Scientia Agriculturae
www.pscipub.com/SA
E-ISSN: 2310-953X / P-ISSN: 2311-0228
DOI: 10.15192/PSCP.SA.2015.9.1.2329

Sci. Agri.
9 (1), 2015: 23-29
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Yield contributing characters effect of submerged water levels of boro Rice (*Oryza sativa* L.)

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Paper Information

Received: 28 September, 2014

Accepted: 19 November, 2014

Published: 20 January, 2015

Citation

Maksudul Haque Md, Rani Majumder R, Kumer Hore T, Romel Biswash Md. 2015. Yield contributing characters effect of submerged water levels of boro Rice (Oryza sativa L.). Scientia Agriculturae, 9 (1), 23-29. Retrieved from www.pscipub.com (DOI: 10.15192/PSCP.SA.2015.9.1.2329)

A B S T R A C T

The field experiment was conducted at the Field Laboratory of Sher-e-Bangla Agricultural University (SAU), Dhaka in boro season with a view to find out the influence of water level and seedling number hill^{-1} on growth and yield of boro rice. The entire yield component was significantly unaffected by seedlings number hill^{-1} but percent filled grains was decreased with increasing seedling number hill^{-1}. Grain yield was significantly influenced by seedling number hill^{-1} but straw yield as well as biological yield was unaffected. The highest grain yield (6.49 t ha^{-1}) was found with 2 seedlings hill^{-1} which was similar to 1 and 3 seedlings hill^{-1} and the lowest grain yield (6.00 t ha^{-1}) was at 4 seedlings hill^{-1}. Interaction effect of water level and seedling number hill^{-1} had significant effect on growth as well as yield contributing characters except duration of flowering, effective tillers hill^{-1} and 1000 grain weight. Among the yield contributing characters total grains panicle^{-1}, filled grains panicle^{-1} and percent filled grains were significantly lowest at saturated condition with 4 seedlings hill^{-1} compared to other treatments. Significantly the highest grain yield was recorded from 1 to 3 seedlings hill^{-1} irrespective of their water level and the lowest grain yield was at 4 seedlings hill^{-1} under continuous saturation as well as submerged condition. Field water use efficiency was significantly higher (6.10 kg ha^{-1} mm^{-1}) at continuous saturated condition and lower (4.57 kg ha^{-1} mm^{-1}) at submerged condition.

Key words: *Submerged, Interaction, Harvest index, Water economy, yield, Boro Rice (Oryza Sativa L.)*

Introduction

Rice (*Oryza sativa* L.) is the primary food for half the people in the world. In many regions it is eaten with every meal and provides more calories than any other single food. Rice is a nutritious food, providing about 90 percent of calories from carbohydrates and as much as 13 percent of calories from protein (Anon., 2005). Rice contributes more than 70% of total production and 60-94% of daily calorie intake in China, India, Pakistan, Bangladesh and Nepal (Prasad et al., 1999).

Rice is the 1st ranking cereal crop in terms of area and production in Bangladesh though the average yield of 2.82 t ha^{-1} is very low as compared to that of Egypt (8.4 tha^{-1}) and USA (6.6 t ha^{-1}) (BBS, 2010). There are many reasons for this low yield. The important one is use of unsuitable aged seedlings and different water levels by farmers. The combined effect of these factors usually produces high seedlings mortality just after transplanting. Seedlings age at transplanting is an important factor for uniform stand of rice and regulating its growth and yield (Bassi et al., 1994). Tiller dynamics of the rice plant greatly depends on the age of seedlings at transplanting (Pasuquin et al., 2008). Tillering and growth of rice proceed normally when optimum aged seedlings are transplanted at the right time (Mobasser et al., 2007). Though about one-third of the country's land area is submerged by monsoon flood in a normal year, no boro crop can be grown without irrigation (Das, 2005).On the other hand, Inefficient water use not only increases cost of irrigation, but declines the water table, increases arsenic contamination and may emit the green house gases from submerged rice field that lead to climate change in the world (Wang et al., 2002). Most farmers maintained standing water in the rice crop to control weeds, but this benefit comes at the expense of substantial water loss by percolation and seepage. The gap between the "true need" and "current use" of water producing rice is very large (Bhuiyan, 1999).

Irrigated area can be extended from its current one-third of the cultivated area to more than one-half. But water is costly resource and its efficient use means bringing additional area under irrigation without making extra investments (Das, 2005). Seedling(s) per hill is an important factor for the growth and yield of rice. Optimal population density and leaf area influences the availability of sunlight and nutrients for growth and development. Competition within the hill is an integral part of the physical environment and the competition by neighbors often create the complexity. Obulamma et al. (2002) recorded the highest grain yield, crop growth rate and net assimilation rate from one seedling hill^{-1}. Panda et al. (1999) found that grain yield was highest with 4 seedlings hill^{-1}. Biswas and Salokhe (2001) revealed similar yield of rice by planting 2-4 vegetative tillers per hill. Because of these conflicting reports about the effect of water level and population density on growth and yield of boro rice, a study has under taken with the following objectives to find out the effect of water level and seedling number hill^{-1}on growth and yield of boro rice, to identify the optimum water level and seedling(s)/hill for boro rice cultivation and to find out the water use efficiency.

Materials and Methods

The field experiment was conducted at the Field Laboratory of Sher-e-Bangla Agricultural University (SAU), Dhaka in boro season during the period from January 2013 to May 2013 with a view to find out the influence of water level and seedling number hill^{-1} on growth and yield of boro rice. The experiment was carried out in split-plot design with 3 replications having two levels of water in main plot and 4 levels of seedling number hill^{-1} in the sub plot. There were 8 treatment combinations. The total numbers of unit plots were 24. The size of unit plot is 5 m x 3 m. The distances between plot to plot and replication to replication were 1 and 1.5 m respectively. The water levels were continuous saturated (S_1) & continuous submerged (S_2) condition as well as seedling numbers were 1 (T_1), 2 (T_2), 3 (T_3) & 4 (T_4) seedlings hill^{-1}. At the time of first ploughing cowdung at the rate of 10 t ha^{-1} was applied. The experimental area was fertilized with 120, 80, 80, 20 and 5 kg ha^{-1} N, P_2O_5, K_2O, S and Zn in the form of urea, triple superphosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate respectively. The entire amounts of triple superphosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate were applied at final land preparation. The first one-third urea was top dressed at 7 days after transplanting (DAT). The rest of urea was top dressed in three equal splits- one at 23 days after transplanting (DAT), second at 38 days after transplanting (DAT), and the other at panicle initiation stage (52 DAT).

Two sets of treatments included in the experiment were as follows:

A. Irrigation water levels (2): S_1= Saturated (No deficit or stagnation of water) and S_2= Submerged (Continuous 2-5 cm standing water)

B. Seedling(s) number hill^{-1} (4): T_1= 1 seedling hill^{-1}, T2= 2 seedlings hill^{-1} ,T_3= 3 seedlings hill^{-1} and T_4= 4 seedlings hill^{-1}

Recording of data of Crop growth characters: Plant height (cm) at 15 days interval, Number of tillers hill^{-1} at 15 days interval, Leaf area index at 15 days interval and Dry weight of plant at 30 days interval and Time of flowering.

The data collected on different parameters were statistically analyzed to obtain the level of significance using the IRRISTAT (Version 7.2, IRRI, Philippines) computer package program developed by IRRI. The mean differences among the treatments were compared by least significant difference test at 5% level of significance.

Table 1. Influence of water level and seedling number hill^{-1}on yield contributing characters of boro rice

Treatment	Effective tillers hill^{-1} (No.)	Panicle length (cm)	Grains /panicle (No.)	Filled grains/ panicle (No.)	Unfilled grains/ Panicle (No.)	Unfilled grains (%)	1000- grain weight (g)
Water level							
S_1	12.28	28.10	153.16	137.20	15.96	10.50	19.86
S_2	12.92	28.42	161.42	145.35	16.07	9.95	19.65
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns
Seedling number hill^{-1}							
T_1	12.37	28.40	157.02	143.04	13.98	8.90	19.89
T_2	12.40	28.23	161.45	146.08	15.37	9.52	20.08
T_3	12.25	28.10	156.53	140.62	15.92	10.17	19.64
T_4	13.38	28.31	154.16	135.37	18.79	12.37	19.41
LSD (0.05)	ns	ns	ns	ns	ns	2.33	ns
Interaction of water level and seedling number hill^{-1}							
S_1 T_1	11.80	28.15	157.65	145.59	12.07	7.65	19.93
S_1 T_2	12.33	28.06	154.97	139.00	15.97	10.23	20.02
S_1 T_3	12.30	27.72	162.18	145.85	16.33	10.06	20.16
S_1 T_4	12.70	28.47	137.82	118.36	19.46	14.12	19.32
S_2 T_1	12.93	28.64	156.38	140.48	15.90	10.17	19.86
S_2 T_2	12.47	28.40	167.92	153.15	14.77	8.81	20.14
S_2 T_3	12.20	28.47	150.88	135.38	15.50	10.28	19.12
S_2 T_4	14.07	28.16	170.50	152.38	18.12	10.62	19.47
LSD (0.05)	ns	1.11	28.62	23.66	7.10	3.30	ns
CV (%)	12.3	2.2	10.2	9.4	24.9	18.1	4.9

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling hill^{-1}, T_2= 2 seedlings hill^{-1}, T_3= 3 seedlings hill^{-1}, T_4= 4 seedlings hill^{-1}

Number of effective tiller hill^{-1} was not significantly influenced by seedlings number hill^{-1} (Table 1). The higher number of effective tiller hill^{-1} (13.38) was counted at 4 seedlings hill^{-1} that followed by other treatments. The findings are in agreement with those stated by BRRI (1999) and Shah et al. (1991) who reported that effective tillers significantly unaffected by the variation of seedling numbers per hill.

Number of effective tillers hill^{-1} was insignificant by the interaction of water level and population density. Maximum and minimum effective tiller hill^{-1} was recorded at continuous submergence with 4 seedlings hill^{-1} (14.07) and saturation with 1 seedlings hill^{-1} (11.80) though the difference was statistically similar (Table 1).

Results and discussion

Number of effective tillers hill^{-1}

The number of effective tillers hill^{-1} was not significantly influenced by different water levels. The number of effective tillers hill^{-1} obtained with submerged condition was (12.92) and with continuous saturated condition was 12.28 (Table 1). The results agreed with Chowdhury (1988) also revealed the highest number of effective tillers m^{-2} with continuous flooding that was significantly different from that obtained with continuous saturation.

Panicle length

The panicle length was not varied significantly due to water levels. The maximum (28.42 cm) and minimum (28.10 cm) panicle length was obtained under submerged and saturated condition respectively which was statistically similar (Table 1). The similar length of panicle under saturated and submerged condition due to adequate supply of water and nutrients might be resulted from similar flag leaf which ultimately caused equal photosynthesis that supplied equal assimilates. Bhuiyan (2001) also reported that rice plant did not suffer from water stress if soil was saturated and there was no standing water.

Panicle length was statistically unaffected by the number of seedlings hill^{-1}. The longest (28.40 cm) and shortest (28.10 cm) panicle was observed in 1 and 3 seedlings hill^{-1} respectively though the value did not differ significantly (Table 1). The results are conformity with Hushine (2004), BRRI (1999) who stated that panicle length was unaffected by the number of seedlings hill^{-1}.

The interaction between water level and seedling number hill^{-1} was significantly influenced the panicle length (Table 1). The longest panicle length (28.64 cm) was obtained under continuous submerged condition with 1 seedlings hill^{-1} and that followed by other treatment combination except saturated condition with 3 seedlings hill^{-1} which gave significantly shortest panicle length (27.72 cm).

Number of grains panicle^{-1}

The number of grains panicle $^{-1}$ significantly unaffected due to the different water levels. Plants grown under continuous standing water (S_2) showed 161.42 grains panicle^{-1}, whereas plants under continuous saturated (S_1) condition gave 153.16 grains plant^{-1} (Table 1). The number of grains panicle^{-1} was 5.39% higher under submerged condition compared to saturated condition. The result was dissimilar with Joseph & Havnagi (1988) who showed that number of spikelets per panicle under standing water was superior than that's of under saturated condition. They found 8.21% more spikelets per panicle over saturated to submerged condition.

Number of grains panicle was not significantly influenced by the number of seedlings hill^{-1}. The maximum (161.45) and lowest (154.16) of grains panicle^{-1} was obtained with 2 and 4 seedling hill^{-1} respectively which was statistically similar (Table 1). The result was agreement with Shah et al. (1991) who stated that total grains per panicle was unaffected by the number of seedlings hill^{-1} and number of grain panicle^{-1} increased with decrease in seedling number hill^{-1}.

Total grains per panicle was significantly influenced by the interaction effect of water levels and seedling number hill^{-1}. Continuous submergence showed higher grains panicle^{-1} irrespective of their seedling number hill^{-1} but in case of in case of saturated condition higher seedling number hill^{-1} resulted the lowest grains panicle^{-1}.

Filled grains panicle^{-1}

The filled grains panicle did not differ significantly for water levels. The maximum number of filled grains (145.35) was found in submerged condition and the minimal number (137.20) of grains panicle^{-1} at saturated condition (Table 1). The percent filled grain was 89.50 and 90.05 of total grains under saturated and submerged condition respectively.

Number of filled grains panicle^{-1} did not differ significantly at different seedling number hill^{-1}. The maximum number of filled grains panicle^{-1} (146.08) was found at 2 seedlings hill^{-1} and the lowest (135.37) at 4 seedlings hill^{-1} (Table 1). The percent filled grain was significantly influenced by seedling number hill^{-1} (Table 1). Filled grain percentage was highest at 1 seedling hill^{-1} (91.10%) which was statistically similar with 2 seedlings hill^{-1} (90.48%) and it was followed by 3 seedlings hill^{-}

^{1}. Significantly the lowest percentage of filled grains (87.63) was observed at 4 seedlings hill^{-1} which was similar to 3 seedlings hill^{-1}. Singh (1990) also revealed that filled spikelets per panicle decreased with increased seedlings per hill.

Interaction effect of water level and population density was significant in respect of filled grains panicle^{-1} (Table 1). The highest number of filled grain panicle^{-1} (153.15) was obtained in submerged condition with 2 seedlings hill^{-1} and it was similar to continuous submergence with 4, 1 and 3 seedlings hill^{-1} at same water level along with saturated condition having 1, 2 or 3 seedlings hill^{-1} but the lowest number of filled grains panicle^{-1} (118.36) was recorded at continuous saturation with 4 seedlings hill^{-1}. Percentage of filled grains was statistically influenced by the effect of water level and population density.

Unfilled grains panicle^{-1}

Analysis of variance showed that number of unfilled grain panicle^{-1} was not statistically differed due to different water levels (Table 1). The maximum (16.07) and minimum (15.96) number of unfilled grains panicle^{-1}was recorded under continuous submergence and saturated condition respectively.

Number of unfilled grains panicle^{-1} was not statistically influenced by the number of seedlings hill^{-1} (Table 1). The minimum number (13.98) of unfilled grains panicle^{-1} was counted at single seedling hill^{-1} and the maximum number (18.79) was found at 4 seedlings hill^{-1}. The unfilled grain was 8.90%, 9.52%, 10.17% and 12.37% at 1, 2, 3 and 4 seedlings hill^{-1} respectively. Hushine (2004) also observed that sterile spikelets panicle^{-1} was unaffected by seedlings number hill^{-1}.

Unfilled grains panicle^{-1} was statistically influenced by interaction effect of water level and population density (Table 1). The highest number (19.46) of unfilled grains panicle^{-1} was recorded under saturated condition with 4 seedlings hill^{-1} whereas the lowest number (12.07) was counted at 1 seedling under saturated condition. Percentage of unfilled grains was also highest at saturated condition with 4 seedlings hill^{-1} and all other treatment combinations showed statistically lowest percent of unfilled grains panicle^{-1}.

Weight of 1000 grains

Weight of 1000 grains was found statistically unaffected by the variation of water levels (Table 1). Comparatively heavier (19.86 g) 1000 grain weight was found under saturated condition which was similar with that of submerge condition. Result was conformity with the findings of Patel (2000) who observed similar 1000 grain weight under saturated and submerged condition.

Weight of 1000 grains was not significantly influenced by the number of seedlings hill^{-1}. The heaviest 1000 grain weight (20.08 g) was found under the transplanting 2 seedling hill^{-1} and the lowest 1000 grain weight (19.41 g) was found at 4 seedlings hill^{-1}. The results showed that 1000 grain weight was declined with increasing seedlings number hill^{-1} (Table 1). The finding was agreement with those stated by Hushine (2004), Faruque (1996) and Shah et al. (1991) who also reported that 1000-grain weight was unaffected by the number of seedlings hill^{-1}. Karim et al. (1992) also reported that 1000-grain weight slightly decreased with increasing plant density.

Weight of 1000 grains was not significantly affected by the interaction effect of water levels and population density (Table 1).

Grain yield

Grain yield of boro rice was not significantly influnced by water level. The maximum grain yield (6.44 t ha^{-1}) was obtained with continuous submerged condition that followed by continuous saturated condition (Table 2). The findings are in agreement with IRRI (1995), Sattar and Bhuiyan (1994) who observed insignificant yield difference under saturated and submerged condition. But the result was disagreed with Gowda (1995) and Islam (1992), who stated statistically higher grain yield at submerged condition than that of saturated condition. Similar grain yield in both the water levels might be due to similar effective tillers hill^{-1}, filled grains panicle^{-1} and 1000-grain weight.

Grain yield was significantly influenced by the number of seedlings hill^{-1}. The highest grain yield (6.49 t ha^{-1}) was found with 2 seedlings hill^{-1} which was statistically similar to 1 and 3 seedlings hill^{-1} and the lowest grain yield (6 t ha^{-1})was found with 4 seedlings hill^{-1} (Table 2). The result was conformity with the findings of Islam et al. (2002), Kabir (2002) and Rajarathinam who observed highest grain yield with 2 seedlings hill^{-1} whereas Shrirame et al. (2000) found similar grain yield under 1, 2 and 3 seedlings hill^{-1}. The result was disagreement with Shahi and Gill (1976) who observed the highest grain yield with 4 seedlings hill^{-1} and lowest at 1 seedling hill^{-1}.

Straw yield

Irrigation treatments showed statistically similar effect on straw yield of boro rice. Comparatively maximum (8.03 t ha^{-1}) and minimum (7.69 t ha^{-1}) straw yield was found under irrigation applied at submerged condition and saturated condition respectively (Table 2). The result was in conformity with that of Patel (2000), who reported significantly unaffected straw yield straw yield under saturated and submerged condition.

Table 2. Yield of boro rice as influenced by water level and seedling number hill^{-1}

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
Water levels			
S_1	6.16	7.69	13.86
S_2	6.44	8.03	14.47
LSD (0.05)	ns	ns	ns
Population density			
T_1	6.29	7.26	13.56
T_2	6.49	7.86	14.35
T_3	6.42	8.21	14.63
T_4	6.00	8.11	14.11
LSD (0.05)	0.43	ns	ns
CV %	5.4	20.6	12.3

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling hill^{-1}, T_2= 2 seedlings hill^{-1}, T_3= 3 seedlings hill^{-1}, T_4= 4 seedlings hill^{-1}

Straw yield was not significantly influenced by the different level of population density. The maximum straw yield (8.21t ha^{-1}) was found with 3 seedlings hill^{-1} and the minimum straw yield (7.26 t ha^{-1}) was at single seedling hill^{-1} (Table 2). Rajarathinam and Balasubramanuyan (1999) also revealed no significant difference of straw yield due to different levels of seedlings hill^{-1}.

Biological yield

Biological yield was not significantly varied for the water levels. The maximum biological yield (14.47 t ha^{-1}) was obtained from continuous submerged condition which was statistically similar (13.86 t ha^{-1}) to saturated condition (Table 2). Statistically similar biological yield might be due to the similar grain yield and stray yield under different water levels.

Biological yield was not significantly influenced by seedling numbers hill^{-1}. Maximum biological yield (14.63 t ha^{-1}) was observed with 3 seedlings hill^{-1} whereas minimum biological yield (13.56 t ha^{-1}) was found with planting single seedling hill^{-1} (Table 2).

Harvest index

Harvest index was not statistically influenced by the water levels. However, the maximum (45.03 %) harvest index was found from irrigation applied at submerged condition and the minimum harvest index (44.65) was at saturated condition (Figure 1). The result was in agreement with the findings of Raju (1980) who reported that treatment having continuous flooding did not improve the harvest index.

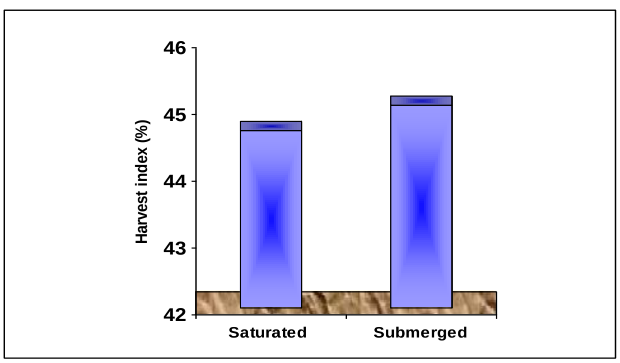

Figure 1. Influence of water level on harvest index of boro rice

Seedling number variation had no significant effect on harvest index. However, One seedling hill^{-1} produced the highest harvest index (46.77%) and the lowest (42.87%) was in 4 seedlings hill^{-1}. The increase of harvest index was more prominent in less population density and it was decreased with increasing planting density (Figure 2). The result was in agreement with the findings of Shah et al. (1991) and Zhang and Huang (1990) who reported that harvest index was unaffected by the number of seedlings hill^{-1} but Shrirame et al. (2000) reported significantly higher harvest index with one seedling hill^{-1}.

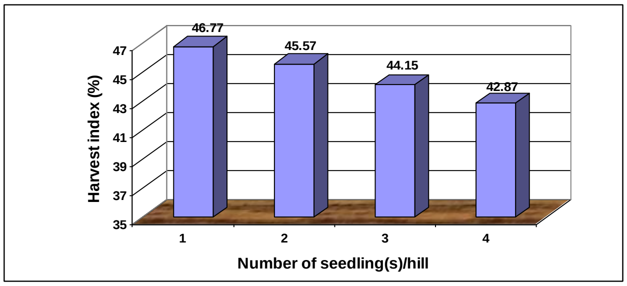

Figure 2. Influence of seedling number $hill^{-1}$ on harvest index of boro rice

Water economy

The applied water was measured as per Islam (1997). It was found that higher amount of water (1410 mm) was required for continuous submerged (2-5 cm standing water) condition where as continuous saturated condition needed 1010mm water. Similar water requirement in submerged and saturated condition was also reported by IRRI (1995), BRRI (1988), Jaggi et al. (1985), and Iruthyaraj (1981) who stated that continuous flooding needed more water than saturated condition. The percent reduction of total water requirement from submerged to saturation was 28.37%. Sattar and Bhuiyan (1994) also reported that under continuous saturated condition, 26-30% water was saved during normal irrigation period over the amount used in farmer's water management practice with continuous 5-7 cm standing water without any significant yield reduction.

Field water use efficiency

Effect of water levels

Field water use efficiency was significantly influenced by irrigation water levels. It was evident that significantly higher (6.10 kg ha^{-1} mm^{-1}) and lower (4.57 kg ha^{-1} mm^{-1}) water use efficiency was recorded with continuous saturated condition (No deficit or stagnation of water) and submerged condition respectively (Figure 3).The result was in agreement with those stated by Patel (2000), Gowda (1995), Maity and Sarkar (1990) who observed the highest water use efficiency in saturated condition than that's of submerged condition.

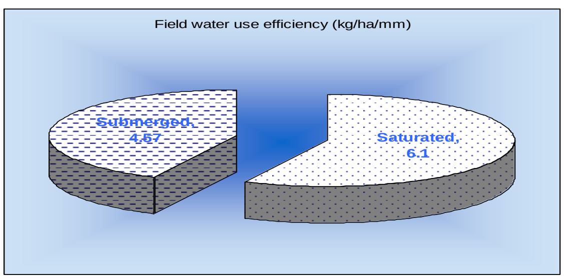

Figure 3. Field water use efficiency as influenced by water level

The maximum percentage of water use efficiency was estimated under 2 seedlings $hill^{-1}$ at continuous saturation (15%) and minimum percentage (10%) was recorded at submerged condition with 4 seedlings $hill^{-1}$ (Figure 4)

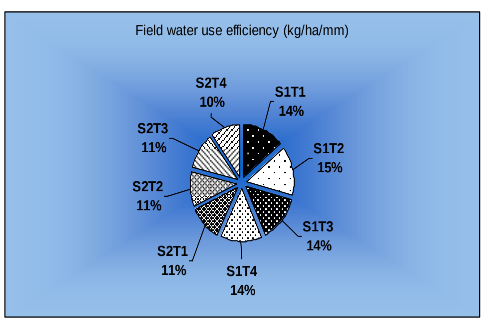

Figure 4. Percentage of water use efficiency under different water levels and seedling number hill-1
S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling $hill^{-1}$, T_2= 2 seedlings $hill^{-1}$, T_3= 3 seedlings $hill^{-1}$, T_4= 4 seedlings $hill^{-1}$

Conclusions

From the overall results it may be concluded that transplanting of younger seedlings in combination with intermittent submerge performed the best in tiller production, growth dynamics, yield contributing characters and produced more productive tillers hill^{-1}. Intermittent submerge was suitable for exploring the physiological potentials of rice seedlings on effective tillers for increasing grain yield.

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