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The Effect of Different Water Levels on Rice Yield and Cu and Zn Concentration

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Abstract: The objective of study was to evaluate the effect of water levels on rice yield and its effect on Cu and Zn concentration. There were five treatments simulating different water depths and durations namely: W_1, W_2, W_3, W_4 and W_5. At harvest, the number of tillers and panicles were counted. Grain yield, number of grains per panicle and weight of 1000 seeds were determined. In addition, the weight of straw was also obtained. The effect of water levels was not significant for tiller number, panicle number, grain yield (t ha^{-1}), straw weight (t ha^{-1}), grain/panicle and 1000 seeds weight (g). The different flooding levels had no significant effect on Cu and Zn concentration analyzed in soil solution at weekly intervals. Overall, this study showed that yields and yield components and nutrients concentration were not affected by different water levels. In addition, 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 without any effect on nutrient concentration.

Key words: Different water levels, concentration of Cu, concentration of Zn, rice

INTRODUCTION

Rice is the staple food for nearly half of the world's population, most of who live in developing countries. The crop occupies one-third of the world's total area planted to cereals and provide, 35-60% of the calories consumed by 2.7 billion people. More than 90% of the world rice is produced and consumed in Asia[1,2]. Rice is the widely grown of the crops under irrigation. More than 80% of developed freshwater resources in Asia and used for irrigation purposes and more than 90% of the total irrigation water is used for rice production[3]. About 75% of the global rice volume is produced in the irrigated lowlands[4]. Decreasing water availability for agriculture threatens the productivity of the irrigated rice ecosystem and ways must be sought to save water and increase the water productivity of rice[5].

Malaysia is very aware that the population growth (2.7% a year) has the potential for outstripping the advances made in providing the population with access to safe drinking water. In fact, water supply coverage grew rapidly between 1990 and 1995 (3.74% per annum) that Malaysia achieved its goal of providing 89% of its population with safe drinking water by 1995. The overall water demand is growing at the rate of 4% annually and projected to be about 20 billion m^3 by 2020 and the annual domestic and industrial water demand will grow to 5.8 billion m^3 and the irrigation water demand to about 13.2 billion m^3 in 2020[6]. The demand for irrigation water increased from 7.4 billion m^3 in 1980 to 9.0 billion m^3 in 1990 and 10.4 billion m^3 in 2000. The aggregate total water demand is, therefore, estimated to be 15.2 billion m^3 by 2000 as compared with 8.7 billion m^3 for 1980 and 11.6 billion m^3 in 1990[7] and the largest withdrawal of 76.6% was for agriculture use.

To increases water productivity of rice production, the interactions between irrigation practice and fertilizer supply should be addressed[8]. The future rice production will therefore depends heavily on developing and adopting strategies and practices through efficient use of resources. Such strategies are producing more rice with low inputs of water. The objective of this study was to evaluate the effect of water levels on rice yield and concentration of Cu and Zn.

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. 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 then 1 cm) and W_5 (continuous flooding at 5 cm in first

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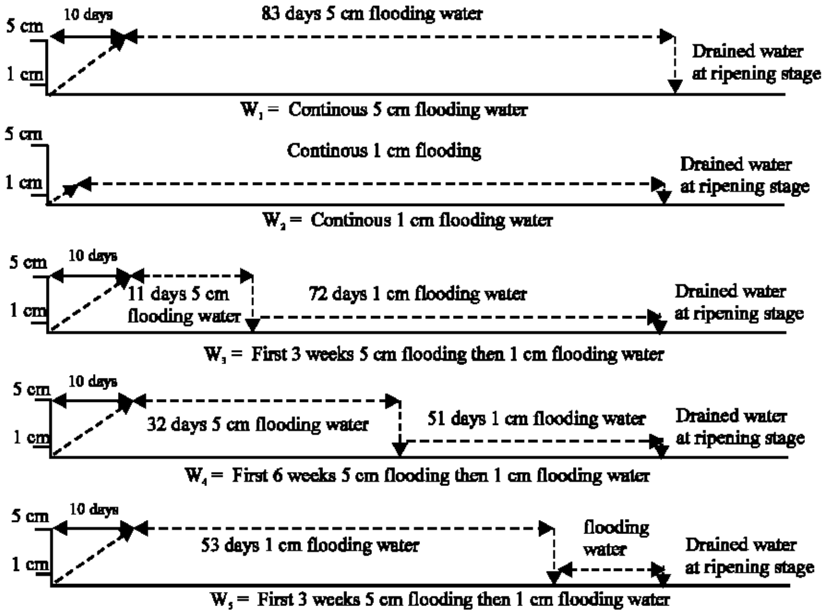

Fig. 1: Graphical presentation of different water saving irrigation techniques of experiment for explanation of the five water treatment

9 weeks then 1 cm) with four replications (Fig. 1). Rice plant grown in cylindrical culvert measuring 90 cm diameter 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.

After harvest, yield and yield components were recorded as tiller and panicle number per plot, straw yield, grain yield, filled grain per panicle, unfilled grain per panicle, 1000 seeds weight. A porous ceramic cup fixed at the bottom of an empty PVC tube. All tubes were inserted into the soil at 3-8 cm depth in order to collect soil extract. A depression was created inside the tube by a pump to create absolute vacuum therefore the soil solution drawn from the soil through the porous ceramic cup into the tube. Then it brought to the laboratory for analysis for essential plant nutrients (Cu and Zn) by auto analyzer. 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[9].

Saving water: Measuring cylinder was used to measure by how much water was applied during rice cultivation. At maturity stage, the containers were kept without standing water to facilitate ripening. The equation of saving water of treatment W_2 (continuous 1 cm flooding) in contrast of W_1 (5 cm continuous flooding) as follows:

$$\text{Save water} = 100 - \frac{W_b \text{ X } 100}{W_a}$$

Where:
W_a = Total water use in continuous 5 cm flooding
W_b = Total water use in continuous 1 cm flooding

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[10]. In this study, all treatments were above saturation level hence; there was no effect of water stress

Table 1: yield and yield components of rice plants grown under different flood regimes

Treatments	Tiller Number m^{-2}	Panicle Number m^{-2}	Straw (dry) t ha^{-1}	Straw (wet) t ha^{-1}	Unfilled Grain /panicle	Filled Grain /panicle	1000 seeds weight (gm)	Yield t ha^{-1}
W_1	691a	657a	14.28a	51.49a	20a	93a	27.7a	12.39a
W_2	696a	665a	14.46a	53.81a	26a	92a	27.2a	11.87a
W_3	682a	647a	13.44a	47.55a	24a	89a	27.8a	12.23a
W_4	679a	641a	13.15a	47.56a	19a	93a	27.4a	12.27a
W_5	674a	636a	13.48a	49.95a	23a	101a	27.2a	12.24a

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

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} (Table 1). The number of panicles produced was not significantly different for rice grown in flooded and saturated condition.

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 (Table 1), which was comparatively similar to the data obtained by MARDI[11]. According to Ishizuka and Tanaka[12], 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 (Table 1).

Weight of 1000 Seeds: Weight of 1000 seeds was in the range of 27.1 to 27.7 g which is comparable to MARDI[4] i.e. 27.1 g. Weight of 1000 seeds was not significantly different under different flooding levels (Table 1).

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 (Table 1). Therefore, in this study, there was no effect of different flooding 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 (Table 1). The overall dry filled grain (containing 12% moisture content) yield was 12 t ha^{-1}, however, MARDI[11] 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[11] 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 m^{-1} therefore, yields of more than up to 12 t ha^{-1} were observed.

Changes in zinc concentration: Figure 2 shows that Zn concentration was not significantly different under different flooding levels at a weekly interval. Generally, the value was less than the critical level[13] in soil solution. When a soil is submerged the concentration of most nutrient elements is increased, Zn is an exception. The concentration of water-soluble zinc decreases and reaches values as low as 0.03 mg L^{-1} despite desorption from Fe^{+3} and Mn^{+4} oxide hydrates. This reflected in Zn uptake by the rice plant[14]. A decrease in concentration of water-soluble zinc is one of the few disadvantages of flooding soil for rice. Zinc deficiency of wetland rice has received more attention than any other minor element problem in recent years. Since, it recognized as a field problem by Nene[15].

Figure 2 shows that the concentration of zinc was relatively constant in soil solution up to 7th week until application of compound fertilizer was made. The concentration of Zn increased to a certain levels after application of compound fertilizer at 7th week and then

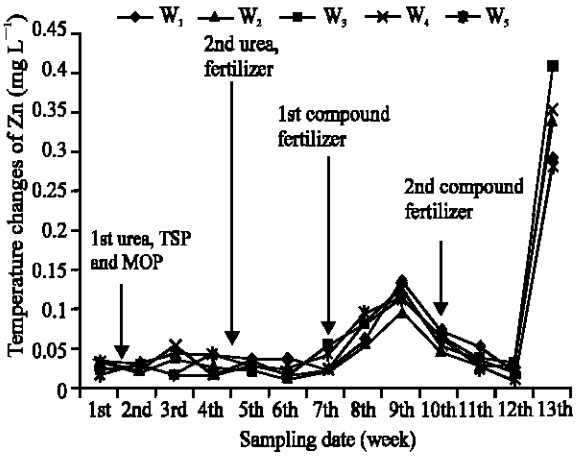

Fig. 2: The concentration of zinc in soil solution under different flooding levels

Table 2: The concentration of copper and zinc in soil and straw at 51 DAS and after harvest

	Concentration of copper				Concentration of zinc			
	Soil		Straw		Soil		Straw	
Treatments	51 DAS	After harvest	51 DAS	After harvest	51 DAS	After harvest	51 DAS	Afterharvest
W_1	1.61a	1.72a	72a	75a	3.1a	5.5a	360a	345a
W_2	1.68a	1.65ab	73a	72a	3.3a	5.5a	341a	380a
W_3	1.71a	1.53ab	90a	97a	3.2a	5.0a	358a	377a
W_4	1.65a	1.61ab	76a	75a	3.3a	5.3a	348a	383a
W_5	2.57a	1.36b	90a	73a	3.3a	5.8a	363a	350a

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

declined again. There was 156 mg kg^{-1} Zn containing in the compound fertilizer were applied.

Nevertheless, Fig. 2 is clearly indicating that the concentration of Zn increased markedly after water was drained out from rice culvert in all treatments. When water was drained from the rice culvert the physio-chemical changes occur in soil, as a result the unavailable Zn form changed to available form. Therefore, Zn concentration increased after drained water and it is highly depended on water regime. Zn concentration is higher in dry soil than flooded soil. Zn deficiency in paddy soils can be prevented by draining and drying the land before planting[14].

Changes in copper concentration: Figure 3 indicates that there was no significant difference for copper concentration under different flooding regimes in soil solution at a weekly interval. The flooding of soil is one of the main causes of deficiency of copper concentration in lowland soil. This finding was due to association with soil oxides. Some crystalline oxides of iron, which have strong capacity for fixing added copper by reductive microbes, explain the low concentration of copper in flooded soil[16].

The concentration of Cu remains constant up to 4th weeks and than decreased markedly. Redox potential has an important role on Cu concentration in soil. At higher redox potential (100 to 500 mV), Cu availability decreases slightly in soil solution due to adsorption of Cu in soil exchange complex. At lower redox potential (0 to -200 mV), Cu availability decreases abruptly in soil solution due to chemical fixation of Cu as sulphide[17].

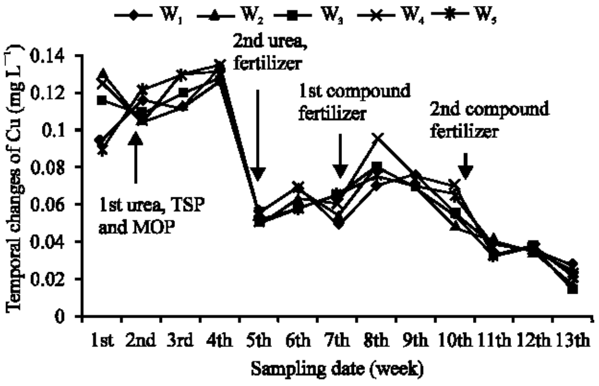

Fig. 3: The concentration of copper in soil solution under different flooding levels

Copper concentration increased again from fifth sampling date to eighth sampling date. It may be due to effect of application of compound fertilizer. Moreover, it was decline again until ripening stage due to uptake by plant or effect of flooding. The Cu concentration in soil solution decreased with the duration of submergence. The concentration of water-soluble copper in a soil decreases on flooding despite desorption from Fe^{+3} and Mn^{+4} oxide hydrates. Another study reported by Norwell and Lindsay[18] that the Cu concentration decreased with flooding water.

Zn concentration in soil and straw: The concentration of zinc was in the range of 3.1 to 3.3 and 5 to 5.8 mg kg^{-1} in soil at 51 DAS and after harvest, respectively. The Zn concentration was found reasonably higher at after harvest than 51 days after land preparation. In straw, the concentration of zinc was in the range of 341 to 363 and 345 to 380 mg kg^{-1} at 51 DAS and after harvest, respectively (Table 2). The concentration of Zn in plant showed more or less similar in both sampling time. The flooding regimes have not affect on uptake of Zn by rice plant.

Cu concentration in soil and straw: The copper concentration was in the range of 1.61 to 2.57 mg kg^{-1} in soil after 51 DAS. However, the concentration of copper found significantly different among treatments after harvest (Table 2). It probably due to the effect of aerobic condition because during ripening water was drained. The concentration of water-soluble copper in a soil decreases on flooding despite desorption from Fe^{+3} and Mn^{+4} oxide hydrates[18]. In straw, copper concentration was not significantly different in all treatments; it was in the range of 72 to 90 and 72 to 97 mg kg^{-1} at 51 DAS and after harvest, respectively. The concentration of copper was more or less similar in straw at different water levels in both sampling time.

$$\text{Save water} = 100 - \frac{W_2 \text{ X } 100}{W_1}$$

$$= 100\text{-}67.79\%$$
$$= 32.2\%$$

Where:
$W_1 = 118$ L; $W_2 = 80$ L

The total water used was significantly different among treatments according to the following sequenced $W_1 > W_5 > W_4 > W_3 > W_2$. The treatments W_2 showed the best performance in this study for rice production and saving water about 32.2% over W_1. The present water domestic and industrial water use is estimated to be 2.6 billion m^3/year. At this level of utilization, about 78% of the total population are served by public water supply, with the serve factor for urban areas being 96% and that for rural areas being 66%. Due to rapid population increase and growth of industry, the annual demand growth rate is about 12%[7]. Therefore, the surplus water from rice production using low water input rice production can be use for domestic purpose and make the fulfill of 100% country demand for fresh water.

CONCLUSIONS

Water in irrigated rice production has been taken for granted for centuries, but the looming water crisis may change the way rice is produced in the future. Water-saving irrigation technologies that were investigated in the early 1970s, such as different flooding levels and alternate wetting and drying, are receiving renewed attention from researchers. These technologies reduce water input for rice production. The current study was therefore attempted to produce more rice under different water input. The different flooding levels did not affect tiller numbers, panicle numbers, grain yield (t ha^{-1}), straw yield (t ha^{-1}), grain per panicle and 1000 seeds weight (g). The tiller numbers and panicle numbers were in the range of 674 to 695 and 636 to 665 m^{-1}, respectively. The unfilled and filled grains per panicle were in the range of 19 to 26 and 89 to 101, respectively. The yield of dry filled grain was in the range of 11.72 to 12.39 t ha^{-1}. The weight of 1000 seeds was in the range of 27.2 to 27.8 g. The results of this study showed that there was no effect of different flooding levels on yield and yield components.

Overall, there was no significant effect of different flooding regimes on the concentration of nutrients in soil solution with time except for few sampling dates. There was an increase in the concentrations of Zn and Cu in the soil solution during the first few weeks of flooding, then the values remained relatively stable until harvest. 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 and insignificant on soil nutrient availability. Therefore, it is suggested that further study should be conducted under natural field condition in order to validate the effects of low water for rice production and role of nutrients under low water rice production. 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.

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