence tolerance *Sub1* gene both are planted two plant spacing S1= 15×10 cm (Row to Row 15 cm and Plant to Plant 10 cm) and spacing S_2= 20×15 cm (Row to Row 20 cm and Plant to Plant 15 cm).

3. RESULTS AND DISCUSSION

3.1 Growth and Yield Attributes

3.1.1 Plant height (cm)

Under submerged condition was recorded the shoot elongation measured as different in plant height before submergence and just after removal of plants from submergence and more elongation being in susceptible variety.

Table 1. No. of tillers per hill at four growth stages of two rice varieties under conventional and flash flooding moisture condition with two plant spacing

	30 DAT			60 DAT			90 DAT			At Harvest		
	V1	**V2**	**Mean**	**V1**	**V2**	**Mean**	**V1**	**V2**	**Mean**	**V1**	**V2**	**Mean**
Conventional	3.7	3.5	3.6	9.2	11.2	10.2	12.0	12.0	12.0	12.2	12.7	12.5
Submerged condition	3.6	4.0	3.8	8.2	8.4	8.3	12.7	14.6	14.2	12.1	14.4	13.2
S1(15×10 cm)	3.28	3.61	3.44	7.94	9.28	8.61	11.94	13.06	12.50	11.17	12.11	11.64
S2(20×15 cm)	4.11	3.94	4.03	9.56	10.39	9.97	12.89	14.61	13.75	13.22	15.00	14.11
Mean	**3.69**	**3.78**		**8.75**	**9.83**		**12.42**	**13.83**		**12.19**	**13.56**	
CD (p<0.05)												
Moisture			NS			0.65			0.70			NS
Spacing			0.25			0.65			0.70			1.12
Variety			NS			0.65			0.70			1.12

Table 2. Dry weight (g) of two rice varieties under conventional and flash flooding moisture condition with two plant spacing

	V1	**V2**	**Mean**
Conventional	387.84	353.68	370.76
Submerged condition	238.24	303.32	270.78
S1(15×10 cm)	327.17	343.84	335.50
S2(20×15 cm)	298.91	313.17	306.04
MEAN	313.04	328.50	
CD (P<0.05)			
Moisture			9.50
Spacing			9.50
Variety			9.50

Table 3. No. of ear bearing tillers in relation to conventional and stangnant flooding under two plant spacing and two varieties of rice

	V1	V2	Mean
Conventional	11.0	9.6	10.3
Submerged condition	11.4	13.2	12.3
S1(15×10 cm)	10.4	10.6	10.5
S2(20×15 cm)	12.0	12.2	12.1
MEAN	11.2	11.4	
CD (P<0.05)			
Moisture			1.08
Spacing			1.08
Variety			NS

Table 4. No. of fertile grains per panicle in relation to conventional and stangnant flooding under two plant spacing and two varieties of rice

	V1	V2	Mean
Conventional	82	75	79
Submerged condition	68	77	73
S1 (15×10 cm)	72	76	74
S2(20×15 cm)	78	76	77
MEAN	75	76	
CD (P<0.05)			
Moisture			2.90
Spacing			NS
Variety			NS

Submergence tolerance cultivar IR-64-Sub1 (V_2) has significant effect in spacing S_1 (15×10 cm; close spacing) and more survival rate was recorded after submergence. Submergence tolerant varieties had relatively lesser elongation and consequently better survival rate. Similar results was findings that Cruj et al. [8] who concluded that plant height was greater under submerged condition than conventional condition. Decreased plant height in conventional condition might be due to enormous weeds which suppressed plant growth and development and such trend was higher at early stage due to highest infestation of weed as suggested by Reddy and Raju [9].

3.1.2 Number of tillers hill^{-1}

The closer spacing are inefficient regarding tillering capacity and provided significantly lower number of tillers. The maximum number of tillers was recorded at 60 DAT and thereafter there was decline in number of tillers up to harvest. Treatment V_2S_1 (V_2= IR-64-Sub1and spacing S_1= 15×10 cm) showed significant and highest number of tillers hill^{-1} in submerged condition. Tillers/hill, panicles/hill and grains/panicle were significantly higher with wider spacing of (30cm×30cm) compared to closer spacing (25 cm × 25 cm) due to advantage of space and less competition for nutrition under wider spacing. An increase of the tune of 8.6% in panicles/hill and 3.4% in grains/panicle under wider spacing (30 cm × 30 cm) compared to closer spacing of 25 cm × 25 cm. Kumar et al. [10] and Thakur et al. [11] also reported similar results.

3.1.3 Dry weight (g)

Significantly higher dry weight (350 g m^{-2}) was registered by treatment V_2S_1 (IR64-Sub1 + 15×10 cm). The accelerated growth and development of the crop under V_2S_1 at successive stages particularly at after submergence phases resulted in higher dry matter accumulation. Raju et al. [12] observed that similar result in dry matter accumulation in close and wider spacing rice plants. Cruj et al. [8] supported that continuous flooding gave greater plant height, higher grain and straw ratio.

3.1.4 Yield attributes

The yield attributes of rice, viz., Number of ear bearing tillers hill^{-1}, No. of fertile grains panicle^{-1}, Number of grains panicle^{-1}.

3.1.5 Number of ear bearing tillers hill^{-1}

The number of ear bearing tillers hill^{-1} obtained with stagnant flooded condition was 12.3 which were significantly higher than conventional condition (10.28). The number of ear bearing tillers hill^{-1} under the plant spacing S_2 (20×15 cm) was 12.1 which were significantly higher than S_1 (15×10 cm) 10.5.

Among varieties, there was no significant difference in the number of ear bearing tillers hill^{-1} and it was recorded to be 11.2 under V_1 (IR-64) and 11.4 under V_2 (IR-64 Sub1).

The results agreed with Krishnamurthy et al. [13]; Dongale and Chavan [14] who observed that submergence of rice field increased number of productive tillers compared to under saturation condition but the difference was significant.

3.1.6 No. of fertile grains panicle $^{-1}$

The No. of fertile grains panicle $^{-1}$ was presented in Table 4. It was observed that the No. of fertile grains panicle $^{-1}$ in conventional condition was 79 which were significantly higher than stagnant flooded condition (73). It was found that the No. of fertile grains panicle $^{-1}$ didn't differ significantly with the plant spacing and it ranged from 74 in S_1 to 77 in S_2. Among varieties, there was no significant difference in the no. of fertile grains per panicle and it was recorded to be 75 under V_1 and 76 under V_2.

Similar result was found that Chakrabortty et al. [15] who reported that the weight and number of fertile grains per panicles than rest of spacing 30 x30 cm and 25 ×25 cm.

4. CONCLUSION

Significantly high grain yield was recorded in conventional condition V_1 (IR64) and submerged condition V_2 (IR-64 Sub1) has significant affect in yield. V_2S_1 (IR-64 Sub1+15×10 cm) has 350 gm^{-2} grain yield in submerged condition. The grain yield was increased on submerged condition at spacing S_1 (15×10 cm; close spacing) because survival rate was high in this condition and plant population per meter square was high. Sarkar et al. [6] found that submergence tolerant cultivar having Sub1 gene showed greater re-growth measured in terms of emergence of new leaves and higher survival percentage.

In flash flooding condition (water level is high 70 cm) submergence tolerance cultivar (V2) planted with close spacing (S_1) found to have more survival rate as compared to wider spacing (S_2).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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