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Original research article

Enhancing Germination and Seedling Vigor of Upland Rice Seed under Salinity and Water Stresses by Osmopriming

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ABSTRACT

The moisture and salinity stress are major constraints of rice production around the world. The combination of low quality native upland rice seeds and abiotic stresses can result in major crop losses and become a major constraint in growing upland rice in both upland and lowland areas. Thus, the purpose of this study was to evaluate the benefit of different seed priming [hydroprimed (control), 0.05% of magnesium chloride ($MgCl_2$), 2% of potassium chloride (KCl) and 1.5% of potassium nitrate (KNO_3)] on seed emergence and seedling vigor of upland rice seeds under both normal and stressed conditions. For abiotic stresses, seeds were grown under drought condition in four different soil moisture contents (5, 27, 52 and 86% soil moisture) as well as different salinity levels (0, 5, 10, 15 and 20 dS/m). The result showed that seeds primed with 0.05% $MgCl_2$ provided high efficiency in enhancing many traits (the mean emergence time (MET), emergence index (EI), vigor index (VI), and shoot and root, either fresh weight or dry weight). Moreover, 0.05% $MgCl_2$ was able to accelerate seed emergence time in both abiotic stresses. The METs of hydroprimed (control) under normal, mild drought stress and severe salinity stress were 1.08, 4.70 and 4.70 days while METs of seed primed with $MgCl_2$ were 0.53, 3.40 and 1.63 days, respectively. The data showed that osmopriming with 0.05% $MgCl_2$ is an efficient method that helps seeds to overcome abiotic stress conditions by enhancing seed emergence and seedling growth of upland rice in both upland and lowland areas.

Keywords: Upland rice; Osmopriming; Seed germination; Moisture stress; Salt stress

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1. Introduction

Rice (*Oryza sativa* L.) is an economic crop that is considered a staple food for at least 3.5 billion people worldwide [1]. Although major agro-ecosystems, which are rainfed lowland and upland rice, account for only 11% of global rice production [2], upland rice is the most popular option for rice production in slope areas under rainfed conditions [3]. Moreover, this type of rice is a rich source of biodiversity; thus, it's often used as a donor for several breeding programs including resistance to disease and insect pests, and improved soil fertility [4-6]. Recently, upland rice has gained interest from farmers because of its distinctive characteristics such as nutrients, flavor, aroma, and disease and pest resistance. Therefore, it is important to cultivate upland rice under both upland and lowland conditions for several purposes such as collecting seeds to use in plant breeding programs and for consumption. However, a major constraint in cultivating upland rice under both upland and lowland conditions is abiotic stress. Salinity stresses and water deficit are the most common abiotic stress factors affecting rice production worldwide [7-9]. Even though rice has been classified as moderately tolerant to salt stress [10-12], it is very sensitive to salinity at early seedlings stages [11]. These abiotic stresses (drought and salinity) have significant impact on young seedlings, which may negatively result in yielding performance. For this reason, the promotion of germination and growth in the early stages of emergence is extremely important.

Seed priming is a technique that can be applied to improve speed of germination resulting in uniform and fast-growing seedlings [13-14], due to an increase in the total sugar content, α-amylase activity and earlier initiation of protein, RNA, and DNA synthetic activity [15]. Consequently, this improves the ability of seed germination and seedling vigor. Therefore, seed priming methods, such as water and osmotic priming including polyethylene glycol (PEG), mannitol, sorbitol, glycerol, and inorganic salts such as NaCl, KCl, KNO_3, K_3PO_4, KH_2PO_4, $MgSO_4$, and $CaCl_2$ are commercially used to improve rate and uniformity of germination of several crops such as onion, canola, rice, and wheat [13,15-17]. Priming methods also provide obvious improvements in germination rates and uniform seedling germination under environmental stresses, such as salinity and drought stress [14,18-19]. For instance, seeds of *Medicago sativa* var. Anand-z that were primed with 0.1% $MgCl_2$ had a high percentage of seed germination and seedling growth [20]. Similarly, 0.01 M $MgCl_2$ was able to enhance seed germination and mass of radish (*Raphanus sativa*) [21]. At the same time, 0.5% KNO_3, 50 to 100 mM of KNO_3 were also recommended for commercial use to enhance seed germination and seed vigor of hybrid sorghum (var. Sugar Grazell, Digestive), and flowering plants (*Gerbara jamesonii* and *Zinnia elegans*), respectively [22-23]. In addition, osmopriming by KNO_3 and KCl increased seed emergence of spring wheat seed that was germinated under salty conditions [24]. Therefore, these successful techniques including $MgCl_2$, KNO_3, KCl were used in this study.

Although seed priming has been successfully improving seed germination under abiotic stresses of several plants including lowland rice [25-27], there is no information on effects of priming on upland rice under both salinity and drought stress. Thus, the objectives of the current study were to determine the ability of chemicals responsible for increasing germination and seedling vigor of upland rice under saline and drought conditions, which are often found in upland area. The data obtained from the study could result in increased ability to cultivate upland rice in both upland and lowland areas to gain benefit in terms of genetic development and the nutrients from upland rice seeds.

2. Materials and Methods

2.1 Plant material and seed preparation

Upland rice seeds from the North and Northeast of Thailand were used in this study. Seeds of "Nam Roo", "Jao Lee Saw", and "Beu Sukee" varieties were harvested from Mae Suai District, Chiang Rai Province. Meanwhile, seeds of "Sakon Nakorn" variety were harvested from Ban Phai District, Khon Kaen Province. All seeds were harvested at maturity stage and cultivated in the field on Silpakorn University Phetchaburi IT Campus from August 2017 to November 2017. Seeds from all varieties were then harvested and heated at 50 °C for four days to break dormancy. Subsequently, all seeds were kept in a paper envelope. The experiments were conducted at a laboratory in Mae Fah Luang University, Chiang Rai, Thailand, from December 2017 to September 2018.

2.2 Seed priming

Seeds in this study were primed using two priming methods: hydropriming, which was used as the control treatment, and osmopriming with a chemical solution ratio of 1:5 (w/v). For priming by water, seeds were submerged in tap water at 30 ^{o}C for 24 hr. As for osmopriming, seeds were soaked in four chemical solutions: 1) 0.05% of magnesium chloride ($MgCl_2$), 2) 2% of potassium chloride (KCl), 3) 4% KCl and, 4) 1.5% of potassium nitrate (KNO_3) for 24 hr. at room temperature. Seeds were then surface dried with blotting paper and placed under shade with forced air at room temperature for 48 hr. or until seeds were completely dry.

2.3 Evaluation of seed emergence and seedling growth under normal conditions

Chemicals for osmopriming were tested with seeds from the four upland rice varieties under normal conditions. Seeds from each of the four upland rice varieties were primed with the osmopriming methods mentioned above and the respective controls were tested for germination and vigor index. Seed germination tests and seed vigor tests were performed using a method described in Zhang *et al*. [4]. Three replicate experiments (50 and 100 seeds for seed germination and vigor test, respectively) were performed for both seed germination and seed vigor tests. Both experiments were repeated twice.

2.4 Evaluation of seed emergence and seedling growth under abiotic stresses

After the most suitable chemical and its concentration were determined, the selected upland rice variety and effective chemical for osmopriming was further investigated under two abiotic stress conditions. Seeds of the upland rice variety "Sakon Nakorn" were primed with three osmopriming methods (0.05% $MgCl_2$, 2% KCl, and 1.5% KNO_3) and stored in a container that contained silica gel for six months. The seeds were then used to perform seed germination and seed vigor tests under different soil conditions with a method slightly modified from Hussain *et al*. [19]. Briefly, to emulate drought conditions, soil was dried in an oven and then 0 ml, 1 ml, 5 ml, and 15 ml of sterile water was added into 10 g of dried soil, with 0 ml and 15 ml representing negative and positive controls, respectively. As for salinity stress, soil was prepared at different salinity levels by adding 15 ml of 50 mM, 100 mM, 150 mM, and 200 mM of sodium chloride (NaCl) into 10 g of dried soil. For control, 15 ml of sterile water was added to the soil. Three replicates were performed for each experiment. Germination tests were performed by adding 10 g of soil with different moisture and salinity content into separate petri dishes. The number of germinated seeds was recorded daily for 7-10 days. Vigor tests were performed separately from germination tests. Vigor tests were conducted by adding 50 g of soil with different moisture and salinity content in separate plastic boxes. Thirty primed seeds were placed in the plastic box and covered with soil at approximately 1 cm in depth. Shoot and root length, and their fresh and dry weight were measured after one week. Three replicate experiments were performed and each experiment was repeated twice.

2.5 Data analysis

All experiments were conducted in triplicate and the results are expressed as Emergence of seedlings percentage (ESP), Emergence rate (ER), Mean emergence time (MET), Emergence index (EI) and Vigor index (VI). These were calculated using the formulas described in Belwal *et al.* [28].

Experimentation was 4x4 (levels of watering for drought stress x different chemical solutions for seed priming) and 5x4 (levels of NaCl concentration for salt stress x different chemical solutions for seed priming) factorials in completely randomized design (CRD) in drought and salt stress tests, respectively with three replications. Data were analyzed using the Two-way Analysis of Variance (ANOVA), and means of treatments were compared by using Duncan's New Multiple Range Test (DMRT) at a 0.05 probability level. Statistical analysis was conducted using R program version 3.4.1 [29].

3. Results and Discussion

3.1 Effects of osmopriming on upland rice seeds

The emergence of seedling percentage (ESP; average of all data was 91.53% to 94.85%) and emergence rate (ER; average of all data was 14.26% to 18.01%) traits were determined as non-significant interactions between different varieties and chemicals used for seed priming. However, mean emergence time (MET), emergence index (EI), and vigor index (VI), which are related to the emergence ability of seeds, were significantly different among chemicals used for priming. Average data from all four upland rice varieties showed that the EI and VI traits of the seeds primed with $MgCl_2$ were significantly higher, while MET was significantly lower (Fig. 1). On the other hand, seeds primed with 4% KCl showed low seed emergence even when compared with the control treatment.

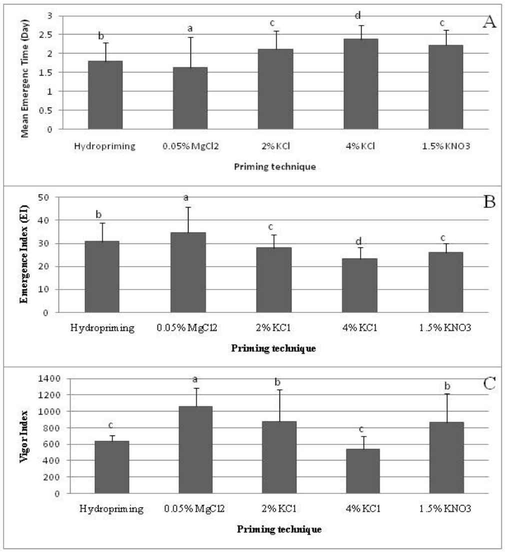

Fig. 1. Emergence related traits (MET, EI, VI)

Four traits of growth index (SFW, SDW, RFW, and, RDW) also showed significant differences on priming solutions. Average data from all four upland rice varieties showed that $MgCl_2$ was the most effective among chemical solutions for primed seeds in all four traits of growth index, followed by 1.5% KNO_3 and 2% KCl (Fig. 2). Even though seeds primed with 4% KCl treatment had lower values of growth index, these were still of higher growth than those in hydroprimed control. These data suggest that type and amount of chemical used in osmopriming can alter emergence ability and, more importantly, seedling vigor of upland rice seeds.

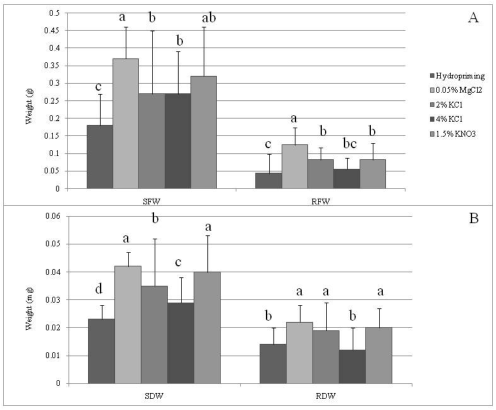

Fig. 2. Growth index (SFW, SDW, RFW, RDW) of average data of four upland rice seeds primed with different priming treatments under normal condition.

Genetics also play a role in how rice plants respond to chemical solutions and/or techniques used for priming rice seeds before germination [30]. As shown in Fig. 3, seeds of "Bue Sukee" variety responded to chemical solution less than the other three varieties. Despite the differences of effect of chemical solution on seed emergence and seedlings vigor on tested varieties, 0.05 % $MgCl_2$ remained the most effective technique in all four varieties. Magnesium is important in high altitude plants because of its role in photosynthesis as a cofactor supporting the activity of the chlorophyll molecule [31-33]. Previously, $MgCl_2$ was reported to assist seed emergence under normal and stress conditions such as ionic and osmotic stress of salinity [34-35]. In addition, $MgCl_2$ showed positive effects on seed emergence when it was used at lower concentration [34]. In contrast, 4% KCl was less effective as shown by the lowest values in seed emergence and seedling growth in normal conditions. Moreover, the 2% KCl and 1.5% KNO_3 treatments negatively affected the ability of seed emergence but not seedling growth under salinity stress. Potassium salts (KCl and KNO_3) are the most commonly used techniques in seed priming [39-40]. However, our finding suggested that using the inappropriate concentration of chemical for priming could have a negative effect on germination and seedling growth especially in upland rice seeds.

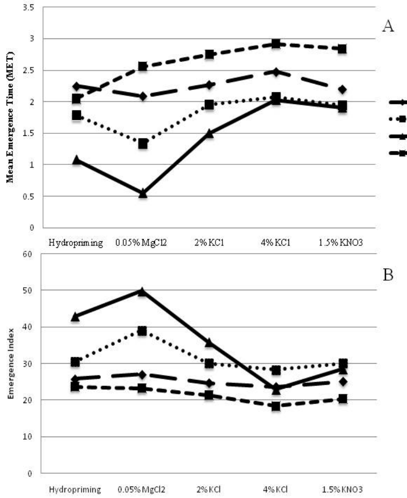

Fig. 3. Emergence related traits (MET, EI) of four upland rice seeds primed with different priming treatments under normal condition.

3.2 Effects of osmopriming on upland rice seeds under water deficit

Priming seeds with 4% KCl was the least successful treatment in terms of stimulating seed germination as well as seedling vigor. Thus, this osmopriming treatment was not considered further. The remaining three priming treatments enhanced the quality of "Sakon Nakorn" seeds more than the other three varieties. Therefore, only seeds from this variety were used for further investigation. Primed seeds were tested in soil containing 0, 1, 5, and 15 ml corresponding to 5, 27, 52, and 86 percent moisture, respectively. The percentage of moisture content was measured daily for 10 days and was consistent for the duration of the experiments.

The ability of seed emergence and seed growth decreased gradually with increasing drought stress levels. There was no seed emergence under severe drought stress (5 and 27% moisture content) in this study. On the other hand, the highest emergence of seedlings was found in 86% moisture as shown in the highest average of seed emergence and seedling growth followed by mild water stress or 52% moisture (Table 1 and Table 2). At 52% moisture, "Sakon Nakorn" seeds primed with $MgCl_2$ germinated faster than seeds primed with other chemicals or water, which had the lowest MET (3.40 days). The other traits, including ER, EI, SFW, RFW, SDW, and RDW, were also significantly higher in seeds primed with $MgCl_2$ (Table 1 and Table 2).

Table 1. Emergence related traits of "Sakon Nakorn" seeds primed with different priming treatments under drought stress (mean±standard error).

The amount of water (A)	Priming treatment (B)	ESP	ER	MET	EI	VI
5 ml	Control	47.78 ± 3.85 a	4.78 ± 0.39 cd	4.77 ± 0.22 a	6.39 ± 0.68 e	232.03 ± 78.93 c
	0.05%$MgCl_2$	47.22 ± 2.55 a	5.67 ± 0.31 c	3.40 ± 0.26 c	9.62 ± 1.67 d	254.17 ± 85.38 c
	2% KCl	35.00 ± 1.67 b	3.72 ± 0.25 d	3.91 ± 0.12 b	5.96 ± 0.46 e	222.09 ± 14.50 c
	1.5% KNO_3	34.45 ± 6.31 b	3.45 ± 0.63 d	3.62 ± 0.05 c	6.28 ± 1.05 e	209.64 ± 7.20 c
Mean (5 ml)		41.11 ±7.50 B	4.40 ± 0.99 B	3.92 ± 0.56 A	7.06 ± 1.80 B	229.48 ± 52.88 B
15 ml	Control	50.55 ± 8.55 a	8.31 ± 0.93 b	2.69 ± 0.18 d	11.75 ± 1.38 d	633.89 ± 127.11 b
	0.05%$MgCl_2$	47.22 ± 0.96 a	11.00 ± 2.60 a	1.23 ± 0.02 g	25.45 ± 0.63 a	698.80 ± 26.03 b
	2% KCl	47.78 ± 2.55 a	5.61 ± 1.65 c	2.23 ± 0.51 e	17.95 ± 4.20 c	885.95 ± 49.42 a
	1.5% KNO_3	45.00 ± 3.33 a	6.33 ± 1.18 c	1.70 ± 0.11 f	20.26 ± 2.20 b	846.78 ± 65.52 a
Mean (15 ml)		47.64 ± 4.58 A	7.81 ± 2.62 A	1.96 ± 0.62 B	18.85 ± 5.56 A	766.28 ± 126.36 A
Mean (B)						
Control		24.58 ± 26.01 M	3.27 ± 3.68 N	1.86 ± 2.10 M	4.53 ± 5.17 O	216.48 ± 277.88 N
0.05% $MgCl_2$		23.61 ± 24.69 M	4.17 ± 4.91 M	1.16 ± 1.45 P	8.77 ± 10.89 M	238.24 ± 300.54 MN
2% KCl		20.69 ± 22.16 N	2.33 ± 2.63 O	1.53 ± 1.73 N	5.98 ± 7.86 N	277.01 ± 379.85 M
1.5% KNO_3		19.86 ± 21.33 N	2.44 ± 2.83 O	1.33 ± 1.56 O	6.64 ± 8.70 N	264.03 ± 363.52 M
F-test (A)		**	**	**	**	**
F-test (B)		**	**	**	**	*
F-test (AxB)		**	**	**	**	**
CV(%)		14.25	28.92	11.77	20.71	19.41

Table 2. Growth traits of "Sakon Nakorn" seeds primed with different priming treatments under drought stress (mean±standard error).

The amount of water (A)	Priming treatment (B)	SFW§	RFW	SDW	RDW
5 ml	Control	0.15 ± 0.03 d	0.10 ± 0.00 d	0.02 ± 0.01 c	0.013 ± 0.006 d
	0.05% $MgCl_2$	0.99 ± 0.11 ab	0.35 ± 0.03 a	0.12 ± 0.04 a	0.037 ± 0.006 a
	2% KCl	0.98 ± 0.13 ab	0.31 ± 0.03 ab	0.10 ± 0.02 ab	0.030 ± 0.000 b
	1.5% KNO_3	0.77 ± 0.04 c	0.24 ± 0.05 c	0.08 ± 0.01 b	0.023 ± 0.006 b
Mean (5 ml)		0.72 ± 0.37 B	0.25 ± 0.10 A	0.08 ± 0.04 B	0.026 ± 0.010 A
15 ml	Control	1.11 ± 0.33 a	0.24 ± 0..12 c	0.12 ± 0.04 a	0.026 ± 0.006 b
	0.05% $MgCl_2$	0.98 ± 0.16 ab	0.24 ± 0.03 c	0.11 ± 0.02 ab	0.026 ± 0.006 b
	2% KCl	0.96 ± 0.12 ab	0.26 ± 0.05 bc	0.10 ± 0.02 ab	0.026 ± 0.006 b
	1.5% KNO_3	0.87 ± 0.04 bc	0.29 ± 0.02 abc	0.09 ± 0.01 ab	0.026 ± 0.006 b
Mean (15 ml)		0.98 ± 0.19 A	0.26 ± 0.06 A	0.10 ± 0.02 A	0.027 ± 0.005 A
Mean (B)					
Control		0.31 ± 0.50 N	0.09 ± 0.12 N	0.03 ± 0.05 O	0.010 ± 0.012 N
0.05% $MgCl_2$		0.49 ± 0.52 M	0.15 ± 0.16 M	0.06 ± 0.06 M	0.016 ± 0.017 M
2% KCl		0.48 ± 0.51 M	0.14 ± 0.15 M	0.05 ± 0.05 MN	0.014 ± 0.015 M
1.5% KNO_3		0.41 ± 0.43 M	0.13 ± 0.14 M	0.04 ± 0.04 NO	0.012 ± 0.014 MN
F-test (A)		**	**	**	**
F-test (B)		**	**	**	**
F-test (AxB)		**	**	**	**
CV(%)		25.07	29.34	35.34	29.11

3.3 Effects of Osmopriming on Upland Rice Seeds under Soil Salinity Stress

All germination traits had the highest values at nil concentration of salt (0 mM NaCl or 0 dS/m), followed by 50 mM NaCl or 5 dS/m, 100 mM NaCl or 15 dS/m, and 150 mM NaCl or 20 dS/m. Similar to drought stress, as salinity stress increased all traits related to seed emergence and growth index were decreased gradually. Interestingly, seeds primed with $MgCl_2$ had high seed emergence and seedling growth at all levels of salinity stress (Table 3 and Table 4). This result corresponds with the effect of osmopriming by $MgCl_2$ on seed emergence at normal conditions and drought stress as described above.

Table 3. Emergence related traits of "Sakon Nakorn" seeds primed with different priming treatments under salinity stress (mean±standard error).

Salinity level (A)	Priming treatment (B)	ESP	ER	MET	EI	VI
0 dS/m	Control	48.89 ± 0.96 a	9.78 ± 0.19 bc	2.11 ± 0.02 d	14.11 ± 0.35 e	549.23 ± 13.48 b
	0.05% $MgCl_2$	48.33 ± 1.67 a	14.50 ± 0.50 a	1.06 ± 0.02 f	28.17 ± 1.04 a	783.90 ± 82.70 a
	2% KCl	32.22 ± 6.73 bc	3.87 ± 0.81 fg	2.92 ± 0.34 c	7.47 ± 2.23 gh	123.16 ± 19.23 f
	1.5% KNO_3	32.22 ± 3.47 bc	3.68 ± 0.74 fg	3.53 ± 0.26 b	5.91 ± 0.87 hi	112.80 ± 25.20 fg
Mean (0 dS/m)		40.42 ± 9.19 A	7.96 ± 4.73 A	2.40 ± 0.99 C	13.91 ± 9.24 A	392.27 ± 301.76 A
5 dS/m	Control	47.22 ± 0.96 a	8.64 ± 1.20 cd	2.30 ± 0.09 d	12.78 ± 0.25 e	403.89 ± 43.16 c
	0.05% $MgCl_2$	48.89 ± 0.96 a	11.45 ± 3.08 b	1.21 ± 0.07 ef	26.55 ± 1.07 b	579.16 ± 41.40 b
	2% KCl	33.33 ± 6.66 b	4.00 ± 0.80 fg	3.39 ± 0.01 bc	6.40 ± 1.37 hi	68.41 ± 11.50 ghi
	1.5% KNO_3	33.33 ± 4.41 b	3.80 ± 0.80 fg	3.37 ± 0.40 bc	6.61 ± 1.24 hi	107.56 ± 15.83 fg
Mean (5 dS/m)		40.69 ±8.45 A	6.97 ± 3.69 B	2.57 ± 0.96 C	13.08 ± 8.60 B	289.76 ±222.55 B
10 dS/m	Control	50.00 ± 1.67 a	7.20 ± 2.63 de	2.93 ± 0.30 c	11.06 ± 0.26 f	291.60 ± 32.74 d
	0.05% $MgCl_2$	50.56 ± 0.96 a	10.11 ± 0.19 bc	1.30 ± 0.03 ef	26.61 ± 0.42 b	300.82 ± 54.41 d
	2% KCl	31.67 ± 3.34 bc	3.40 ± 0.40 fg	3.79 ± 0.29 b	5.30 ± 0.30 ij	48.22 ± 4.43 hij
	1.5% KNO_3	30.00 ± 1.67 bcd	2.86 ± 0.30 g	4.89 ± 0.58 a	4.00 ± 0.59 jk	32.39 ± 7.92 hij
Mean (10 dS/m)		40.56 ± 10.33 A	5.89 ± 3.29 C	3.23 ± 1.41 B	11.74 ± 9.39 C	168.26 ± 136.58 C
15 dS/m	Control	47.22 ± 0.95 a	5.34 ± 0.44 ef	3.72 ± 0.14 b	8.36 ± 0.80 g	220.81 ± 8.20 e
	0.05% $MgCl_2$	49.44 ± 0.97 a	9.06 ± 1.36 cd	1.53 ± 0.03 ef	23.22 ± 1.11 e	283.58 ± 18.73 d
	2% KCl	20.56 ± 0.96 ef	2.72± 0.48 g	3.37 ± 0.21 bc	3.59 ± 0.27 jk	17.00 ± 0.89 ij
	1.5% KNO_3	25.56 ± 0.98 de	2.97 ± 0.68 g	3.85 ± 0.71 b	4.14 ± 0.71 jk	11.67 ± 0.30 j
Mean (15 dS/m)		35.70 ± 13.38 B	5.02 ± 2.75 C	3.12 ± 1.03 B	9.83 ± 8.33 D	133.26 ± 126.68 D
20 dS/m	Control	26.67 ± 1.66 cd	2.29 ± 0.15 g	4.70 ± 0.16 a	3.78 ± 0.21 jk	71.06 ± 17.58 fgh
	0.05% $MgCl_2$	49.44 ± 0.96 a	9.06 ±1.36 cd	1.63 ± 0.12 e	21.61 ± 0.82 d	201.35 ± 22.45 e
	2% KCl	29.45 ± 6.94 bcd	2.52 ± 0.59 g	4.67 ± 0.17 a	4.11 ± 0.84 jk	3.12 ± 2.57 j
	1.5% KNO_3	19.44 ± 4.19 f	2.33 ± 0.50 g	3.78 ± 0.09 b	3.18 ± 0.77 k	2.53 ± 0.63 j
Mean (20 dS/m)		31.25 ± 12.15 C	4.05 ± 3.09 D	3.70 ± 1.31 A	8.17 ± 8.14 E	69.52 ± 85.53 E
Mean (B)						
Control		44.00 ± 9.10 N	6.65 ± 2.95 N	3.15 ± 1.00 O	10.02 ± 3.81 N	307.32 ± 169.28 N
0.05% $MgCl_2$		49.33 ± 1.23 M	10.83 ± 2.52 M	1.34 ± 0.22 P	25.23 ± 2.63 M	429.76 ± 229.66 M
2% KCl		29.44 ± 6.66 O	3.30 ± 0.82 O	3.63 ± 0.64 N	5.37 ± 1.81 O	51.98 ± 44.67 O
1.5% KNO_3		28.11 ± 5.94 O	3.13 ± 0.76 O	3.89 ± 0.68 M	4.77 ± 1.51 O	53.39 ± 50.42 O
F-test (A)		**	**	**	**	**
F-test (B)		**	**	**	**	**
F-test (AxB)		**	**	**	**	**
CV (%)		8.75	19.07	9.12	7.88	13.98

Table 4. Growth traits of "Sakon Nakorn" seeds primed with different priming treatments under salinity stress (mean±standard error).

Salinity level (A)	Priming treatment (B)	SFW	RFW	SDW	RDW
0 dS/m	Control	0.44 ± 0.05 cdef	0.20 ± 0.02 cdef	0.047 ± 0.006 ab	0.000 ± 0.000
	0.05% $MgCl_2$	0.59 ± 0.09 abc	0.21 ± 0.01 cde	0.053 ± 0.006 ab	0.023 ± 0.003 bcd
	2% KCl	0.57 ± 0.06 bcd	0.25 ± 0.02 bc	0.050 ± 0.010 ab	0.023 ± 0.005 bcd
	1.5% KNO_3	0.45 ± 0.08 cdef	0.17 ± 0.04 defg	0.040 ± 0.010 b	0.013 ± 0.006 e
Mean (0 dS/m)		0.51 ± 0.09 A	0.21 ± 0.04 A	0.05 ± 0.01	0.015 ± 0.011 C
5 dS/m	Control	0.34 ± 0.21 efg	0.09 ± 0.06 hi	0.037 ± 0.021 b	0.000 ± 0.000 f
	0.05% $MgCl_2$	0.74 ± 0.31 ab	0.37 ± 0.14 a	0.067 ± 0.032 ab	0.043 ± 0.012 a
	2% KCl	0.41 ± 0.03 def	0.20 ± 0.03 cdefg	0.040 ± 0.010 b	0020 ± 0.000 cde
	1.5% KNO_3	0.33 ± 0.02 efg	0.21 ± 0.03 cde	0.030 ± 0.000 b	0.017 ± 0.006 de
Mean (5 dS/m)		0.45 ± 0.24 AB	0.22 ± 0.13 A	0.04 ± 0.02	0.020 ± 0.017 AB
10 dS/m	Control	0.47 ± 0.08 cde	0.24 ± 0.06 bcd	0.047 ± 0.012 ab	0.027 ± 0.006 bc
	0.05% $MgCl_2$	0.76 ± 0.07 a	0.30 ± 0.03 ab	0.073 ± 0.012 ab	0.030 ± 0.000 b
	2% KCl	0.33 ± 0.03 efg	0.18 ± 0.03 cdefg	0.030 ± 0.000 b	0.013 ± 0.005 e
	1.5% KNO_3	0.30 ± 0.02 efg	0.14 ± 0.02 efgh	0.027 ± 0.012 b	0.017 ± 0.004 de
Mean (10 dS/m)		0.47 ± 0.20 AB	0.22 ± 0.07 A	0.04 ± 0.02	0.022 ± 0.008 A
15 dS/m	Control	0.37 ± 0.06 ef	0.16 ± 0.03 defgh	0.030 ± 0.000 b	0.017 ± 0.004 de
	0.05% $MgCl_2$	0.69 ± 0.01 ab	0.16 ± 0.02 defgh	0.070 ± 0.001 ab	0.020 ± 0.000 cde
	2% KCl	0.35 ± 0.02 efg	0.14 ± 0.01 efgh	0.030 ± 0.000 b	0.017 ± 0.006 de
	1.5% KNO_3	0.27 ± 0.02 fg	0.12 ± 0.01 gh	0.117 ± 0.159 a	0.013 ± 0.005 e
Mean (15 dS/m)		0.42 ± 0.20 AB	0.14 ± 0.02 B	0.06 ± 0.08	0.017 ± 0.005 BC
20 dS/m	Control	0.06 ± 0.02 h	0.01 ± 0.00 j	0.003 ± 0.006 b	0.000 ± 0.000 f
	0.05% $MgCl_2$	0.68 ± 0.03 ab	0.12 ± 0.06 fgh	0.067 ± 0.012 ab	0.013 ± 0.005 e
	2% KCl	0.28 ± 0.04 fg	0.12 ± 0.02 fgh	0.027 ± 0.006 b	0.013 ± 0.006 e
	1.5% KNO_3	0.18 ± 0.04 gh	0.04 ± 0.02 ij	0.017 ± 0.006 b	0.000 ± 0.000 f
Mean (20 dS/m)		0.30 ± 0.24 C	0.07 ± 0.06 C	0.03 ± 0.03	0.007 ± 0.008 D
Mean (B)					
Control		0.34 ± 0.18 NO	0.14 ± 0.09 O	0.03 ± 0.02	0.009 ± 0.012 O
0.05% $MgCl_2$		0.69 ± 0.14 M	0.23 ± 0.11 M	0.07 ± 0.02	0.026 ± 0.012 M
2% KCl		0.39 ± 0.11 N	0.18 ± 0.05 N	0.04 ± 0.01	0.017 ± 0.006 N
1.5% KNO_3		0.31 ± 0.10 O	0.14 ± 0.06 O	0.05 ± 0.07	0.012 ± 0.008 O
F-test (A)		**	**	NS	**
F-test (B)		**	**	NS	**
F-test (AxB)		**	**	NS	**
CV (%)		22.14	25.23	82.85	32.30

Note: NS Non significant different at 95 percent of confident ($P<0.05$).
** Significant different at 99 percent of confident ($P<0.01$).
A, B,…, different letter on means of salinity levels means significant different at 95 percent of confident ($P<0.05$).
M, N, …., different letter on priming treatments means significant different at 95 percent of confident ($P<0.05$).
a, b, …, different letter on means of interaction between salinity levels and priming treatments means significant different at 95 percent of confident ($P<0.05$).

Drought and salinity are abiotic stresses that affect seed emergence and physiological characteristics of both seeds and seedlings, as they limit plant growth and development [38-39]. In this study, all characteristics related to germination and seedling growth decreased with a reduction of the amount of water and an increase of salinity level for primed seeds. Moreover, seed emergence was still observed at the highest level of salinity in the soil, while there was no seed germination at severe drought stress. These data suggest that emergence of upland rice seeds is usually less affected by salinity stress than by to drought stress. A previous study showed that hydropriming was able to increase seed germination and seedling vigor of two upland rice varieties including "BRSGO Serra Dourada" and "BRS Esmeralda" [40]. Conversely, osmopriming seed with 0.05% $MgCl_2$ resulted in the highest values across all traits related to seed emergence and growth index of upland rice seeds under both normal and abiotic stress conditions (drought and salinity stress) in this study. This may be due to the fact that environmental stress factors affect the efficiency of priming chemicals and techniques during seed germination [41-42].

From the results of this study, osmopriming with 0.05% $MgCl_2$ is strongly recommended for upland rice seeds. Seed emergence and seedling related traits (growth and development) are the most critical stages to consider during water deficiency and salinity stress, and this priming technique has the ability to increase seed emergence efficiency and improve uniformity of seedling in all soil conditions. This will result in increasing seedling vigor as well as developing strong plants, consequently increasing yield even with plants that are grown under drought and salinity stress.

4. Conclusion

Direct seeding is a common practice in growing upland rice in both upland and lowland conditions. Thus, osmopriming with $MgCl_2$ is an appropriate and effective method to regulate seed germination of upland rice seed of "Sakon Nakorn", "Nam Roo", and "Jaw Lee Saw". $MgCl_2$ solution used in seed priming is proven more efficient to enhance all traits in germination and growth of seedling than hydropriming and osmopriming with KCl or KNO_3 in all soil conditions. These findings can be beneficial for farmers or rice breeders to overcome obstacles of planting upland rice in the lowland condition especially the area with problem of salinity and/or drought stresses.

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