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SUITABLE PRIMING FOR RICE YIELD IMPROVEMENT

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ABSTRACT. Low yield of rice has made reaching self-sufficiency level in Malaysia elusive. So, Malaysia has become a target of rice exporting countries within and outside Asia. To solve this problem, a pre-sowing seed treatment was used as a physiological intervention to alleviate the impeding problems of achieving better growth and yield of Malaysian rice variety MR219. A glass house experiment, which involved the use of solutions of osmotic salts and plant hormones, was used for this investigation. Data on germination percentages, height, number of tillers and productive tillers, tiller efficiency and yield were taken. In both osmopriming and hormonal priming treatments, the highest number of tillers and productive tillers were from pre-germination. The tallest plants from osmopriming were from 150mM treatment, while 50 ppm GA_3 had the tallest in hormonal priming. The highest tiller efficiency for osmopriming was from 150mM and and 200mM sodium chloride, while in hormonal priming it was 200 ppm salicylic acid. For yield per panicle in osmopriming, it was 50mM and 100mM magnesium chloride that had the highest, while in hormonal priming it was 200 ppm methyl jasmonate. Finally, the highest grain yield per hill was produced by 200 ppm methyl jasmonate in hormonal priming, while 50Mm magnesium chloride had the highest yield in osmotic priming. So, it is concluded that the use of 200 ppm methyl jasmonate and 50Mm magnesium chloride could be used as potential hormonal priming and osmopriming, respectively, for yield improvement of MR219 rice in Malaysia.

Keywords: osmopriming; hormonal priming; MR219 rice; growth; yield

INTRODUCTION

At the current growth rate of the world population, rice requirement increases dramatically and many nations are facing second generation challenge of producing more rice at

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less cost in a deteriorating environment (Tiwari *et al.,* 2011). From time immemorial, transplanting nursery rice seedlings into the puddle field has been the practice in rice cultivation and this requires a continuous supply of water throughout the production (Farooq *et al.,* 2007).

Since the requirements of this method (water availability and high cost of labour) are difficult to be provided, alternative methods of rice establishment are highly needed (Pandey and Velasco, 1998). The basic approach to solving this problem in rice farming is to grow the crop as an irrigated upland crop, like wheat or maize, through the use of seed priming (Balasubramanian and Hill, 2002).

Seed priming is widely used nowadays for betterment of seed performance in terms of higher rate of germination and uniformity of establishment (Farooq *et al.,* 2006). Also, reduction in emergence time, accomplishment of uniform emergence and betterment of crop stand in many horticultural crops are known to be achieved by seed invigoration techniques, like seed priming (Ashraf and Foolad, 2005).

Osmopriming and hormonal priming are terminologies used in describing soaking of seeds in aerated low-water potential solutions to control water uptake and prevent radicle protrusion (Bray, 1995). When these treatments are followed by dehydration, they become more effective in improving germination of different types of vegetable seeds, most especially when the environmental conditions are at suboptimal levels (Bradford and Haigh, 1994). One of the advantages of osmopriming is that it makes the treated seeds less sensitive to temperature and oxygen deprivation (Corbineau *et al.,* 1994). Furthermore, the uses of calcium chloride, potassium nitrate, sodium chloride and polyethylene glycol-8000 have been proved to lessen mean germination time (Ruan *et al.,* 2002). In the same vein, priming with PEG-8000 has led to accelerated germination of both coarse and fine rice (Basra *et al.,* 2005). Moreover, nutri-priming (the use of fertilizer for priming solution) of direct-seeded summer rice with 4% mono-ammonium phosphate produced higher number of effective tillers and grain yield (Kalita *et al.,* 2002). In line with this also was the use of lanthanum nitrate solution for priming, which accelerated germination, increased vigour and finally brought about higher and vigorous root growth (Zhang *et al.,* 2005). Contrary to the above established achievement of osmopriming, priming of fine and coarse rice with urea, nitrophos, diammonium phosphate and potassium sulphate resulted in a complete failure of germination and emergence as a result of membrane damage, which was revealed by higher electrical conductivity of the seed leachates (Farooq *et al.,* 2005). Priming with plant growth regulators and various other organic chemicals has the potential to further enhance the uniformity of germination, stand establishment, growth and harvestable yield (Farooq *et al.,* 2010).

Among these growth regulators, gibberellic acid is well known for breaking down of starch stored in seeds to be utilized by growing embryos during germination (Lopez *et al.,* 2008). So, when gibberellic acid was used as a priming solution for four rice cultivars, it resulted in significant increase in seedling emergence and dry matter production (Chen *et al.,* 2004).

Furthermore, salicylicate, which is an endogenous growth regulator of phenolic nature, participates in regulation of physiological processes, like ion uptake and membrane permeability in plants (Barkosky and Einhelling, 1993). It also induces increase in resistance of seeds to osmotic stress (Borsani *et al.,* 2001), as well as high or low temperature stress by activation of glutathione reductase and guaiacol peroxidise (Kang and Saltveit, 2002).

When methyl salicylicate was used for priming coarse rice seeds, it brought about higher vigour enhancement (Basra *et al.,* 2006).Similarly, incorporation of other plant growth regulators, like polyamines and certain organic chemical sources during priming and other pre-sowing treatments in many vegetable and field crops, including rice, has led to improved seed performance (Lee *et al.,* 1998).

A rice farmer or producer, especially in Malaysia, should be able to know the best priming solution that is equally cost effective (since there is existing non cost effective pre-sowing treatment chemical, called ‘Zappa’) to meet his target of early seedling establishment and high profit through yield increase at the end of production period.

The farmer may equally want to know whether any useful difference(s) occur(s) between those priming media, so that he/she can freely choose among the highly rated ones along with their methodology. To solve this problem, this experiment was conducted to evaluate the efficacy of different available priming media in enhancing growth and yield of MR219 rice.

MATERIAL AND METHODS

Experimental sites

The priming procedures were carried out in ITA physiology laboratory of UPM-MTDC, while controlled production of the crop was carried out at Agrotech glass house of Taman Pertanian Universiti (TPU). Both sites belong to Universiti Putra, Malaysia.

Treatments and experimental design

The priming agents used were water, Zappa, indol-3-acetic acid, gibberellic acid, kinetin, methyl jasmonate, salicylic acid, calcium chloride dihydrate, magnesium chloride hexahydrate, sodium chloride, PEG 6000. Each osmotic priming media had four concentrations: 50,100,150 and 200mM.

For phytohormones, the concentrations were 50, 100, 150 and 200 ppm. Only PEG concentration was in w/v. So, the concentrations were 10, 20, 30 and 40% (w/v). For Zappa, the recommended concentration of 1% (v/v) was used. The control treatment was seed pre germination, which is the practice of the farmers in Malaysia (*Tables 1 and 2*).

MR219 rice seeds of approximate weight of 100 g were soaked in each of the prepared priming media for 24 h at room temperature. After that, the seeds were removed, washed with water three times and dried under shade on filter paper until the initial weight was regained, so as to achieve hardening after priming.

Table 1 - Treatments used in osmotic priming experiment

S/N	Chemical name	Concentration
1	Sodium chloride	50mM
2	Sodium chloride	100mM
3	Sodium chloride	15 mM
4	Sodium chloride	200 mM
5	Calcium chloride dihydrate	50mM
6	Calcium chloride dihydrate	100mM
7	Calcium chloride dihydrate	150mM
8	Calcium chloride dihydrate	200mM
9	Magnesium chloride hexahydrate	50mM
10	Magnesium chloride hexahydrate	100mM
11	Magnesium chloride hexahydrate	150mM
12	Magnesium chloride hexahydrate	200mM
13	Polyethylene glycol-6000	10% (w/v)
14	Polyethylene glycol-6000	20% (w/v)
15	Polyethylene glycol-6000	30% (w/v)
16	Polyethylene glycol-6000	40% (w/v)
17	Zappa	1% (v/v)
18	Water	
19	Pre-germination	

Crop husbandry

The seeds were directly seeded in the pots, having three-quarters of their volumes filled with soil to allow flooding during production.

For the section of osmotic priming, there were 19 treatments including the control, while the section of hormone priming had a total of 21 treatments with inclusion of control also. Each treatment was replicated four times to have a total of 76 pots in the first section and 84 pots in the second segment. After the seedling establishment (24 days after planting), the seedlings were thinned to two per pot to give room for better development and ease of data collection.

Twenty five days after planting, the first split of NPK fertilizer was applied in form of urea, triple super phosphate (TSP) and muriate of potash (MOP), respectively, while the second split was applied 50 days after planting. The application rates were 120 kg/ha for urea, 70 kg/ha for TSP and 80 kg/ha for MOP. At regular intervals, weeds were controlled through hand weeding to prevent inter-specific completion between the crops and weeds. The experiment was laid out in completely randomized design (CRD) with four replications.

Data collection

Ten days after planting, data on germination was collected and subsequently germination percentage (GP) was calculated for each treatment using the following formula:

$$GP = \frac{number\ of\ germinated\ seeds}{number\ of\ planted\ seeds} \times 100$$

At grain filling stage, tiller number and plant height were determined for each treatment. In addition, data on productive tillers and tiller efficiency were collected. Tiller efficiency was calculated using the following formula:

$$Tiller\ efficiency\ P = \frac{number\ of\ panicle\ bearing\ tillers}{number\ of\ tillers\ per\ plant} \times 100$$

Statistical analysis

All the data collected were analysed using analysis of variance (ANOVA) and significant means were separated using Duncan Multiple Range Test (DMRT) at $p < 0.05$ with the aid SAS 9.2 package.

Table 2 - Treatments used in hormonal priming experiment

S/N	Chemical name	Concentration
1	Kinetin	50mM
2	Kinetin	100mM
3	Kinetin	150mM
4	Kinetin	200mM
5	Indol-acetic acid	50mM
6	Indol-acetic acid	100mM
7	Indol-acetic acid	150mM
8	Indol-acetic acid	200mM
9	Gibberrelic acid	50mM
10	Gibberrelic acid	100mM
11	Gibberrelic acid	150mM
12	Gibberrelic acid	200mM
13	Methyl jasmonate	50mM
14	Methyl jasmonate	100mM
15	Methyl jasmonate	150mM
16	Methyl jasmonate	200mM
17	Salicylic acid	50mM
18	Salicylic acid	100mM
19	Salicylic acid	150mM
20	Salicylic acid	200mM
21	Pre-germination	

RESULTS

Osmopriming

Germination percentage, number of tillers, productive tillers and plant height

Various osmotic salt solutions used for priming exhibited significant influences on germination percentages of the rice variety under considera-tion. The highest germination percen-tage (90%) was from 30% (w/v) PEG and was 33.33% above the least germination percentage (60%) pro-duced by Zappa, 150mM NaCl, 200mM $CaCl_2$, 150mM $MgCl_2$, 10 and 20% (w/v) PEG, as well as hydropriming, followed 30% (w/v)

PEG in their performances. All these priming media were just 5.2% lower than the best osmotic priming salt solution in this research work. Pre-germination is not considered for germination percentage here since all the seeds sown were germinating seeds. Here, the seeds were used as checks to know, which of the priming treatments will produce result close to it or better than it.

As it could be found from the results of *Table 3*, 30% (w/v) PEG was only 5.2% lower in performance than pre-germination at the time germination percentage was determined for all the treatments. The result from pre-germination could aptly be termed as survival percentage because the seeds had already germinated before plan-ting them in the experimental pots (*Table 3*).

Furthermore, osmotic priming treatments significantly increased the number of tillers produced by the crop under consideration. As could be seen, pre-germination had the highest number of tillers (45). This was immediately followed by 150mM $MgCl_2$ (41), while the least number (34) was from 150mM NaCl and $CaCl_2$. Pre-germination was 24.88% better than 150mM NaCl and $CaCl_2$ that had the least number of tillers. However, 150 mM $MgCl_2$, which was next to the best, was 17.56% better than the least tiller producing osmopriming treatments (*Table 3*). The number of panicle-bearing tillers was significantly affected by the treatments applied through osmopriming. The control (pre-germination) had the highest number of panicles (44) to follow the pattern of tiller production. This result was followed by 150 mM $MgCl_2$ (41). The least number of panicle producing tillers was from 150mM NaCl.

The superiority of the control over the least-panicle producing tillers was 22.99%, while the superiority of the second best over the same treatment (150mM NaCl) was 17.89% (*Table 3*).

In the same vein, osmo-priming significantly improved height of rice plant even above pre-germination with exception of some treatments.

Application of 150mM $CaCl_2$ led to production of the tallest plants (120.7 cm) and was followed by 100mM NaCl with plant height of 118.4 cm. The shortest plants (110.cm) were produced by hydropriming and Zappa treatments, 150mM $CaCl_2$ was 8.12% above the treatments that had shortest plants (hydro-priming and Zappa treatments). These shortest plants are 6.33% shorter than the plants from the second best priming (100mM NaCl treatment (*Table 3*).

Tillering efficiency, yield per panicle and hill

Tiller efficiency, which is a measure of percentage of the panicle bearing tillers to total number of tillers produced, was significantly influenced by the different osmopriming treatments as well as their myriads of concentrations examined. The highest tiller efficiency (100%) was from treatments 200mM NaCl and 150mM $CaCl_2$ and was immediately followed by 99.4% from 150mM $MgCl_2$. The least tiller efficiency (96.81%) was from pre-germination treatment despite its edge above the rest treatment at the beginning of their life cycles. The best priming treatments with respect to this parameter were 0.6% better than the second best, while they were 3.19% better than the least efficient treatment (*Table 4*). Both yield per panicle and yield per pot, both of them were improved by osmopriming treatments. The heaviest panicles (1.8 g each) were from 50mM and 100mM $MgCl_2$ treatments, followed by the treatment with 150mM $CaCl_2$ (1.7 g each). However, the lightest panicles were from 150mM $MgCl_2$ treatment. The heaviest panicles were 66.67% better than the lightest panicles, while the second best was 64.71% heavier than the lightest panicles. In the same pattern, 50mM $MgCl_2$ had the highest grain yield (70.6 g) per pot, followed by treatment with 100mM $MgCl_2$, which had the yield of 66.4 g per pot while the least (24.9 g) was produced by hydropriming and treatments with 150mM $MgCl_2$. The highest yield producer was 64.73% better than the least yield producer, while the second best was 62.5% better than least yield producer (*Table 4*).

Table 3 - Effect of osmopriming on germination percentage, number of tillers, productive tillers and plant height of MR219 rice

Treatments	Germination percentage	Number of tillers	Productive tillers	Plant height (cm)
NaCl 50	80 b	36.0 bd	36.0 bc	117.1 ac
NaCl 100	75 bc	38.0 bc	37.0 bc	118.4 ab
NaCl 150	85 a	34.0 cd	34.0 c	116.4 ac
NaCl 200	75 bc	38.0 bc	38.0 ac	115.8 ac
$CaCl_2$ 50	80 b	37.0 bd	37.0 ac	117.2 ac
$CaCl_2$ 100	80 b	36.0 bd	36.0 bc	117.2 ac
$CaCl_2$ 150	75 bc	34.0 cd	34.0 c	120.7 a
$CaCl_2$ 200	85 a	37.0 bd	36.0 bc	117.4 ac
$MgCl_2$ 50	75 bc	39.0 ac	38.0 ac	111.6 bc
$MgCl_2$ 100	90 a	39.0 ac	38.0 ac	113.9 ac
$MgCl_2$ 150	85 a	41.0 ab	41.0 ab	113.4 bc
$MgCl_2$ 200	75 bc	38.0 bc	37.0 bc	114.9 ac
PEG 10	85 ab	38.0 bc	38.0 ac	115.3 ac
PEG 20	85 ab	38.0 bc	37.0 bc	118.3 ab
PEG 30	90 a	34.0 bd	34.0 bc	114.5 ac
PEG 40	85 ab	35.0 bd	35.0 bc	114.6 ac
Water	85 ab	39.0 ac	38.0 ac	110.9 c
Zappa	60 c	37.0 bd	37.0 ac	110.9 c
Pre-germination (Control)	95 a	45.0 a	44.0 a	112.7 bc

Means with the same letter (s) in the same column are not significantly different from one another at 0.05 probability level.

Table 4 - Effect of osmopriming on tiller efficiency, yield per panicle and yield per pot of MR219 rice

Treatment	Tillering efficiency (%)	Yield per panicle(g)	Yield per pot (g)
NaCl 50	99.4 a	1.4 ac	49.4 ac
NaCl 100	97.4 a	1.5 ac	54.4 ac
NaCl 150	99.3 a	1.4 ac	46.9 ac
NaCl 200	100.0 a	0.8 bc	32.6 ac
$CaCl_2$ 50	99.4 a	1.6 ab	57.3 bd
$CaCl_2$ 100	99.4 a	1.4 ac	51.5 ac
$CaCl_2$ 150	100.0 a	1.7 ab	56.1 ac
$CaCl_2$ 200	97.6 a	1.2 ac	45.8 ac
$MgCl_2$ 50	97.3 a	1.8 a	70.6 a
$MgCl_2$ 100	97.9 a	1.8 ab	66.4 ab
$MgCl_2$ 150	99.4 a	0.6 c	24.9 cd
$MgCl_2$ 200	97.3 a	1.1 ac	37.4 ac
PEG 10	97.9 a	0.8 bc	29.4 bd
PEG 20	97.4 a	1.1 ac	40.8 ac
PEG 30	99.3 a	1.4 ac	49.2 ac
PEG 40	98.4 a	1.3 ac	44.2 ac
Water	98.1 a	0.7 c	24.9 cd
Zappa	99.2 a	1.3 ac	47.3 ac
Pre-germination (Control)	96.81a	1.3 ac	54.9 ac

Means with the same letter (s) in the same column are not significantly different from one another at 0.05 probability level.

Hormonal priming

Germination percentage, number of tillers, productive tillers and plant height

The peak germination percentages (90%) were from 150 ppm GA_3 and 50 ppm methyl jasmonate. Closely following the best treatments was 200ppm GA_3, which had 85% germination and was just 5.56% lower than the best treatments (150 ppm GA_3 and 50 ppm methyl jasmonate). The best treatments were 80% higher than the treatments with lowest germination percentages (50). The best hormonal priming treatments for seed germination were 5.2% lower than pre-germination that was used as the check. Pre-germination treatment had 90% betterment over 150 ppm methyl jasmonate and kinetin, which had the lowest germination percentages (*Table 5*).

As for number of tillers, the highest number of tillers (45) was produced by the control (pre-germination).

This was followed by 200 ppm IAA and salicylic acid (41). Finally, the lowest number of tillers was from 100 ppm methyl jasmonate. The betterment of pre-germination (the control) over 100 ppm methyl jasmonate was 27.78%. For 200 ppm

IAA and salicylic acid, their betterment was 19.97% above 100 ppm methyl jasmonate treatment (*Table 5*).

Hormonal priming agents also had significant influence on productivity of MR219 rice tillers. The highest number of panicle production (44) was still from the control and was followed by 200 mM salicylic acid and IAA (40). The lowest number of panicles (32) was produced by plants treated with 100 and 150 ppm methyl jasmonate. The control was 26.90% better than 100 and 150 ppm methyl jasmonate treatments.

However, 200mM salicylic acid treatment (the second best) was 21.09% better than 100 and 150 ppm methyl jasmonate treatment (*Table 5*).

For plant height, 50 ppm GA_3 treatment produced the tallest plants (118.2 cm). This was followed by 200 ppm IAA treatment that produced plants that were 117.8 cm tall. The shortest plants (107.8 cm) were from 50 ppm salicylic acid treatment; 50 ppm GA_3 treatment was 8.80% better than 50 ppm salicylic acid treatment. In the same vein, 200 ppm IAA was 8.49% lower than 50 ppm salicylic acid treatment (*Table 5*).

Table 5 - Effect of hormonal priming on germination percentage, number of tillers, productive tillers and plant height of MR219 rice

Treatment	Germination percentage	Number of tillers	Productive tillers	Plant height (cm)
Kinetin 50	70 de	36.0 ac	35.0 b	112.4 ab
Kinetin 100	70 de	39.0 ac	37.0 ab	110.1 ab
Kinetin 150	50 g	39.0 ac	37.0 ab	112.9 ab
Kinetin 200	80 c	36.0 ac	35.0 b	113.9 ab
IAA 50	75 cd	38.0 ac	37.0 ab	115.7 ab
IAA 100	65 ef	36.0 ac	35.0 ab	115.4 ab
IAA 150	75 cd	36.0 ac	35.0 ab	116.3 ab
IAA 200	75 cd	41.0 ab	40.0 ab	117.8 a
GA 50	80 b	35.0 bc	33.0 b	118.2 a
GA 100	65 ef	34.0 bc	33.0 b	113.3 ab
GA 150	90 ab	37.0 ac	37.0 ab	114.1 ab
GA 200	85 bc	38.0 ac	37.0 ab	113.6 ab
Methyl 50	90 ab	37.0 ac	35.0 b	115.1 ab
Methyl 100	75 cd	33.0 bc	32.0 b	112.9 ab
Methyl 150	50 g	34.0 bc	32.0 b	112.3 ab
Methyl 200	80 c	39.0 ac	37.0 ab	115.8 ab
Sali 50	70 de	35.0 bc	34.0 b	107.8 b
Sali 100	60 f	40.0 ac	37.0 ab	111.1 ab
Sali 150	80 c	40.0 ac	38.0 ab	112.3 ab
Sali 200	60 f	41.0 ab	40.0 ab	115.8 ab
Pre-germination (Control)	95 a	45.0 a	44.0 a	112.7 ab

Means with the same letter (s) in the same column are not significantly different from one another at 0.05 probability level.

Tiller efficiency, yield per panicle and hill

In this work, 200 ppm salicylic acid treatment produced plants with the highest tiller efficiency (99.5%), followed by 150 ppm IAA (98.7%), while the least (93.8%) was from 150 ppm methyl jasmonate treatment.

The best treatment (200 ppm salicylic acid) was 6.06% better than 150 ppm methyl jasmonate treatment and 0.8% better than 50 ppm IAA treatment (*Table 6*). In the same vein, hormonal priming contributed significantly to improvement of grain yield per panicle and per pot above the control used, except for some treatments.

On yield per panicle basis, the highest (2 g) was from 200 ppm methyl jasmonate treatment, followed by 200 ppm kinetin and salicylic acid treatments (1.9 g), while the least (0.8 g) was produced by treatment with 150 ppm IAA treatment. The heaviest panicle-producing treatment was 60% better than the lightest panicle-producing treatment. The second best treatment was 57.89% better than the treatment with the lightest panicle-producing treatment (*Table 6*).

Table 6 - Effect of hormonal priming on tiller productivity percentage, yield per panicle and yield per pot of MR219 rice

Treatment	Tiller efficiency (%)	Yield per panicle (g)	Yield per pot (g)
Kinetin 50	95.7 a	1.2 ad	42.4 ac
Kinetin 100	97.4 a	1.2 ad	39.9 ac
Kinetin 150	95.1 a	0.9 bd	33.9 ac
Kinetin 200	97.1 a	1.9 ab	62.5 ab
IAA 50	98.9 a	0.8 cd	29.9 bc
IAA 100	97.4 a	1.4 ad	51.4 ac
IAA 150	98.7 a	1.3 ad	47.9 ac
IAA 200	97.5 a	1.6 ac	64.1 ab
GA 50	94.4 a	1.2 ad	39.9 ac
GA 100	98.6 a	1.5 ac	52.0 ac
GA 150	98.8 a	1.5 ad	55.2 ab
GA 200	98.0 a	1.1bd	40.0 ac
Methyl 50	95.4 a	1.2 ad	43.9 ac
Methyl 100	97.9 a	1.7 ac	58.8 ac
Methyl 150	93.5 a	1.63 ac	52.3 ac
Methyl200	96.2 a	2.0 a	68.3 a
Sali 50	97.8 a	1.8 ab	59.4 ab
Sali 100	93.8 a	1.7 ac	62.0 ab
Sali 150	96.3 a	1.6 d	20.8 cd
Sali 200	99.5 a	1.9 bd	38.7 ac
Pre-germination (Control)	96.8 a	1.3 ad	54.9 ac

Means with the same letter (s) in the same column are not significantly different from one another at 0.05 probability level.

For yield production per pot, the trend of yield per panicle was followed for the highest grain yield per pot. So, 200mM methyl jasmonate treatment had the highest grain yield (68.3 g) per pot. This was followed by 200 ppm IAA treatment (64.1 g), while the lowest yield per pot (20.8 g) was from treatment with 150mM salicylic acid; 200mM methyl jasmonate treatment was 69.55% better than 150mM salicylic acid, which had the lowest yield. Furthermore, 200 ppm IAA treatment (the second best) was better than 150mM salicylic acid (the treatment with the least yield) (*Table 6*).

DISCUSSION

The result on germination percentage from pre-germination treatment was logical because only germination seeds were selected for planting. That implied that the percentage germination was 100 % from the beginning. The reduction that was found could be accounted for by the death of one of them in one of the replicates through unforeseen abiotic environmental condition, like flood, since water stress was neither imposed nor experienced before securing proper establishment in the soil. The reason for the success of the pre-germinated seeds was still the same as highlighted above under the use of osmotic salts as priming media. That is why pre-germination remains the choice of those interested in optimum and uniform seed performance, speedy emergence and uniformity of seedling (McDonald, 2000).

The failure of the plant hormone in giving better germination result could be explained in two ways. It could be because of viability state of the used seeds before priming or it might be the result of the damage that might have been caused by the priming media to the primed seeds. This might result from high concentration of the priming media, which then led to damage of the seed cotyledon and the consequential reduction in germination percentage. This is so because the result was less than what was obtainable from the untreated seeds that came from the same seed lot. If the damage had not been done to the cotyledon by the priming chemical, then the result should have been the same with those of untreated seeds. For viability issue, the used seed lot did not have 100% viability and at the end of the treatment viability status was not enhanced. This, therefore, implies that seed priming does not change seed viability status, but only enhances the viable seeds if only the right concentration of the priming media is used. This is true because the purpose of seed priming is to shorten the time between planting and emergence (Farooq *et al.,* 2006b) and to protect seeds from biotic and abiotic stresses during critical phase of seedling establishment (Shakirova *et al.,* 2003). Furthermore, priming treatment synchronizes emergence, which in turn results in uniform stand and improved yield. It could, therefore, be concluded that viability of seeds is highly germane for any priming treatment to work perfectly.

It has been revealed from this work that the highest and the lowest plant height from the osmopriming were higher than their respective counterparts from hormonal priming. This might be because the hormones were exogenously applied and, therefore, could not act as they would when they exist endogenously in the body of the plants. Moreover, the hormones were not absorbed by the seeds, but they only acted in controlling seed hydration so that radicle protrusion would be prevented (Taylor *et al.,* 1998).

Light interception is a function of the plant height, angle of inclination of the leaves as well as leaf openness and area. Therefore, tall plants do have privilege of intercepting adequate solar radiation, which is very essential for sound photosynthetic activities and consequent assimilate accumulation. Since the three uppermost leaves are the sink sources for grain filling after heading stage, it is, therefore, desirable of rice plant to have an appreciable height to have the opportunity of intercepting adequate solar radiation.

Furthermore, any method, for instance the present seed priming that can be applied to have the achievement of this goal of height improvement should be given attention. This does not go without mentioning the pitfall of tallness, which is lodging. Furthermore, tallness is accompanied by reduction in population of tillers per plant because the reduction has been compensated for by height gain. This phenomenon is detrimental to the target of the rice producers at any level because the higher the population of tillers, the higher the yield. Higher yield is not the utmost for farmers only, but also for all agronomic, physiological and genetic manipulations of the agricultural experts.

The production of tillers is a significant determinant of yield in rice because it determines the number of panicles to be produced. This, therefore, serves as the index of productivity. This very important factor was better enhanced by the use of hormones than osmotic chemicals, as revealed by this experiment. This is so because hormones are responsible for regulation of the internal environment of the plants and enhancement of growth and development.

The observation here could be linked to the fact that hormonal priming has got a lot of growth repair in the plants that led to production of higher number of productive tillers than osmopriming counterpart. In that case, the choice may go to hormonal priming since all efforts are only made to increase the number of productive tillers because it closely predicts the yield. In the same vein, the more the panicles, the more the spikelets and the more the sink capability of the economic part so that partitioning of assimilates becomes effective because it is to the intended target.

This, therefore, gives opportunity for higher yield gain, which is the utmost aim of seed priming. Nonetheless, osmotic priming equally performed the type of repair got from hormones. The explanation for salicylic acid performance was due to the fact that it aided the cell division within the apical meristem of the roots and shoots and, therefore, higher tiller population. Moreover, salicylic acid maintained IAA and cytokinin levels in plant tissues, which in turn enhanced cell division (Sakhabutdinova *et al.,* 2003).

It is a known fact that whatever the number of tillers produced by a rice plant, the tiller efficiency is very important to producers because it is the predictor of the yield. If the productivity percentage is low, the treatment(s) concerned would have only succeeded in aiding vegetative life of the plant and not the targeted reproductive aspect. From our results, 200mM NaCl was better than pre-germination despite its desirable results from other measured parameters. For tiller efficiency in this work, any form of priming treatment is recommended because of their better performance over the control consequent upon their well-known biochemical attributes of metabolic repair during imbibition (Bray *et al.,* 1989), a build-up of germination promotion metabolites (Farooq *et al.,* 2006b) and osmotic adjustment (Bradford and Haigh, 1994). This could be attributed to production of vigorous tillers by the resulting plants from primed seeds. The tillers with less vigour, therefore, had difficulty in panicle production. Having very small number of tillers consequently results in reduction in tiller efficiency.

Contrary to the expectation from pre-germination, which had the highest number of productive tillers, the highest yield per pot or panicle in the osmopriming was from 50Mm magnesium chloride, while 200 ppm methyl jasmonate had the highest from hormonal priming. This might have resulted from grain filling problem (panicle blanking), which was better alleviated by 50Mm magnesium chloride and 200 ppm methyl jasmonate. This could equally be attributable to higher weight of individual grain, which reflected in the yield per panicle (Farooq *et al.,* 2011). Finally, if the sterility level of the tillers is very low, it could result in higher yield production.

Yield increase has been the achievement of seed priming technique and has been reported by several researchers (Tilahun-Tadesse, 2013) with corroboration from this research finding. This increase in yield might also be attributed to well-developed root system of the plants of the treated seeds, which led to increase in nutrient uptake by the plants and in turn improved growth characters and consequently higher number of panicles, better grain filling and higher yield.

CONCLUSIONS

From this study, it can be categorically said that priming of all forms gave betterment to the early growth performance of MR219 rice. However, the best priming media for yield increase for this rice variety were 50 Mm magnesium chloride for osmopriming and 200 ppm methyl jasmonate for hormonal priming. These are better and cheaper than Zappa. They also have appreciable edge over the already being used pre-germination, which does not give room for seed storage after treatment.

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