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**GROWTH AND YIELD RESPONSE TO WATER AVAILABILITY AT DIFFERENT
GROWTH STAGE OF RICE**

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ABSTRACT

The effect of different water regime treatments on rice growth and yield response was evaluated. Five water regime treatments were used namely, continuous field capacity, continuous flooding condition until maturity, Field capacity at panicle initiation, Field capacity at active tillering, and field capacity at first flowering condition. Field capacity at panicle initiation stage produced the highest tiller number. Highest number of panicle was found in field capacity at first flowering treatment. Highest grain yield, spiklet number, filled grain and panicle length was found in field capacity.

Keywords: Water Regimes, Rice, Grain Yield, Water Use Efficiency

INTRODUCTION

With increasing water scarcity in agriculture, there is a need to increase water-use efficiency in rice (*Oryza sativa* L.). Food security in Asia is challenged by increasing food demand and threatened by declining water availability. Rice is the most important staple in Asia, where it provides 35–80% of total calorie intake [1]. More than 75% of the rice supply comes from 79 million ha of irrigated land. Thus, Asia's

present and future food security depends largely on the irrigated rice production system. However, the water-use efficiency of rice is low, and growing rice requires large amounts of water. In Asia, irrigated agriculture accounts for 90% of total diverted freshwater, and more than 50% of this is used to irrigate rice. Until recently, this amount of water has been taken for granted, but now the global “water crisis”

threatens the sustainability of irrigated rice production. The available amount of water for irrigation is becoming scarce [2, 3]. The reasons for this are diverse and location-specific, but include decreasing quality (chemical pollution, salinization), decreasing resources (e.g., falling groundwater tables, silting of reservoirs), and increased competition from other sectors such as urban and industrial users. Because of the increasing scarcity of water, the costs of its use and resource development are increasing as well. Therefore, farmers and researchers alike are looking for ways to decrease water use in rice production and increase its use efficiency. The aim of this study was to determine the rice growth and yield response in water availability at different growth stage exposed to flooded condition and field capacity.

MATERIALS AND METHODS

Experimental Site

This experiment was carried out in Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, Serdang, Selangor Darul Ehsan, Malaysia. The MR220 as the commercial rice variety was used in this experiment. The soil type sandy clay loam were utilised and was spread on the glasshouse floor and left to air drying. The dry soil was crushed and sieved

to pass through a 5.0 mm mesh to remove gravels and large debris.

Experimental Design

The experimental design used was a Randomized Complete Block Design (RCBD), consisting five combination of treatments (1: Field capacity, 2: Flooded, 3: Field capacity at panicle initiation, 4: Field capacity at active tillering, 5: Field capacity at first flowering) with four replications. The treatment consisted of five water availability at different growth stage.

Tiller Number

Tiller number for each treatment were counted at maturity stages and recorded the productive tillers (tillers that produced panicles).

Yield and Yield Components

At maturity, the plants in each pot were harvested for the determination of yield and yield components. Grain yield per pot was obtained from the weight of filled grains and calculated at 14 percent moisture. The panicles in each plant were counted to determine the panicle number per plant. All spikelets were separated from the panicles, weighted and counted to determine the number of spikelets per panicle. Filled grains were separated from unfilled and partially filled grains by using salt solution with a specific gravity of 1.06. The filled grains then were dried, counted and the

percentage of filled grains as well as the 1000-grain weight determined.

Water Use Efficiency

WUE were calculated for each treatment as the harvest yield divided by the total amount of water actually irrigated as follows:

$$\text{WUE} = \frac{\text{Yield (g)}}{\text{Gross irrigation (kg)}}$$

Day of Flowering

The flowering date was defined as occurring when 50% of the panicle had emerged. Flowering delay was calculated as the difference between the treatment in date of 50% panicle emergence.

RESULTS

Tiller Number

Tiller production of rice was influenced by water availability at different stage as shown in **Figure 1**. Under field capacity at active tillering stage more tillers were observed than other treatment. Treatment under flooded and field capacity at panicle initiation and first flowering was comparable in number of tiller. However, as rice growth advanced, the reduced amount of water under field capacity condition had limited the tiller production, respectively (**Figure 1**).

Panicle Number

Rice grown under field capacity condition produced lower number of panicle than rice grown in other treatments. The number of panicle under flooded and field capacity at

first flowering stage was comparable. A reduction of 45 percent in the number of panicles was observed for rice grown under field capacity as compared to rice grown under flooded and field capacity at active tillering stage (**Figure 2**). At maturity stage, more panicles were recorded to represent the high tillering rice growth under flooding. The field capacity treatments apply during panicle initiation which reduced the number of panicle, even though the number of tiller was high. On the other hand the reduction of water under panicle initiation was reduced the number of panicle even number of tiller was high.

Panicle Length

The panicle length was influenced by water availability at different stages (**Figure 3**). The panicle lengths vary between under flooded and field capacity at the first flowering stage. The number of panicle was decreased when soil subjected to field capacity and also influenced the panicle length at maturity. However the panicle length under field capacity and field capacity at active tillering stage differ and lower than the other treatments.

Grain Yield

Figure 4 shows the effect of water availability at different stage on grain yield. There was a yield reduction of 55 percent when grown in field capacity as compared to flooded condition (control) The yield

reduction was observed when soil subjected to field capacity at the first flowering stage, however it was still comparable with flooded treatment. Field capacity during panicle initiation also showed the reduction in grain yield about 30 percent compared to flooded condition but still higher than field capacity and field capacity at active tillering. Panicle initiation is the critical stage, as the reduction amount of water at this stage influenced the grain.

Spikelets Number

The effect of water availability on number of spikelets/panicle at different growth stage is shown in **Figure 5**. The number of spikelets was higher and comparable under flooded and field capacity at the first flowering stage than the others. However the number of spikelet was varied and reduced when soil subjected to field capacity at panicle initiation as compared to flooded condition (control). In line with the parameter study, the rice grown under field capacity showed lower in number of spikelet, which explained the reduction amount of water. However, its only at the critical stage (soil subjected to field capacity or drought condition) especially during panicle initiation or before the stage.

Filled Grain

The water availability at different stage influenced the percentage of grain filled of rice (**Figure 6**). Soil subjected to field

capacity at panicle initiation reduced the percentage of grain filled as compared to under flooded treatment and less different as compared to under field capacity. However soil subjected to field capacity at the first flowering stage shows the difference when compared to flooded condition. The increasing percentage of grain filled was related with amount of water and yet field capacity during first flowering was also effected.

Water Use Efficiency (WUE)

The effect of water availability on water use efficiency of rice explained in **Figure 7**. Water use efficiency was high under field capacity as compared to the other treatments. Rice growth utilised water very efficiently under field capacity but wasted water under flooded condition as shown in **Figure 7**. However field capacity at the first flowering stage shows the varies in which rice is grown with this treatment was higher than flooded and field capacity at active tillering and panicle initiation stage. The efficiency of utilising water during the first flowering stage showed, eventhough water availability change at this stage. The water use efficiency rate during field capacity at active tillering and panicle intiation is comparable with minor different.

Days of Flowering

Water influenced and regulated so many things in rice growth. The days of flowering

was also affected by when water was subjected to drought or field capacity. **Figure 8** shows that, the rice grown under field capacity leads to the flowering stage as compared to under flooded condition. From the observation, when the soil is subjected to field capacity at vigorous stage,

the days of flowering are affected either much or less. The days of flowering is comparable between field capacity and field capacity at active tillering stage and its shows the reduction amount of water during vegetative stage.

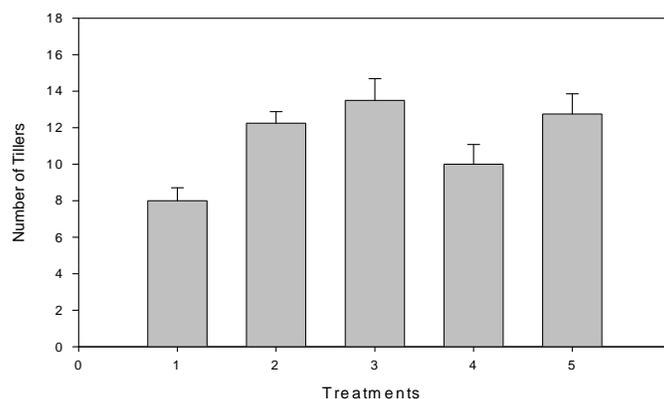


Figure 1: Number of Panicle Under Different Water Availability at Different Growth Stage
 #Bars Represent SE ± 4 Replicates (1: Field Capacity, 2: Flooded, 3: Field Capacity at Panicle Initiation, 4: Field Capacity at Active Tillering, 5: Field Capacity at First Flowering)

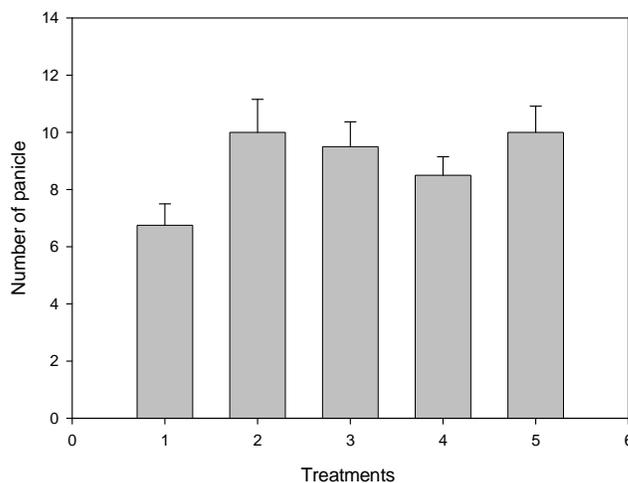


Figure 2: Number of Panicle Under Different Water Availability at Different Growth Stage
 #Bars Represent SE ± 4 Replicates (1: Field Capacity, 2: Flooded, 3: Field Capacity at Panicle Initiation, 4: Field Capacity at Active Tillering, 5: Field Capacity at First Flowering)

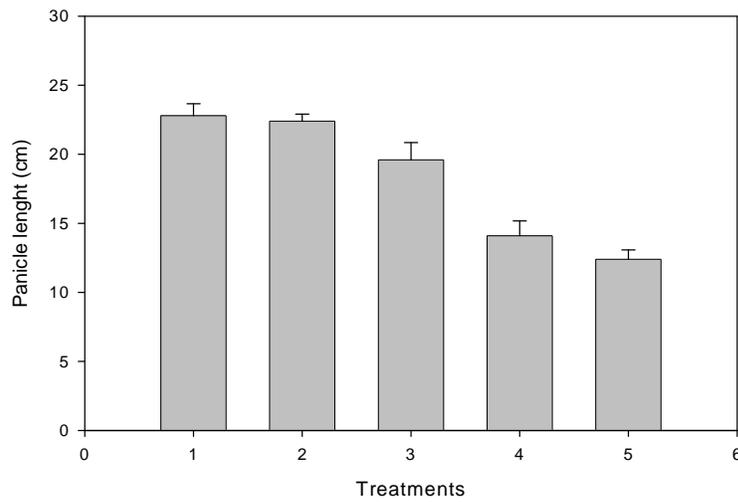


Figure 3: Panicle Length Under Different Water Availability at Different Growth Stage
#Bars represent SE \pm 4 Replicates (1: Flooded, 2: Field Capacity at First Flowering, 3: Field Capacity at Panicle Initiation, 4: Field Capacity at Active Tillering, 5: Field Capacity)

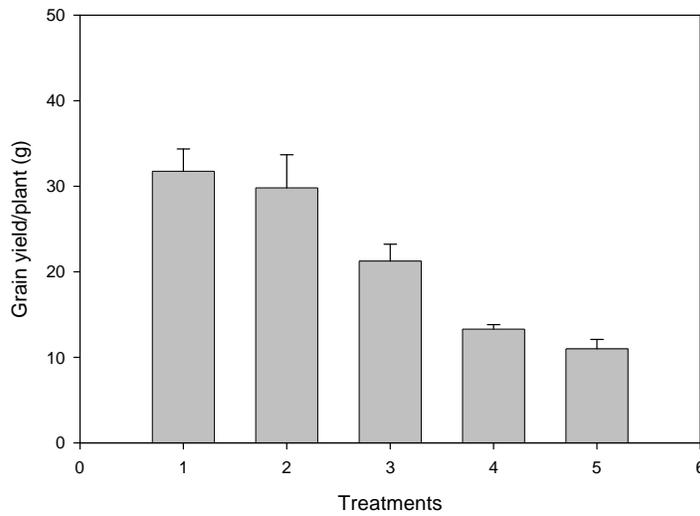


Figure 4: Grain yield per plant under different water availability at different growth stage
#Bars Represent SE \pm 4 Replicates (1: Flooded, 2: Field Capacity at First Flowering, 3: Field Capacity at Panicle Initiation, 4: Field Capacity at Active Tillering, 5: Field Capacity)

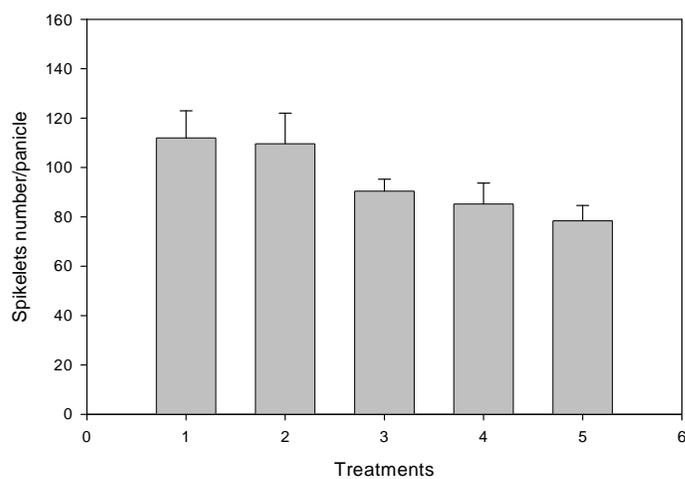


Figure 5: Spikelets Number Per Panicle Under Different Water Availability at Different Growth Stage.
#Bars Represent SE ± 4 Replicates (1: Flooded, 2: Field Capacity at First Flowering, 3: Field Capacity at Panicle Initiation, 4: Field Capacity at Active Tillering, 5: Field Capacity)

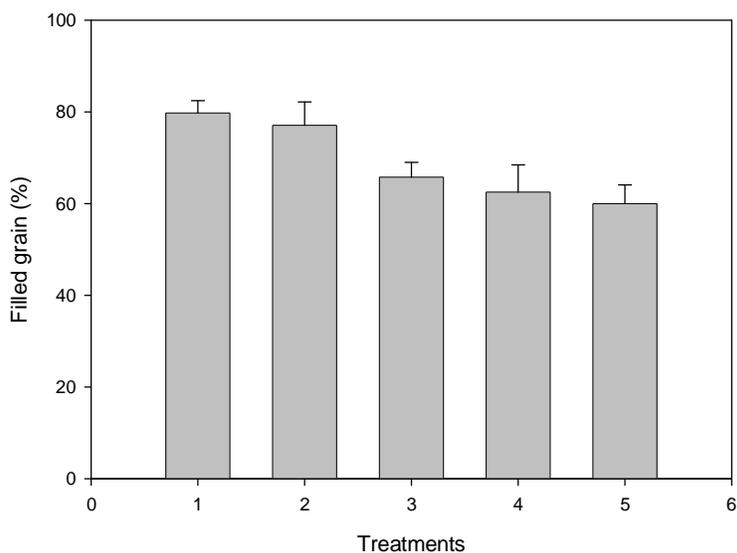


Figure 6: Filled Grain Under Different Water Availability at Different Growth Stage
#Bars Represent SE ± 4 Replicates (1: Flooded, 2: Field Capacity at First Flowering, 3: Field Capacity at Panicle Initiation, 4: Field Capacity at Active Tillering, 5: Field Capacity)

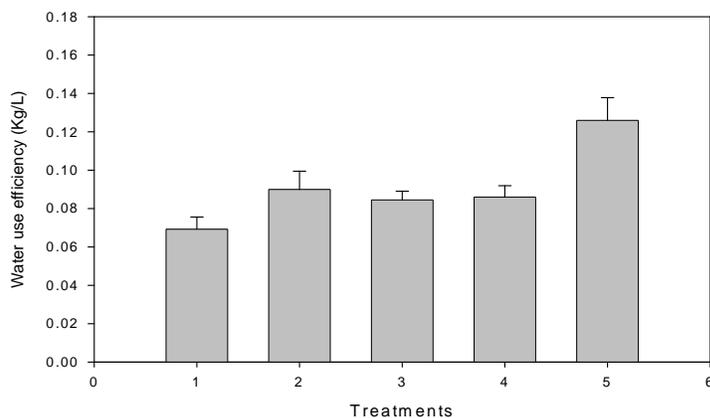


Figure 7: Water Use Efficiency Under Different Water Availability at Different Growth Stage
 #Bars Represent SE \pm 4 Replicates (1: Flooded, 2: Field Capacity at First Flowering, 3: Field Capacity at Panicle Initiation, 4: Field Capacity at Active Tillering, 5: Field Capacity)

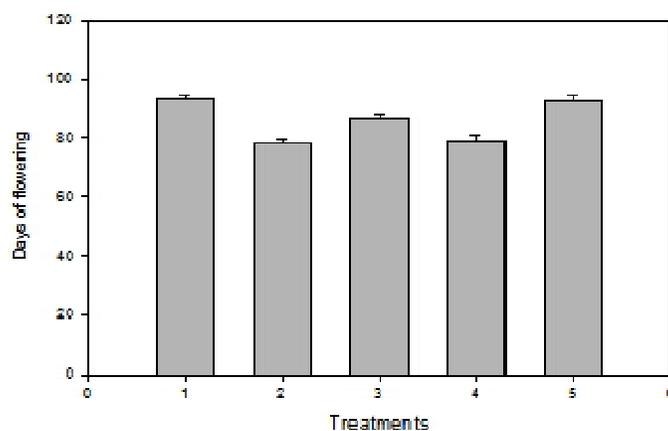


Figure 8: Days of flowering under different water availability at different growth stage
 #Bars Represent SE \pm 4 Replicates (1: Field Capacity, 2: Flooded, 3: Field Capacity at Panicle Initiation, 4: Field Capacity at Active Tillering, 5: Field Capacity at First Flowering)

DISCUSSION

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 saturated soil culture and alternate wetting

and drying, are receiving renewed attention from researchers.

Number of Tiller

The number of tiller was affected by water availability at different growth stage of the rice. As rice growth advanced, the reduced amount of water under field capacity condition had limited tiller production, respectively (**Figure 1**). These results were

quite in agreement with the findings of [4]. Drought strongly affects the morphology of the rice plant. Leaf area development may be hampered due to reduced leaf expansion, leaf rolling and early senescence and tillering and panicle development may be reduced under limited water condition.

Grain Yield

The effects of water availability at different growth stage showed in yield reduction when grown in field capacity as compared to flooded condition (**Figure 4**). These results also match with findings of [5, 6, 7]. Field capacity during panicle initiation shows the reduction in grain yield to about 30 percent than flooded condition. On the other hand, panicle initiation is the critical stage, where reduced amount of water may reduced the yield as the number of panicle is reduced [8]. The sensitivity of rice to water stress is most pronounced during the reproductive stage and grain yield may be drastically reduced when water deficit coincides with the flowering period [6, 7, 9]. Other have reported that grain yield is more sensitive to water deficit that occurs during reproductive stage development than during vegetative [10]. Water deficit at any growth stage may reduced grain yield, the magnitude of the reduction depends on the severity, timing and duration [11].

Panicle Development and Yield Component

Field capacity during panicle development shows the reduced number of panicle and panicle length per plant as shown in **Figures 2 and 3**. These results agreed with the finding of [12]. **Figure 5 and 6** show the reduced number of spikelets per panicle and filled grain yield per plant under field capacity and field capacity at panicle stage as compared to under flooded. The reduced number of spikelets and filled grain during soil being subjected to field capacity have provided into the causes of sterility induced by field capacity. This finding was positively agreed with studies of panicle water relation by [13]. Water stress or reduced assimilate supply during early panicle development would decrease number of spikelets per panicle while stress between meiosis and anthesis increased sterility. [14] concluded that the ability of cultivar to recover quickly from stress was more important to grain yield than tolerance during the stress. However, [15] found that genotypic variation in the ability of the rice to recover was related to its ability to tolerate severe water deficit. Ability to recover may be particularly important when panicle development occurs during the recovery phase as assimilate supply during panicle development which determine

spikelet number and therefore potential grain yield.

Days of flowering

Figure 8 shows the delayed number of days of flowering under field capacity and other treatment compared to flooded condition. This finding was positively agreed with [9] and the others have reported that water stress cause delay in panicle initiation [16].

Water Use efficiency

Rice growth under field capacity condition showed higher in water use efficiency as compared to under flooded condition. It means rice growth under flooded condition was sufficient in water utilising. On the other hand, under limited water, rice use more water to make sure all the physiological and biochemical processes were done but it was different under flooded condition. Water was much lost through transpiration, evapotranspiration and percolation. This finding was positively agreed by [17]. The water use efficiency on different crop also have been reported in grapevines [18], maize [19], tomato [20], pear [21] and hot pepper [23]. It shows high water use efficiency under limited water

availability compared to under normal condition. Water use efficiency of rice growth have also been supported by stomata conductance [24]. Under limited water availability the stomata conductance was closed for a reduced transpiration process, and at the same time help the plant to use their water uptakes almost fully.

CONCLUSION

Water supply is the most important factor which influence rice growth and yield of irrigated rice. The objectives of these studies are to determine growth and yield response on water availability at different growth stage. Water availability at different stage has significantly affected the rice growth and yield development. From the observation, panicle initiation was examined as a critical stage, for rice to produce good yield. On the other hand, the yield reduction was more sensitive when field capacity was imposed at reproductive stage than rice subjected to the vegetative phase. However field capacity imposed at vegetative phase also delayed phenological development as shown in **Figures 9, 10, 11**.

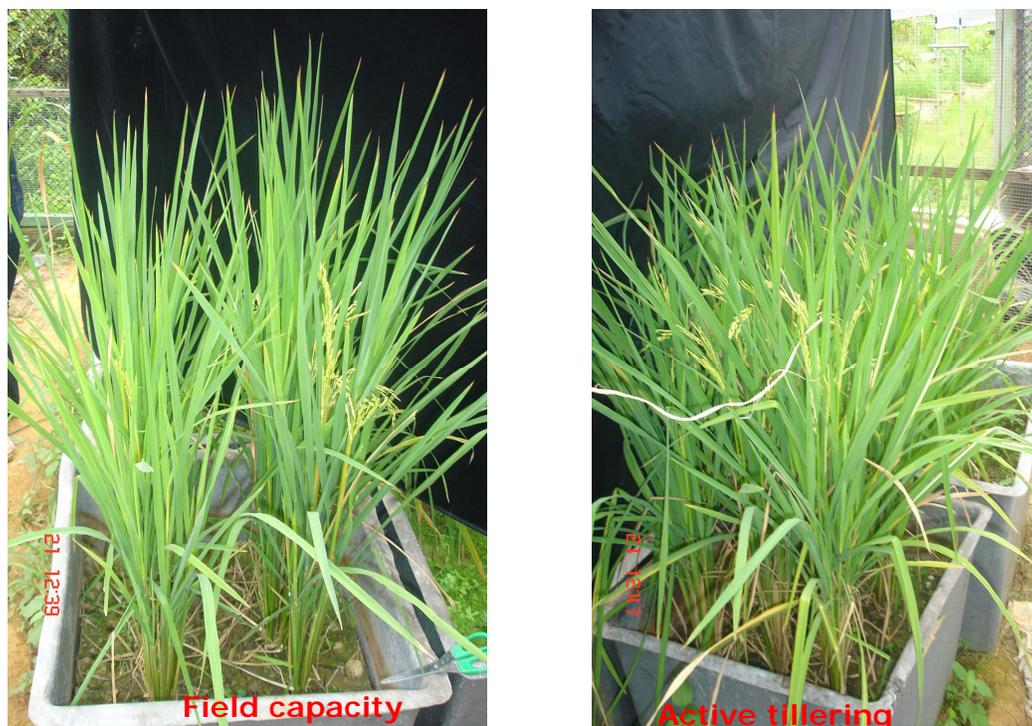


Figure 9: Growth of MR220 at 100 Days After Germination Under Field Capacity and Field Capacity at Active Tillering Stage



Figure 10: Growth of MR220 at 100 Days After Germination Under Flooding and Field Capacity at Panicle Initiation



Figure 11: Growth of MR220 at 100 Days After Germination Under Field Capacity and Flooding Condition

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