SEEDLING GROWTH PERFORMANCE AND SALINITY TOLERANCE OF TWO RICE (Oryza sativa L.) VARIETIES UNDER DIFFERENT PRIMING TREATMENTS

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By

FATOUMATA JAMMEH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirements for the Degree of Master of Science

December 2018

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DEDICATION

The work is dedicated to Almighty Allah and my family

Abstract of a thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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December 2018

Chairman : Professor Adam bin Puteh, PhD
Faculty : Agriculture

Salinity is the presence of dissolved salts in soil and it affects vast areas of agricultural land which is a threat to rice production. There is a need to develop new techniques in order to improve rice tolerance to salinity. The study aimed to evaluate the effects of different priming agents on seed germination and early seedling growth and performance under saline environments. The experiment was conducted using a Gambian (IR72402–B-25-3-1-B) and a Malaysian (MR219) rice varieties. In the first experiment, rice seeds were primed with choline and NaCl solutions and sown in sand medium with EC 0, 1, 2, and 3 dS m^{-1} for 14 days. Seed priming has improved the germination percentage and germination index, germination rate and seedling vigor index under saline environments. However, varieties responded differently with different priming concentrations and salinity levels. The IR72402 rice variety recorded 100% germination at the higher salinity level compared with MR219 variety. The 5 mM choline recorded the lowest mean germination time in both rice varieties. In the second experiment, one week old seedlings were primed in choline or NaCl solutions and grown in different concentration of NaCl solution for four weeks in polyethylene bags containing rice soil in the glasshouse. Rice seedlings exposed to salinity at 3 dS m^{-1} is detrimental to seedling growth. Seedling priming using 25 mM NaCl or5 mM choline improved seedling height when grown at 2 dS m^{-1} salinity level for both varieties.Similarly, seedling priming with 25 mM NaCl had higher shoot fresh and dry weights for both rice varieties when grown at 2 dS m^{-1}salinity level.Seedling priming with 5 mM choline improved root traits of seedlings when grown under saline environments.Seedling priming with choline and NaCl increased the total chlorophyll content in both rice varieties with a maximum total chlorophyll content of ±5.82 mg cm^{-2}.Following seedling priming, proline content in both rice varieties increased with increase in salinity level.Priming seedlings increased phosphorus, potassium,and nitrogen content in the shoot of both rice varieties under saline environment. The increase in N, P, and K explained increased seedling performance observed in this

study. Primed seedlings had lower sodium content in the shoot relative to the control. This suggests that primed seedlings are able to reduce sodium uptake. This study indicates that NaCl as well as choline used as priming agents on seeds or seedlings can be a beneficial and practical approach to alleviate salinity problem in rice production.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PRESTASI PERTUMBUHAN DAN TOLERANSI SALINITI OLEH DUA VARIETI PADI (*Oryza sativa* L.) DI BAWAH RAWATAN PRIMING YANG BERBEZA

Oleh

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Saliniti terjadi disetabkan kehadiran garam terlarut di dalam tanah dan ia memberi kesan kepada kawasan pertanian yang luas dan merupakan ancaman kepada pengeluaran padi. Terdapat keperluan untuk membangunkan teknik baru untuk meningkatkan toleransi padi kepada persekitaran yang salin. Kajian ini bertujuan untuk menilai kesan agen priming yang berbeza terhadap percambahan biji benih dan pertumbuhan awal anak benih bawah persekitaran salin.Eksperimen ini dijalankan menggunakan varieti padi IR72402–B-25-3-1-B dari Gambia dan MR219 dari Malaysia. Untuk eksperimen pertama, biji padi direndam dengan larutan choline dan NaCl dan ditanam dalam media pasir dan kemudian disiram dengan larutan mengandungi EC 0, 1, 2, dan 3 dS m-1 NaCl selama 14 hari. Rawatan priming biji benih telah meningkatkan peratusan dan indeks percambahan, kadar dan indeks kesegahan anak benih di bawah persekitaran salin. Walau bagaimanapun, kedua-dua varieti ini menunjukkan respons yang berbeza terhadap kepekatan larutan yang berlainan di kedua-dua keadaan salin. Varieti IR72402 mencatatkan 100% percambahan pada tahap saliniti yang lebih tinggi berbanding varieti MR219. Rawatan 5 mM choline menunjukkan purata kadar percambahan yang rendah bagi kedua-dua varieti. Dalam eksperimen kedua, anak benih berusia satu minggu dirawat menggunakan choline atau larutan NaCl dan ditanam pada kepekatan NaCl yang berbeza selama empat minggu di dalam beg polyethylene yang mengandungi tanah sawah di dalam rumah kaca. Anak benih yang tumtuh pada keadaan 3 dS m^{-1} salin telah merencatkan pertumbuhan anak benih. Anak benih yang dirawat menggunakan 25 mM NaCl atau 5 mM choline telah mempercepatkan pertambahan tinggi apabila ditanam pada 2 dS m^{-1} bagi kedua-dua varieti padi. Rawatan dengan 25 mM NaCl mencatatkan berat basah dan kering yang lebih tinggi bagi kedua-dua varieti pada keadaan 2 dS m^{-1}.Rawatan anak kenihdengan 5 mM choline memperbaiki ciri akar apabila ditanam pada persekitaran salin. Rawatan anak benih dengan choline dan NaCl meningkatkan jumlah klorofil bagi kedua-dua varieti dengan jumlah maksimum

kandungan klorofil pada ±5.82 mg cm^{-2}. Selepas rawatan anak benih, kandungan proline dalam kedua-dua varieti padi meningkat apabila tahap saliniti bertambah. Kandungan phosphorus, potassium, dan nitrogen di pucuk turut meningkat. Peningkatan N, P dan K menjelaskan peningkatan pertumbuhan anak benih yang direkodkan dalam kajian ini. Anak benih yang dirawat mempunyai kandungan sodium yang rendah di pucuk berbanding dengan kawalan. Ini menunjukkan bahawa anak benih yang dirawat mampu mengurangkan pengambilan sodium. Kajian ini menunjukkan bahawa NaCl dan choline yang digunakan sebagai agen priming biji benih atau anak benih adalah berfaedah dan merupakan kaedah praktikal untuk mengurangi masalah saliniti dalam pengeluaran padi.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Cl^-	Chloride Ion
cm	Centimeter
dS m-1	DeciSiemens per centimeter
FGP	Final germination percentage
IR72402	IR72402–B-25-3-1-B
K^+	Potassium ion
mg/plant	milligram per plant
mg/L	milligram per liter
MGT	Mean germination time
mmol	Millimole
MR219	Malaysian rice variety 219
N	Nitrogen
Na^+	Sodium ion
Na^+Cl^-	Sodium and Chloride Ions
NaCl	Sodium Chloride
P	Phosphorus
PEG	polyethylene glycol
µmol/g	micromole per gram

CHAPTER 1

INTRODUCTION

Rice, Oryza sativa, is a staple food consumed by many nations across the globe particularly those living in the tropics and subtropics. Rice is popularly grown in about one hundred and fourteen countries across Africa, Asia, Latin America, North America and Europe. An area of 161.86 million hectares is being cultivated annually with a production of 483.8 million tonnes (Childs & Skorbiansky, 2017). It is the second largest world production after wheat and serves as a source of employment and income and as the primary source of calories for most rural farmers in Asia (Rad et al., 2012).

Among the cereals, rice is the most sensitive to salinity (Rana Munns & Tester, 2008) but the sensitivity varies among varieties (Khan et al., 1997). The level of damage depends on the growth stages, hence most varieties suffer more at germination and seedling stages (Lutts et al., 1995), which denotes an adverse effect of salinity on early plant growth. Therefore, a successful crop establishment depends not only on germination of the seed but also on a uniform and rapid germination under saline condition. Yet, rice is susceptible to salinity stress with a threshold level of 3 dS m^{-1} for most cultivated varieties, which could reduce grain yield by 12% (Fageria, 1985; Radanielson et al., 2018).

Salinity is a worldwide problem. Soil salinity is a term used to describe solvable salts that enclose cations like sodium, potassium, calcium, and magnesium along with anions chloride, sulfate, nitrate bicarbonate and carbonate (Akbarimoghaddam et al., 2011). Salt is a naturally occurring mineral inside soil and water that upsets the growth and strength of plants(Grattan & Grieve, 1999). Salinity can be influenced through numerous causesgoing from human influence to environmental causes. More than 830 million hectares of agricultural land is salt-affected which accounts for 5% of world total land mass, with a yearly increase of two million hectares of uncultivated land owing to excess salt accumulation (Abraha & Yohannes, 2013). Salinity caused reduced water uptake in the sprouting seed as a result of low water potential thus affect seedling emergence and growth. Correspondingly, the toxic effect of Na^+ and Cl^- ion on seedling growth is having an injurious impact on leaf growth, shoot development and dry matter production (Horie et al., 2012).

Many research work has been done on the exposure of plants to moderate stress to improve adaptation to stress conditions of different environment. This is commonly being practiced for young plant produced through tissue culture techniques which are called acclimatization. Pre-treatment of tomato plants at 5 leaf-stage with low NaCl concentration has improved the yield than non-acclimatized plants (Cayuela et al., 2001).

On the other hand, protecting the seeds during early germination stage can be an excellent strategy to ensure seedling emergence. However, seed priming is considered as a method of preparing seed for planting by pre-soaking them in nanoparticle solution. Seeds are said to be an important part of crop life cycle as it influences the propagation of critical stages like germination and dormancy. The beneficial effects of seed priming using several methods of priming on seed quality, seedling performance, and yields have been reported. Seed priming in adverse field conditions is being utilized to enhance the germination of seeds and seedling growth to overcome salinity problem in the agricultural field (Jisha et al., 2013). In particular, seed pre-treatment is a pre-sowing treatment utilized to improve seed performance by increasing the germination rate and seedling establishment (Bradford, 1986). The process involves partial hydration of the seeds in a solution to stimulate germination while preventing radicle protrusion and drying back the seeds to its origin moisture level(Bewley & Nonogaki, 2001).

Furthermore, there is no much information relatedto seed priming influence on rice seedling development under saline condition. Consequently, this necessitates the study to examine how priming influence seed germination and seedling emergence of rice under saline environment. Insufficient literature have been reported for improving the performance of direct-seeded rice(Farooq et al., 2006).

Information on the application of priming on young seedlings of rice before planting is limited. This principle may be similar to acclimatization of young plants derived from micro propagation technique. Its potential in improving the rice seedling to saline environment is not well-known.

This study was conducted to evaluate the effect of priming on germination and young seedling performance in rice under salt stress condition with the following objectives.

1. To examine the effect of choline, sodium chloride ions on rice seed germination and seedling establishment under salt stress.
2. To evaluate the effect of seedling priming on the growth and development of rice seedlings under soil salinity condition.

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