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Influence of Priming Treatments on Growth and Yield of Rice Under Different Irrigation Regimes

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Abstract

This experiment was conducted to determine the effect of priming treatments on growth and yield of rice under different irrigation regimes. In this work, six priming treatments(48-hour priming with 100 mM calcium chloride dihydrate, 24-hour priming with 100 mM calcium chloride dihydrate, 48-hour priming with 40% (w/v) polyethyl glycol(PEG) 6000, 24-hour priming with 40% (w/v) polyethyl glycol (PEG) 6000, 24-hour priming with 100 ppm kinetin and 48-hour priming with 100 ppm kinetin) were tested under two irrigation regimes (normal and water stress conditions). The experiment was laid out in split-plot design with three replications. The main plot consisted of the irrigation regimes while the sub-plot comprised the priming treatments. Plants were assessed using number of tillers, number of productive tillers, rate of photosynthesis, stomatal conductance, intercellular carbon dioxide, transpiration rate, shoot fresh mass, shoot dry mass, 100-grain mass, grain yield, harvest index, grain length, grain width and grain size. The results showed that 48-hour priming with 100 mM calcium chloride dihydrate was 33.74% better than 24-hour priming with 100 mM calcium chloride dihydrate, 48-hour priming with 40% (w/v) polyethyl glycol PEG) 6000 was 26.86% better than 24-hour priming with 40% (w/v) polyethyl glycol PEG) 6000and 24-hour priming with 100 ppm kinetin was 23.69% better than 48-hour priming with 100 ppm kinetin in yield production in both irrigation regimes. Therefore, it is recommended that, subject to further research, rice seed priming with 100mM calcium chloride and 40% (w/v) PEG6000 should not exceed 48hours while priming with 100ppm kinetin should not exceed 24hours for effectiveness and avoidance of resource wastage.

1. Introduction

Seed priming has a great potential in enhancing rapid germination, growth synchronization and high seedling vigour which result in higher yield in field crops [1]. This process involves soaking seeds of interest in solutions of low water potential to allow controlled hydration of the seeds with eventual prevention of radicle protrusion [2]. An important factor to consider in seed priming is the priming duration which should not exceed the safe limit. Otherwise, there will be seed or seedling damage as a result of premature germination [3]. This is because success in priming is influenced by some factors such as plant species, type of priming media, temperature, concentration, priming duration, seed viability, oxygen and the storage condition of the seeds [4]. Summarily, effectiveness of seed priming on invigoration and final yield is well rooted in the priming duration [5] as well as priming agent. Throughout the period of growth and development of plants, they experience different environmental stresses (drought, salinity, high and low temperatures) as a result of their exposure [6]. Environmental stresses play significant roles in causing unpredictable and substantial yield loss in agricultural productions [7]. The stresses have also been reported to cause various physiological, biochemical and metabolic changes [8] that cause oxidative stress which disturbs plant performance and metabolism as well as yield [9]. Among the physiological aspects affected is photosynthetic rate which decreases when plants are moisture-stressed. This comes partly because the transpiration rate should be lowered through stomatal closure. So, if the stomatal conductance is high, there will be higher photosynthetic rate [10].

All modern agricultural strategies aim at increasing yield per unit area and reducing production losses caused by environmental stresses before and after harvesting [11]. The problem of environmental stress like drought could be solved using seed priming procedure which is a simple process that is cost effective and could be easily be practiced by all farmers whether literate or less-educated. However, only chemicals that can reduce the adverse effects of different environmental stresses should be given prime consideration [12]. There is need for a priming treatment that could be effectively used for rice production under stress and normal condition. Therefore, this experiment was conducted to determine effective priming treatments for growth and yield of rice under different irrigation regimes.

2. Methodology

2.1. Experimental Site

This experiment was conducted in the glass house of the Rice Research Centre of the Universiti Putra Malaysia (UPM), Serdang, Selangor, Malaysia (3^0 02' N, 101^0 42' E). The average monthly maximum and minimum temperatures are 33.5^{o}C and 21.5^{o}C respectively while the relative humidity is 92.5%. The sunshine hour is 6.6 h /day while the average rainfall and evaporation are 9.8 mm/day and 4.6 mm/day respectively.

2.2. Seed Treatment

Priming was carried out by soaking rice seeds in 100 mM calcium chloride dehydrate, 40% (w/v) polyethyl glycol 6000 and 100 ppm kinetin for 24 and 48 hours (Table 1). After the designated priming durations, the soaked seeds were drained of the priming chemicals and washed three times with water to free the seeds of the traces of the priming chemicals. The seeds were then air-dried on filter paper for three days to have final moisture content of 11%. The seeds were then kept between 4 and 8^{o}C in the refrigerator until sowing.

Table 1. Treatments used in determining the effects of priming treatments on growth and yield of rice under different irrigation regimes

Treatment	Concentration	Duration
Calcium chloride dehydrate [$CaCl_2$-100 (24h)]	100 mM	24 Hours
Calcium chloride dehydrate [$CaCl_2$-100 (48h)]	100 mM	48 Hours
Polyethyl glycol $_{6000}$ [PEG-40 (24h)]	40% (w/v)	24 Hours
Polyethyl glycol $_{6000}$ [PEG-40 (24h)]	40% (w/v)	48 Hours
Kinetin [Kinetin-100 (24h)]	100 ppm	24 Hours
Kinetin [Kinetin-100 (24h)]	100 ppm	48 Hours

2.3. Crop Husbandry, Experimental Design and Water Management

The primed seeds were sown directly in pots filled with 18 kg of clay loamy soil. The area of each pot was 780 cm^2. The experiment was laid out in split-plot design with three replications. The main plot consisted of irrigation regimes (normal and water stress conditions) while the sub-plot comprised the six priming treatments (48-hour priming with 100 mM calcium chloride dihydrate, 24-hour priming with 100 mM calcium chloride dihydrate, 48-hour priming with 40% (w/v) polyethyl glycol(PEG) 6000, 24-hour priming with 40% (w/v) polyethyl glycol (PEG) 6000, 24-hour priming with 100 ppm kinetin and 48-hour priming with 100 ppm kinetin)(Table 1). Irrigation was withdrawn for 15 days at tillering stage for imposition of stress condition. The final soil moisture content before restoration of irrigation was 8%n. For normal condition, there was no irrigation withdrawal till the end of the experiment and the least of water level maintained above the soil level was around 1 cm. After seedling establishment, the seedlings were thinned to two per pot. Throughout the experimental period, hand weeding was used to free the crop of weeds.

2.4. Data Collection and Analysis

2.4.1. Leaf Gas Exchange

Data on net photosynthetic rate (μmol m^{-2} s^{-1}), stomatal conductance (μmol H_2O m^{-2} s^{-1}), transpiration rate (mmol m^{-2} s^{-1}), and intercellular carbon dioxide (μmolCO_2m^{-1}) were taken with a closed infra-red gas analyser LICOR 6400 Portable Photosynthesis System (IRGA, Licor Inc., Lincoln, NE, USA) following Ibrahim and Jaafar [13]. Leaf surfaces were cleaned and dried using tissue paper before being enclosed in the leaf cuvette. Optimal conditions were set at 400 μmol mol^{-1} CO_2, 30°C cuvette temperature, 60% relative humidity with air flow rate set at 500 cm^3 min^{-1} and modified cuvette conditions of 225, 500, 625 and 900 μmolm^{-2} photosynthetic photon flux densities (PPFD) respectively were used for the measurements. Gas exchange measurements were carried out when the sun was fully bright using fully expanded young leaves to record net photosynthetic rate (A).

2.4.2. Tiller Characteristics, Yield, Shoot Mass, Harvest Index and Seed Dimension

At grain filling stage, number of tillers and productive tillers were counted per pot for each treatment. Plant height was measured from the ground level of the plants to the tip of the longest leaf using a measuring tape. Subsequently, tiller efficiency was calculated using Equation 1.

Tiller Efficiency (%) = $\frac{Number\ of\ \ panicle\ bearing\ tillers\ per\ pot}{Total\ number\ of\ tillers\ per\ pot} x100$ (1)

At harvest, mass of threshed grains per pot was measured using weighing balance to determine yield per pot. The whole shoot was then cut from the ground level and weighed fresh per pot and recorded. The shoot was then dried in the oven at 65^{o}C until a constant mass and recorded. Thereafter, harvest index was calculated using Equation 2.

Harvest Index = $\frac{Economic\ yield}{Total\ \ biological\ yield} x100$ (2)

After threshing, seed length and width were measured using Nikon E600 compound microscope and the images were captured with a Nikon DXM1200 digital imaging system equipped with Nikon ACT-1 software. Then, seed dimension was calculated using Equation 3.

Seed Size (Seed length to width ratio) = $\frac{Seed\ Length}{Seed\ width}$ (3)

2.5. Data Analysis

All the data collected were subjected to analysis of variance (ANOVA) with the aid of SAS 9.2 package while significant means were separated using Least Significant Difference (LSD).

3. Results and Discussion

3.1. Effects of Priming Treatments on Number of Tillers of Rice under Different Irrigation Regimes

The performance of the priming treatments in improving the number of tillers produced was affected by irrigation regime despite the fact that differences among priming treatments and between irrigation regimes were also significant at p=0.05. Except PEG-40 (24h) and $CaCl_2$-100 (24h), all the priming treatments produced higher number of tillers under normal condition than moisture stress condition. On average, $CaCl_2$-100 (48h) had the highest number of tillers followed by kinetin-100 (24h) while the least was from $CaCl_2$-100 (24h). The highest number of tillers was from kinetin-100 (48h) when the plants were stressed while the lowest number was from $CaCl_2$-100 (24h).Under normal condition, the highest number of tillers was from $CaCl_2$-100 (48h) while the lowest number from PEG-40 (48h) (Table 2).

Table 2. Effects of priming treatments on number of tillers of rice under different irrigation regimes

	Number of Tillers (no/pot)		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	58.00b	58.00d	58.00
$CaCl_2$-100 (48h)	62.00a	78.00a	70.00
PEG-40 (24h)	62.00a	65.00c	63.50
PEG-40 (48h)	60.00a	59.00d	59.50
Kinetin-100 (24h)	62.00a	71.00b	66.50
Kinetin-100 (48h)	63.00a	69.00b	66.00
Average	61.17	66.67	

Means with the same letter in each column are not significantly different at 5% probability level.

Reduction in the number of tillers produced by moisture stressed plants could be linked to growth cessation that occurred when water supply became limiting. This might have hindered the mitotic cell division as well as cell enlargement which could have resulted in more tiller production. Therefore, the un-stressed plants took the advantage of continuous growth to produce more tillers than the stressed plants. Similarly, reduction in the number of tillers produced under moisture stress might have resulted from low production of assimilates when water is limiting coupled with inhibition of cell division at the meristem of different parts of the plant [14]. Better overall performance of $CaCl_2$-100 (48h) is an indication of its relative stability under normal and moisture stress conditions.

3.2. Effects of Priming Treatments on Number of Productive Tillers and Tiller Efficiency of Rice under Different Irrigation Regimes

The performance of the priming agents in improving the number of productive tillers was affected by irrigation regime though the differences between the irrigation regimes and among priming treatments were significant at p=0.05. All the priming treatments under moisture stress condition had lower productive tillers than the plants under normal condition with the exception of PEG-40 (48h). On average, $CaCl_2$-100 (48h) had the highest number of productive tillers while PEG-40 (48h) had the lowest. The highest number of productive tillers was from PEG-40 (48h) when the plants were stressed while the lowest number was from $CaCl_2$-100 (24h).Under normal condition, the highest number of productive tillers was from $CaCl_2$-100 (48h) while the lowest number from PEG-40 (48h) (Table 3).

Table 3. Effects of priming treatments on number of productive tillers of rice under different irrigation regimes

	Productive Tillers (no/pot)		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	46.00b	55.00c	50.50
$CaCl_2$-100 (48h)	48.00b	70.00a	59.00
PEG-40 (24h)	50.00a	63.00b	56.50
PEG-40 (48h)	51.00a	48.00d	49.50
Kinetin-100 (24h)	50.00a	62.00b	56.00
Kinetin-100 (48h)	47.00b	64.00b	55.50
Average	48.67	60.33	

Means with the same letter in each column are not significantly different at 5% probability level.

The effectiveness of priming treatments on tiller efficiency was also affected by irrigation regimes despite the significant differences that existed among the priming treatments and irrigation regimes at p=0.05. With the exception of PEG-40 (48h), tiller efficiency was higher under normal condition than moisture stress condition. Averagely, PEG-40 (24h) had the highest tiller efficiency while the lowest was from PEG-40 (48h). The highest tiller efficiency was from PEG-40 (48h) when the plants were stressed while the lowest was from kinetin-100 (48h). Under normal condition, the highest tiller efficiency was from PEG-40 (24h) while the lowest was from PEG-40 (48h) (Table 4).

Table 4. Effects of priming treatments on tiller efficiency of rice under different irrigation regimes

	Tiller Efficiency (%)		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	79.44b	94.79a	87.12
$CaCl_2$-100 (48h)	78.24b	89.74b	83.99
PEG-40 (24h)	80.14b	96.51a	88.33
PEG-40 (48h)	84.75a	81.81c	83.28
Kinetin-100 (24h)	80.14a	87.24b	83.69
Kinetin-100 (48h)	75.41c	93.28a	84.35
Average	79.69	90.56	

Means with the same letter in each column are not significantly different at 5% probability level.

Better stress tolerance with PEG-40 (48h) priming could be attributed to adaptation to moisture stress conferred to the plants through seed priming. This could be likened to vaccine given to animals before the occurrence of a disease so that the animals could have produced enough anti-body against the disease. In this case, the seeds have memory of physiological change which has conferred ability to withstand future stress on them. This is to forestall detrimental effect that will disrupt the overall performance of the resulting plants [15]. Moreover, the ability to produce higher number of effective tillers led to having highest tiller efficiency. Therefore, the problem of panicle blanking has been appreciably arrested with PEG-40 (48h) priming. This finally affected the yield because effective tillers are parts of yield determinants in rice. It is worth noting that the major problem of the stressed plants is that they do not have access to nutrients because the nutrients are no longer in solution. Through water stress also, soil nutrients get fixed to the clay minerals. Consequently, nutrient becomes limiting and the growth is checked. With the resumption of irrigation, the checked growth starts again. However, the resumption of growth will certainly be from the point at which the stress was imposed.

3.3. Effects of Priming Treatments on Leaf Gas Exchange Characteristics of Rice under Different Irrigation Regimes

Irrigation regimes affected the performance of priming treatments in enhancing net photosynthesis. Despite that fact, significant differences were found between irrigation regimes and among the priming treatments at $p = 0.05$. Net photosynthesis was lower in all the priming treatments under moisture stress than normal condition with the exception of CaCl2-100 (24h). The highest net photosynthesis was from kinetin-100 (48h) on average basis while $CaCl_2$-100 (24h) had the lowest. The highest net photosynthesis was from $CaCl_2$-100 (24h) when the plants were stressed while the lowest net photosynthesis was from $CaCl_2$-100 (48h). Under normal condition, the highest net photosynthesis was from kinetin-100 (48h) while the lowest from $CaCl_2$-100 (24h) (Table 5).

Table 5. Effects of priming treatments on net photosynthesis of rice under different irrigation regimes

	Net Photosynthesis ($\mu molCO_2m^{-2}s^{-1}$)		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	16.72a	2.82f	9.77
$CaCl_2$-100 (48h)	9.74f	58.09b	33.92

PEG-40 (24h)	12.87d	28.74e	20.81
PEG-40 (48h)	15.86b	54.01c	34.94
Kinetin-100 (24h)	13.57c	45.60d	29.59
Kinetin-100 (48h)	11.20e	71.24a	41.22
Average	13.33	43.42	

Means with the same letter in each column are not significantly different at 5% probability level.

Similar to the results of net photosynthesis is stomatal conductance, performance of the priming treatments was also affected by the irrigation regimes though significant differences were also found among priming treatments and between irrigation regimes at p=0.05. With the exception of $CaCl_2$-100 (24h), all the priming treatments under moisture stress had lower values of stomatal conductance than those under normal condition. The highest stomatal conductance on average was from kinetin-100 (48h) while the lowest was from $CaCl_2$-100 (24h). The highest stomatal conductance was from $CaCl_2$-100 (24h) when the plants were stressed while the lowest stomatal conductance was from PEG-40 (24h).Under normal condition, the highest stomatal conductance was from kinetin-100 (48h) while the lowest was from $CaCl_2$-100 (24h) (Table 6).

Table 6. Effects of priming treatments on stomatal conductance of rice under different irrigation regimes

	Stomatal Conductance (molH$_2$O m^{-2}s^{-1})		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	0.49a	0.24f	0.37
$CaCl_2$-100 (48h)	0.29c	2.44d	1.37
PEG-40 (24h)	0.26c	2.15e	1.21
PEG-40 (48h)	0.33b	2.64c	1.49
Kinetin-100 (24h)	0.32b	3.03b	1.68
Kinetin-100 (48h)	0.28c	3.77a	2.03
Average	0.33	2.38	

Means with the same letter in each column are not significantly different at 5% probability level.

Irrigation regimes also affected the enhancement of intercellular carbon dioxide by the priming agents. However, within priming treatments and irrigation regimes, there were significant differences at p=0.05. Without exception, all the priming treatments under normal condition outperformed their equals under moisture stress in enhancing intercellular carbon dioxide. The best performance on average was from $CaCl_2$-100 (24h) while the worst was from PEG-40 (48h). The highest intercellular carbon dioxide was from $CaCl_2$-100 (48h) when the plants were stressed while the lowest was from PEG-40 (48h). Under normal condition, the highest intercellular carbon dioxide was from $CaCl_2$-100 (24h) while the lowest was from $CaCl_2$-100 (48h) (Table 7).

Table 7. Effects of priming treatments on intercellular carbon dioxide of rice under different irrigation regimes

	Intercellular Carbon dioxide ($\mu molCO_2m^{-1}$)		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	305.64b	363.28a	334.46
$CaCl_2$-100 (48h)	317.07a	321.70f	319.40
PEG-40 (24h)	287.25e	351.79b	319.52
PEG-40 (48h)	285.05f	329.40d	307.23
Kinetin-100 (24h)	297.46d	342.04c	319.75
Kinetin-100 (48h)	304.81c	324.58e	314.70
Average	299.55	338.80	

Means with the same letter in each column are not significantly different at 5% probability level.

Irrigation regimes also affected the efficacy of priming treatments in improving transpiration rate. Despite that, there were significant differences within the priming treatments and irrigation regimes at p=0.05. As found in in the other aspects of gas exchange characteristics, the pattern of transpiration rate was also not different. With the exception of $CaCl_2$-100 (24h), all the priming treatments had lower transpiration rates under moisture stress than normal condition. Averagely, the highest transpiration rate was from kinetin-100 (48h) while the lowest was from $CaCl_2$-100 (24h). The highest transpiration rate was from $CaCl_2$-100 (24h) when the plants were stressed while the least transpiration rate was from PEG-40 (24h). Under normal condition, the highest transpiration rate was from kinetin-100 (48h) while the lowest from $CaCl_2$-100 (24h) (Table 8).

Table 8. Effects of priming treatments on transpiration rate of rice under different irrigation regimes

	Transpiration Rate ($mmolH_2Om^{-2}s^{-1}$)		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	7.04a	6.15e	6.60
$CaCl_2$-100 (48h)	5.34c	32.46c	18.90
PEG-40 (24h)	5.00d	29.84d	17.42
PEG-40 (48h)	5.91b	32.95c	19.43
Kinetin-100 (24h)	5.34c	35.62b	20.48
Kinetin-100 (48h)	5.04d	39.08a	22.06
Average	5.61	29.35	

Means with the same letter in each column are not significantly different at 5% probability level.

The general reduction in gas exchange characteristics was because net CO_2 assimilation and transpiration are generally reduced by water deficit condition [16]. Reduction in CO_2 assimilation (photosynthesis) was a result of stomatal closure and damage to photosynthetic apparatus [17]. Despite the general reduction from all the priming treatments, plants from $CaCl_2$-100 (24h) treatment had the highest photosynthetic rate and best stomatal conductance. However, the highest grain yield was from $CaCl_2$-100 (48h) treatment. This implies that very low relationship exists between net photosynthesis and grain yield. Nevertheless, net photosynthesis is related directly to the biological yield. The grain yield is predicted by effective partitioning of photo-assimilates. So, if there is effective partitioning, the filling grains will have substantial share and the harvest index will be consequently higher. Moreover, reduction in net photosynthesis might have resulted from having droopy leaves with higher angle of inclination as a result of leaf rolling which led to decrease in the leaf area for solar interception [18]. This further leads to reduction in rate of transpiration which is rather a beneficial adaptation to water conservation under stressful conditions. The ultimate detrimental effect of reduction in net photosynthesis under moisture stress is low grain yield which may probably be a result of decrease in assimilate production and imbalance partitioning of photo-assimilates between the grains and straw during grain filling stage [19]. Reduction in net photosynthesis, transpiration and stomatal conductance has been established to be characteristics of plants experiencing moisture stress [17]. This fact is also established by this work. So, the best enhancement by any priming treatment will be enhancement of assimilate partitioning and remobilization of dry matter from the vegetative parts to the filling grains.

3.4. Effects of Priming Treatments on Shoot Fresh and Dry Masses of Rice under Different Irrigation Regimes

The ability of priming treatments to improve shoot fresh mass was not affected by irrigation regimes at p=0.05. However, there were significant differences within the priming treatments as well as irrigation regimes at p=0.05. The performance of priming treatments in enhancing fresh shoot mass was averagely better under moisture stress condition than that of normal condition. $CaCl_2$-100 (24h), PEG-40 (24h) and kinetin-100 (24h) were better than their equals under normal conditions in fresh shoot production while the rest of the priming treatments were less effective under moisture stress. Finally, $CaCl_2$-100 (48h) produced the heaviest fresh shoot on average basis while $CaCl_2$-100 (24h) had the lightest fresh shoot. The heaviest fresh shoot was from $CaCl_2$-100 (48h) when the plants were stressed while the lightest was from $CaCl_2$-100 (24h). Under normal condition, the heaviest fresh shoot was from $CaCl_2$-100 (48h) while the lightest was from $CaCl_2$-100 (24h) (Table 9).

Table 9. Effects of priming treatments on shoot fresh mass of rice under different irrigation regimes

	Shoot Fresh Mass (g/pot)		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	325.50e	325.25e	325.38
$CaCl_2$-100 (48h)	424.50a	429.00a	426.75
PEG-40 (24h)	408.00b	356.50d	382.25
PEG-40 (48h)	370.50c	413.50b	392.00
Kinetin-100 (24h)	401.50b	378.00c	389.75
Kinetin-100 (48h)	348.50d	358.50d	353.50
Average	379.75	376.79	

Means with the same letter in each column are not significantly different at 5% probability level.

The performance of priming treatments in enhancing dry shoot mass was affected by irrigation regimes. In the same vein, significant differences existed among the priming treatments and between the irrigation regimes at p=0.05. The performance of priming agents in enhancing dry shoot mass was averagely better under moisture stress condition than that of normal condition. $CaCl_2$-100 (24h), $CaCl_2$-100 (48h), kinetin-100 (24h) and kinetin-100 (48h) were better under moisture stress than their equals under normal condition. $CaCl_2$-100 (48h) was averagely the best in enhancing dry shoot production while $CaCl_2$-100 (24h) was the worst. The highest shoot dry mass was from $CaCl_2$-100 (48h) when the plants were stressed while the least shoot dry mass was from $CaCl_2$-100 (24h). Under normal condition, the heaviest dry shoot was from PEG-40 (24h) while the lightest was from $CaCl_2$-100 (24h) (Table 10).

Table 10. Effects of priming treatments on shoot dry mass of rice under different irrigation regimes

	Shoot Dry Mass (g/pot)		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	104.97e	95.34e	100.16
$CaCl_2$-100 (48h)	134.25a	127.81b	131.03
PEG-40 (24h)	125.01b	134.44a	129.73
PEG-40 (48h)	118.93c	126.24b	122.59
Kinetin-100 (24h)	116.53c	106.51d	111.52
Kinetin-100 (48h)	111.44d	111.16c	111.30
Average	118.52	116.92	

Means with the same letter in each column are not significantly different at 5% probability level.

Decrease in weight of fresh shoot as observed in this work might be partly due to reduction in leaf area resulting from leaf rolling, total dryness or death. Since rice is a C_3 plant, its carbon utilization and fast assimilate translocation are not as effective as its C_4 counterpart which could make effective utilization of limited carbon resources. So, ineffectiveness of C_3 pathway results in lower grain yield. As it is widely known, assimilate partitioning is based on availability of dry matter which has been reduced in this case.

However, dry matter production was better under stress condition. It is known that higher photo-assimilate production is the basis of dry matter accumulation. So, it might be that priming has enhanced crop growth rate, net assimilation rate and leaf area index to have increased the final dry shoot weight [1]. It should be noted that higher biological yield at the expense of economic yield is detrimental to the target of the farmers whose target is the grain yield. Nevertheless, higher biological yield could be advantageous if the objective of production is fodder production because biological yield will be the economic yield in that case. Finally, it is evident from this result that plants produced under normal conditions did not produce better dry matter rather they had higher moisture content than the stressed plants (Tables 9 and 10).

3.5 Effects of Priming Treatments on Grain Yield and Harvest Index of Rice under Different Irrigation Regimes

Yield enhancement by priming treatments was affected by irrigation regimes. Both priming treatments and irrigation regimes differ significantly within themselves at p=0.05. Yield production was better under normal condition than moisture stress without any exception. On average, $CaCl_2$-100 (48h) produced the highest grain yield followed by kinetin-100 (24h) while the lowest was from PEG-40 (24h). The highest yield was from $CaCl_2$-100 (48h) when the plants were stressed while the lowes was from kinetin-100 (48h). Under normal condition, the highest yield was from $CaCl_2$-100 (48h) while the lowest was from PEG-40 (24h) (Table 11).

Table 11. Effects of priming treatments on grain yield of rice under different irrigation regimes

	Grain Yield (g/pot)		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	68.56b	113.06d	90.81
$CaCl_2$-100 (48h)	84.39a	158.52a	121.45
PEG-40 (24h)	69.01b	97.16e	83.09
PEG-40 (48h)	84.20a	126.63c	105.41
Kinetin-100 (24h)	80.55a	136.55b	108.54
Kinetin-100 (48h)	62.18c	109.32d	85.75
Average	74.81	123.54	

Means with the same letter in each column are not significantly different at 5% probability level.

The performance of the priming treatments in improving the harvest index was not affected by irrigation regimes at p=0.05. Despite that fact, there were significant differences among the priming treatments and within irrigation regimes at p=0.05. All the priming treatments had higher harvest index under normal condition than their equals under moisture stress without any exception. The highest harvest index on average basis was from PEG-40 (48h) while the lowest was from PEG-40 (24h). The highest harvest index was from PEG-40 (48h) when the plants were stressed while the lowest was from kinetin-100 (48h). Under normal condition, the highest harvest index was from $CaCl_2$-100 (24h) while the lowest was from PEG-40 (24h) (Table 12).

Table 12. Effects of priming treatments on harvest index of rice under different irrigation regimes

	Harvest Index (%)		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	40.00b	54.23a	47.11
$CaCl_2$-100 (48h)	39.00b	53.75a	46.38
PEG-40 (24h)	38.00b	46.98c	42.49
PEG-40 (48h)	45.50a	49.32b	47.41
Kinetin-100 (24h)	43.00a	49.93b	46.47
Kinetin-100 (48h)	36.50c	48.71b	42.61
Average	40.33	50.49	45.41

Means with the same letter in each column are not significantly different at 5% probability level.

The production of grain yield depends on effective partitioning of photo-assimilates. So, if there is effective partitioning, the economic yield will have a substantial share which consequently leads to having higher harvest index. This could be further substantiated with the finding of Singh [18] that long and droopy leaves (leaves with higher angle) resulted in leaf rolling which decreased the intercepting area of solar radiation and that culminated into decrease in transpiration rate and assimilate production.

The yield increase by $CaCl_2$-100 (48h) priming might be attributed to its production of the highest number of tillers which gave opportunity for better capture of resources for photosynthate production and partitioning which led to higher number of panicle-bearing tillers and finally higher yield [20]. Similarly, better moisture and nutrient absorption by plants from seed priming might have led to better fertilization and final higher yield [21]. In the same vein, Farooq et al.[1] made it evident that kernel improvement, increases in straw yield and harvest index could enhance better and effective assimilate partitioning to the grains. In addition to that, reduction in the number of sterile spikelets, abortive as well as the opaque seeds could account for yield increase. Finally, researchers like Kaur et al. [22], Farooq et al. [20] and Anwar et al. [21] also found yield increase as a result of priming treatments.

Reduction in grain yield under moisture stress may probably be the result of decrease in assimilate production or inadequate supply of photo-assimilates needed for grain filling as the grains developed despite the unchanged sink size [19]. Furthermore, water stress might lead to considerable increase in secondary rachis branch abortion which leads to reduced number of filled spikelets per panicle [23]. In the same vein, slow and poor filling of the inferior spikelets resulting from moisture stress may even result in sterile spikelets or non-consumable grains which contribute majorly to low yield production in rice [24]. However, increase in number of filled grains could be a result of increase in photosynthetic rate that leads to higher assimilate production which is effectively partitioned into the developing grains with consequent increase in the final yield [25] and harvest index. Harvest index (HI) measures effectiveness in assimilate partitioning. It should be noted that despite the superiority of $CaCl_2$-100 (48h) in grain yield, it did not have the highest HI. This was because it produced the heaviest dry shoot which was more than half of the whole biological yield (Table 10).

3.6 Effects of Priming Treatments on 100-Grain Mass of Rice under Different Irrigation Regimes

Irrigation regimes did not affect the performance of the priming treatments in improving individual grain mass at p=0.05. The priming treatments as well as irrigation regimes differ within themselves at p=0.05. Without any exception, the performance of the priming treatments in seed mass improvement was better under normal condition than moisture stress. PEG-40 (24h) produced the heaviest grains on average while the lightest grains were produced by kinetin-100 (24h). The heaviest grains were from kinetin-100 (48h) when the plants were stressed while the lightest were from PEG-40 (48h). Under normal condition, the heaviest grains were from PEG-40 (24h) while the lightest were from kinetin-100 (24h) (Table 13).

Table 13. Effects of priming treatments on 100-grain mass of rice under different irrigation regimes

	100-Grain Mass (g)		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	2.39b	2.55b	2.47
$CaCl_2$-100 (48h)	2.41b	2.53b	2.47
PEG-40 (24h)	2.43a	2.62a	2.53
PEG-40 (48h)	2.38b	2.55b	2.47
Kinetin-100 (24h)	2.41b	2.51b	2.46
Kinetin-100 (48h)	2.48a	2.52b	2.50
Average	2.42	2.55	

Means with the same letter in each column are not significantly different at 5% probability level.

Individual grain mass is a very important determinant of the mass of the final grain yield. In this study, higher grain masses recorded for both $CaCl_2$-100 (48h) and kinetin-100 (24h) priming treatments contributed to the final yield. This might be attributed to better assimilate partitioning to the spikelets (economic sink). It might equally be because increase in 1000-grain weight and number of effective tillers result in yield improvement [26].

Having reduction in grain mass of rice under water stress is a common phenomenon because researchers like Venuprasad et al. [27] have also reported the same result. It has been found that moisture deficit contributes to photosynthetic reduction and decrease in assimilate translocation to the grains which results in reduction of grain mass [28]. In addition to that, moisture stress could lower kernel sink potential by decreasing the number of endospermic cells and the amyloplast formed [29]. Therefore, the level of grain mass correlates with the capacity of starch accumulation in the endosperm [30]. The poor filling of grains which results in lighter grains could be attributed to limited carbohydrate supply [30]. So, whenever poor grain filling results from moisture stress, individual seeds will become lighter and there will be consequential reduction in the final yield.

3.7 Effects of Priming Treatments on Seed Length of Rice under Different Irrigation Regimes

The efficiency of priming treatments on seed length improvement was not affected by irrigation regimes at p=0.05. Nevertheless, there were significant differences among the priming treatments and between irrigation regimes at p=0.05. With the exception of $CaCl_2$-100 (24h) and PEG-40 (48h), the priming treatments under normal condition outperformed their equals under moisture stress. PEG-40 (24h), on average basis, produced the longest seeds while kinetin-100 (48h) had the shortest seeds. The longest seeds were from $CaCl_2$-100 (24h) when the plants were stressed while the shortest seeds were from kinetin-100 (48h). Under normal condition, the longest seeds were from PEG-40 (24h) while the shortest ones were from PEG-40 (48h) (Table 14).

Table 14. Effects of priming treatments on seed length of rice under different irrigation regimes

	Seed Length (mm)		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	10.09a	10.09c	10.09
$CaCl_2$-100 (48h)	9.99b	10.25b	10.12
PEG-40 (24h)	10.04a	10.35a	10.20
PEG-40 (48h)	10.21a	10.06c	10.14
Kinetin-100 (24h)	10.11a	10.14c	10.13
Kinetin-100 (48h)	9.95b	10.07c	10.01
Average	10.07	10.16	

Means with the same letter in each column are not significantly different at 5% probability level.

3.8 Effects of Priming Treatments on Seed Width of Rice under Different Irrigation Regimes

Irrigation regimes had no effect on the performance of priming treatments in enhancing seed width at p=0.05. However, there were significant differences among priming treatments as well as between irrigation regimes at p=0.05. All the priming treatments performed better under normal condition than their equals under moisture stress with the exception of kinetin-100 (48h). $CaCl_2$-100 (24h) was averagely the best in seed width enhancement while kinetin-100 (24h) was worst in width enhancement. The broadest seeds were from kinetin-100 (48h) when plants were stressed while the narrowest seeds were from kinetin-100 (24h). Under normal condition, the broadest seeds were from $CaCl_2$-100 (24h) while the narrowest ones were from Kinetin-100 (48h) (Table 15).

Table 15: Effects of priming treatments on seed width of rice under different irrigation regimes

	Seed Width (mm)		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	2.39b	2.51a	2.45
$CaCl_2$-100 (48h)	2.40b	2.45b	2.43
PEG-40 (24h)	2.40b	2.44b	2.42
PEG-40 (48h)	2.36c	2.48b	2.42
Kinetin-100 (24h)	2.30c	2.48b	2.39
Kinetin-100 (48h)	2.46a	2.37c	2.42
Average	2.39	2.46	

Means with the same letter in each column are not significantly different at 5% probability level.

3.9 Effects of Priming Treatments on Seed Length-Width Ratio (Seed Size) of Rice under Different Irrigation Regimes

Irrigation regimes affected the influence of priming treatments on seed size (seed length to width ratio) with significant differences between irrigation regimes and among priming treatments at p=0.05. $CaCl_2$-100 (24h), PEG-40 (48h) and kinetin-100 (24h) under moisture stress were better than their equals under normal condition and, therefore, the average performance of the priming agents under moisture stress was better than normal condition. On average, the biggest seeds were from kinetin-100 (24h) while the smallest ones were from $CaCl_2$-100 (24h). The biggest seeds were from kinetin-100 (24h) when the plants were stressed while the smallest seeds were from kinetin-100 (48h). Under normal condition, the biggest seeds were from kinetin-100 (48h) while the smallest seeds were from $CaCl_2$-100 (24h) (Table 16).

Table 16. Effects of priming treatments on seed length-width ratio of rice under different irrigation regimes

	Seed Length-Width Ratio		
Priming Agent	Moisture Stress	Normal Condition	Average
$CaCl_2$-100 (24h)	4.22b	4.02b	4.12
$CaCl_2$-100 (48h)	4.17b	4.19a	4.18
PEG-40 (24h)	4.19b	4.24a	4.22
PEG-40 (48h)	4.34a	4.05b	4.20
Kinetin-100 (24h)	4.40a	4.10b	4.25
Kinetin-100 (48h)	4.04c	4.26a	4.15
Average	4.23	4.14	

Means with the same letter in each column are not significantly different at 5% probability level.

Despite stress imposition, 50% of the treatments were still better than the ones under normal condition. This could be attributed to the possibility of finding differences in both kernel length and width with osmotic priming [1]. However, Mostajeran and Rahimi-Eichi [31] established that moisture stress reduced the grain size and the reduction was cultivar dependent. The balance between these two schools of thought is that seed dimension is genetically controlled and that the full expression of the trait is influenced by the environment. This is true for other traits also. For instance, a genetically tall plant could become stunted with environmental stress like drought. Despite tallness is genetically controlled, it becomes modified by the environment. However, when normal growth conditions are available, the plant will show its hidden potential trait fully.

4. Conclusion

An experimental analysis of effect of priming treatments on growth and yield of MR219 rice under different irrigation regimes has been presented in this paper. It was found that 48-hour priming with 100 mM calcium chloride dihydrate was 33.74% better than 24-hour priming with 100 mM calcium chloride dihydrate, 48-hour priming with 40% (w/v) polyethyl glycol PEG) 6000 was 26.86% better than 24-hour priming with 40% (w/v) polyethyl glycol PEG) 6000and 24-hour priming with 100 ppm kinetin was 23.69% better than 48-hour priming with 100 ppm kinetin in yield production in both irrigation regimes yield production under normal and stressful conditions.

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References

[1] Farooq, M., Basra, S.M.A., Wahid, A. and Khan, M.B. (2006). Rice seed invigouration by hormonal and vitamin priming. *Seed Science Technology*. 34:775-780

[2] Giri, G.S. and Schilinger, W.F. (2003) Seed priming winter wheat for germination, emergence and yield. *Crop Science*. 43: 2135-2141.

[3] Harris, D., Tripathi, R. S. and Joshi, A. (2002). On-farm seed priming to improve crop establishment and yield in dry direct-seeded rice. Direct seeding: Research Strategies and Opportunities, International Research Institute, Manila, Philippines, 231-240.

[4] Mubshar, H., Farooq, M., Basra, S.M.A.and Ahmad, N. (2006). Influence of seed priming techniques on the seedling establishment, yield and quality of hybrid Sunflower. *Integrated Journal of Agricuture and Biology.* 8**(**1**):** 14-18.

[5] Ashraf, M. and Foolad, M.R. (2005). Pre-sowing seed treatment-ashotgum approach to improve germination, plant growth and crop yield under saline and non-saline conditions. *Advances in Agronomy*. 88:223-271.

[6] Zhao, T. J., Liu, Y., Yan, Y. B., Feng, F., Liu, W. Q. and Zhou, H. M. (2007). Identification of the amino acids crucial for the activities of drought responsive element binding factors (DREBs) of *Brassica napus*. *FEBS Letters*. 581 (16): 3044-3050.

[7] Jakab, G., Ton, J., Flors, V., Zimmerli, L., Métraux, J. P. and Mauch-Mani, B. (2005). Enhancing Arabidopsis salt and drought stress tolerance by chemical priming for its abscisic acid responses. *Plant Physiology*. 139 (1): 267-274.

[8] Xiong, L, Schumaker, K.S. and Zhu, J.K. (2002). Cell signaling during cold, drought, and salt stress. *Plant Cell.* 14: S165–S183.

[9] Shafi, M., Bakht, J., Hassan, M.J., Raziuddin, M. and Zhang, G. (2009). Effect of cadmium and salinity stresses on growth and antioxidant enzyme activities of wheat (*Triticum aestivum* L.*). Bulletin of Environmental Contamination and Toxicology*. 82:772–776.

[10] Carmo-Silva, A.E., Powers, S.J., Keys, A.J., Arrabaça, M.C. and Parry, M.A.J. (2008). Photorespiration in C_4 grasses remains slow under drought conditions. *Plant Cell and Environment.* 31: 925-940.

[11] Gust, A. A., Brunner, F. and Nürnberger, T. (2010). Biotechnological concepts for improving plant innate immunity. *Current Opinion in Biotechnology*. 21(2): 204-210.

[12] Uchida, A., Jagendorf, A.T., Hibino, T. and Takabe, T.(2002). Effects of hydrogen peroxide and nitric oxide on both salt and heat stress tolerance in rice. *Plant Science*. 163:515–523.
[13] Ibrahim, M.H., Jaafar, H.Z., Karimi, E. and Ghasemzadeh, A. (2014). Allocation of secondary metabolites, photosynthetic capacity, and antioxidant activity of Kacip Fatimah (*Labisia pumila* Benth) in response to and light intensity. *The Scientific World Journal*. 2014:1-14.
[14] Zubaer, M. A., Chowdhury, A. K. M. M. B., Islam, M. Z., Ahmed, T. and Hasan, M. A. (2007). Effects of water stress on growth and yield attributes of Aman rice genotypes. *International Journal of Sustainable Crop Production.* 2 (6): 25-30.
[15] Chen, K.., and Arora, R. (2013). Priming memory invokes seed stress-tolerance. *Environmental and Experimental Botany*. 94: 33-45.
[16] Akram, M., Ajmal, S.U. and Munir M. (2007). Inheritance of traits related to seedling vigor and grain yield in rice (Oryza sativa L.). Pakistan Journal of Botany. 39(1): 37-45.
[17] Mahmood, T., Ashraf, M. and Shahbaz, M. (2009). Does exogenous application of glycinebetaine as a pre-sowing seed treatment improve growth and regulate some key physiological attributes in wheat plants grown under water deficit conditions? *Pakistan Journal Botany*. 41(3): 1291-1302.
[18] Singh, K. and Kakralya, B.L. (2001). Seed physiological approach for evaluation of drought tolerance in groundnut stress and environmental plant physiology, In: K. K. Bora, K. Singh and A. Kumar, Eds., Pointer Publishers, Jaipur, Rajasthan, pp. 45-152.
[19] Abdoli, M., Saeidi, M., Jalali-honarmand, S., Mansourifar, S., Ghobadi, M. and Cheghamirza, K..(2013). Effect of source and sink limitation on yield and some agronomic characteristics in modern bread wheat cultivars under post anthesis water deficiency. Acta Agriculturae Slovenica. 101(2): 173 – 182
[20] Farooq, M., Wahid, A., Kobayashi, N., Fujita, D. and Basra, S.M.A. (2009). Plant drought stress: effects, mechanisms and management. *Agronomy for Sustainable Development*. 29: 185–212.
[21] Anwar, M. P., Juraimi, A. S., Puteh, A., Selamat, A., Rahman, M. M. and Samedani, B. (2012). Seed priming influences weed competitiveness and productivity of aerobic rice. *Acta Agriculturae Scandinavica, Section B-Soil & Plant Science*. 62(6): 499-509.
[22] Kaur, S., Gupta, A.K. and Kaur, N. (2005). Seed priming increases crop yield possibly by modulating enzymes of sucrose metabolism in chickpea. *Journal of Agronomy and Crop Science*. 191**:** 81-87
[23] Katoa, Y., Kamoshitab, A. and Yamagishia, J.(2008). Pre-flowering abortion reduces spikelet number in upland rice (Oryza sativa L.) under water stress. *Crop Science Society of America*. 48 (6): 2389-2395.
[24] Ishimaru, T., Hirose, T., Matsuda, T., Goto, A., Takahashi, K., Sasaki, H., Terao, T., Ishii, R. and Yamagishi, T. (2005). Expression patterns of genes encoding carbohydrate-metabolizing enzymes and their relationship to grain filling in rice (Oryza sativa L.): comparison of caryopses located at different positions in a panicle. *Plant and Cell Physiology*. 46 (4): 620-628.
[25] Xu, Z.Z. and Zhou, G.S (2007). Photosynthetic recovery of a perennial grass *Leymus chinesis* after different periods of soil drought. *Plant Production Science*. 10(3): 277-285.
[26] Farooq M., Siddique, K.H.M., Rehman, H., Aziz, T., Lee, D.J. and Wahid, A. (2011). Rice direct seeding: Experiences, challenges and opportunities. *Soil and Tillage Research*. 111:87–98.
[27] Venuprasad, R., Lafitte, H.R. and Atlin G.N. (2007). Response to direct selection for grain yield under drought stress in rice. *Crop Science*. 47, 285–293.
[28] Van Heerden, P.D.R. and Laurie, R. (2008). Effects of prolonged restriction in water supply on photosynthesis, shoot development and storage root yield in sweet potato. *Physiologia Plantarum*. 134(1): 99-109.
[29] Yang, J., Zhang, J., Wang, Z., Liu, K. and Wang, P. (2006). Post-anthesis development of inferior and superior spikelets in rice in relation to abscisic acid and ethylene. *Journal of Experimental Botany*. 57 (1): 149-160.
[30] Yang, J. and Zhang, J. (2006). Grain filling of cereals under soil drying. *New Phytologist*. 169 (2): 223-236.
[31] Mostajeran, A. and Rahimi-Eichi, V. (2009). Effects of drought stress on growth and yield of rice (*Oryza sativa* L.) cultivars and accumulation of proline and soluble sugars in sheath and blades of their different aged leaves). *American-Eurasian Journal of Agricultural and Environmental Science.* 5 (2): 264-272.