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Full Length Article

Impact of Water Management on Fertilizer and Tillering Dynamics in Rice

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Abstract

Tiller is an important agronomic trait for rice yield production and its development could have been affected by different water management practices as it influences nutrient availability. This paper aims to evaluate tillering development under varying water depths and different fertilizer dosages from contrasting water management i.e. flooded and aerobic rice. Results showed that tillering development was affected by water depths and the response to fertilizer treatments altered with the change in water management where increase in tillering occurred during the early stages in flooded rice and at later stage in aerobic rice. Additionally, it takes only small percentage of fertilizer increased to boost tiller development in flooded rice whereas tillering in aerobic rice requires large percentage of fertilizer increased for it to be augmented. Therefore, increasing fertilizer dosages was found as ineffective and an alternative approach is needed to boost tiller development in aerobic rice. © 2018 Friends Science Publishers

Keywords: Water management; Fertilizer dosages; Tiller development; Rice

Introduction

Tillering is an important agronomic trait for rice yield (Li *et al*., 2003). High tillering capacity is associated as required for panicles (Miller *et al*., 1991), yield components (Ishii *et al*., 2011; Shimono, 2011) and yield production (Counce *et al*., 1996). Rice tillers are developed from tiller primordia which relied on the plant nutrient status (Yoshida, 1981). Nitrogen application has great impact on crop yield in rice when acquired during early and mid tillering stages (Murty *et al*., 1992). Highest panicle density was reported in aerobic rice when nitrogen fertilizers applied during the early vegetative stage at relatively high rates which also resulted in highest tiller density (Lampayan *et al*., 2010).

The water management in aerobic rice affects soil aeration and nutrient availability (Prasad, 2011) including soil nitrogen dynamics (Cassman *et al*., 1998) and consequently, tiller development. Tiller development in aerobic rice was not affected by different fertilizer dosages of 0 kg N ha^{-1} and 150 kg N ha^{-1} (Zhang *et al*., 2009) which is in contrast with the finding by Lampayan *et al*. (2010). However, the observation by Lampayan *et al*. (2010) was made during wet-season and Zhang *et al*. (2009) reported that the number of tillers differed significantly between two locations with different depths of groundwater table and soil water potential. This implied that the effect of fertilizer dosages on tiller development in aerobic rice is influenced by the amount of water availability in the soil.

The objective of this study was to investigate the impact of the change in water management on tiller development, and this was carried out in two parts; firstly by varying fertilizer dosages on both flooded and aerobic rice and secondly varying water depths designed to provide information on tiller development to elucidate any discrepancy observed in tiller development between two rice systems.

Materials and Methods

Research Location

Aerobic rice was grown in a greenhouse on the grounds of Institute of Biological Sciences, University of Malaya, Kuala Lumpur (3°07'15''N, 101°39'23''E). The greenhouse was built using wire nets to allow exposure to natural air flow, sunlight and rainfall.

Crop Management

Rice plants were grown in pots, one for each rice hill. Seeds of aerobic rice were grown in a plastic tray for 2 weeks before being transplanted, with three seedlings per hill. Plants were watered daily to maintain water depths for flooded rice whereas for aerobic rice, water is applied just to keep the soil moist but not saturated (Tuong *et al.*, 2005). Meanwhile, insecticides and fertilizers were applied according to crop requirement (Table 1).

Experimental Design, Tiller Measurement and Statistical Analysis

Fertilizer dosages on flooded rice: Five different fertilizer dosages were administered to MR232 at the times and types of fertilizers described in Table 1: F_{70} (140 kg ha^{-1}; 70% of the recommended dosage), F_{85} (170 kg ha^{-1}; 85% of the recommended dosage), F_{115} (230 kg ha^{-1}; 115% of the recommended dosage), F_{130} (260 kg ha^{-1}; 130% of the recommended dosage) and the control treatment, C_F (200 kg ha^{-1}; 100% of the recommended dosage).

Fertilizer dosages of aerobic rice: Five different fertilizer dosages were administered to MRQ74 at the times types of fertilizers described in Table 1: A_0 (0 kg ha^{-1}; no fertilizer applied), A_{50} (100 kg ha^{-1}; 50% of the recommended dosage), A_{150} (300 kg ha^{-1}; 150% of the recommended dosage), A_{200} (400 kg ha^{-1}; 200% of the recommended dosage) and the control treatment, C_A (200 kg ha^{-1}; 100% of the recommended dosage).

Water depths of flooded rice: MR232 was subjected to five different water depths: W_0 (0 cm), W_4 (4 cm), W_8 (8 cm), W_{12} (12 cm) and W_{16} (16 cm).

Pots were arranged in a complete randomized design with eight replications while the number of tillers per hill was counted manually. The data was subjected to analysis of variance (ANOVA) and significant differences between means were analyzed using Least Significant Difference (LSD) test. All data analysis were carried out using SPSS 19.0.

Results

Effects of Varying Fertilizer Dosages on Tillering

In flooded rice, F_{70} and F_{85} developed fewer tillers than C_F

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after four weeks of sowing, while a higher number of tillers was observed in F_{115} and F_{130} after 4 and 6 weeks of sowing (Fig. 1). In aerobic rice, tillering development A_{200} increased from 11 week to onwards while no significant effects was observed prior to this growth period (Fig. 2). We inferred that fertilizer dosages affect tiller development in flooded rice during the early growth period from 4–6 week while the effects in aerobic rice were observed during the later growth period from 11 week to onwards. Additionally, tillers in flooded rice peaked at week 6 and then started decline (Fig. 1), whereas tillers in aerobic rice continued to rise from week 1 to 12 with sharp increases between week 6 and 10 (Fig. 2).

Effects of Varying Water Depths on Tillering Development

Water depth at 4 cm developed higher number of tillers than water depth at 12 cm and 16 cm from 7 to 15 week, whereas water depth at 0 cm and water depth at 4 cm developed higher numbers of tillers than water depth at 8 cm, 12 cm and 16 cm during 12 to 14 week (Fig. 3). There is a large difference in tiller development between rice that was grown in shallow water (0 cm and 4 cm water depths) than with rice grown in deep water i.e., at 8 cm, 12 cm and 16 cm water depths.

Discussion

It is undeniable that the water depths in which rice was grown influenced tiller development (Fig. 3). It is reported that floodwater depth influences soil aeration and nutrient availability, including soil nitrogen dynamics: nitrate and ammonium are the dominant form of nitrogen in shallow and deep floodwater, respectively (Cassman *et al*., 1998) and these can be utilized by the rice plant although ammonium is regarded as a better source during the seedling stage and nitrate after panicle initiation (Yoshida, 1981). Hence, by varying water depths in rice, soil nitrogen dynamics was also inadvertently changed and had maximum tillering in flooded (Fig. 1) and aerobic rice (Fig. 2), with more tillers developed at water depth of 0 cm and 4 cm than water depth of 8 cm, 12 cm and 16 cm after the seedling stage (Fig. 3).

The change in water management influenced the timing of fertilizer effects on tiller development that was augmented during the early growth period in flooded rice (Fig. 1) and during the later growth period in aerobic rice (Fig. 2). The timing of tiller development is essential in ensuring better yield production and tillers developed during early growth stage normally produce panicles than developed later may or may not (Yoshida, 1981). In addition, tillers initiated later are of inferior quality compared to the earlier initiated ones (Wang *et al*., 2007). Hilyah *et al*. (2015) found that increasing fertilizer dosages did not result in higher spikelet production, filled grains and weight of 1000 grains (Table 2) and this could be attributed to the timing of tillering increase in aerobic rice, which occurred during the later growth period (Fig. 2). It was also noted that no significant effects were observed on the pattern of tiller development in aerobic rice prior to week 11 (Fig. 2), hence increasing fertilizer dosages may not be a viable option for increasing yield production in aerobic rice.

In flooded rice, reducing fertilizer dosages by 15% and 30% lowered tiller development by 10 and 25%, respectively, whereas increasing fertilizer dosages by 15% and 30% improved tiller development by up to 60% and74%, respectively (Fig. 1). In contrast, it was only when fertilizer dosage in aerobic rice increased by 200% then number of tillers significantly increased by up to 68% (Fig. 2). This comparison shows that it takes small percentages of changes in fertilizer dosages (15 – 30%) to affect tiller development in flooded rice, whereas it requires large percentages of increased fertilizer (200%) for tiller development in aerobic rice to be increased. However, it did not result in higher spikelet production, filled grains and weight of 1000 grains (Table 2).

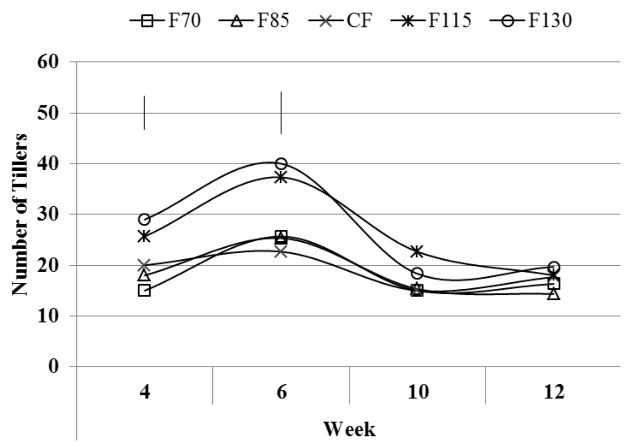

Fig. 1: Effects of different fertilizer dosages on tiller development in flooded rice. Vertical lines represent LSD (p=0.05)

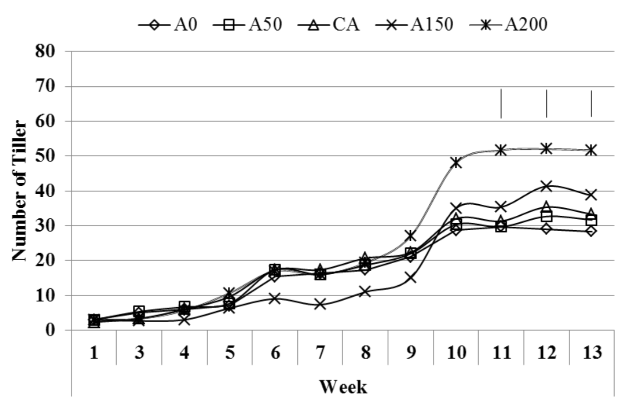

Fig. 2: Effects of varying fertilizer dosages tiller development in aerobic rice. Vertical lines represent LSD (p = 0.05)

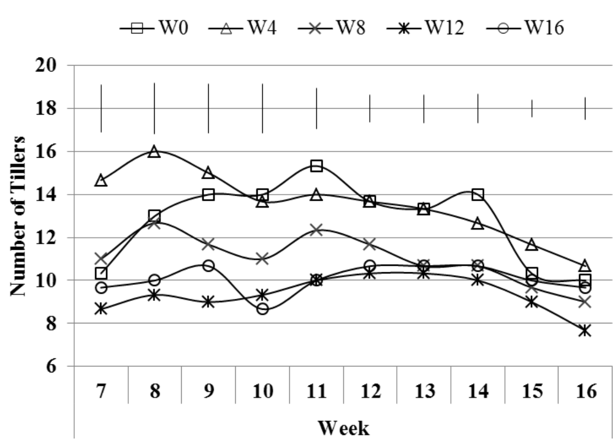

Fig. 3: Effects of different water depths on tiller development. Vertical lines represent LSD (p=0.05)

By growing rice aerobically, soil water availability may become a limiting factor; nutrient transport through the soil via mass flow and diffusion is slowed down with declining soil moisture (Marschner, 1995) and hence, only a large percentage of increased fertilizer can make a significant impact on tiller development. Additionally, this can also be explained by the observation of Bouman and Tuong (2001) that nitrogen uptake in flooded was quadruple of the uptake in aerobic rice. Similar observation was also made by Nie *et al*. (2012).

Overall, the change in water management was found to affect the timing of tiller development and the stage of maximum tillering, as well as the effectiveness of fertilizer application on its growth. The relationship of these effects is shown by strong correlation observed between fertilizer dosages and tiller increase during the early weeks (4 and 6) for flooded rice, and during the later weeks (10 and 12) for aerobic rice (Fig. 4). As these effects ultimately affect rice yield production, it is recommended to find alternate means to boost yield production in aerobic rice.

Table 1: Conventional approach for fertilizer application in aerobic rice cultivation

Day after transplant (DAT)	N:P:K	Recommended amount	Type of fertilizer
20	15:15:15	200 kg ha^{-1}	Granular
40			
65	13:13:22		
85	12:12:17 + MgO_2		

Table 2: Effects of varying fertilizer dosages on the yield components of aerobic rice MRQ74

Yield Components	Fertilizer Treatments				
	F_0	F_{50}	$Control_{VFD}$	F_{150}	F_{200}
Spikelets per hill	434 ± 261	984 ± 391	589 ± 158	153 ± 22	543 ± 336
Filled Spikelet	355 ± 215	852 ± 336	440 ± 212	114 ± 35	431 ± 262
Empty Spikelet	79 ± 45	132 ± 64	83 ± 23	40 ± 15	112 ± 28
Percentage of Filled Spikelet	80.27 ± 2.67	85.90 ± 2.80	83.95 ± 5.17	70.20 ± 15.17	80.45 ± 2.13
Percentage of Empty Spikelet	19.73 ± 2.67	14.10 ± 2.80	16.05 ± 5.17	29.80 ± 15.17	19.55 ± 2.13
Weight of 1000 grains (g)	17.75 ± 1.84	16.14 ± 0.53	17.01 ± 1.04	21.29 ± 2.70	16.54 1.77

Average of five replicates. Data presented as means ± SE. Data adapted from Hilyah *et al.* (2015).

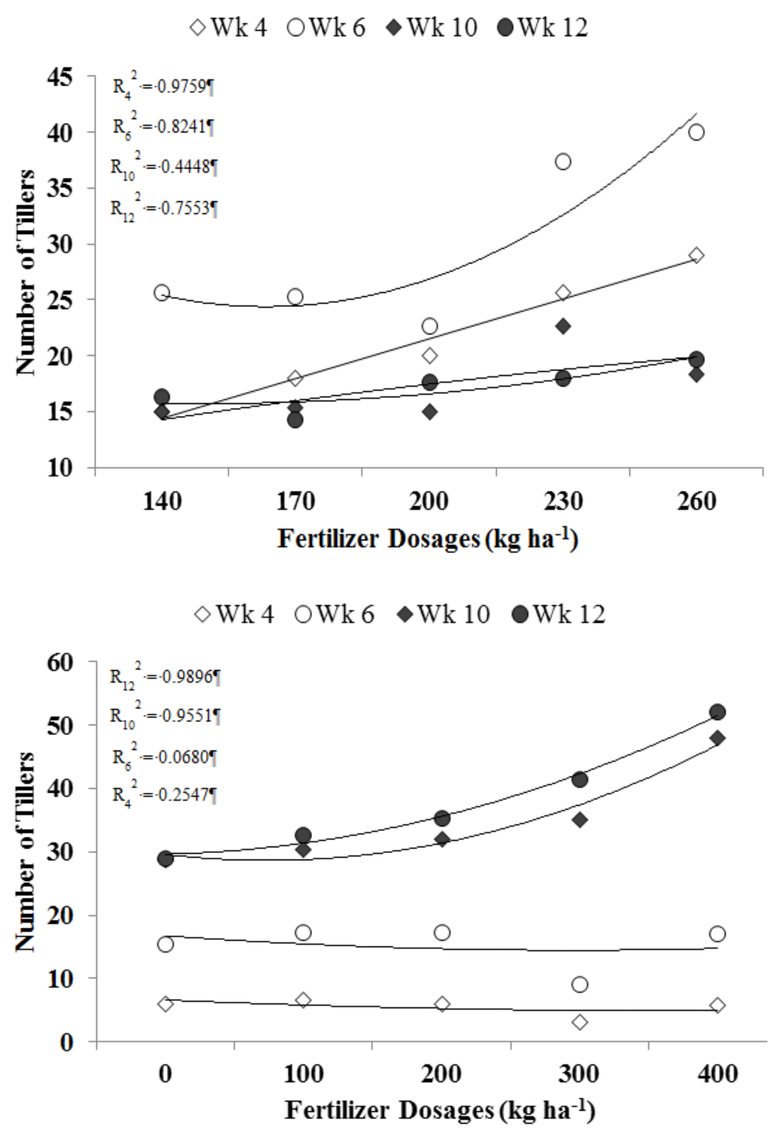

Fig. 4: Correlations between fertilizer dosages and tiller development in flooded (left) and aerobic rice (right)

Conclusion

Varying water depths influences tiller development in rice, while changing water management from flooded to aerobic affects the timing of tiller development and hence, rice yield production as well as the effectiveness of fertilizer application in promoting tiller proliferation. Hence, broadcasting fertilizer is more favourable than flooded rice, while an alternative approach is needed that favours tiller development and yield production in aerobic rice.

Acknowledgements

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