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Comprehensive Effect of Zinc Boron with NPK and Salicylic Acid Foliar Application Treatments on Rice Yield and Grain Quality Under Salty Soil Conditions

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ABSTRACT

High levels of soil salt significantly decrease rice productivity and quality in coastal and Semi-arid areas as Egypt conditions. A field trial was performed at El-Sirw Agriculture Research Station, Damietta Governorate-Egypt, during seasons of 2022 and 2023.This endeavor showcases a practical approach of integrated boron and zinc fertilization along with other chemicals on rice productivity and quality under salt stress. Treatments were comprised in a split plot design with four replications, the main plots consisted of three different rice varieties; Sakha Super300, Giza183 and Giza 179 and the sub plots included six treatments: control, zinc boron, zinc boron plus di ammonium phosphate (DAP), zinc boron plus NPK, zinc boron plus K and zinc boron plus salicylic acid(SA). The result indicated that the two nutrients solitary or combined with other chemicals showed great effect in enhancing physiological traits by reduce hazard effect of free radicals and increase the efficiency of antioxidant system of rice under salt stress. Furthermore, applied of zinc boron alone or along with other inert, particularly salicylic acid significantly improved growth, yields and optimized rice grains qualities under salt stress. To sum up under salt affected soil which, hinder rice productivity, applying of zinc boron mixed with SA could be considered as successful solution for boosting rice production and standard marketing criteria

Keywords: Rice, Zinc, Boron, Salicylic acid, Grain yield

INTRODUCTION

Roughly 20% of land that is suitable for farming and close to half of land that is being artificially watered is experiencing salt stress, affecting around 1.0–1.5 million hectares yearly and this is anticipated to increase (Xu *et al*., 2020). Salt affected soil is considered one of the most common environmental stresses in the world (Dramalis *et al*.,2021). Rice cultivated area globally is profoundly impacted by high levels of salt concentration (Ltaeif *et al*., 2021). Zhang *et al*., (2022) discovered that high levels of soil salt can lower rice yield components like panicle number, filled grains per panicle, 1000-grain weight, and overall yield. Additionally, salt stress can elevate brown rice and milled rice rates, resulting in a notable increase in head milled rice rate for salt-sensitive varieties but a decrease for salt-tolerant ones (Zayed *et al*., 2023). Grain yield was still severely reduced under salinity stress (Li *et al*., 2023). Consumer purchasing habits and the market prices are influenced by the quality and yield of rice (Sangwongchai *et al*., 2021). The main factors affecting the market price of rice are the quality of milling, appearance, cooking and eating, as well as nutrition (Bian *et al*., 2018). Minerals are essential for our health and are important components in food (Razzaq *et al*., 2020). Micronutrient deficiencies, also known as hidden hunger, are widespread in developing nations due to the high consumption of nutrient-poor rice, particularly deficient in zinc (Fitzgerald *et al*., 2009). Deficiency of boron is primarily issue after zinc deficiency globally (Shukla *et al*., 2014). Zinc and boron are two micronutrients that are crucial for agricultural productivity (Bareddy *et al*., 2020). Zinc and boron very important plant micronutrients for plant productivity their value is enormous comparable to the main nutrients (Padbhushan and Kumar, 2014). Zinc application had a notable positive impact on the growth, yield characteristics, and yield of rice, as well as enhancing total chlorophyll, net photosynthetic rate, and grain quality (Suman and Sheeja 2018). Zinc is necessary for the metabolism of carbohydrates, activation of carbonic anhydrase and aldolase, and therefore it controls enzymatic reactions, stability of cellular membranes, oxidation reactions, synthesis of proteins, biosynthesis of chlorophyll, and the regulation of growth, making it a crucial element for the growth of plants (Mousavi *et al*., 2013). Zinc fertilization improved the quality of rice grain (Khan *et al*., 2009). Boron has a principal role in carbohydrates regulation, boron deficiency during the flowering stage can lead to deformities in the pollen tube, hindering fertilization and ultimately resulting in empty seeds due to its impact on cell division, protein metabolism (Pandey and Gupta, 2013). Sukhmeen *et al*., (2023) reported that boron (B) plays a role in controlling the cell wall and plasma membrane structure, ion movement, cell growth and division, reproductive growth, carbohydrate and protein synthesis, phenol and auxin metabolism, nitrogen fixation, disease resistance, and managing abiotic stress. The use of B can decrease the build-up of harmful substances like cadmium and aluminum in plants and ease their toxic effects (Long and Peng 2023). Rahman *et al*., (2021) Assess how external boron (B) helps reduce varying degrees of salt stress by improving the scavenging of reactive oxygen species (ROS), defense mechanisms of antioxidants, and glyoxalase systems. Combining Zn with B boosts Zn levels in plants, promoting flower production and reducing fruit drop (Mousavi *et al*.,

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2007; Safdar., 2023 and Atika et al.,2024). Enrichment in plant uptake and positive influence of Zn and B in several crops due to survival of mutually beneficial interaction between B and Zn has been distinguished by various studies (Kour *et al*., 2017; Shoja *et al.*,2018; Kumar *et al*., 2019; Mehera, 2022 and Khan *et al*., 2024). Optimal levels of potassium, along with other nutrients, are crucial for metabolism, plant growth, and plant resilience to salt stress (Min *et al*.,2013). P deficiency under salt stress is common due to the impact of ionic strength, the sorption capacity of soil particles is high and mineral solubility is low in saline soil, causing reduced plant growth under salt stress. DAP foliar spray can provide plants with necessary phosphorus (Opez-Arredondo *et al*., 2014). SA foliar spray can improve plant tolerance to a biotic stress (Ravin and Sharma., 2022 and Yang and Zhou 2023). K considered as a key element in rice, implementation of K as a foliar spray augment the ability of plants to fulfill their metabolic process in the existence of salinity by using higher K^+ fluxes and lower Na^+ fluxes that result in a higher K/Na selectivity ratio (Min *et al*., 2013 and Amira *et al*., 2019) Exogenous implementation of zinc and boron along with NPK enhanced grain quality of rice (Mohan *et al*. 2017).

The purpose of present study is, amplify rice crop efficiency, increase grain yield and get-well grain quality parameters by zinc and boron fertilization mixed with some chemical.

MATERIALS AND METHODS

Two field trails were implemented throughout the two seasons of 2022 and 2023 at the Research Farm of El-Sirw Agricultural Research Station, Damietta Governorate, Egypt. The design of the experiments was a split plot with four replications. Three rice varieties Viz; Sakha super300, Giza183 and Giza179 were arranged in the main plots meanwhile, the sub plots including six treatments: control, (zinc boron) at the concentration 1l/fed in this treatment and other treatments, zinc and boron plus di ammonium phosphate (DAP) 2%, zinc and boron plus K at the concentration of 2% , zinc and boron plus NPK (20-20-20) 2%, zinc and boron plus salicylic acid (SA 300ppm). Rice seed rate at 160 kg/ha were soaked in the running water for 36 hours and incubated for 36 hours therefore, they were manually broadcasted. The preceding crop was clover (*Trifolium alexandrinum*, L.) in the two seasons. Permanent land was well prepared, thirty days old seedlings were transplanted 20cm row-to-row, 3-4 seedling per hill and 20cm hill to hill apart. The plot included ten rows for each one, five meter in length and two meters in width, (area $10m^2$). The nursery was well preformed fertilizer with recommended rates of nitrogen, phosphorus, potassium and zinc. The other typical farming activities were carried out according to national rice program recommendation package.

Soil samples: Randomly soil samples were collected before preparation of land in depths of 0-15cm from the soil surface. The samples were transferred to soil lab at RRTC, Sakha, Kferelshikh province, Egypt and analyzed according to Piper (1950). Results of chemical and physical properties of the experimental site are listed in Table 1.

Table1. Chemical and physical properties of experimental soil

season	Soil texture	pH	ECe dSm^{-1}	Cation meq l^{-1}			Anion meq l^{-1}		
				$Ca^{++}+Mg^{++}$	Na^+	K^+	SO_4^-	Cl^-	HCO_3^-
2022	clayey	8.21	8.01	37.2	42.6	0.30	30.5	39.1	10.5
2023	clayey	8.22	7.84	36.6	41.5	0.31	29.5	38.7	10.2

Plant samples: At heading stage, plants of five hills were taken randomly from each plot to estimate flag leaf area, total pigment content, according to (Lichtenthaler and Buschmann, 2001). Determination of lipid peroxidation as measured by malondialdehyde (MDA) activity, and H2O2 (MDA) by using the method of (Change *et al.*, 2015). Determination of Antioxidant Enzymes: Colorimetric Method (Zhang., 2004).

Yield and its component: During the harvest period, the plant's height, the length of the panicle, and the number of panicles per hill were calculated. Ten randomly gathered panicles were used to determine the weight, length, filled and unfilled grain count, and 1000-grain weight of each panicle. The grain and straw yields of the six inner rows in each plot were harvested, dried, threshed, and calculated with a moisture content of 14%.

Characteristics of grain quality: Each sample consisted of approximately 150 grams of grain treatment is combined and then transferred to the grain quality lab of the RRTC will evaluate certain aspects of the grain's quality attributes as outlined in the procedures detailed by (Adair., 1952, Juliano., 1971 and Kush *et al.,* 1979)

Statically analysis: The data obtained was analyzed using variance analysis as described by (Gomez and Gomez 1984). Duncan's Multiple Range Test (Duncan, 1955) was used to compare treatment means. Statistical analysis was conducted using the analysis of variance method with the assistance of the "COSTAT" computer software package.

RESULTS AND DISCUSSIONS

1.Physiological characteristics:

Physiological status represented in stomata conductivity, relative water content, lipid oxidase activity, H_2O_2, membrane stability, catalase, peroxidase, super oxide dismutase and total pigment are listed in (Tables 2, 3 and 4). It was noticed that Sakha super300 differentiated higher amount of total pigment in both seasons and relative water in the second season only. Stomata conductance, membrane stability, catalase and peroxidase were increased in Giza179 rice variety than other tested rice varieties. Meanwhile, Giza183 rice variety differentiated by higher level of super oxide dismutase. The impact of salt stress on plant physiology, immune response, and soil parameters such as pH and nutrient levels can be attributed to alterations in the composition and abundance of root exudates. The plan for sustainable development will involve cultivated salt-tolerance plant varieties and prompting cultivated plants to withstand biotic stresses through provisory resistance mechanisms. The three tested rice varieties known as salt tolerance rice varieties so etch one have a good physiological figurine, and effective genetic background (Zayed *et al*., 2023 and Yang and Zhou 2023).

Compared to the control, the tested treatments statically increased the rice physiological traits. However, rice physiological traits were significantly varied with the different treatment application protocols. The maximum amount of total pigments contents, membrane stability, antioxidants levels were recorded under the application of zinc boron+ salicylic acid recorded lowest amount of lipid oxidase and H_2O_2 during alternate years. Zinc boron mixed with different chemicals statically increased relative water content without significant difference among them compared to zinc boron individually. The most affected physiological trait under salt stress affected by salt stress is cell membrane as a result of deterioration in membrane system by peroxidation of lipids leading to higher permeability of the membrane (Kaya *et al*., 2009 and Pokotylo *et al*.,2021). Salinity stress induces reactive oxygen species (ROS) and hydrogen peroxide (H_2O_2) is one of them. At the same time, high level of H_2O_2 (lipid peroxidation) has the potential to induce issues within cells, such as ion leakage and dysfunction within the cellular level, therefore reduce plant growth parameters and rice yield production by oxidative stress (Ravin and Sharma.,2022). Plants have developed both enzymatic and non-enzymatic antioxidant defense systems in order to regulate levels of reactive oxygen species (ROS). From current results the tested treatments successes in maintaining high antioxidant capacity of rice plant and this refers to increase stress tolerance by aiding a plant in defending itself from oxidative damage through quickly removing ROS in its cells and keeping redox balance. Zinc (Zn) and boron (B) have shown promise in reducing the negative impacts of salinity stress on plants. These key micronutrients are crucial for plant functioning. Zinc and boron, play a significant role in regulation nutrients homeostasis in cytoplasm and they can enhance physiological traits of plants (Zewail *et al* 2020, Kirkby., 2023 and Khan and Bibi .,2024). Foliar spray of DAP which content both N (18%) and P (46% P_2O_5) under salt stress might boost up salinity tolerance of rice plants and enhance physiological process Lin et al., (1993). Applied potassium in a combination with zinc boron enhance physiological parameters that might be due to its role as a necessary nutrient that affects most of the physiological and biochemical processes such as, Metabolism, activation of enzymes, elongation of cells, and efficiency in water use are important for maintaining cell turgor and making osmotic adjustments, as well as for combating sodium during periods of salt stress. Plants must increase their K^+ fluxes and decrease their Na^+ fluxes to maintain a higher K/Na ratio this ability is crucial for salt tolerance in rice (Min *et al*.,2013 and Amira *et al*., 2019). Applied SA reduces salt stress by enhancing levels of RWC, photosynthetic pigments, antioxidant activity, ion homeostasis, reducing membrane damage and ROS production, thus preventing oxidative reactions (Ravin and Sharma., 2022 and Yang and Zhou 2023).

Table2. Effect of zinc boron fertilization along with some chemicals on physiological status of rice under salt stress

Factors	Stomata conductivity mol H_2O $m^{-2}s^{-1}$		RWC %		Lipid oxidase (nmolg^{-1}fresh weight)		H_2O_2 (nmol g^{-1}fresh weight)	
	2022	2023	2022	2023	2022	2023	2022	2023
Varieties(V)								
SakhaSuper300	0.57b	0.56b	74.6	79.7a	25.6a	25.8a	18.6a	18.7a
Giza183	0.63a	0.61a	70.1	69.5b	21.1b	22.0b	17.7b	17.9b
Giza179	0.63a	0.62a	69.6	67.1c	20.0c	19.85c	16.9c	17.3c
LSD0.05	0.03	0.01	NS	1.81	0.85	0.98	0.63	0.31
Treatments (T)								
Control	0.58d	0.58cd	63.2c	63.2c	31.1a	29.0a	20.3a	20.9a
Zn+ B	0.63ab	0.61ab	65.3bc	72.1b	25.9b	24.0b	18.7b	18.5b
Zn+ B+DAP	0.61cd	0.58d	75.3a	74.2ab	25.1b	23.6bc	17.8c	18.2b
Zn+ B+NPK	0.61bc	0.59bcd	73.9ab	73.3ab	23.1c	22.5cd	17.0d	17.4c
Zn+ B+K	0.61bc	0.60bc	74.8a	74.2ab	22.5c	21.5d	17.0d	17.0d
Zn+ B+SA	0.639a	0.62a	76.2a	75.5a	15.8d	14.9e	15.7e	15.8e
LSD0.05	0.02	0.01	8.90	2.41	1.15	1.19	0.55	0.40
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

Table3. Effect of zinc boron fertilization along with some chemicals on physiological statue of rice under salt stress

Factors	Membrane stability		Catalase (μmol g^{-1}min protein		Peroxidase (μmol g^{-1}min protein		Super oxide dismutase	
	2022	2023	2022	2023	2022	2023	2022	2023
Varieties(V)								
S. Super300	27.2c	27.6b	12.7b	12.2c	12.9c	13.1c	17.4b	19.17a
Giza183	39.9b	39.6a	17.8a	17.5b	17.2b	17.2b	18.0a	18.80a
Giza179	40.6a	40.5a	19.8a	18.5a	18.4a	19.1a	16.9c	16.90b
LSD0.05	0.649	0.879	2.83	0.322	0.258	0.31	0.293	0.419
Treatments (T)								
Control	32.0c	32.4c	14.2d	14.1d	15.10d	15.2d	16.0d	16.3e
Zn+ B	36.2b	36.3b	16.4bcd	15.6c	15.90c	16.8b	18.3a	17.8d
Zn+ B+DAP	36.0b	35.7b	15.1cd	16.1bc	16.4bc	16.4c	17.5b	18.3cd
Zn+ B+NPK	36.3b	36.3b	17.5abc	16.7b	16.1bc	16.2c	17.3bc	19.0b
Zn+ B+K	36.3b	36.6b	18.1ab	16.4b	16.6ab	16.7b	16.9c	18.6bc
Zn+ B+SA	38.8a	38.6a	19.3a	17.4a	17.00a	17.6a	18.4a	19.70a
LSD0.05	1.2	1.04	2.5	0.66	0.49	0.29	0.34	0.55
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

Table4. Effect of zinc and boron fertilization along with some chemicals on total pigments content, flag leaf area, plant height and panicles number of rice under salt stress

Factors	Total pigments contents (mg/g fw)		Flag leaf area cm		Plant height cm		Panicle number hill^{-1}	
	2022	2023	2022	2023	2022	2023	2022	2023
				Varieties(V)				
S. Super300	5.48a	5.35a	35.6a	38.4a	119.1a	119.7a	12.2b	12.4b
Giza183	4.67c	4.51c	23.3c	23.2b	93.3b	93.3b	14.3a	15.6a
Giza179	4.83b	4.87b	24.9b	25.6b	93.0b	93.3b	14.1a	15.0a
LSD0.05	0.143	0.061	0.849	3.38	1.48	1.20	0.730	0.86
				Treatments (T)				
Control	4.44c	4.37d	23.6c	22.2d	97.5c	98.81c	12.0d	12.0c
Zn+ B	4.97b	4.88c	27.8b	27.4c	103.0ab	102.6ab	13.7bc	13.4b
Zn+ B+DAP	4.98b	4.95bc	29.3ab	28.6bc	103.8a	103.3a	13.6bc	13.6b
Zn+ B+NPK	5.06b	5.00abc	32.6a	30.0a	102.3b	103.1ab	13.4c	13.7b
Zn+ B+K	5.24a	5.09ab	30.4ab	29.3ab	101.8b	102.4b	14.9ab	13.9ab
Zn+ B+SA	5.27a	5.16a	30.9ab	30.2a	102.6ab	102.5b	14.2a	14.4a
LSD0.05	0.131	0.163	3.59	1.18	1.26	0.798	0.431	0.55
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

2. Growth traits

Data presented in Table4 showed that flag leaf area, plant height (cm) and panicle number per hill differed among the three tested rice varieties. Sakha super 300 recorded a larger flag leaf area and the tallest plant. Meanwhile, Giza183 was better in panicle number without considerable difference with Giza179 during the two years of study. The resilience rice variety had effective genetic background and optimum structure which enable it to do high photosynthesis rate and better growth traits (Zayed *et al*., 2023). Flag leaf area, plant height and panicle number were greatly impacted by utilizing various mixtures of Zn and B in addition to certain chemicals, the entire treatment improve the growth traits over control treatment. Flag leaf area was increased by application of the combination of Zn B along with NPK, K and SA without significant difference among them. Furthermore, application of the combination Zn B alone or along with DAP increased plant height over other treatments. Regarding to the better treatment for number of panicles it was the treatment of Zn B plus SA or the treatments of Zn B+ K. It was noticed that zinc boron plus salicylic acid was oblige in distinguish growth characteristics. Salinity impacts the growth of rice, consequently impacting rice production (Genyou *et al*., 2018). The number of panicles is seen as the primary factor influencing the rice yield (Zhang *et al*., 2022). Productivity of rice depends upon the adequate and balance amount of all essential nutrients including the micronutrients like boron and zinc. Boron and zinc are crucial micronutrients for plants, and their significance for crop yield is comparable to that of primary nutrients (Padbhushan and Kumar 2014). Applying boron accelerates photosynthesis and chlorophyll levels, resulting in enhanced plant growth and productivity (Rehman *et al*., 2022). Improved plant height in rice is due to the active participation of boron in promoting the growth of continuously balanced meristems and providing adequate nutrients in the early stages, leading to vigorous plant growth and a potential increase (Bareddy *et al*., 2020). Zinc is necessary for plant growth, as it activates carbonic anhydrase and aldolase to control enzymatic reactions. It is crucial for carbohydrate metabolism, cellular membrane stability, oxidation reactions, protein synthesis, and chlorophyll biosynthesis. Adequate zinc availability is vital for the growth of developing and young plants, especially in stressful conditions (Mousavi *et al*., 2013) Boron and zinc application enhanced growth might be caused by increased rate of cellular division, photosynthesis and metabolisms, these elements are implicated in growth hormones activation, enzymes of photosynthetic, translocation and metabolism of sugars (Tanaka and Fujiwar, 2008 and Mehera,2022). Frequent studies noted that regular application of private B and Zn has enhanced the growth and yield of various crops such as sunflower, maize, cotton, and rice. About the role of potassium in plant growth Min *et al*., (2013) stated that ensuring a balanced K nutrition along with other nutrients is crucial for plant metabolism, growth, and resilience to salt stress. As for DAP in the mixture, it is satisfactory to mention here that, The availability of P is decreased when exposed to salt stress because of the impact of ionic strength, as well as the soil's strong ability to retain P and the limited solubility of minerals in salty soil (O pez-Arredondo *et al*., 2014). DAP content of phosphorus which considered an important element in compounds involved in photosynthesis and respiration (ATP, NADPH, and sugar phosphates) as well as other functions, it also serves a key function in nitrogen compound metabolism, signal transduction, carbohydrate transportation, and carbohydrate and lipid metabolism (N the second component of DAP) all of this reflect on enhancing plant growth (Dey, *et al.,* 2021). The combination of zinc boron and salicylic acid participating in mounting growth parameter may be due to role of zinc boron in plant beside role of SA in regulating physiological processes and the underlying physiological mechanisms (Yang and Zhou 2023)

Yield and yield attributes

Yield and yield attributes and their interaction are listed in Tables5,6,7,8 and 9. It was noticed that Giza179 exceed other rice varieties in panicle length, panicle weight, number of filled grains as well as grain yield and harvest index. Sakha super300 surpassed others in1000-grain weight and biological yield. Meanwhile, Giza183 did not materialize any significant difference with Giza179 in filled grains per panicles and1000-grain weight, alongside occupied the second rank in grain yield production during study seasons. Salinity stress greatly impacts the rice yield characteristics, including seed setting rate, tillers number, panicles number and panicle length. (Shereenetal., 2005 and Zayed *et al*., 2023). All of treatment protocols enhanced yield and yield attributes over control treatment. The topmost principles of panicle length, panicle weight, filled grains per panicle, 1000-

grain weight as well as, grain yield were received preferentiality by the combination of Zn B+SA.

In croplands with high soil pH, the most common micronutrient deficiencies are B and Zn, which result in decreased crop yield (Rehman *et al*., 2018 and Rehman *et al*., 2022). Implementation of boron improved yield and its attributes might be due to B contributes to reproductive growth by enhancing panicle fertility in rice (Rehman *et al.* 2014). Liew *et al.* (2012) proclaimed that B inadequacy, especially at the panicle arrangement organize, would incredibly lessen the development of panicles and assume imperative parts in photosynthesis and breath, starch digestion and transport of sugar in rice. Anand *et al.,(*2020) discovered that applying boron to leaves can enhance plant growth and seed production. Boron is important for protein formation, nitrogen metabolism, cell division, cell membrane integrity, cell wall formation, nucleic acids, and antioxidative systems. The right amount of boron and zinc helped plants improve growth and yield characteristics (Hall, 2008). The presence of a synergistic relationship between B and Zn results in enhanced plant uptake and beneficial effects in various crops (Shoja *et al*., 2018 ; Kumar *et al*., 2019 and Mehera 2022). Furthermore, the reduction in growth and seed production without Zn and B occurred because of a decrease in enzymatic reactions, cell division, and elongation (Hall, 2008 and Silva *et al*., 2011). Several research studies have demonstrated that applying B and Zn individually can enhance the growth and yield of various crops such as sunflower, maize, cotton, and rice (Rehman *et al*., 2019; Rehman *et al*., 2022 and Safdar *et al*., 2023). The superiority of Zn+ B+SA treatment for increasing studied traits may be due to SA foliar spray can improve plant tolerance to a biotic stress. From the beginning of seed germination to full maturity, SA receptor protein plays a crucial role in various physiological processes like plant growth, development, ripening, and defense responses. Additionally, zinc boron also contributes to enhancing the growth and yield of rice plants (Hall, 2008, Rivas-San and Plasencia, 2011, Verma and Agrawal 2017 and Pokotylo *et al*., 2021).

Table5. Effect of zinc and boron fertilization along with some chemicals on some yield attributes of rice under salt stress

Factors	Panicle length cm		Panicle weight gm.		filled grains panicle^{-1}		Unfilled grains panicle^{-1}	
	2022	2023	2022	2023	2022	2023	2022	2023
Varieties(V)								
Sakha Super300	19.0b	18.9b	2.98a	3.00a	109.8b	112.9b	26.9a	30.3a
Giza183	18.9b	18.9b	2.60b	2.59c	118.6ab	120.6ab	11.4b	12.9b
Giza179	20.16a	18.9a	2.98a	3.01a	127.2a	130.0a	10.5b	12.2b
LSD0.05	0.49	0.21	0.10	0.08	12.8	12.4	6.29	5.03
Treatments (T)								
Control	18.2d	18.1d	2.42d	2.37c	98.9d	100.4d	27.0a	30.5a
Zn+ B	19.3bc	19.1c	2.97ab	2.88b	115.7c	118.6c	15.3c	16.8c
Zn+ B+DAP	19.8ab	19.7a	2.86bc	2.92b	116.5c	119.0c	22.3b	24.5b
Zn+ B+NPK	19.6ab	19.5abc	2.94ab	2.91b	121.9b	126.5b	11.5d	13.6d
Zn+ B+K	19.2c	19.2bc	2.75c	2.83b	122.9b	125.8b	10.7d	13.0d
Zn+ B+SA	20.1a	19.5ab	3.09a	3.07a	135.3a	136.7a	10.5d	11.9d
LSD0.05	0.59	0.44	0.16	0.11	4.90	5.28	3.31	3.12
Interaction	NS	NS	NS	NS	**	**	NS	NS

Table6. Effect of the interaction between zinc and boron fertilization and rice varieties on filled grains/panicle

Factors	2022			2023		
	Sakha Super300	Giza183	Giza179	Sakha Super300	Giza183	Giza179
Control	96.8j	98.8ij	101.1hij	98.03g	100.2fg	102.9efg
Zn+ B	107.5g-j	122.2def	117.6efg	111.8def	123.5cd	120.6cd
Zn+ B+DAP	110.0f-i	108.8f-j	130.6bcd	112.8def	111.4def	132.9bc
Zn+ B+NPK	110.5f-i	127.7cde	127.6cde	115.4de	131.7bc	132.5bc
Zn+ B+K	112.9fgh	115.5efg	140.2ab	115.3de	118.5d	143.7ab
Zn+ B+SA	120.9d-g	138.8abc	146.1a	124.3cd	138.3ab	147.4a
LSD0.05		8.50			9.14	

Table7. Effect of zinc and boron fertilization along with some chemicals on1000-grain weight, yields per hectare and harvest index

Factors	1000-grain weight (g)		Grain yield (t ha^{-1})		Biological yield(t ha^{-1})		Harvest index %	
	2022	2023	2022	2023	2022	2023	2022	2023
Varieties(V)								
Sakha Super300	26.4a	26.9a	5.86c	5.66c	18.6a	18.2a	30.9c	31.7c
Giza183	23.3b	22.9b	6.55b	6.48b	16.6b	16.1b	38.8b	40.0b
Giza179	23.3b	23.1b	6.94a	6.85a	17.06b	16.4b	40.1a	41.6a
LSD0.05	0.893	0.416	0.117	0.279	0.60	16.4	0.85	1.34
Treatments (T)								
Control	23.3c	22.5d	5.67e	5.65e	15.2e	15.2c	36.6bc	37.1cd
Zn+ B	24.5ab	24.2c	6.26d	6.17d	17.2d	16.9b	36.05cd	36.5d
Zn+ B+DAP	24.1b	24.4bc	6.53c	6.34c	17.5cd	17.2ab	36.8bc	36.9cd
Zn+ B+NPK	24.3ab	24.8ab	6.60c	6.44c	18.4a	17.3ab	35.3d	37.7bc
Zn+ B+K	24.8a	25a	6.74b	6.59b	17.8bc	17.3ab	37.3ab	38.4ab
Zn+ B+SA	24.5ab	25a	6.93a	6.81a	18.1ab	17.5a	37.8a	38.9a
LSD0.05	0.61	0.45	0.11	0.12	0.41	0.36	0.92	1.08
Interaction	NS	NS	**	**	NS	NS	NS	NS

Table8. Effect of the interaction between zinc boron fertilization and rice varieties on grain yield t ha^{-1}

Factors	2022			2023		
	Sakha Super300	Giza183	Giza179	Sakha Super300	Giza183	Giza179
Control	5.13h	5.87fg	6.82f	4.90i	5.90efg	6.16de
Zn+ B	5.68g	6.48cd	6.63c	5.47h	6.27cd	6.74b
Zn+ B+DAP	6.00f	6.47cd	7.13b	5.72g	6.41c	6.89b
Zn+ B+NPK	5.86fg	6.75c	7.08b	5.82fg	6.48c	6.89b
Zn+ B+K	6.13ef	6.74c	7.35a	6.03def	6.77b	6.99b
Zn+ B+SA	6.13ef	7.06b	7.40a	6.04def	7.03b	7.36a
LSD0.05		0.249			0.230	

The interaction effect was significant for filled grains and yield of rice in both seasons Tables6 and8. Giza179 variety and the mixture of zinc boron with salicylic acid yielded the greatest number of filled grains and grain yield production. It was noticed also this combination is reasonable for Giza183 and Sakha super300 to introduce higher number of filled grains and yield. Salt stress could reduce number of filled grains and grain yield, The impact of salinity stress on rice yield traits like panicle number, and panicle length may be attributed to the decrease in seed setting rate, which is the primary factor behind yield reduction in saline conditions (Shereen *et al*.,2005 and Zhang et .,2022). From our result zinc boron application plus salicylic acid succeeds in overcome salt stress by enhancing physiological traits and consequently growth traits which reflects on grain yield and its attributes (Safdar *et al*., 2023).

Rice grain quality:

The quality of rice is crucial for the well-being of individuals who consume it as their main food source (Ali *et al*., 2020). The physical appearance of rice plays a crucial role in its appeal to consumers, with chalkiness being the primary factor influencing appearance quality (Ayaad *et al*., 2021). Good rice grain quality is characterized by transparent grains with minimal chalkiness, medium gel consistency, and medium amylose content (Rao *et al*., 2013). The amount of amylose in rice is crucial for determining its quality. Rice varieties with high amylose content will expanded in volume when cooked, resulting in a less soft and more firm texture after cooling. Rice varieties with low amylose content and good taste become moist and sticky when cooked (Juliano, 1971).

Data in Tables 9 and 10 indicated that Sakha super300 surpassed other tested rice varieties in Hulling%, milling% and head rice%, elongation during alternative seasons and gelatinization temperature in the first season only. Sakha super300 also produced highest values of chalkiness % in both seasons. Both of Giza179 and Giza183 ranked the second order after Sakha super300 in hulling% and chalkiness % without significant different between each other, Giza183 occupied the second order in milling and head rice%. Regarding to amylose content the result didn't show any significant difference among the tested rice cultivars in amylose content.

Table9. Effect of zinc and boron fertilization along with some chemicals on some grain quality traits

Factors	Hulling%		Milling %		Head rice %	
	2022	2023	2022	2023	2022	2023
			Varieties(V)			
Sakha Super300	86.5a	86.4a	72.9a	72.9a	66.4a	66.6a
Giza183	82.7b	82.8b	71.4b	71.3b	60.8b	61.1b
Giza179	82.0b	82.2b	68.1c	67.9c	58.7c	58.5c
LSD0.05	0.623	0.567	0.401	0.145	0.719	0.227
			Treatments (T)			
Control	82.6b	82.6b	69.2c	68.9b	56.8d	57.04d
Zn+ B	84.0a	83.9a	70.7b	70.9a	61.5c	61.3c
Zn+ B+DAP	83.8a	83.9a	71.2a	71.0a	62.9b	62.8b
Zn+ B+NPK	83.9a	84.2a	71.3a	71.2a	63.2ab	63.6a
Zn+ B+K	84.0a	84.1a	71.1a	71.0a	63.8a	63.9a
Zn+ B+SA	84.0a	84.1a	71.2a	71.1a	63.5a	63.7a
LSD0.05	0.610	0.458	0.284	0.433	0.602	0.464
Interaction	NS	NS	NS	NS	NS	NS

Table 10. Effect of zinc and boron fertilization along with some chemicals on some grain quality traits

Factors	Gelatinization temperature		Elongation%		Amylose%		Chalkiness%	
	2022	2023	2022	2023	2022	2023	2022	2023
				Varieties(V)				
Sakha Super300	5.61a	5.5	51.1a	51.1a	18.4	18.4	18.3a	18.9a
Giza183	5.27ab	5.38	34.7b	34.15b	18.6	18.4	15.84b	16.6b
Giza179	5.11b	5.27	30.4c	30.85c	18.6	18.5	15.7b	16.8b
LSD0.05	0.377	NS	1.102	1.088	NS	NS	0.669	0.385
				Treatments (T)				
Control	4.55b	5. 00b	34.15d	34.65c	18.8	18.7	19.5a	20.1a
Zn+ B	5.44a	5.44a	39.2bc	38.95b	18.2	18.2	16.6b	17.5b
Zn+ B+DAP	5.55a	5.44a	39.3bc	39.35b	18.4	18.3	16.6b	17.7b
Zn+ B+NPK	5.33a	5.44a	38.45c	38.85b	18.5	18.3	16.2b	16.8c
Zn+ B+K	5.66a	5.34a	40.95a	40.65a	18.5	18.4	14.8c	16.4c
Zn+ B+SA	5.44a	5.66a	40.2ab	40.52a	18.5	18.2	16.1b	16.3c
LSD0.05	0.46	0.32	1.31	1.04	NS	NS	0.54	0.50
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

The tested treatments had positive impact on hulling, milling and head rice percentages, Gelatinization temperature, elongation% and chalkiness% and had no significant impact on amylose content in both seasons. The control treatment had the lowest recorded values of hulling%, milling%, head rice%, gelatinization temperature and elongation in the first and second seasons also recorded the greatest principles of chalkiness% in both seasons. The entirely treatment which included zinc boron fertilization individually or along with chemicals increased hulling, milling, and head rice percentages, gelatinization temperature and elongation during alternative years meanwhile, reduced chalkiness% in both seasons.

Several research studies have indicated that salinity stress can reduce the nutritional quality of rice (Yajuan *et al*., 2019, Rao *et al*., 2013). Saline stress was found to enhance the absorption of Na, K, and Mg in rice grains, Whereas K and Mg levels show insignificant increases, while Ca, Fe, Mn, Zn, and boron uptake decreased. (Sangwongchai *et al*., 2021., Zhang.,2022). High chalkiness in rice grains leads to easy breakage during milling, resulting in decreased market value, whereas transparent grains with minimal chalkiness are preferable qualities for high rice quality (Sawada *et al*., 2016). The results described that the chalkiness rate increased under the salinity stress and decreased by various regimes of combination Zn B with NPK and SA exogenous application could possibly due to role of zinc boron and other chemicals in improving grain filling and increasing filled starch cells and endosperm size reaching to complete grain filling and reducing bracts size. Furthermore, the improvement in seed quality factors was attributed to the enhanced movement and utilization of boron as a transporter for phosphate nutrients, especially into the seed. It also serves as a catalyst for enzymes such as trans-phosphorylase, dehydrogenase, and carboxylase. Additionally, the increased storage of metabolites during seed development and enhanced DNA repair mechanism due to heightened enzyme activity contribute to the increased vigor of the seed. The improvement of grain quality with zinc boron may result from decreased panicle sterility and reduced pollen abortion. Improvement in seed weight might be a result of boron involvement in the fertilization, flowering, and seed-setting stages of plants, which could be linked to its contribution to producing more reproductive structures and preventing abortive pollens (Ganapathy *et al*., 2008 ;Ousavi *et al* 2013 and Ali *et al.*, 2016)). Treating plant with boron enhanced seed set by delaying abscission of flowers (Smit and Combrink, 2004). Treating crops with B Zn can not only boost crop yields, but also improve the quality of grains as a helpful strategy (Ngozi., 2013 and Rahman *et al*., 2019). Applying of zinc boron with NPK and SA enhancing cooking traits and reduce chalkiness percentage. Spray zinc boron at late growth stage might be increased starch translocation from stored organs to grain as well as, increase current photosynthesis resulted in improving grain filling feature and giving high hulling, milling and head rice% (Khan *et al.* 2024). Salinity caused abnormal accumulation of macro and micro elements. Foliar fertilization methods, particularly for micronutrients have the potential to increase nutrient utilization efficiency and mitigate the adverse effects of salinity. NPK and SA foliar spray with zinc boron distinguish grain quality by enhanced grain filling, effective starch formation and sugar translocation are crucial for carbohydrate-rich rice, playing a key role in minimizing chalkiness in rice grains during periods of stress (Zayed et al.,2011, Nessreen, 2019 and Amira et al.,2019).

CONCLUSION

Foliar application of zinc and boron mixing with NPK plus SA is effective in improving rice performance by mitigating salinity enhancing physiological attributes, growth, yield, and grain quality of rice.

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التأثير المتكامل للرش بالزنك بورون مع النيتروجين والفسفور والبوتاسيوم وحمض السالسليك على محصول الأرز وجودة الحبوب تحت ظروف الأراضي الملحية

اميره عكاشه ، محمد عبد الحميد ، سماح عامر وعبدالفتاح جابر

قسم بحوث الارز –معهد بحوث المحاصيل الحقليه – مركز البحوث الزراعيه

الملخص

أقيمت التجارب بمحطة بحوث السرو الزراعية بمحافظة دمياط خلال موسمي الزراعه2022 و2023 وكان الهدف من هذا العمل ، هو الدراسة المتكاملة للتسميد بالزنك بورون سواء كان منفردا أو مع بعض الكيماويات. كان التصميم المستخدم في التجربة هو القطاعات المنشقة مرة واحدة في أربعة مكررات حيث احتوت القطع الرئيسيه على الأصناف وهم سخا سوبر300 جيزه183 وجيزه179 واحتوت القطع الشقية على المعاملات وهى معامله المقارنة، الزنك بورون ،الزنك بورون مع داي أمونيوم فوسفات(DAP) ،الزنك بورون مع NPK والزنك بورون مع حمض السالسليك. وأثبت التجارب أن الزنك بورون سواء أكان منفردا او مع الكيماويات الأخرى كان ذو فاعلية في زيادة الصفات المدروسة بالمقارنة بمعامله الكنترول. كان التفوق واضح للمعاملة الزنك بورون مع حمض السلسيلك فى زيادة الصفات الفسيولوجية وأيضًا المحصول ومكوناته بالإضافة الى صفات الجودة في كلا موسمي الدراسة ويمكن القول أن الرش بالزنك بورون حل أمثل للحصول على أعلى محصول وأيضا لأفضل صفات تسويق لأصناف الأرز المنزرعة تحت ظروف الأراضي الملحية.