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Low Water Rice Production and its Effect on Redox Potential and Soil pH

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Abstract: This research was conducted to determine the effect of different water regimes in rice yield on redox potential and soil pH. There were five treatments simulating different flooding depths and durations, W_1 (continuous flooding at 5 cm), W_2 (continuous flooding at 1 cm), W_3 (continuous flooding at 5 cm in the first 3 weeks then 1 cm), W_4 (continuous flooding at 5 cm in the first 6 weeks then 1 cm) and W_5 (continuous flooding at 5 cm in first 9 weeks then 1 cm). Metller Toledo pH meter were used to measure redox potential and soil pH. In addition to yield and yield component, redox potential was more negative and significantly lowers under treatments, which were subjected to 5 cm flooding than 1 cm flooding. Therefore, maintaining the redox potential value kept the soil oxidized to rice low reduced condition could be implemented without effect on yield under low water input.

Key words: Water saving irrigation, redox potential, soil pH, rice

INTRODUCTION

Rice is the most important staple food in Asia, providing an average of 32% of total calorie uptake[1]. About 75% of the global rice volume produced in the irrigated lowlands[1]. The Malaysian scenario shows that the increase in rice production is not parallel with the increase in the country's population. In order to meet the demand, rice is imported from neighboring countries, especially from Thailand and Vietnam with the amount valued at about RM 501 million per year as reported by Asian Food Security Information System[2]. Increased productivity with optimum input should be the direction forward. One of the major inputs for rice production is water. About 75% of the global rice volume produced is in the irrigated lowlands[1]. Decreasing water availability for agriculture threatens the productivity of the irrigated rice ecosystem and ways must be sought to save water and increase the productivity of rice[3]. However, water is becoming increasingly scarce. In many Asian countries, per capita availability declined by 40-60% between 1955 and 1990 and expected to decline further by 15-54% over the next 35 years[4].

Water logging is the given environment for lowland soils, which is suitable for rice production. However, it is concurrently one important factor in determining a condition for the production and emission, flooding rice fields were largely accused as a critical source of methane emission contributing to global worming. When oxygen is absent, a portion of methane produced in submerged paddy soils gradually emits methane. Water management with shallow water regime and drainage is, therefore suggested to be an important mitigation action for methane from rice paddies by enhancement of oxidation and reduction of methane formation as well as its total emission. The production of methane is influenced by varies underlying variables including temperature, soil pH, soil redox potential and amount of easily degradable carbon forming substrates for anaerobic microorgamism[5]. Redox potential is one the important factor to know the methane emission from rice field whether it occurred or not. Therefore, changes in water management may help to save water resources without a compromise in yield and productivity, as well as to reduce CH_4 fluxes[6].

The future rice production will therefore depend heavily on developing and adopting strategies and practices through efficient use of resources. In relation to this current issue, the objective of this study was to evaluate the effect of different flooding regimes on yield and redox potential and soil pH.

MATERIALS AND METHODS

The experiment was carried out in the field at Universiti Putra to evaluate the effect of different water input on rice production in relation to redox potential and soil pH. The experiment was laid out in a Completely Randomized Design (CRD) consisting of five different water regimes namely: W_1 (continuous flooding at 5 cm), W_2 (continuous flooding at 1 cm), W_3 (continuous flooding at 5 cm in the first 3 weeks then 1 cm), W_4 (continuous flooding at 5 cm in the first 6 weeks

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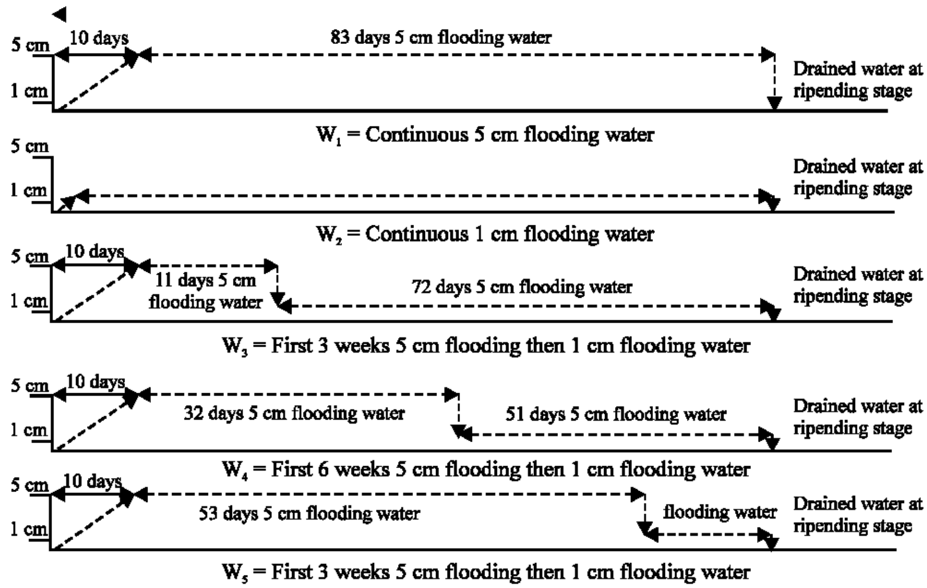

Fig. 1: Graphical presentation of different water saving irrigation techniques of experiment for explanation of the five water treatments

then 1 cm) and W_5 (continuous flooding at 5 cm in first 9 weeks then 1 cm) with four replications (Fig. 1). Rice plant grown in cylindrical culvert measuring 90 cm diameter X 60 cm height and all culverts were filled with soil around 210 kg. The soils were filled up to 40 cm leaving with allowance of 20 cm from the top of the container. Two holes were made at 1 and 5 cm above from the soil level in each culvert. The holes were attached to plastic tube equipments with flow regulators for adjusting required water levels. Healthy rice seeds of variety MR 219 used at a sowing rate of 150 kg ha^{-1}. Fertilizer urea as N 110 kg ha^{-1} with two splits (2/3 as basal + 1/3 at active tillering), P_2O_5 (60 kg ha^{-1}) as Triple Super Phosphate (TSP) and K_2O (65 kg ha^{-1}) as Muriate of Potash (MOP) were applied as basal dressings. Compound fertilizer (N: P: K= 12:12:17) was applied twice at 50 and 71 days after planting at the rate of 300 and 200 kg ha^{-1}, respectively.

Mattler Toledo pH meter was used to measure the soil pH and redox potential in soil at weekly interval. The data were analyzed for analysis of variance (ANOVA). The means were compared using Duncan's Multiple Range Test (DMRT) at 5% level of significance using Statistical Analysis System software version 6.12[7].

RESULTS AND DISCUSSION

Yield and yield components

Tiller and panicle number: In this study, there was no significant effect of different flooding regimes on tiller numbers. The tiller numbers were in the range of 674 to 696 m^{-2}. Tiller production was found to be significantly lower under field capacity than flooded and saturated conditions[8]. In this study, all treatments were above saturation level hence; there was no effect of water stress on tiller production. Therefore, the tiller numbers remained unchanged under different flooding levels. There was no significant difference for number of panicles among treatments. The numbers of panicles were in the range of 636 to 665 m^{-2} (Fig. 2). The number of panicles produced was not significantly different for rice grown in flooded and saturated condition.

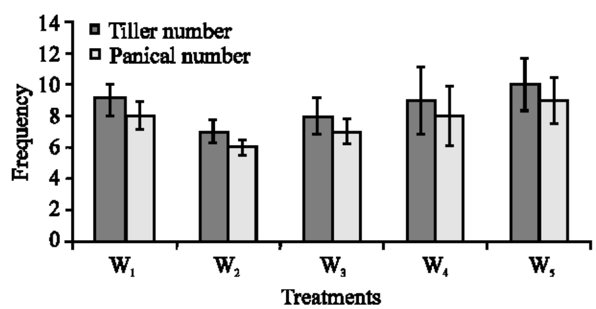

Fig. 2: The effect of different water levels on number of tillers and panicles

Grains per panicle: There was no significant difference for filled grains per panicle observed under different flooding levels. The filled grains were in the range of 89 to 101 per panicle (Fig. 3), which was comparatively similar to the data obtained by MARDI[9]. According to Ishizuka and Tanaka[10], increased in filled grain might have due to contribution of carbohydrates. In this study, the rice leaves appeared dark green during ripening, which may help to accumulate more carbohydrates through photosynthesis and resulted better-filled grain. There was no significant effect of different flooding levels on unfilled grains per panicle. The number of unfilled grains per panicle was in the range of 20 to 26 per panicle under different flooding levels (Fig. 3).

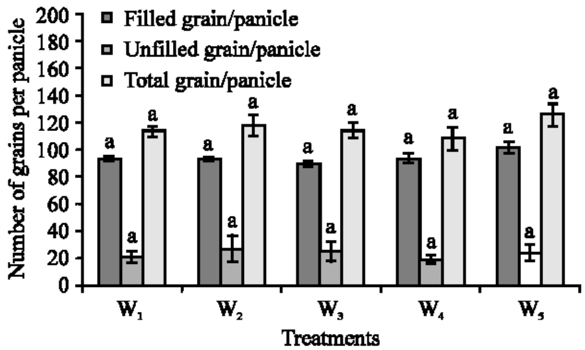

Fig. 3: The effect of different water levels on number of grains per panicle

Straw yield: There was no significant difference between straw weight and different flooding levels. The straw weight was found to range between 13.15 to 14.46 t ha^{-1} as dry condition and 47.56 to 53.81 t ha^{-1} as wet condition, respectively (Fig. 4). Therefore, in this study, there was no effect of different flooding levels on straw yield.

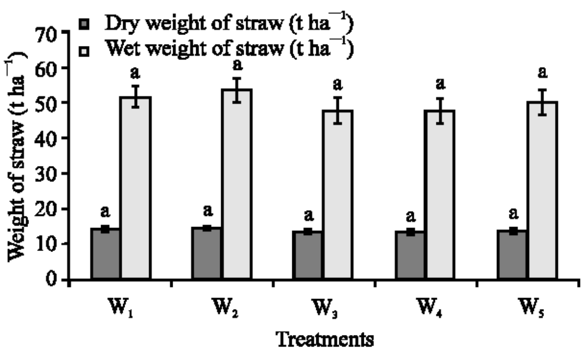

Fig. 4: The effect of different water levels on straw yield

Yield: There was no significant difference of yield under different flooding regimes in respect to wet yield (together with filled and unfilled grains weight just after harvest) and dry yield (dry filled grain). The yield was in the range of 19.46 to 20.08 t ha^{-1} and 12.39 to 11.87 t ha^{-1} as wet and dry grain, respectively (Fig. 5). The overall dry filled grain (containing 12% moisture content) yield was 12 t ha^{-1}, however, MARDI[9] had reported 10.70 t ha^{-1} of MR219 variety. Khanif (2002, unpublished) found 10.30 t ha^{-1} for the same rice variety MR219 in an experiment conducted at MARDI rice research station Tanjang Karang, Selangor. MARDI[9] also reported that in order to achieve a yield of 10 t ha^{-1}, the number of panicles in one square meter should be more than 500. In this study, the panicle numbers range between 674 and 696 per square meter; therefore, yields of more than up to 12 t ha^{-1} were observed.

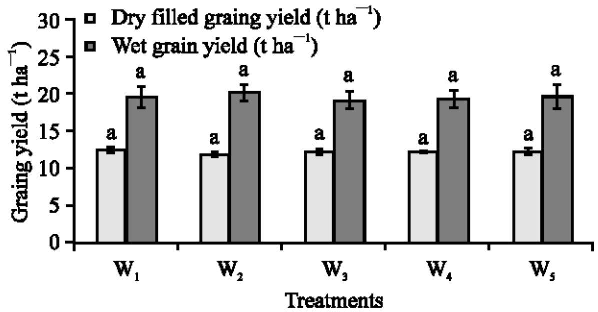

Fig. 5: The effect of different water levels on grain yield

Redox potential (Eh): There was no effect of different flooding levels on redox potential in the first two weeks because water was applied thereafter. After application of water according to the treatment, the redox potential value changed rapidly within a couple of days according to the water depth and duration. The redox values was found to be negatively lower in treatments which were under continuous 5 cm flooding water than 1 cm flooding water with time. W_2 always showed significantly higher redox value than W_1. Treatments, which were under 5 cm flooding was not significantly different with time, similarly treatments which were under 1 cm flooding with time was not significantly different (Table 1). The redox potential value was statistically significant between 5 cm flooding water and 1 cm standing water.

After the 5th weeks, the flooding levels changed from 5 to 1 cm in treatment W_3. The redox value was significantly different in W_2 and W_3 with other treatments. Alternatively, the Eh value of W_1, W_4 and W_5 were not significantly different. Same results were found at the 7th weeks under different water levels.

After the 7th weeks, the flooding levels of treatment W_4 had been changed from 5 to 1 cm flooding. Therefore, the redox value of W_2, W_3 and W_4 was significantly different from treatments W_1 and W_5 at the 8th and 9th weeks. During this time, the redox value was in the range of 43 to -03 mV and -65 to -104 mV under continuous 1 cm flooding water and continuous 5 cm flooding water, respectively. The redox potential was negatively higher in treatments, which were under 5 cm flooding water with

Table 1: The effect of different flooding water levels on redox potential (Eh) value in soil

	Redox potential value (mV) in soil solution in every week														
Treatments	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th
W_1	11a	25a	-63b	-52ab	-77b	-63c	-23b	-88b	-104b	-123c	-108c	-115c	-107c	68b	295b
W_2	10a	18ab	38a	-27a	-17a	-4b	73a	43a	9a	17a	23a	16a	-18a	106a	321a
W_3	-22a	1ab	-62b	-82bc	-43ab	42a	61a	40a	-3a	-6a	12a	11a	-26a	85ab	308ab
W_4	-25a	-11b	-88b	-94c	-74b	-81c	-86b	30a	-3a	-5a	8a	5a	-16a	102a	303ab
W_5	11a	2ab	-78b	-52bc	-49ab	-75c	-78b	-65b	-94b	-93b	-69b	-20b	-50b	88ab	309ab

Means with the same letter are not significantly different in column at $p = 0.05$

time. Similar results were found at 10th weeks and the redox value was in the range of 17 to -6 mV in W_2, W_3, W_4 and -93 to -123 in W_1, W_5, respectively. The redox value of W_2, W_3 and W_4 treatments was significantly different from W_1 and W_5. At the same time, the redox value of W_1 was negatively higher than W_5. After 10th weeks, the flooding level changed from 5 to 1 cm in treatment W_5. Although, the water level had been changed but the redox value was similar with previous sampling date. Similar results found at 12th and 13th weeks. At the ripening stage, water was drained from the experimental culvert and soil condition changed from reduced to oxidized condition, as a result, the redox value increased markedly. From the above discussion, is it to be concluded that the redox value were negatively higher in treatments which were under 5 cm flooding water then treatments, which were under 1 cm flooding water.

The continuous flooding with 5 cm water always showed negative value in most of the sampling date, but this value was not lower than -150 mV. W_3, W_4 and W_5 were under 5 cm flooding water in the first 3, 6 and 9 weeks, respectively. After changing the flooding water level from 5 to 1 cm, the redox potential value increased positively and showed significantly different from treatments which were under 5 cm flooding water with time. Therefore, redox value strongly related with duration and depth of standing water. According to Connel and Patrick[11], the emission of redox potential, which is a measure of oxidation-reduction status of the soil, has to be essentially below -150 mV to initiate the action of methanogenic bacteria for CH_4 production. In this study, the yield was 12 t ha^{-1}, it might effect of net photosynthesis rate. Rice plants were appeared very dark green during ripening and leaves were directly exposed to sunshine, which may increase photosynthesis rate. It is one of the most important factors for increasing the rice yield. According to Kim *et al.*[12], the net photosynthesis activity was reduced under strongly reduced soil condition (-150 mV).

Soil pH: There was no significant difference of soil pH under different flooding levels at weekly interval (Fig. 6). The soil pH values were in the range of 5.4 to 6.6 throughout the rice growing time. After application of fertilizer, the pH value decreased in soil solution due to effect of fertilizer. Therefore, on the 3rd and 4th sampling time, the pH level was lower than other sampling date and was in the range of 5.4 to 5.7. Same effect was found at the 11th sampling time after application of fertilizer, because of increased cation in soil solution. The soil pH is one of the most important factors to know the availability of most nutrients in soil solution in a given environment. The results obtained from this study reveal that most of the nutrients were available for uptake by plant at the soil pH of 5.4 to 5.7.

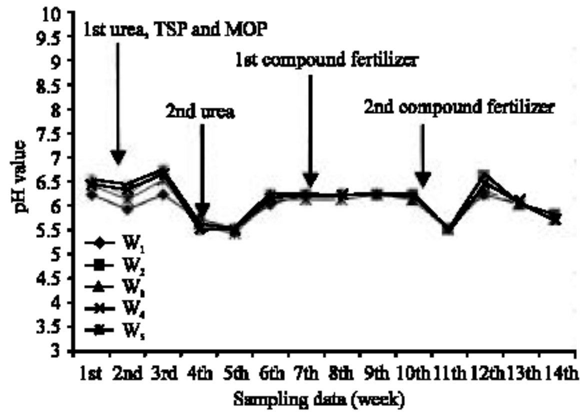

Fig. 6: The effect of different flooding regimes on soil pH

Issues related to water availability and distribution will be increasingly important globally in the coming years. The impact of greater water scarcity on agriculture will be manifested prominently in the rice production sector. It is therefore important to determine how to grow more rice with less water. In doing so, we must consider the irrigated rice production system as a whole and address its issues holistically, with full attention to interactions among them. In conclusion, this study clearly shows that it is highly possible to produce rice under low water input, which is capable of saving between 25-30% of water. The study also demonstrated that in addition to saving water, yield is not affected. Redox value was more negative and significantly lower in treatment, which was under 5 cm flooding water than treatments, which were under 1 cm flooding water. The overall redox value was not less than -145 mV at 4 cm depth of soil. The results showed that soils with 5 cm floodwater were more reduced than soils under 1 cm flooding. This condition remains until water was drained at ripening stage. Redox value strongly related to the depth and duration of standing water. This study revealed that the redox value was dissimilar under different water depth and duration. Therefore, it is recommended to use low flooding water for rice cultivation to reduce or prevent the methane emission from rice field as well as to keep the environment friendly. The different flooding levels showed no significant effect on soil pH over time and the soil pH was found to be moderately acid to near neutral (5.4 to 6.6). Most of the essential plant nutrients are available for plant uptake under this pH range.

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