Combined Silicon dioxide and Salicylic acid Mediated Approach in Stimulating Germination and Seedling growth of Rice Var. FARO44

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Abstract

Seed presoaking is an essential approach that improves germination, seedling growth and vigour of variety of arable crops. Seed presoaking study was performed with combined 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA on FARO44 rice on field conditions. In this study, laboratory experiments were undertaken to determine the effect of combined silicon dioxide and salicylic acid presoaking in increasing germination and seedling growth of FARO44 rice. In the laboratory, FARO44 rice seeds presoaked in 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA were germinated in specimen bottles for two weeks. Each treatment was replicated five times. The results found that 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA presoaking significantly improved germination index and decreased germination time of FARO44 rice. However, seed presoaking had not improved germination percentage of FARO44 rice compared to unpresoaked seeds. Furthermore, presoaking of FARO44 rice in 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA stimulated seedling growth by increasing seedling length and root length. However, plumule length was not positively affected compared to control. Similarly, seedling biomass and vigour were increased by 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA presoaking. Thus, presoaking of FARO44 rice with combined silicon dioxide and salicylic acid were suggested for increased germination and seedling growth.

Key words: Seed presoaking, germination percentage, germination index, silicon dioxide, salicylic acid

Introduction

Seed presoaking generally refers to the physiological process of soaking sterilized seeds in organic and inorganic salts, hormones, water, plant extracts or exposure to temperature to activate important pre-germination metabolic processes prior to appearance of the radicle (Jisha et al., 2013; Jisha & Puthur, 2014). This approach enhances germination and seedling emergence, improves seedling growth and stress resistance in crops such as rice, wheat, maize, tomato and Chinese cabbage (Bhargava, 2013; Jisha et al., 2013; Yan, 2015; Jisha et al., 2016; Abdel Latef & Tran, 2016). Several studies reported that seed pre-soaking enhances germination, field crop performances and imparts environmental stress resistance to crops (Jisha et al., 2013; Paparella et al., 2015; Zheng et al., 2016). There are different approaches of pre-soaking of seeds practiced worldwide which include hydropriming, osmopriming or halopriming, hormonal priming, biopriming, nutrient priming, thermopriming and solid matrix priming (Jisha & Puthur, 2014; Jisha & Puthur, 2013; Langeroodi & Noora, 2017).

Silicon (Si) is one of the most plenty mineral element within the soil which is a key nutrient for the growth and development of plants. Silicon is found to activate some plant defence mechanisms. Silicon is also reported to regulate numerous physiological activities/processes which involve plant defence mechanisms (Sirisuntornlak et al., 2019). Application of silicon exogenously enhances germination, seedling growth and drought, salinity and extreme temperature tolerance of rice, wheat, sorghum and maize (Biju et al., 2017; Cuon et al., 2017; Ullah et al., 2017). Silicon also remediates imbalance of nutrients and can improve photosynthetic activities in plants (Guntzer et al., 2012). Salicylic acid (SA) is an important plant growth substance found in flowers and leaves, it plays several essential roles in the physiological activities of plants (Tavares et al., 2014). Studies have found that two maize varieties presoaked in 1.0 and 1.5 mM of silicon exposed to drought and alkalinity stresses in significantly showed increased plant height, leaf size, number of leaf, chlorophyll content, root and shoot dry biomass, cob length, kernel cob number and grain yield (Abdel-Latef & Tran, 2016; Sirisuntornlak et al., 2018). Study has shown that SA improved seed germination and seedling growth of different species of plants such as rice, wheat and maize, it may also promote drought and salt stress tolerance of many varieties of crops through the stimulation of vast stress adaptation mechanisms (Horváth et al., 2007; Tavares et al., 2014).

Several rice-growing areas in northern Nigeria practice direct seed broadcasting system under rain-fed agriculture because this system has less input cost, resource use effective and produce higher yield. However, drought due to limited rainfall annually affect germination, emergence and establishment of FARO44 rice variety which is produced mainly by farmers. Poor germination and establishment of seedlings lead to decline in the yield of FARO44 rice (Emoghene et al., 2015). In spite of the effectiveness of combined salicylic acid (SA) and silicon dioxide (SiO_2) priming in increasing seed germination and growth of seedling, there has been dearth of study on applying this technique on FARO44 rice to induce fast germination and seedling growth. Thus, this study was undertaken to determine the effect of combined salicylic acid and silicon dioxide priming in increasing germination and seedling growth of FARO44 rice.

Materials and methods

Study site

This study was performed in the Biology Laboratory of the Department of Science Laboratory Technology, School of Science, Mai Idris Alooma Polytechnic, Geidam, Yobe State, Nigeria.

Sample collection

FARO44 rice seeds were bought from Rice Research Institute at Badeggi town in Niger State, Nigeria in West Africa. FARO44 rice is a new rice variety developed in Nigeria, it is cultivated in different ecological zones of Nigeria under rain-fed and irrigation agriculture (Oluwaseyi & Nehemmiah, 2016).

Preparation of suitable presoaking chemicals

Several presoaking experiments were performed on FARO44 rice using different concentrations of salicylic acid and silicon dioxide based on germination and seedling growth performance before arriving at 3% SiO_2 and 350 mM SA being the suitable concentrations that produced better germination and seedling growth of FARO44 rice. Thus, these concentrations were used in combination.

Prior to pre-soaking of seeds, all beakers and specimen bottles, Petri dishes were kept in an oven for 20 hours at 60 ºC; while the different soaking solutions of SA and SiO_2 were prepared and kept in a refrigerator.

Presoaking of seeds and germination

Sterilized FARO44 rice seeds were presoaked separately in 10 ml each of 3% SiO_2+350 mM SA (w/v) and 3.5% SiO_2+200 mM SA for 8 hours as described by Chunthaburee et al. (2014), Yan (2015) & Abdel Latef & Tran (2016). The systems were placed in laboratory growth room at 25±2ºC, relative humidity of 50-70% and photoperiod of 12h light/12 h dark. The ratio of 1:5 (w/v) seeds weight to solution volume was maintained throughout the presoaking process. The seeds were then well rinsed with distilled water and air under shade for 48 hours to regain their original weight of 10.1% at 25 ºC (Anosheh et al., 2011; Khan et al., 2019)

Presoaked rice seeds in 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA were germinated in Petri dishes lined with Whatman filter (No.1 90mm) wetted with 6 ml distilled water for two weeks in laboratory growth room with temperature of 25 ±2ºC, relative humidity of 50-70% and photoperiod of 12h light/12 h dark (Anwar et al., 2013; Khan et al., 2019). Each treatment was replicated five times. The first record of germinations was taken on the second day while the last was taken on the fourteenth day. Seed was considered germinated if the appeared radicle measures at least 2 mm long (Chunthaburee et al., 2014; Ruttanaruangboworn et al., 2017). All the measurements were based on six randomly selected normal rice seedlings from each replicate. At the end of the experiments, final germination percentages were computed (Yan, 2015).

Statistical analyses

The seed presoaking experiments were placed in a completely randomized design with five replicates per treatment (Azeem et al., 2015). Normality of the data was checked with Shapiro Wilk test before statistical analyses. One-way analysis of variance (ANOVA) was carried out to compare the effect of various treatments on germination and seedling growth attributes of rice studied (Khatami et al., 2015).

Effect of combined SiO_2 and SA on germination of FARO44 rice

The result of variance analyses showed that 3% SiO_2+350mM SA and 3.5% SiO_2+200mM SA had no significant ($P < 0.05$) on germination percentage of FARO44 rice as detailed in Table 1 below. PFARO44 rice seeds treated with 3% SiO_2+350mM SA and 3.5% SiO_2+200mM SA recorded higher germination indices of 3.4 and 3.5 compared to lower germination index value of 2.3 for control. However, there was no significant difference in germination index between the two treatments. Rice seeds treated with 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA had significantly lower mean germination time of 2 days, 4 hours and 2 days, 3 hours for completion of germination compared to 3 days and 5 hours for untreated seeds. However, the mean germination time was not significantly different between the two treatments.

Table 1: Effects of SiO_2+SA treatments germination percentage, germination index and mean germination time of FARO44 Rice

Presoaking agents	Germination Percentage (%)	Germination Index	Mean Germination Time (Days)
Control	100 ± 0.0^a	2.3 ± 0.2^b	3.5 ± 0.0^a
3% SiO_2+350 mM SA	97.5 ± 2.5^a	3.4 ± 0.1^a	2.4 ± 0.0^b
3.5% SiO_2+200 mM SA	97.5 ± 2.5^a	3.5 ± 0.1^a	2.3 ± 0.1^b
Levels of Significance	0.619	0.000	0.000

Means ± SE values in the columns having the same letter (s) are not significantly different according to Duncan's Multiple Range Test ($P < 0.05$), while figures with different letters were statistically different.

Effects of combined SO_2 and SA on rice seedling growth

Results of the variance analyses showed that 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA treated rice had recorded significantly ($P < 0.05$) longer seedling length and root length compared to control as shown in Table 2 below. Although, 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA treatments had no significant effects on plumule length of FARO44 rice seedlings. Rice seedlings treated with 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA have seedling heights of 12.8 cm and 12.9 cm and root lengths of 6.9 cm and 7.5 cm compared to untreated seedlings with seedling height of 10.7 cm and root length of 5.2 cm. There were no significant differences between the two combined SiO_2 and SA treated rice seedlings in plumule and root lengths.

Table 2: Effect of SiO_2+SA treatments on seedling growth FARO44 rice

Presoaking agents	Seedling Length (cm)	Plumule Length (cm)	Root Length (cm)
Control	10.7 ± 0.4^b	5.7 ± 0.1^a	5.2 ± 0.3^b
3% SiO_2+350 mM SA	12.8 ± 0.4^a	5.9 ± 0.2^a	6.9 ± 0.4^a
3.5% SiO_2+200 mM SA	12.9 ± 0.5^a	5.7 ± 0.2^a	7.5 ± 0.4^a
Levels of Significance	0.000	0.713	0.000

Means ± SE values in the columns having the same letter (s) are not significantly different according to Duncan's Multiple Range Test ($P < 0.05$), while figures with different letters are statistically different.

Effects of combined SiO_2 and SA on seedling biomass and seedling vigour of FARO44 rice

Combined SiO_2 and SA treatment had significant effect ($P < 0.05$) in improving seedling fresh and dry biomass and vigour indices of FARO44 rice as shown in Table 3 and 4 below. Rice seedlings treated with 3% SiO_2+350 mM SA had seedling fresh weight of 114.6 mg and 28.8 mg seedling dry weight while 3.5% SiO_2+200 mM SA treated rice seedlings had 117.4 mg seedling fresh weight and 28.9 mg seedling dry weight. Untreated rice seedlings had seedling fresh weight of 110.6 mg and 27.8 mg seedling dry weight. However, there were no significant differences in fresh and dry seedling weights between SiO_2 and SA treated rice seedlings.

Table 3. Effect of combined SiO_2 and SA treatments on fresh and dry biomass of FARO44 rice seedlings

Presoaking agents	Seedling fresh weight (mg)	Seedling dry weight (mg)
Control	110.6 ± 0.9^{b}	27.9 ± 0.2^{b}
3% SiO_2+350 mM SA	114.6 ± 1.0^{a}	28.8 ± 0.3^{a}
3.5% SiO_2+200 mM SA	117.4 ± 1.3^{a}	28.9 ± 0.1^{a}
Levels of Significance	0.000	0.000

Means ± SE values in the columns having the same letter (s) are not significantly different according to Duncan's Multiple Range Test ($P < 0.05$), while figures with different letters were statistically different.

There were marked significant effect of 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA treatments on seedling vigour index I (SVI I) of FARO44 rice seedlings. However, SiO_2 and SA treatments had no effect on rice seedling vigour index II as shown in Table 4 below. Rice seedlings treated with 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA had SVI I of 1242.2 and 1252.3. SiO_2 and SA treatments had no significant effects in increasing seedling vigour index II of FARO44 rice seedlings compared to control.

Table 4: Effect of combined SiO_2 and SA treatment on seedling vigour of FARO44 rice

Presoaking agents	Seedling Vigour Index I (GP× Seedling Length)	Seedling Vigour Index II (GP× Seedling dry weight)
Control	1069.7 ± 39^{b}	2798.7 ± 21.1^{a}
3% SiO_2+350mM SA	1242.2 ± 28.8^{a}	2809 ± 23.5^{a}
3.5% SiO_2+200mM SA	1252.3 ± 36.3^{a}	2815.6 ± 21.5^{a}
Levels of Significance	0.001	0.860

Means ± SE values in the columns having the same letter (s) are not significantly different according to Duncan's Multiple Range Test ($P < 0.05$), while figures with different letters were statistically different.

Discussion

Presoaking of FARO44 rice in 3% SiO_2+350mM SA and 3.5% SiO_2+200mM SA improved germination index and decreased germination time. However, seed presoaking had not improved germination percentage of FARO44 rice compared to unpresoaked seeds. Furthermore, presoaking of FARO44 rice in 3% SiO_2+350mM SA and 3.5% SiO_2+200mM SA stimulated seedling growth by increasing seedling length and root length. However, plumule length was not positively affected compared to control. Similarly, seedling biomass and vigour were increased by 3% SiO_2+350mM SA and 3.5% SiO_2+200mM SA presoaking. Shinwari et al. (2015) reported that two rice varieties pre-soaked in SA under chromium toxicity stress recorded increased shoot and root length as well as increased proline, glycine betaine and soluble protein contents. In agreement with these results, the earlier study of Islam et al. (2012) found that 4 rice varieties primed with $CaCl_2$, NaCl and KCl exhibited enhanced seedling vigour, percent germination and faster growth. Soliman et al. (2016) reported that priming faba beans with lower concentrations of SA (0.5mM) improved seed vigour, seedling vigour index and seedling growth compared to higher concentration of SA. Exogenously applied silicon to lentil increased seedling vigour index, growth, activities of SOD, CAT, APX, alpha-amylase, beta-amylase, contents of soluble sugar, glycine betaine and decreased proline and malondialdehyde content (Biju et al., 2017). The study of Jisha & Puthur (2014) found that hydroprimed and NaCl primed rice varieties under drought and salt stresses showed improved seedling vigour, seedling growth and increased antioxidant enzyme activities and lesser lipid peroxidation. Heydariyan et al. (2014) reported that GA_3, SA and ascorbic acid priming enhanced seedling vigour index and seedling growth of caper under drought conditions. Bell pepper primed with GA_3 exhibited improved seedling vigour index I & II, shoot and root dry biomass (Yogananda et al., 2004).

Conclusion

This study found that 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA presoaking significantly improved germination index and decreased germination time of FARO44 rice. However, combined SiO_2+SA seed presoaking had not improved germination percentage of FARO44 rice compared to unpresoaked seeds. Furthermore, presoaking of FARO44 rice in 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA stimulated seedling growth by increasing seedling length and root length. However, plumule length was not positively affected compared to control. Similarly, seedling biomass and vigour were increased by 3% SiO_2+350 mM SA and 3.5% SiO_2+200 mM SA presoaking. Thus, presoaking of FARO44 rice with combined silicon dioxide and salicylic acid were suggested for increased germination and seedling growth.

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