ROLE OF MODIFIED CHITOSAN ON RICE (BRRI dhan29) CULTIVATION IN SALINE SOIL

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ROLE OF MODIFIED CHITOSAN ON RICE (BRRI dhan29) CULTIVATION IN SALINE SOIL

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CERTIFICATE

This is to certify that the thesis entitled "**Role of modified chitosan on rice (BRRI dhan29) cultivation in saline soil"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in Soil Science, embodies the result of a piece of *bonafide* research work carried out by **Samiha Marzan Shithy,** Registration number: **15-06916** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

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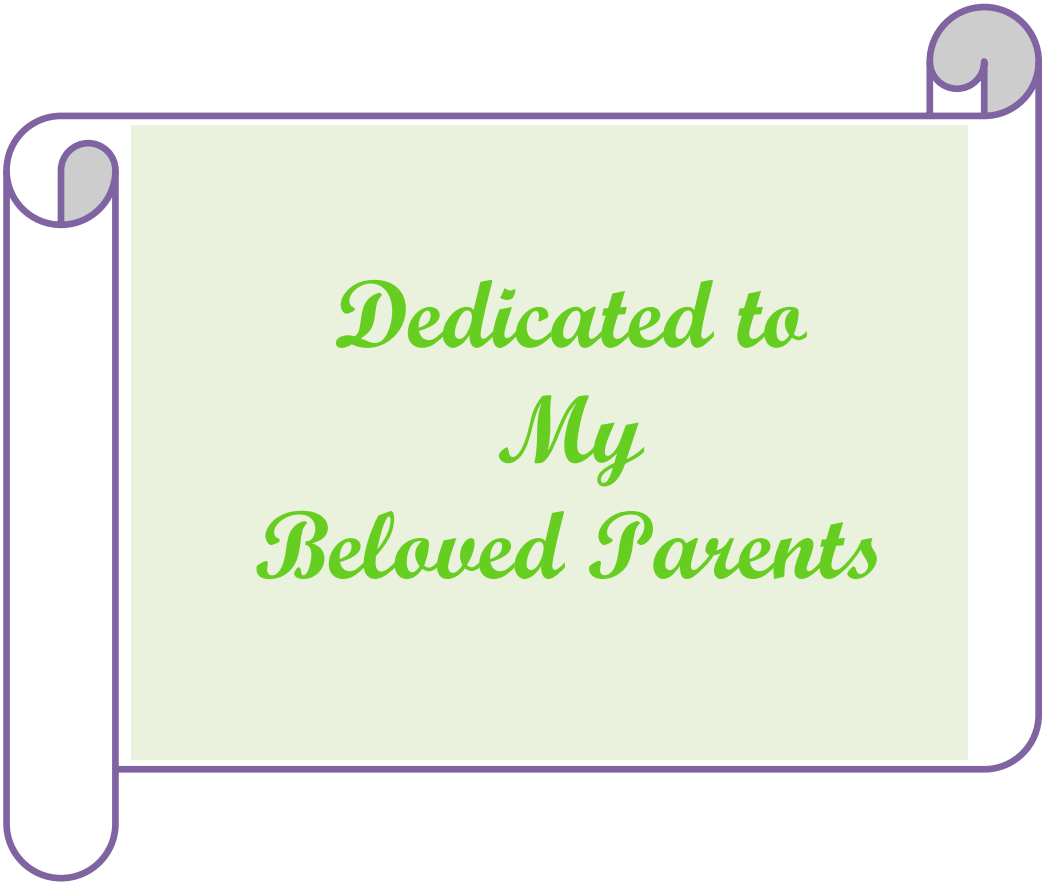
Dedicated to
My
Beloved Parents

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ABSTRACT

A pot experiment was conducted in the net house of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from December 2015 to April 2016 to study the role of modified chitosan on rice (BRRI dhan29) cultivation in saline soil. BRRI dhan29 was used as the test crop in this experiment. The experiment consists of 2 factors i.e. salinity and modified chitosan. Different doses of modified chitosan (C_0-0 g modified chitosan/pot, C_1-20 g modified chitosan/pot and C_2-40 g modified chitosan/pot). Different levels of salinity were (S_0- normal soil, S_1- 4dSm^{-1}, S_2- 8dsm^{-1}and S_3- 12dsm^{-1}). The experiments was laid out in randomized complete block design (RCBD) with 3 replications. There were 12 treatment combinations. Results revealed that salinity had significant effect on the yield and yield parameters. The highest value of effective tillers/hill, plant height, panicle length, number of filled grain/panicle, 1000 grain weight, grain yield and straw yield were observed when the level of salinity was S_0 (normal soil) and the lowest value was observed when the level of salinity was S_3 (12 dsm^{-1}). The Yield contributing characters and yields were significantly affected by application of modified chitosan. The highest effective tillers/hill (23.91), plant height (60.24 cm), panicle length (19.37cm), 1000 grain wt. (14.83g), grain yield (38.08g) and straw yield (47.08g) were found from C_1(20 g modified chitosan/pot). On the other hand in most cases lowest values were obtained from C_2 (40 g modified chitosan/pot). The highest values of effective tillers/hill (49.00), plant height (78.687), panicle length (27.87), 1000 seed wt.(21.33), and grain yield (85.00), recorded from (S_0C_1- normal soil + 20 g modified chitosan/pot). The lowest values were observed from (S_3C_2-12dsm^{-1} + 40 g modified chitosan/pot). Our results concluded that application of modified chitosan (20 g modified chitosan/pot) could play significant role to increase the grain yield of rice and could improve the salt tolerance in rice.

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INTRODUCTION

Rice (*Oryza sativa)* is the second most widely grown cereal and primary source of food for more than half of the world population. About 90% of the world rice is grown in Asia which is carrying about 60% of the world population (Iqbal *et al*.,2007). Salinity is a major factor reducing plant growth & productivity throughout the world. Approximately 10% of the world's 7×10^9 ha arable land surface consist of saline or sodic soils. The percentage of cultivated land affected by salts is even greater of the 1.5×10^9 ha. Cultivated lands, 23% are considered saline & another 37% are sodic & it has been estimated that one-half of the all irrigated land 2.5×10^8 ha are seriously affected by salinity & water logging (Francois & Maas, 1999). Salinity problem is more serious in the agriculture of south & southeast Asia, which accounts for more than 90% of world rice production (Aslam *et al*., 1993). In Bangladesh, the adverse effect of salinity is significant in the southwest coastal agriculture. Most of the rice land kept fellow except Aman season due to the extreme presence of salinity of the southwest coastal region. Southwest coastal regions contribute approximately 16%of the total rice production of Bangladesh & in recent year's production of crop yield by gradual change & total or partial damage due to extreme salinity (BBS, 2005). Accumulation of salt whether in soil or water adversely affects various physiological & biochemical processes, for example, reduction in photosynthesis under saline conditions in Safflower (Siddiqi *et al*.,2009) and sunflower (Noreen, 2008). Accumulation of salts in the growth medium induces the formation of toxic reactive oxygen species (ROS) including singlet oxygen and superoxide and hydroxyl radical. These reactive oxygen species injured chloroplasts and mitochondria by damaging their cellular structure (Mittler, 2002). To overcome these reactive oxygen species, plants generate antioxidant enzyme (Gill, 2010).

It was also suggested that salt tolerance could be promoted by increasing antioxidant defense system in plants.

Chitosan is a linear polysaccharide composed of randomly distributed β-(1-4)-linked D-glucosamine (deacetylated unit) and N-acetyl-D-glucosamine (acetylated unit). It is made by treating the chitin shells of shrimp and other crustaceans with an alkaline substance, like sodium hydroxide.

Chitosan is a natural biopolymer modified from chitin, which is the main structural component of squid pens, cell walls of some fungi and shrimp and crab shells. Chitin and chitosan are copolymers found together in nature. They are inherent to have specific properties of being environmentally friendly and easily degradable. Therefore, there are abundant raw materials for chitosan production. Chitosan has a wide scope of application. With high affinity and non-toxicity, it does no harm human beings and livestock. Chitosan regulates the immune system of plants and induces the excretion of resistant enzymes. Moreover, chitosan not only activates the cells, but also improves its disease and insect resistant ability. Chitosan has strong effects on agriculture such as acting as the carbon source for microbes in the soil, accelerating of transformation the process of organic matter into inorganic matter and assisting the root system of plants to absorb more nutrient from the soil. Chitosan is absorbed to the root after being decomposed by bacteria in the soil. Application of chitosan in agriculture, even without chemical fertilizer, can increase the microbial population by large numbers, and transforms organic nutrient into inorganic nutrient, which is easily absorbed by the plant roots.

Biopolymer “Chitosan” has received much interest for potential wide application in agriculture due to its excellent biocompatibility, biodegradability and bioactivity. This naturally occurring molecule with interesting physiological potential has been getting more attention in recent years. Chitosan enhanced the efficacy of plants to reduce the deleterious effect of unfavorable conditions as well as on plant growth. Chitosan affects various physiological responses like plant immunity, defense mechanisms involving various enzymes such as, phenylalanine ammonium lyase, polyphenol oxidase, tyrosine ammonia lyase & antioxidant enzyme viz., activities superoxide dismutase, catalase & peroxide against adverse condition. Recent studies have shown that chitosan induces mechanisms in plants against various biotic (fungi, bacteria, & insects) & abiotic (salinity, drought, heavy metal & cold) stresses & helps in formation of barriers that enhances plant’s productivity (Deepmalakatiyar *et al*., 2015).

Chitosan active biopesticides represent a new tier of cost-effective biological control of crops for agriculture. The biocontrol mode of action of chitosan elicits natural innate defense responses within plant to resist insects, pathogens, and soil-borne diseases when applied to foliage or the soil. Chitosan increases photosynthesis, promotes and enhances plant growth, stimulates nutrient uptake, increases germination and sprouting. Chitosan destroys parasitic cyst nematodes without harming beneficial nematodes and organisms.

Agricultural applications of chitosan can reduce environmental stress due to drought. Chitosan is typically used as a natural seed treatment and plant growth enhancer, and as an ecologically friendly bio pesticide substance that boosts the innate ability of plants to defend themselves against fungal infections.

Objective of research work:

1. To investigate the effect of modified chitosan on the improvement of saline tolerance of rice.
2. To examine yield performance of rice (BRRI dhan29) under salt stress using modified chitosan.

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REVIEW OF LITERATURE

Plant growth regulators are the substances that standardize the growth in an incredible form. Chitosan is a natural biopolymer which stimulates growth and increases yield whose functions are very nearer to Gibbrelic acid (GA_3). Chitosan enhanced the efficacy of plants to reduce the deleterious effect of unfavorable condition as well as on plant growth. Chitosan affects various physiological responses like plant immunity, defense mechanisms involving various enzyme such as, phenylalanine ammonium lyase, polyphenol oxidase, tyrosine ammonia lyase, and antioxidant enzymes viz., activities superoxide dismutase, catalase and peroxide against adverse conditions. On the other hand, Salinity is a major factor reducing plant growth & productivity throughout the world. In Bangladesh, the adverse effect of salinity is significant in the southwest coastal agriculture. Extensive studies of the regulatory effects of Chitosan and salinity on various crops have been carried out worldwide by different workers. Some or the related reports are reviewed below.

2.1 EFFECTS OF CHITOSAN

Germination Percentage

(Batool Mahdavi, Asghar Rahimi 2013) reported that chitosan would be able to stimulate germination and growth of ajowan. It is also resulted that soaking ajowan seeds with chitosan, may alleviate the inhibitory effect of salt stress on the plant growth.

(Ruan songlin 2002) found that chitosan coting (hybrid rice seed) significantly improved germination percentage AND activities of β –amylase under normal or salt stress conditions, and decreased activities of α-amylase under salt stress conditions as compared with control (non-coating treatment). They also suggested that chitosan coating was able to improve the salt tolerance of seed lings in hybrid rice.

Plant Height

Supachitra *et al*. (2011) conducted an experiment to determine the plant growth stimulating effects of Chitosan on Thai indica rice (*Oryza sativa* L.) cv. Leung Pra Tew 123. Rice seedlings were treated with oligomeric Chitosan with 80% degree of deacetylation at the concentration of 40 mg L^{-1} by seed soaking overnight before sowing, followed by spraying on 2-week and 4-week old seedlings, respectively. The oligomeric Chitosan stimulated plant height.

Boonlertnirun *et al*. (2008) revealed that application of Chitosan on rice plants did not influence the plant height significantly. Sultana (2007) applied Miyobi on rice and reported that plant height increased in Miyobi applied plant than control.

Chinese cabbage seeds incorporated with chitosan followed by foliar spraying reacted with increased plant height and leaf area of chinese cabbage plants.This is in accord with work of (Khan *et al*. 2002) who found that foliar application of oligomeric chitosan did not affect soybean height. The same result in rice, applied with oligomeric chitosan in combination with chemical fertilizer was also reported (Boonlertnirun *et al.,* 2006).

A positive effect of Chitosan was observed on the growth of roots, shoots and leaves of several crop plants (Chibu and Shibayama, 2001). Chitosan under low temperature increased shoot height and root length in maize plants compared to that of the control (Guan *et al.*, 2009).

Number of tillers hill^{-1}

The application of polymeric chitosan by seed soaking before planting followed by four foliar spraying throughout cropping season significantly increased the number of tillers per plant (Boonlertnirun *et al.*, 2006).

Hoque (2002) carried out an experiment on seed germination and seedling growth by seed soaking of different wheat cultivars with 0.16 mlL^{-1}, 0.33 mlL^{-1}and 0.66 mlL^{-1} of CI-IAA, GABA and TNZ-303. The number of tiller enhanced significantly at 0.33 mlL^{-1} of PGR compared to that of control.

Number of leaves hill^{-1}

Plant growth stimulating effects of Chitosan was tested on Thai indica rice (*Oryza sativa* L.) cv. Leung PraTew 123. Rice seedlings were treated with oligomeric Chitosan with 80% degree of deacetylation at the concentration of 40 mg L^{-1}by seed soaking overnight before sowing, followed by spraying on 2-week and 4-week old seedlings, respectively. The oligomeric Chitosan stimulated significantly stimulated plant growth indicated by the increase in leaf and root fresh weights, leaf and root dry weights, plant height and root length (Supachitra *et al*., 2011).

The experiment was conducted during Aman season of 2007 to investigate the seedling criterion against transplanting shock in the saline environment with Zn treatment by (Ansari *et al*., 2011). Data was taken on the number of leaf exist, the number of leaf fired and the number of new leaf emerged at 7 days after transplanting.

Leaf area index

Nguyen *et al*. (2011) were investigating on the effects of Chitosan and Chitosan oligomer solutions on growth and development of coffee have been investigated. Spraying of oligo Chitosan@600 mg L^{-1} increase stem diameter up to 30.77% and the leaf in area by up to 60.53%. In addition application of oligo Chitosan reduced by 9.5–25.1% transpiration of the leaves at 60 and 120 min.

Chibu and Shibayama (2001) studied Chitosan application on early growth of four crops: soybean, lettuce, tomato and rice. The results showed that Chitosan at 0.1 or 0.5% increased leaf area and leaf length of soybean, lettuce and rice whereas Chitosan at 0.1% showed positive effects on leaf area and leaf length of tomato.

Leaf greenness

Soaking the seeds in chitosan solution before planting and soil application four times tended to show the maximum value of leaf greenness over the other treatments, (Yue**,** *et al.* 2001) found that the changing regulation of chlorophyll content (leaf greenness) correlated with the change in chitosan concentration.

(Limpanavech *et al.* 2008) reported that chitosan O-80 significantly increased the chloroplast diameter of Dendrobium 'Eiskul' in young leaves, when the plants were treated with 10 and 50 ppm of chitosan O-80. At concentration of 50 ppm, chitosan O- 80 also significantly caused chloroplast enlargement in the old leave.

Total dry matter

Total dry mass per plant of okra was increased with increasing concentration of chitosan until 25 ppm (Mondal *et al*., 2012). The similar result studied in cucumber that the foliar application with chitosan at rates of 4 mlL^{-1} recorded the best treatment to obtain the highest vegetative growth.

Chitosan under low temperature increased shoot and root dry weight in maize plants compared to that of the control (Guan *et al.*, 2009).

Siddique (2009) sprayed Myobi @1, 2 and 3 mg L^{-1} on boro rice. Myobi increased total dry matter production with the increased concentration of Myobi. In general, that the best response was obtained when seeds were treated with 1 mgL^{-1} Chitosan during four hours, as this concentration stimulated significantly plant dry weight, although the other indicators were not modified (Martinez *et al*., 2007).

Chibu and Shibayama (1999) studied Chitosan application on four crops: soybean, lettuce, tomato and rice. The results showed that Chitosan at 0.1 or 0.5% leaf dry weight of soybean, lettuce and rice whereas Chitosan at 0.1% showed positive effects on dry weight of tomato. Chibu and Shibayama (1999) found that dry weight of dry-land rice cv. Misatohatamochi grown with both 0.1 and 0.5% of Chitosan were increased over the control.

Effective tiller hill^{-1} and length of panicle

Islam (2007) applied Miyobi on rice at the rate of 1.0, 2.0, 3.0 and 4.0 mgL^{-1} and reported that panicle length increased with increasing hormone concentration and the highest panicle length was recorded in 4.0 mgL^{-1} Miyobi. Similar result was also reported by Sultana (2010) in rice.

The panicle numbers and yield of wheat (Triticumaestivum L.) were increased after application of polymeric or oligomeric chitosan.(Boonlertnirun, *et al*. 2005) reported that rice yield cultivar Suphan Buri 1 was significantly increased over the control (no chitosan) after application of polymeric chitosan at the concentration of 20 ppm.

Lu *et al.* (2002) found that the panicle numbers of rice were increased after watering with Chitosan at the rate of 0.4 g /50 cm3 (Chitosan: water). Hoque (2002) was conducted the field experiment and observed that the wheat cv. Treated with GABA (0.33 mlL^{-1}) produced the tallest spike (9.00 cm) followed by TNZ-303 (8.10 cm) and CL-IAA (7.95 cm). The length of spike in GABA treated plant was significantly higher than the other treatments.

The maximum tiller numbers obtained from treatment of seed soaking in chitosan solution before planting and soil application. A similar result showed that node and branch numbers of soybean increased after application of chitosan in the soil. (Ohta, *et al.* 2001) also reported that the application of soil mixed with chitosan 1% w/w at sowing remarkably increased flower numbers of Eustoma grandiflorum.

Number of filled and unfilled grains panicle^{-1}

Boonlertnirun *et al.* (2005) indicated that seed numbers per panicle of rice plant cv. Suphan Buri-1 were not affected by various Chitosan concentrations.

Hoque (2002) observed that concentration 0.33 $mlL^{-1}$of GABA has produced the highest filled grain per spike (41.4) significantly higher over other treatments of TNZ-303 in wheat. Ohta *et al.* (2001) also reported that the application of a soil mix of Chitosan 1% w/w at sowing remarkably increased flower numbers of *Eustoma grandiflorum.*

Thousand grain weight

An experimental trial was carried out by Ghoname *et al*., (2010) in the two successive seasons of 2008 and 2009 to investigate and compare the enhancing effects of three different bio stimulation compounds on growth and production of sweet pepper plants. Three weeks after transplanting, plants were sprayed with any of the individual Chitosan (2, 4 and 6 cm /l). Data showed that individual fruit weight and number of fruits were also improved (Ghoname *et al*., 2010).

Islam (2007) conducted a field experiment on rice. He sprayed Myobi@2, 3 and 4 mg L^{-1} and GABA at 2, 3 and 4 mgL^{-1} as foliar application. He observed highest 1000-seed weight for 2 mgL^{-1} GABA followed by 2 mgL^{-1} Myobi.

A greenhouse experiments were conducted to determine the effect of Chitosan on drought recovery and grain yield of rice under drought conditions. Results revealed that the Chitosan applied before drought treatment gave the highest 1000-seed yield and also showed good recovery on yield (Boonlertnirun *et al*., 2008).

Grain yield

Sultana (2010) from BAEC, Bangladesh reported that the Oligo-Chitosan was applied for its potential use as plant growth promoter on growth and productivity of Maize (*Zea mays* L) plants. The foliar spraying of oligo-Chitosan (molecular weight 7,000 Da) with the concentration of 25, 50 and 75 mg L^{-1} was applied. The results showed that the application of oligo-Chitosan, at the concentration of 75 mg L^{-1}, plays a significant role in terms of plant height, weight of cob and weight of seeds per Maize.

Chitosan application proved to stimulate early growth stages of lettuce, soybean and upland rice. More recently, Abdel-Mawgoud *et al*., (2010) found an improvement effects on strawberry production or yield as a result of Chitosan application.

Boonlertnirun *et al*. (2008) conducted an experiment on application of Chitosan in rice production. The results showed that application of Chitosan by seed soaking and soil application four times throughout cropping season significantly increased rice yield over the other treatments.

Harvest index

The highest harvest index (38.50%) was observed from 50 mg L^{-1} GA_3 which was statistically identical with 25 mg L^{-1} and the lowest harvest index (32.96%) was obtained in control (Akter *et al*., 2007).

Hoque (2002) soaked wheat seeds in 0.16, 0.33 and 0.66 mlL^{-1}solutions of GABA, TNZ-303 and CI-IAA respectively and observed that 0.33 $mlL^{-1}$of GABA was enhanced the highest harvest index (47.19%) which was statistically identical to that of 0.66 mlL^{-1}(46.4 1%) of same PGR.

Seed number

Application of chitosan by seed soaking in chitosan solution before planting and then applying in soil tended to produce more panicle numbers than the other methods. However, it was not significantly different from the other treatments and the control. This result indicated that seed numbers per panicle of rice plant cv. Suphan Buri 1 were not affected by various chitosan concentrations .(Lu *et al*., 2002).

Plant's productivity

Chitosan induces mechanisms in plants against various biotic (fungi, bacteria and insects) and abiotic (salinity, drought, heavy metal and cold) stresses and helps in formation of barriers that enhance s plant's productivity.

Application of fertilizer in combination with chitosan had positive trends on panicle numbers of both inoculated and non inoculated rice plant. Chitosan application improved yield components (number and weight) of strawberry plants (Abdel-Mawgoud *et al*., 2010).

Disease resistance

The plants with high content of chitin enzyme had better external disease resistance to pathogen than the others. Moreover, chitosan was shown to be able to activate plant defensive genes through the octadecanoid pathway. (Akter *et al*., 2007) observed that application of chitosan by seed soaking before planting and four times of soil application throughout cropping season increased fiber percentage in rice plants greater than the other treatment.

In rice (Oryza sativa) chitosan showed marked antifungal activity against (*Rhizoctonia solan),* the rice sheath blight pathogen (Liu, H.,Tian, *et al.* ,2012).

Several chitosan studies about controlling plant disease were positively achieved such as in horticultural commodities groundnut *(Arachis hypogaea)* (Sathiyabama and Balasubramanian, 1998), pear fruit (Meng *et al*., 2010) and tobacco plants (Falcon-Rodriguez *et al*., 2011).

Chitosan affect the properties on plant disease control (Rodriguez et al., 2007; Ben Shalom *et al*., 2003). Chitosan inhibited growth of Botrytis cinerea in liquid culture and suppressed grey mold disease caused by the fungus on detached grapevine leaves and bunch rot in Chardonnay and Sauvignon blanc wine grapes.

In particular, the potential of use of chitosan for genetic transformation is suggested by its capability to form, through electrostatic interactions, a complex where DNA is protected from nuclease degradation. Interesting results were obtained by (Wang *et al*., 2013), who prepared QD-labeled CHT-DNA complexes to monitor nanoparticle-mediated genetic transformation of cultured cells of Jatropha curcas. This method gave rise to stable transformants with higher efficiency than other traditional methods of gene delivery.

2.3 EFFECTS OF SALINITY

Salinity at higher levels causes both hyperionic and hyperosmotic stress and can lead to plant demise. The outcome of these effects may cause membrane damage, nutrient imbalance, altered levels of growth regulators, enzymatic inhibition and metabolic dysfunction, including photosynthesis which ultimately leads to plant death (Mahajan and Tuteja 2005 ; Hasanuzzaman *et al*. 2012) .

High salt concentration in the soil or in the irrigation water can also have a devastating effect on plant metabolism, disrupting cellular homeostasis and uncoupling major physiological and biochemical processes. Biochemical and molecular studies of salt stress responses in plants have revealed significant increases of reactive oxygen species (ROS), including singlet oxygen (1 O_2), superoxide (O_2^-), hydroxyl radical (OH •) and hydrogen peroxide (H_2O_2) (Tanou *et al*. 2009).

Rezaei *et al*. (2010) showed that a vast area of Guilan province, though suitable for rice cultivation, is suffering from groundwater salinity.

The negative effects of salinity have been attributed to increase in $Na^+$and Cl^- ions in different plants hence these ions produce the critical conditions for plant survival by intercepting different plant mechanisms. Although both Na^+ and Cl^- are the major ions which produce many physiological disorders in plants, Cl^- is the most dangerous (Tavakkoli *et al*. 2010).

Rice is affected by salinity during transplanting, after transplanting and flowering, however it logarithmically endure salinity stress until ripening (Falah, 2010). In reproductive stage, salinity decreases the number of filled panicles, fertile panicle, weight of 1000 grains and percentage of fertile grains and increases fertile tillers.

Increased salinity of agricultural land is expected to have destructive global effects, resulting in up to 50% loss of cultivable lands by the middle of the twenty- first century (Mahajan and Tuteja 2005).

During germination, rice is very tolerant against salinity but it is very sensitive in seedling and reproductive stages. However it is less sensitive during tillering and grains filling (Lafitte *et al*, 2004).

Salinity before heading influences the number of tiller, which influences the number of panicle and weight of each panicle during the period of 3 leaf stage until booting (Zeng and Shannon, 2003).

High salinity causes both hyperionic and hyperosmotic stresses and can lead to plant death (Hasegawa *et al*. 2000). It is reported that plants growing under saline conditions are affected in three ways: reduced water potential in root zone causing water deficit, phytotoxicity of ions such as Na^+ and Cl^- and nutrient imbalance depressing uptake and transport of nutrients. Na^+ competes with K^+ for binding sites essential for cellular functions (Munns 2002).

Stress timing had a large influence on the overall sensitivity of rice to salinity (Zeng *et al*. 2001). The reductions in spikelets per panicle, seed weight per panicle and tillers per plant were greatest when plants were stressed between the three-leaf and panicle-initiation stages.

Salinity also significantly reduced seedling growth (Zeng and Shannon 2000a). Seedling growth of rice is dependent on both salt concentration and time of exposure. 3.2 dS/m significantly reduced seedling biomass at 17 days after seeding.

Salinity dramatically reduced seedling survival (Zeng and Shannon 2000a), seedling survival was reduced about 20% at 3.0 dS/m.

Salinity sensitivity increased with increasing seeding density (Zeng and Shannon 2000b). Grain weight per plant decreased and sterility increased with increasing seeding density.

Rice is a very sensitive plant to salinity of water and soil; this sensitivity is so that if we use high quality and not saline water in saline soils, yield and water of stem would decrease (Casanova, *et al*.,1999).

Greenhouse studies from the United Kingdom showed that salinity delayed flowering, and reduced productive tiller number, fertile florets per panicle, weight per grain and overall grain yield (Khatun *et al*., 1995).

Salinity of irrigation in reproductive growth stage decreases weight of 100 grains (Homaee, 2001). It delays ripening of rice about one week; weight of 1000 kernels significantly decreases with salinity increase (Gridhar, 1988).

Salinity decreases photosynthesis thus, unfilled spikelet increases and consequently the creation of filled grain in the panicle decreases (Munns and Termaat, 1986).

Proline accumulation can serve as a selection criterion for the tolerance of most species to stressed conditions (Parida and Das 2005). ABA also play important roles in many physiological processes like seed dormancy and delays in germination, development of seeds, acceleration of stomatal closure, synthesis of storage proteins and lipids, leaf senescence, etc. (Tuteja 2007).

Recent decades exogenous protectant such as osmo protectants, plant hormone, antioxidants, signaling molecules, polyamines, trace elements have been found effective in mitigating the salt induced damage in plant (Hoque *et al*., 2007).

MATERIALS AND METHODS

The pot experiment was carried out in the net house of soil science department at Sher –e – Bangla Agricultural University, Dhaka Bangladesh, during the period from December 2015 to April 2016. To study the role of modified chitosan on rice (BRRI dhan29) cultivation in saline soil. This chapter includes materials and methods that were used in conducting the experiment. The details are presented below under the following headings –

3.1 Experimental site and soil

The experiment was conducted in typical rice growing silt loam soil at the Sher-e-Bangla Agricultural University, Dhaka during the Boro season of 2015-2016. The morphological, physical and chemical characteristics of the soil are shown in the Table 3.1 and 3.2.

3.2 Climate

The climate of the experimental area is characterized by high temperature, high humidity and medium rainfall with occasional gusty winds during the kharif season (March-September) and a scanty rainfall associated with moderately low temperature in the *rabi* season (October-March). The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental site during the cropping season December 2015 to April 2016 have been presented in Appendix I.

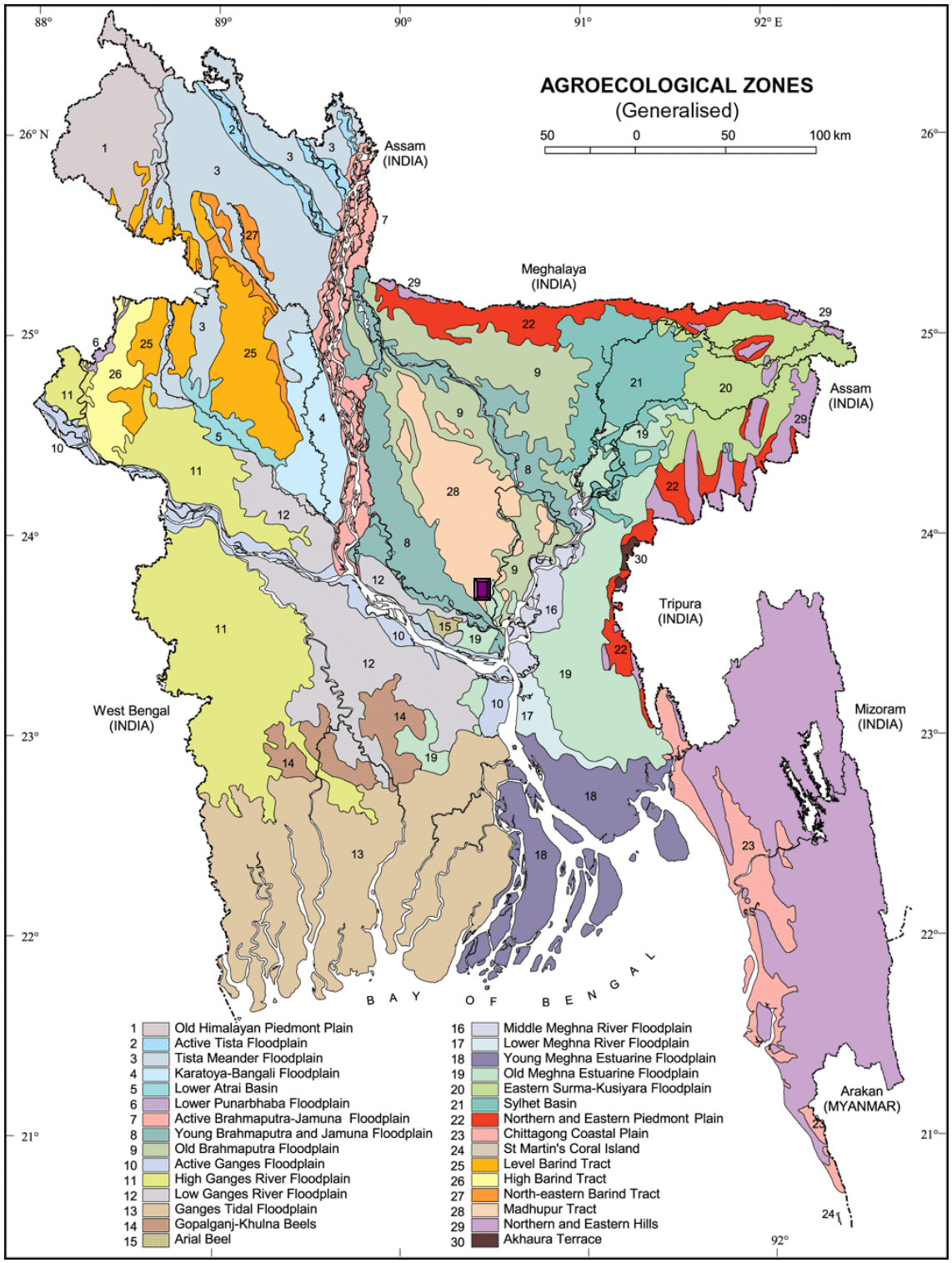


Figure1. Map showing the experimental sites under study

Table 3.1 Morphological characteristics of the experimental field

Morphology	Characteristics
Location	SAU Farm, Dhaka.
Agro-ecological zone	Madhupur Tract (AEZ- 28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur Clay
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

(FAO and UNDP, 1988)

Table 3.2 Initial physical and chemical characteristics of the soil

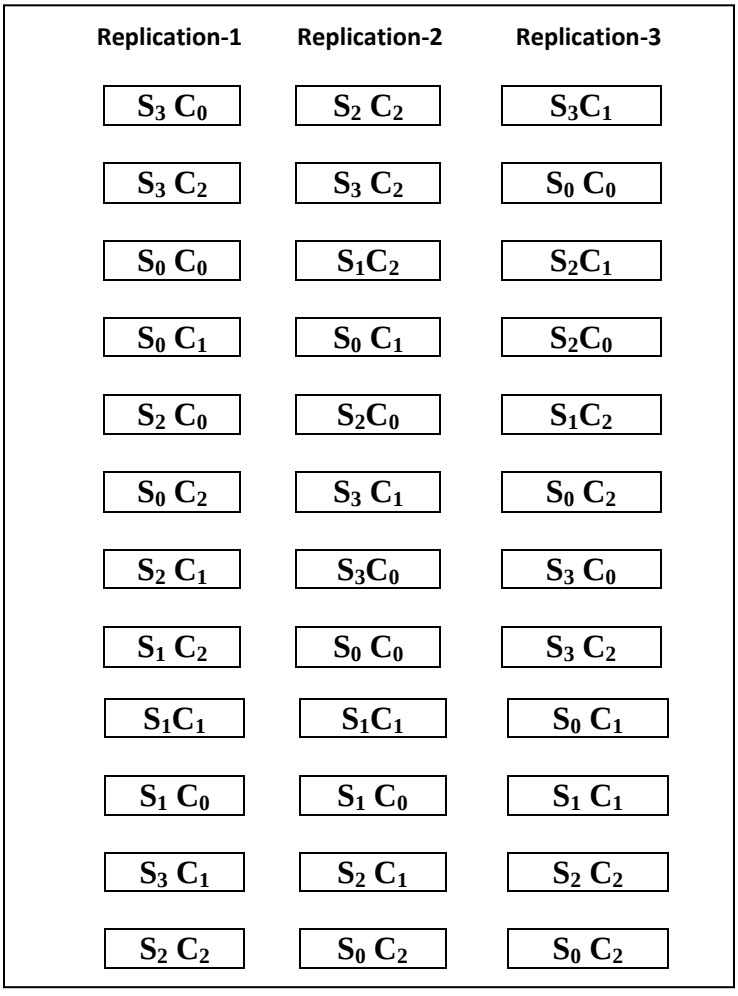
Characteristics	Value
Mechanical fractions: % Sand (2.0-0.05 mm) % Silt (0.05-0.002 mm) % Clay (<0.002 mm)	 22.30 56.90 20.80
Textural class	Silt Loam
pH (1: 2.5 soil- water)	6.1
Organic Matter (%)	1.09
Total N (%)	0.05
Available K (meq K/100 g soil)	0.07
Available P (ppm)	12.88
Available S (ppm)	10.06

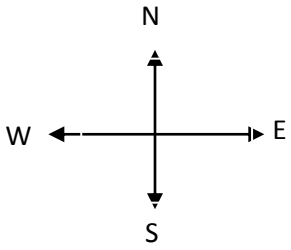
3.3 Planting material:

BRRI dhan29 was used as the test crop in this experiment. This variety was developed at the Bangladesh Rice Research Institute from the cross between BG 90-2 and BR 51-46-5 in 1994. It is recommended for Boro season. Average plant height of the variety is 90-95 cm at the ripening stage. The grains are medium fine and white. It requires about 155-160 days completing its life cycle with an average grain yield of 5.0-5.5 t/ha (BRRI, 2004).

3.4 Experimental design and layout

The experiments was laid out in randomized complete block design (RCBD) with three replications.





Factor A: Modified Chitosan

C_0-0 g modified chitosan/pot,

C_1-20 g modified chitosan/pot

C_2-40 g modified chitosan/pot

Factor B: Salinity

S_0- seedling transplanted in normal soil

S_1-seedling transplanted in 4 dSm^{-1} saline soil

S_2-seedling transplanted in 8 dSm^{-1} saline soil

S_3-seedling transplanted in 12 dSm^{-1} saline soil

Figure 2. Layout of the pot experiment

3.5 Initial soil sampling:

Before pot preparation, initial soil samples were collected from the experimental pots. The composite soil sample were air-dried, crushed and passed through a 2 mm (8 meshes) sieve. After sieving, the soil samples were kept in a plastic container for physical and chemical analysis of the soil.

3.6 Treatments:

The experiment consists of 2 factors: Modified chitosan and salinity. Details of factors and their combinations are presented below:

Factor A: Modified Chitosan

C_0-0 g modified chitosan/pot

C_1-20 g modified chitosan/pot

C_2-40 g modified chitosan/pot

Factor B: Salinity

S_0- seedling transplanted in normal soil

S_1-seedling transplanted in 4 dSm^{-1} saline soil

S_2-seedling transplanted in 8 dSm^{-1} saline soil

S_3-seedling transplanted in 12 dSm^{-1} saline soil

Treatments combination

S_0C_0 (seedling transplanted in normal soil + 0 g modified chitosan/pot)

S_0C_1 (seedling transplanted in normal soil + 20 g modified chitosan/pot)

S_0C_2 (seedling transplanted in normal soil + 40 g modified chitosan/pot)

S_1C_0 (seedling transplanted in 4 dSm^{-1} saline soil + 0 g modified chitosan/pot)

S_1C_1 (seedling transplanted in 4 dSm^{-1} saline soil + 20 g modified chitosan/pot)

S_1C_2 (seedling transplanted in 4 dSm^{-1} saline soil + 40 g modified chitosan/pot)

S_2C_0 (seedling transplanted in 8 dSm^{-1} saline soil + 0 g modified chitosan/pot)

S_2C_1 (seedling transplanted in 8 dSm^{-1} saline soil + 20 g modified chitosan/pot)

S_2C_2 (seedling transplanted in 8 dSm^{-1} saline soil + 40 g modified chitosan/pot)

S_3C_0 (seedling transplanted in 12 dSm^{-1} saline soil + 0 g modified chitosan/pot)

S_3C_1 (seedling transplanted in 12 dSm^{-1} saline soil + 20 g modified chitosan/pot)

S_3C_2 (seedling transplanted in 12 dSm^{-1} saline soil + 40 g modified chitosan/pot)

3.7 Pot preparation:

The collected soil was pulverized & dried in the sun. Plant propagules, inert materials, visible insects & pests was removed from this soil. Then the prepared medium was used for filling the pot.

3.8 Fertilizer application:

The pot soil was fertilized with urea, TSP, MoP, gypsum & Zinc sulphate as source of N, P, K, S & Zn at the rate of 150 Kg N, 22Kg P, 80 Kg K, 15 Kg S & 2Kg Zn per ha. Full amounts of TSP, MP, gypsum and Zinc sulphate were applied as basal dose before transplanting of rice seedlings. Urea were applied in 3 equal splits: one third was applied at basal before transplanting, one third at active tillering stage (30 DAT) and the remaining one third was applied at 5 days before panicle initiation stage (55 DAT).

3.9 Modified Chitosan incorporation:

Treatment wise doses of modified chitosan was added in the pot soil as a basal dose before three days of seedling transplanting. Chemical compositions of the modified chitosan used have been presented in (Table 3.3).

Table 3.3 Chemical compositions of the modified chitosan

Name of Nutrients	Value
N	4.06 %
P	0.643 %
K	0.28 %
S	0.092 %
Zn	92.03 ppm

3.10 Raising of seedlings

The seedlings of rice were raised wet-bed methods. Seeds (95% germination) @ 5 kg/ha were soaked and incubated for 48 hour and sown on a well-prepared seedbed. During seedling growing, no fertilizers were used. Proper water and pest management practices were followed whenever required.

3.11 Transplanting of seedlings in pots:

After final preparation the pot soil moistened with water. Six weeks old seedlings of selected variety per hill and one hill per pot was transplanted in respective pot.

3.12 Salinity Treatment

The four salinity level was 0 (control), $4dSm^{-1}$, $8dSm^{-1}$and $12dSm^{-1}$.The different salinity level was obtain by dissolving Commercial salt (NaCl) at the rate of 640 mg per litre distilled water for 1 dSm^{-1} salinity level.

3.13 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.13.1 Irrigation

Necessary irrigations were provided to the pots as and when required during the growing period of rice crop

3.13.2 Weeding

The pots were infested with some common weeds, which were removed by uprooting them from the pot three times during the period of the cropping season.

3.13.3 Insect and pest control

There was no infestation of diseases in the pot but leaf roller (*Chaphalocrosismedinalis*, Pyralidae, Lepidoptera) was observed in the pot and used Malathion @ 1.12 L ha^{-1}.

3.14 Crop harvest

The crop was harvested at full maturity when 80-90% of the grains were turned into straw colored on 15 April, 2016. The crop was cut at the ground level and pot wise crop was bundled separately and brought to the threshing floor.

3.15 Yield components

3.15.1 Total no. of effective tiller/hill

The total number of effective tiller $hill^{-1}$ was counted as the number of panicle bearing hill/plant. Data on effective tiller/hill were counted from one hill and value was recorded.

3.15.2 Total no. of non effective tiller/hill

The total number of non-effective tiller/hill was counted as the number of non-panicle bearing plant/hill. Data on non effective tiller/hill were counted from one hill and value was recorded.

3.15.3 Plant height (cm)

The height of plant was recorded in centimeter (cm) at harvesting stage. The height was measured from the ground level to the tip of the panicle.

3.15.4 Length of panicle (cm)

The length of panicle was measured with a meter scale and the average value was recorded as per plant.

3.15.5 Number of unfilled and filled grain per panicle

The total numbers of unfilled grains were calculated from plants of each pot on the basis of not grain in the spikelet and then average numbers of unfilled grain per panicle was recorded. Similarly filled grains panicle^{-1}were counted.

3.15.6 Weight of 1000 seeds (g)

One thousand seeds were counted randomly from the total cleaned harvested seeds and then weighed in grams and recorded.

3.15.7 Straw yield (g)

Straw obtained from each pot were sun-dried and weighed carefully. The dry weight of straw of the respective pot yield was recorded.

3.15.8 Grain yield (g)

Grains obtained from each pot were sun-dried and weighed carefully. The dry weight of grains of the respective pot yield was recorded.

3.16 Chemical analysis of plant samples

3.16.1 Collection and preparation of plant samples

Grain and straw samples were collected after threshing for N, P, K and S analyses. The plant samples were dried in an oven at 70 ^{0}C for 72 hours and then ground by a grinding machine (wiley-mill) to pass through a 20-mesh sieve. The samples were stored in plastic vial for analysis of N, P, K and S. The grain and straw samples were analyzed for determination of N, P, K and S concentrations. The methods were as follows:

3.16.2 Digestion of plant samples with sulphuric acid for N

For the determination of nitrogen an amount of 0.5 g oven dry, ground sample were taken in a micro kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se in the ratio of 100: 10: 1), and 7 ml conc. H_2SO_4 were added. The flasks were heated at 160^{0}C and added 2 ml 30% H_2O_2 then heating was continued at 360^{0}C until the digests become clear and colorless. After cooling, the content was taken into a 50 ml volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

3.16.3 Digestion of plant samples with nitric-perchloric acid for P, K and S

A sub sample weighing 0.5 g was transferred into a dry, clean 100 ml digestion vessel. Ten ml of di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flasks were heated at a temperature slowly raised to 200^{0}C. Heating were stopped when the dense white fumes of $HClO_4$ occurred. The content of the flask were boiled until they were became clean and colorless. After cooling, the content was taken into

a 50 ml volumetric flask and the volume was made up to the mark with de-ionized water. P, K and S were determined from this digest by using different standard methods.

3.16.4 Determination of P, K and S from plant samples

3.16.4.1 Phosphorus

Plant samples (grain and straw) were digested by diacid (Nitric acid and Perchloric acid) mixture and P content in the digest was measured by blue color development (Olsen *et al.*, 1954). Phosphorus in the digest was determined by using 5 ml for grain and straw sample from 50 ml digest by developing blue color with reduction of phosphor molybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al*., 1982).

3.16.4.2 Potassium

One milli-liter of digest sample for the grain and straw were taken and diluted 20 ml volume to make desired concentration so that the flame photometer reading of samples were measured within the range of standard solutions. The concentrations were measured by using standard curves.

3.16.4.3 Sulphur

Sulphur content was determined from the digest of the plant samples (grain and straw) with $CaCl_2$ (0.15%) solution as described by Page *et al*. 1982. The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter, 1984).

3.17 Nutrient Content

After chemical analysis of straw and grain samples the nutrient contents were calculated and from the value of nutrient contents.

3.18 Post harvest soil sampling

After harvest of crop soil samples were collected from each pot at a depth of 0 to 15 cm. Soil sample of each pot were air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.19 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz. organic matter, pH, EC, total N and available P, K, and S contents. The soil samples were analyzed by the following standard methods as follows:

3.19.1 Textural class

Mechanical analysis of soil were done by hydrometer method (Bouyoucos, 1926) and the textural class was determined by plotting the values of % sand, % silt and % clay to the Marshall's textural triangular co-ordinate following the USDA system.

3.19.2 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 (Jackson, 1962).

3.19.3 Organic matter

Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black (1935). The underlying principle was used to oxidize the organic matter with an

excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_2O_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.*, 1982).

3.19.4 Electrical Conductivity (EC)

Soil electrical conductivity was measured with the help of EC meter, the soil water ratio being maintained at 2: 5.0

3.19.5 Total nitrogen

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 7 ml H_2SO_4 were added. The flasks were swirled and heated 160 ^{0}C and added 2 ml H_2O_2 and then heating at 360 ^{0}C was continued until the digest was clear and colorless. After cooling, the content was taken into 50 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al*., 1982).

Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected

the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water.

Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink.

The amount of N was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100 / S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.19.6 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated the standard P curve (Page *et al*. 1982).

3.19.7 Available potassium

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al*. 1982).

3.19.8 Available sulphur

Available S content was determined by extracting the soil with $CaCl_2$ (0.15%) solution as described by (Page *et al*. 1982). The extractable S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths.

3.20 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different treatments on yield and yield contributing characters of BRRI dhan29. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The results of different yield attributes, yield and nutrient concentrations in the plant and grains and availability of different nutrients in the soil after harvest of rice are presented this chapter.

4.1 Effective tiller

4.1.1 Effect of salinity on the effective tillers/hill of rice

A significant variation was observed in effective tillers/hill of rice due to the different levels of salinity presented in (Table 4.1). Effective tiller number was decreased in a dose dependent manner with increasing the salinity levels. Maximum effective tiller (42.88) was found in the S_0 (seedling transplanted in normal saline soil) and minimum effective tiller (13.56) was found in the S_2 (seedling transplanted in 8 dSm^{-1}saline soil). The effective tillers was zero (0) in the S_3 (seedling transplanted in 12 dSm^{-1}saline soil). The production of effective tiller in the S_1 (seedling transplanted in 4 dSm^{-1}saline soil) was (26.33) which was not statistically identical with the other treatments. Salinity dramatically reduced seedling survival (Zeng and Shannon, 2000a), seedling survival was reduced about 20% at 3.0 dSm^{-1}.

Table 4.1 Effect of salinity on effective and non-effective tillers/hill of rice

Salinity level	No. of effective tiller/ hill	No. of non- effective tiller/ hill
S_0	42.88 a	3.78
S_1	26.33 b	4.44
S_2	13.56 c	3.78
S_3	0.00 d	4.33
CV%	13.87	41.33
LSD (0.05)	2.80	1.65

S_0- Seedling transplanted in normal soil

S_1- Seedling transplanted in 4 dSm^{-1} saline soil

S_2.Seedling transplanted in 8 dsm^{-1} saline soil

S_3.Seedling transplanted in 12 dsm^{-1} saline soil

4.1.2 Effect of modified chitosan on the effective tillers/hill of rice

Application of modified chitosan showed significant variations in respect of effective tillers/hill of rice (Table 4.2). C_1 (20 g modified chitosan/pot) showed the highest number of effective tillers/hill (23.91) which was statistically different and higher than all other treatments. On the contrary, the lowest number of effective tillers/hill (16.750) was observed with C_2 (40 g modified chitosan/pot).

Table 4.2 Effect of modified chitosan on the effective and non-effective tillers/hill of rice

Modified Chitosan Level	No. of effective tiller/ hill	No. of non effective tiller/ hill
C_0	21.41 b	4.25
C_1	23.91 a	4.00
C_2	16.75 c	4.00
CV%	13.87	41.33
LSD (0.05)	2.43	1.42

C_0-0 g modified chitosan/pot,

C_1-20 g modified chitosan/pot

C_2-40 g modifiedchitosan/pot

4.1.3 Combined effects of salinity and modified chitosan on the number of effective tillers/hill of rice

The significant variation was observed on the combined effect ofsalinity and modified chitosan on the number of effective tillers/hill of rice due to the different levels of salinity and different doses of chitosan presented in (Table 4.3). The highest number of effective tillers/hill of rice (49.00) was recorded with the treatment combination of S_0C_1 (seedling transplanted in normal soil +20 g modified chitosan/pot). On the other hand, the lowest number of effective tillers/hill (11.66) was found in S_2C_2 (seedling transplanted in 8 dSm^{-1} saline soil + 40 g modified chitosan/pot,) treatment combination.

Table 4.3 Combined effects of salinity and modified chitosan on the number of effective and non-effective tillers/hill of rice

Treatment combination	No. of effective tiller/ hill	No. of non effective tiller/ hill
S_0C_0	46.33 a	2.33 b
S_0C_1	49.00 a	4.33 ab
S_0C_2	33.33 b	4.66 ab
S_1C_0	26.66 cd	5.00 ab
S_1C_1	30.33 bc	3.00 ab
S_1C_2	22.00 d	5.33 a
S_2C_0	12.66 e	4.33 ab
S_2C_1	16.33 e	4.00 ab
S_2C_2	11.66 e	3.00 ab
S_3C_0	0.00 f	5.33 a
S_3C_1	0.00 f	4.66 ab
S_3C_2	0.00 f	3.00 ab
CV%	13.87	41.33
LSD (0.05)	4.86	2.85

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.2 Non-effective tiller

4.2.1 Effect of salinity on the non-effective tillers/hill of rice

The effects of salinity on the non- effective tillers/hill of rice are presented in (Table 4.1). Results revealed that variation in the number of non-effective tillers/hill of rice was not significant. S_1 (seedling transplanted in 4 dSm^{-1} saline soil) showed the highest number of effective tillers/hill (4.44) which was similar to S_0 (seedling transplanted in normal soil), S_2 (seedling transplanted in 8 dSm^{-1} saline soil) & S_3 (seedling transplanted in 12 dSm^{-1} saline soil).

4.2.2 Effect of modified chitosan on the non- effective tillers/hill of rice

Different doses of modified chitosan showed insignificant variations in respect of non-effectivetillers/hill of rice (Table 4.2). C_0 (0 g modified chitosan/pot) showed the highest number of non-effective tillers/hill (4.25) which was similar to C_1 (20 g modified chitosan/pot) & C_2 (40 g modified chitosan/pot).

4.2.3 Combined effects of salinity and modified chitosan on the number of non-effective tillers/hill of rice

The significant variation was observed on the combined effect of salinity and modified chitosan on the number of non- effective tillers/hill of rice due to the different levels of salinity and different doses of chitosan presented in (Table 4.3). The highest number of non-effective tillers/hill of rice (5.33) was recorded with the treatment combination S_1C_2 (seedling transplanted in 4 dSm^{-1} saline soil+40 g modified chitosan/pot). On the other hand, the lowest number of non-effective tillers/hill (2.33) was found in S_0C_0 (seedling transplanted in normal soil+0 g modified chitosan/pot) treatment combination.

4.3 Plant height

4.3.1 Effect of salinity on the plant height of rice

A Significant variation was observed on the plant height of rice due to different levels of salinity presented in (Table 4.4). Plant height of rice was decreased in a dose dependent manner with increasing the salinity levels. S_0 (seedling transplanted in normal soil) showed the highest plant height (77.81cm) and S_3 (seedling transplanted in 12 dSm^{-1} saline soil) showed lowest plant height (36.87cm).

Table 4.4 Effect of salinity on the plant height and panicle length of rice

Salinity level	Plant height (cm)	Panicle length (cm)
S_0	77.81 a	28.08 a
S_1	69.35 b	25.85 b
S_2	46.62 c	18.76 c
S_3	36.87 d	0.00 d
CV%	10.77	8.44
LSD (0.05)	6.07	1.50

4.3.2 Effect of modified chitosan on the plant height of rice

Rice plants showed significant variation in respect of plant height when modified chitosan of different doses were applied (Table 4.5). Among the different modified chitosan doses C_1 (20g modified chitosan/pot) showed the highest plant height (60.24 cm), which was closed to (60.22cm) by C_0 (0 g modified chitosan/pot). On the other hand the lowest plant height (52.52cm) was observed on C_2 (40 g modified chitosan/pot). Supachitra *et al*. (2011) found that the oligomeric Chitosan stimulated plant height.

Table 4.5 Effect of modified chitosan on the plant height and panicle length of rice

Modified Chitosan Level	**Plant height (cm)**	**Panicle length (cm)**
C_0	60.22 a	18.52 a
C_1	60.24 a	19.37 a
C_2	52.52 b	16.62 b
CV%	10.77	8.44
LSD (0.05)	5.25	1.29

4.3.3 Combined effects of salinity and modified chitosan on the plant height of rice

The significant variation was observed on the combined effect of salinity and modified chitosan on the plant height of rice due to the different levels of salinity and different doses of modified chitosan presented in (Table 4.6). The highest plant height (78.68 cm) was recorded with S_0C_1 (seedling transplanted in normal soil+20 g modified chitosan/pot) treatment. On the other hand, The lowest plant height (30.14cm) was observed in the treatment combination S_3C_2 (seedling transplanted in 12 dSm^{-1} saline soil + 40 g modified chitosan/pot).

Table 4.6 Combined effect of salinity and modified chitosan on the plant height and Panicle length of rice

Treatment combination	Plant height (cm)	Panicle length (cm)
S_0C_0	77.69 a	28.81 a
S_0C_1	78.68 a	27.87 a
S_0C_2	77.06 a	27.56 a
S_1C_0	73.80 a	26.66 a
S_1C_1	73.70 a	28.31 a
S_1C_2	60.57 b	22.59 b
S_2C_0	47.97 c	18.61 c
S_2C_1	49.55 c	21.33 b
S_2C_2	42.33 c	16.33 c
S_3C_0	41.42 c	0.00 d
S_3C_1	39.04 cd	0.00 d
S_3C_2	30.14 d	0.00 d
CV%	10.77	8.44
LSD (0.05)	10.51	2.59

4.4 Panicle length

4.4.1 Effect of salinity on the panicle length of rice

A Significant variation was observed on the panicle length of rice due to different levels of salinity presented in (Table 4.4). Plant height of rice was decreased in a dose dependent manner with increasing the salinity levels. S_0 (seedling transplanted in normal soil) showed the highest panicle length (28.083 cm) and S_2 (seedling transplanted in 8 dSm^{-1} saline soil) showed lowest panicle length (18.76 cm).). In case of S_3 (seedling transplanted in 12 dSm^{-1} saline soil) total number of panicle length was 0. Because, after transplanting of seedling in soil having 12dSm^{-1}(S_3) did not survive. (Zengand Shannon, 2003) found that salinity affect the no. of panicle length and weight of panicle.

4.4.2 Effects of modified chitosan on the panicle length of rice

Rice plants showed significant variation in respect of panicle length when different doses of modified chitosan were applied (Table 4.5). Among the different doses of modified chitosan C_1 (20 g modified chitosan/pot) showed the highest panicle length (19.37 cm), which was statistically identical to C_0 (0 g modified chitosan/pot). On the other hand the

lowest panicle length (16.623 cm) was observed in the C_2 (40 g modified chitosan/pot). (Lu *et al.,* 2002) found that the panicle numbers of rice were increased after watering with chitosan at the rate of 0.4 g /50 cm^3 (chitosan: water).

4.4.3 Combined effects of salinity and modified chitosan on the panicle length of rice

The significant variation was observed on the combined effect of salinity and modified chitosan on the panicle length of rice due to the different levels of salinity and different doses of chitosan presented in (Table 4.6). The highest panicle length (28.810) was observed in the treatment combination of the S_0C_0 (seedling transplanted in normal soil + 0 g modified chitosan/pot) treatments which was similar to S_0C_1 (seedling transplanted in normal soil + 20 g modified chitosan/pot), S_0C_2 (seedling transplanted in normal soil + 40 g modified chitosan/pot), S_1C_0 (seedling transplanted in 4 dSm^{-1} saline soil + 0 g modified chitosan/pot), S_1C_1 (seedling transplanted in 4 dSm^{-1} saline soil + 20 g modified chitosan/pot). The lowest panicle length (16.33 cm) was observed in the treatment combination of the S_2C_2 (seedling transplanted in 8 dSm^{-1} saline soil + 40 g modified chitosan/pot) treatments.

4.5 Number of filled grain per panicle

4.5.1 Effect of salinity on the number of filled grain per panicle of rice

A Significant variation was observed on the number of filled grain per panicle of rice due to different levels of salinity presented in (Table 4.7). Plant height of rice was decreased in a dose dependent manner with increasing the salinity levels. S_0 (seedling transplanted in normal soil) showed the highest number of filled grain per panicle (133.39) and S_2 (seedling transplanted in 8 dSm^{-1} saline soil) showed lowest number of filled grain per

panicle (48.22). The number of filled grain per panicle was zero (0) in the S_3 (seedling transplanted in 12 dSm^{-1}saline soil).

Table 4.7 Effect of salinity on the no. of filled grains/panicle and unfilled grains/panicle of rice

Salinity level	No. of filled grain/ panicle	No. of unfilled grain/ panicle
S_0	133.39 a	42.80 b
S_1	94.98 b	60.35 a
S_2	48.22 c	35.66 c
S_3	0.00 d	0.00 d
CV%	26.68	23.95
LSD (0.05)	18.03	8.12

4.5.2 Effect of modified chitosan on the number of filled grain per panicle of rice

There was significant variation was observed in number of filled grain per panicle of rice when different doses of modified chitosan were applied (Table 4.8). The highest number of filled grain per panicle (80.22) was recorded in C_1 (20 g modified chitosan/pot) treatment.The lowest number of filled grain per panicle (53.81) was recorded in C_2 (40 g modified chitosan/pot).

Table 4.8 Effect of modified chitosan on the no. of filled grains/panicle and unfilled grains/panicle of rice

Chitosan Level	No. of filled grain/ panicle	No. of unfilled grain/ panicle
C_0	73.40 a	32.64 b
C_1	80.22 a	29.60 b
C_2	53.81 b	41.86 a
CV%	26.68	23.95
LSD (0.05)	15.621	7.037

4.5.3 Combined effects of salinity and modified chitosan on the number of filled grain per Panicle of rice

The significant variation was observed on the combined effect of salinity and modified chitosan on the number of filled grain per panicle of rice due to the different levels of salinity and different doses of chitosan presented in (Table 4.9). The highest number of filled grain per panicle of rice (145.40) was recorded with the treatment combination S_0C_1 (seedling transplanted in normal soil + 20 g modified chitosan/pot) treatment. On the other hand, the lowest number of filled grain (47.00) was found in S_2C_0 (seedling transplanted in 8 dSm^{-1} saline soil+0 g modified chitosan/pot) treatment combination.

Table 4.9 Combined effects of salinity and modified chitosan on the no. of filled grains/panicle and no. of unfilled grains/panicle of rice

Treatment combination	No. of filled grain/ panicle	No. of unfilled grain/ panicle
S_0C_0	135.50 ab	39.66 bcd
S_0C_1	145.40 a	38.40 bcd
S_0C_2	119.27 ab	50.33 b
S_1C_0	111.13 b	50.23 b
S_1C_1	118.83 ab	48.70 bc
S_1C_2	55.00c	82.13 a
S_2C_0	47.00 c	40.66 bcd
S_2C_1	56.66 c	31.33 d
S_2C_2	41.00 c	35.00 cd
S_3C_0	0.00 d	0.00 e
S_3C_1	0.00 d	0.00 e
S_3C_2	0.00 d	0.00 e
CV%	26.68	23.95
LSD (0.05)	31.24	14.07

4.6 Number of unfilled grain per panicle

4.6.1 Effect of salinity on the number of unfilled grain per panicle of rice

The effects of salinity on the number of unfilled grain per panicle of rice are presented in (Table 4.7). There was significant variation on the number of filled grain per panicle of rice. S_1 (seedling transplanted in 4 dSm^{-1} saline soil) showed the highest number of unfilled grain per panicle (60.35) and S_2 (seedling transplanted in 8 dSm^{-1} saline soil) showed lowest number of filled grain per panicle (35.66). The number of unfilled grain per panicle was zero (0) in the S_3 (seedling transplanted in 12 dSm^{-1}saline soil).

4.6.2 Effect of modified chitosan on the number of unfilled grain per panicle of rice

There was significant variation observed in number of unfilled grain per panicle of rice when different doses of modified chitosan were applied (Table 4.8). The highest number of unfilled grain per panicle (41.86) was recorded in C_2 (40 g modified chitosan/pot) treatment. The lowest number of unfilled grain per panicle (29.60) was recorded in C_1 (20 g modified chitosan/pot) which is similar to in C_0 (0 g modified chitosan/pot).

4.6.3 Combined effects of salinity and modified chitosan on the number of unfilled grain per panicle of rice

The significant variation was observed on the combined effect of salinity and modified chitosan on the number of unfilled grain per panicle of rice due to the different levels of salinity and different doses of chitosan presented in (Table 4.9). The highest number of unfilled grain perpanicle of rice (82.13) was recorded with the treatment combination S_1C_2 (seedling transplanted in 4 dSm^{-1} saline soil + 40 g modified chitosan/pot) treatment. On the other hand, the lowest number of unfilled grain (31.33) was found in S_2C_1 (seedling transplanted in 8 dSm^{-1}saline soil+20 g modified chitosan/pot) treatment combination.

4.7 1000 grain wt. of rice

4.7.1 Effect of salinity on the 1000 grain wt. of rice

A Significant variation was observed on the1000 grain wt. of rice due to different levels of salinity presented in (Table 4.10). 1000 grain wt. of rice was decreased in a dose dependent manner with increasing the salinity levels. S_0(seedling transplanted in normal soil) showed the highest 1000 grain wt. (20.11 g) which is closed to S_1(seedling transplanted in 4 dSm^{-1} saline soil). S_2 (seedling transplanted in 8 dSm^{-1} saline soil) showed lowest 1000 grain wt. (16.55 g).1000 grain wt. of rice waszero (0) in the S_3 (seedling transplanted in 12 dSm^{-1}saline soil). Falah, (2010) showed that salinity reduce the weight of 1000 grains and percentage of fertile grains.

Table 4.10 Effect of salinity on 1000 grain wt., straw yield and grain yield of rice

Salinity level	1000 seed weight (g)	Straw yield (g)	Grain yield (g)
S_0	20.11 a	90.33 a	68.89 a
S_1	19.44 a	51.00 b	33.89 b
S_2	16.55 b	28.56 c	18.89 c
S_3	0.00 c	0.00 d	0.00 d
CV%	12.95	18.61	13.74
LSD (0.05)	1.77	7.72	4.08

4.7.2 Effect of modified chitosan on the 1000 grain wt. of rice

Rice plants showedsignificant variation in respect of 1000 grain wt. of rice when modified chitosan of different doses were applied (Table 4.11). Among the different fertilizer doses, C_1 (20 g modified chitosan/pot) showed the highest 1000 grain wt. (14.83 g). On the other hand, the lowest 1000 grain wt. (13.25 g) was observed in the C_2 (40 g modified chitosan/pot).

Table 4.11 Effect of modified chitosan on 1000 grain wt., straw yield and grain yield of rice

Modified Chitosan Level	1000 seed weight (g)	Straw yield (g)	Grain yield (g)
C_0	14.00ab	39.66 b	30.41 b
C_1	14.83 a	47.08 a	38.08 a
C_2	13.25 b	40.67 ab	22.75 c
CV%	12.95	18.61	13.74
LSD (0.05)	1.53	6.69	3.53

4.7.3 Combined effects of salinity and modified chitosan on the 1000 grain wt. of rice

The significant variation was observed on the combined effect of salinity and modified chitosan on the 1000 grain wt. of rice due to the different levels of salinity and different doses of chitosan presented in (Table 4.12).The highest 1000 grain wt. of rice (21.33 g) was recorded with the S_0C_1 (seedling transplanted in normal soil +20 g modified chitosan/pot) treatment combination. On the other hand, the lowest 1000 grain wt. (16.00g) was found in S_2C_2 (seedling transplanted in 8 dSm^{-1} saline soil +40 g modifiedchitosan/pot) treatment combination.

Table 4.12 Combined effect of salinity and modified chitosan on the 1000 grain wt., straw yield and grain yield of rice

Treatment combination	1000 seed weight (g)	Straw yield (g)	Grain yield(g)
S_0C_0	20.33ab	73.66 c	68.33 b
S_0C_1	21.33 a	90.33 b	85.00 a
S_0C_2	18.66 abc	107.00 a	53.33 c
S_1C_0	19.66 ab	55.33 d	35.66 e
S_1C_1	20.33 ab	61.66cd	43.00 d
S_1C_2	18.33 abc	36.00 e	23.00 f
S_2C_0	16.00 c	29.66 ef	17.66 fg
S_2C_1	17.66 bc	36.33 e	24.33 f
S_2C_2	16.00 c	19.66 f	14.66 g
S_3C_0	0.00 d	5.54 g	0.00 h
S_3C_1	0.00 d	5.43 g	0.00 h
S_3C_2	0.00 d	4.89 g	0.00 h
CV%	12.95	18.61	13.74
LSD (0.05)	3.076	13.38	7.07

4.8 Straw yield

4.8.1 Effect of salinity on the straw yield of rice

The effects of salinity on the straw yield of rice are presented in (Table 4.10). Significant variation was observed on the straw yield of rice. S_0 (seedling transplanted in normal soil) showed the highest straw yield (90.33g) and S_2 (seedling transplanted in 8 dSm^{-1} saline soil) showed lowest straw yield (28.55g). Straw yield of rice was zero (0) in the S_3 (seedling transplanted in 12 dSm^{-1}saline soil).

4.8.2 Effect of modified chitosan on the straw yield of rice

The effects of modified chitosan on the straw yield of rice are presented in (Table 4.11). Significant variation was observed on the straw yield of rice C_1 (20 g modified chitosan/pot) showed the highest straw yield (47.08g) and C_0 (0 g modified chitosan/pot) showed lowest straw yield (39.66g).

4.8.3 Combined effects of salinity and modified chitosan on the straw yield of rice

The significant variation was observed on the combined effect of salinity and modified Chitosan on the straw yield of rice due to the different levels of salinity and different doses of chitosan presented in (Table 4.12).The highest straw yield of rice (107.00 g) was recorded with the S_0C_2 (seedling transplantedin normal soil+ 40 g modified chitosan/pot)treatment combination. On the other hand, the lowest straw yield of rice was (4.89g) was found in S_3C_2 (seedling transplanted in 12 dSm^{-1} saline soil +40 g modified chitosan/pot) treatment combination.

4.9 Grain yield

4.9.1 Effect of salinity on the grain yield of rice

The effects of salinity on the grain yield of rice are presented in (Table 4.10). There was significant variation on the grain yield of rice. S_0 (seedling transplanted in normal soil) showed the highest grain yield (68.88g) & S_2 (seedling transplanted in 8 dSm^{-1} saline soil) showed lowest grain yield (18.88g). Grain yield of rice was zero (0) in the S_3 (seedling transplanted in 12 dSm^{-1}saline soil).

4.9.2 Effect of modified chitosan on the grain yield of rice

The effects of modified chitosan on the grain yield of rice are presented in (Table 4.11). There was significance variation on the grain yield of rice. C_1 (20 g modified chitosan/pot) showed the highest grain yield (38.08g) and C_2 (40 g modified chitosan/pot) showed lowest grain yield (22.75g). Boonlertnirun, *et al.*, (2006) reported that rice yield cultivar Suphan Buri1 was significantly increased after application of polymeric chitosan at the concentration of 20 ppm.

4.9.3 Combined effects of salinity and modified chitosan on the grain yield of rice

The significant variation was observed on the combined effect of salinity and modified chitosan on the grain yield of rice due to the different levels of salinity and different dosesof chitosan presented in (Table 4.10). The highest grain yield of rice (85.00 g) was recorded with the S_0C_1 (seedling transplanted in normal soil+20g modified chitosan/pot) treatment combination. On the other hand, the lowest straw yield of rice was (14.66g) was found in S_2C_2 (seedling transplanted in 8 dSm^{-1} saline soil + 40 g modified chitosan/pot) treatment combination.

4.10 NPKS concentration in rice straw

4.10.1 Effect of salinity on N concentration in rice straw

The effects of salinity on N concentration in straw of boro rice was significant are presented in (Table 4.13). S_2 (seedling transplanted in 8 dSm^{-1} saline soil) showed the highest N concentration in straw (1.74%) and S_3 (seedling transplanted in 12 dSm^{-1} saline soil) showed the lowest N concentration in straw (0.87%).

Table 4.13 Effect of salinity on NPKS concentration in rice straw

Treatments	Concentration (%) in straw			
	N	P	K	S
S_0	1.382 c	0.153a	0.338 b	0.460 a
S_1	1.592 b	0.141 b	0.344 a	0.263 b
S_2	1.744 a	0.127 c	0.322 c	0.184 c
S_3	0.875 d	0.099 d	0.314 d	0.119 d
CV%	1.48	0.69	0.35	3.07
LSD (0.05)	0.02	8.78	1.14	7.71

4.10.2 Effect of modified chitosan on N concentration in rice straw

Nitrogen concentrations in straw of boro rice showed significant variation due to the application of different doses of modified chitosan are presented in (Table 4.14). The highest N concentration in straw (1.50%) was recorded from C_2 (40 g modified chitosan/pot). On the other hand, the lowest N concentration in straw (1.29%) was found from C_1 (20 g modified chitosan/pot).

Table 4.14 Effect of modified chitosan on NPKS concentration in rice straw

Treatments	Concentration (%) in straw			
	N	P	K	S
C_0	1.402 b	0.136 a	0.335 a	0.287 b
C_1	1.290 c	0.125 c	0.326 c	0.188 c
C_2	1.503 a	0.128 b	0.328 b	0.294 a
CV%	1.48	0.69	0.35	3.07
LSD (0.05)	0.17	7.61	9.87	6.68

4.10.3 Combined effects of salinity and modified chitosan on the N concentration of rice straw

The significant variation was observed on the combined effect of salinity and modified chitosan on the N concentration of rice straw due to the different levels of salinity and different doses of modified chitosan presented in (Table 4.15). The highest N concentration in boro rice straw (1.903%) was recorded with the treatment combination of S_1C_2 (seedling transplanted in 4 dSm^{-1} saline soil + 40 g modified chitosan/pot). On the other hand, the lowest N concentration in straw of rice (0.885%) was found in S_3C_2 (seedling transplanted in 12 dSm^{-1} saline soil + 40 g modified chitosan/pot) treatment combination.

Table 4.15 Combined effects of salinity and modified chitosan on the NPKS concentration in rice straw

Treatments	Concentration (%) in straw			
	N	P	K	S
S_0C_0	1.300 f	0.158 b	0.335 d	0.530 a
S_0C_1	1.396 e	0.146 e	0.343 b	0.404 c
S_0C_2	1.450 d	0.156 c	0.337 d	0.447 b
S_1C_0	1.716 c	0.160 a	0.346 a	0.371 d
S_1C_1	1.156 g	0.153 d	0.340 c	0.124fg
S_1C_2	1.903 a	0.112 g	0.348 a	0.295 e
S_2C_0	1.726 c	0.118 f	0.327 f	0.135 f
S_2C_1	1.733 c	0.108 i	0.303 h	0.115 g
S_2C_2	1.773 b	0.155 c	0.337 d	0.304 e
S_3C_0	0.866 h	0.110 h	0.333 e	0.115 g
S_3C_1	0.876 h	0.094 j	0.320 g	0.111 g
S_3C_2	0.885 h	0.092 k	0.291 i	0.132 f
CV%	1.48	0.69	0.35	3.07
LSD (0.05)	0.03	1.52	1.97	0.01

4.10.4 Effect of salinity on P concentration in rice straw

The effects of salinity on P concentration in straw of boro rice are presented in (Table 4.13). Significant variation was observed on P concentration in straw of rice. S_0 (seedling transplanted in normal soil) showed the highest P concentration in straw (0.153%) and S_3 (seedling transplanted in 12 dSm^{-1} saline soil) showed the lowest P concentration in

straw (0.099%). P concentration was decreased in a dose dependent manner with increasing the salinity levels.

4.10.5 Effect of modified chitosan on P concentration in rice straw

Phosphorus concentrations in straw of boro rice showed significant variation due to the application of different doses of modified chitosan are presented in (Table 4.14). The highest P concentration in straw (0.136%) was recorded from C_0 0 g modified chitosan/pot). On the other hand, the lowest P concentration in straw (0.125%) was found from C_1 (20 g modified chitosan/pot).

4.10.6 Combined effects of salinity and modified chitosan on the P concentration of rice straw

The significant variation was observed on the combined effect of salinity and modified chitosan on the P concentration of rice straw due to the different levels of salinity and different doses of chitosan presented in (Table 4.15). The highest P concentration in boro rice straw (0.160%) was recorded with the treatment combination of S_1C_0 (seedling transplanted in 4 dSm^{-1} saline soil + 0 modified chitosan/pot). On the other hand, the lowest P concentration in straw of rice (0.092%) was found in S_3C_2 (seedling transplanted in 12 dSm^{-1} saline soil + 40 g modified chitosan/pot) treatment combination.

4.10.7 Effect of salinity on K concentration in rice straw

The effects of salinity on K concentration in straw of boro rice are presented in (Table 4.13). Significant variation was observed on K concentration in straw of rice when the pot was added by saline water. S_1 (seedling transplanted in 4 dsm^{-1} saline soil) showed the highest K concentration in straw (0.344%) and S_3 (seedling transplanted in 12 dSm^{-1} saline soil) showed the lowest K concentration in straw (0.314%).

4.10.8 Effect of modified chitosan on K concentration in rice straw

The K concentrations in straw of boro rice showed significant variation due to the application of different doses of modified chitosan are presented in (Table 4.14). The highest K concentration in straw (0.335%) was recorded from C_0 (0 g modified chitosan/pot). On the other hand, the lowest K concentration in straw (0.326%) was found from C_1 (20 g modified chitosan/pot).

4.10.9 Combined effects of salinity and modified chitosan on the K concentration in rice straw

The significant variation was observed on the combined effect of salinity and modified chitosan on the K concentration of rice straw due to the different levels of salinity and different doses of chitosan presented in (Table 4.15). The highest K concentration in boro rice straw (0.346%) was recorded with the treatment combination of S_1C_0 (seedling transplanted in 4 dSm^{-1} saline soil + 0 g modified chitosan/pot). On the other hand, the lowest K concentration in straw of rice (0.291%) was found in S_3C_2 (seedling transplanted in 12 dSm^{-1} saline soil + 40 g modified chitosan/pot) treatment combination.

4.10.10 Effect of salinity on S concentration in rice straw

The effects of salinity on S concentration in straw of boro rice are presented in (Table 4.13). Significant variation was observed on S concentration in straw of rice when the pot was added by saline water. S_0 (seedling transplanted in normal soil) showed the highest S concentration in straw (0.460%) and S_3 (seedling transplanted in 12 dSm^{-1} saline soil) showed the lowest S concentration in straw (0.119%). S concentration was decreased in a dose dependent manner with increasing the salinity levels.

4.10.11 Effect of modified chitosan on S concentration in rice straw

The S concentrations in straw of boro rice showed significant variation due to the application of different doses of modified chitosan are presented in (Table 4.14). The highest S concentration in straw (0.294%) was recorded from C_2 (40 g modified chitosan/pot). On the other hand, the lowest S concentration in straw (0.188%) was found from C_1(20 g modified chitosan/pot).

4.10.12 Combined effects of salinity and modified chitosan on the S concentration in rice straw

The significant variation was observed on the combined effect of salinity and modified chitosan on the S concentration of rice straw due to the different levels of salinity and different doses of chitosan presented in (Table 4.15). The highest S concentration in boro rice straw (0.530%) was recorded with the treatment combination of S_0C_0 (seedling transplanted in normal soil + 0 g modified chitosan/pot). On the other hand, the lowest S concentration in straw of rice (0.111%) was found in S_3C_1 (seedling transplanted in 12 dSm^{-1} saline soil + 20 g modified chitosan/pot) treatment combination.

4.11 NPKS concentration in rice grain

4.11.1 Effect of salinity on N concentration in rice grain

The effects of salinity on N concentration in boro rice grain are presented in (Table 4.16). Significant variation was observed on N concentration in grain of rice due to different levels of salinity. S_1 (seedling transplanted in 4 dSm^{-1} saline soil) showed the highest N concentration in grain (2.312%) and S_2 (seedling transplanted in 8 dSm^{-1} saline soil) showed the lowest N concentration in straw (1.498%). N concentration was zero (0) in the S_3 (seedling transplanted in 12 dsm^{-1} saline soil).

Table 4.16 Effect of salinity on NPKS concentration in grain

Treatments	Concentration (%) in grain			
	N	P	K	S
S_0	1.623 b	0.143 a	0.318 a	0.059 a
S_1	2.312 a	0.145 a	0.314 b	0.043 c
S_2	1.498 c	0.124 b	0.272 c	0.050 b
S_3	0.000 d	0.000 c	0.000 d	0.000 d
CV%	1.74	2.23	1.17	5.82
LSD (0.05)	0.0231	2.32	2.59	2.19

4.11.2 Effect of modified chitosan on N concentration in rice grain

Nitrogen concentrations in grain of boro rice showed significant variation due to the application of different doses of modified chitosan are presented in (Table 4.17). The highest N concentration in grain (1.589%) was recorded from C_2 (40 g modified chitosan/pot). On the other hand, the lowest N concentration in grain (1.075%) was found from C_0 (0 g modified chitosan/pot).

Table 4.17 Effect of modified chitosan on NPKS concentration in grain

Treatments	Concentration (%) in grain			
	N	P	K	S
C_0	1.075 c	0.100 b	0.214 b	0.025 c
C_1	1.410 b	0.110a	0.232 a	0.040 b
C_2	1.589 a	0.110 a	0.232 a	0.048 a
CV%	1.74	2.30	1.17	5.82
LSD (0.05)	0.02	2.01	2.24	1.89

4.11.3 Combined effects of salinity and modified chitosan on the N concentration of rice grain

The significant variation was observed on the combined effect of salinity and modified chitosan on the N concentration of rice grain due to the different levels of salinity and different doses of chitosan presented in (Table 4.18). The highest N concentration in boro rice grain (2.88%) was recorded with the treatment combination of S_1C_2 (seedling transplanted in 4 dSm^{-1} saline soil + 40 g modified chitosan/pot). On the other hand, the lowest N concentration in grain of rice (1.396%) was found in S_2C_0 (seedling transplanted in 8 dSm^{-1} saline soil + 0 g modified chitosan/pot) treatment combination. In case of S_3C_1, S_3C_1, S_3C_2 plants were not survive.

Table 4.18 Combined effects of salinity and modified chitosan on the NPKS concentration in rice grain

Treatments	Concentration (%) in grain			
	N	P	K	S
S_0C_0	1.450 g	0.150 a	0.320 a	0.033fg
S_0C_1	1.543 e	0.130 c	0.314 b	0.054 d
S_0C_2	1.876 c	0.150 a	0.321 a	0.092 a
S_1C_0	1.456 g	0.140 b	0.310bc	0.035 f
S_1C_1	2.596 b	0.147 a	0.323 a	0.065 c
S_1C_2	2.883 a	0.150 a	0.309 c	0.031 g
S_2C_0	1.396 h	0.110 e	0.227 f	0.035 f
S_2C_1	1.503f	0.121 d	0.291 e	0.044 e
S_2C_2	1.596 d	0.141 b	0.300 d	0.072 b
S_3C_0	0.000 i	0.000 f	0.000 g	0.000 h
S_3C_1	0.000 i	0.000 f	0.000 g	0.000 h
S_3C_2	0.000 i	0.000 f	0.000 g	0.000 h
CV%	1.74	2.30	1.17	5.82
LSD (0.05)	0.04	4.03	4.49	3.79

4.11.4 Effect of salinity on P concentration in rice grain

The effects of salinity on P concentration in grain of boro rice are presented in (Table 4.16). Significant variation was observed on P concentration in grain of rice due to different levels of salinity. S_1 (seedling transplanted in 4 dSm^{-1} saline soil) showed the highest P concentration in grain (0.145%) and S_2 (seedling transplanted in 8 dSm^{-1} saline

soil) showed the lowest N concentration in grain (0.124%). P concentration was zero (0) in the S_3 (seedling transplanted in 12 dSm^{-1} saline soil).

4.11.5 Effect of modified chitosan on P concentration in rice grain

Phosphorus concentrations in grain of boro rice showed significant variation due to the application of different doses of modified chitosan are presented in (Table 4.17). The highest P concentration in (0.110%) was recorded from C_1 (20 g modified chitosan/pot). On the other hand, the lowest P concentration in grain (0.100%) was found from C_0(0 g modified chitosan/pot).

4.11.6 Combined effects of salinity and modified chitosan on the P concentration of rice grain

The significant variation was observed on the combined effect of salinity and modified chitosan on the P concentration of rice grain due to the different levels of salinity and different doses of chitosan presented in (Table 4.18). The highest P concentration in boro rice grain (0.150%) was recorded with the treatment combination of S_0C_0 (seedling transplanted in normal soil + 0 gmodified chitosan/pot). On the other hand, the lowest P concentration in grain of rice (0.110%) was found in S_2C_0 (seedling transplanted in 8 dSm^{-1} saline soil + 0 g modified chitosan/pot) treatment combination.

4.11.7 Effect of salinity on K concentration in rice grain

The effects of salinity on K concentration in grain of boro rice are presented in (Table 4.16). Significant variation was observed on K concentration in grain of rice. Concentration of K was decreased in a dose dependent manner with increasing the salinity levels. S_0 (seedling transplanted in normal soil) showed the highest K concentration in grain (0.318%) and S_2 (seedling transplanted in 8 dSm^{-1} saline soil) showed the lowest K concentration in grain (0.272%). K concentration was zero (0) in the S_3 (seedling transplanting in 12 dSm^{-1} saline soil).

4.11.8 Effect of modified chitosan on K concentration in rice grain

The K concentrations in grain of boro rice showed significant variation due to the application of different doses of modified chitosan are presented in (Table 4.17). The highest K concentration in grain (0.232%) was recorded from C_1 (20 g modified chitosan/pot) which is similar to C_2 (40 g modified chitosan/pot). On the other hand, the lowest K concentration in grain (0.214%) was found from C_0 (0 g modified chitosan/pot).

4.11.9 Combined effects of salinity and modified chitosan on the K concentration in rice grain

The significant variation was observed on the combined effect of salinity and modified chitosan on the K concentration of rice grain due to the different levels of salinity and different doses of chitosan presented in (Table 4.18). The highest K concentration in boro rice grain (0.320%) was recorded with the treatment combination of S_0C_0 (seedling transplanted in normal soil + 0 g modified chitosan/pot). On the other hand, the lowest K concentration in grain of rice (0.227%) was found in S_2C_0 (seedling transplanted in 8 dSm^{-1} saline soil + 0 g modified chitosan/pot) treatment combination.

4.11.10 Effect of salinity on S concentration in rice grain

The effects of salinity on S concentration in grain of boro rice are presented in (Table 4.16). Significant variation was observed on S concentration in grain of rice. S_0 (seedling transplanted in normal soil) showed the highest S concentration in grain (0.059%) and S_1 (seedling transplanted in 4 dSm^{-1} saline soil) showed the lowest S concentration in grain (0.043%). S concentration was zero (0) in the S_3 (seedling transplanted in 12 dSm^{-1} saline soil).

4.11.11 Effect of modified chitosan on S concentration inrice grain

The S concentrations in grain of boro rice showed significant variation due to the application of different doses of modified chitosan are presented in (Table 4.17). The highest S concentration in grain (0.048%) was recorded fromC_2(40 g modified chitosan/pot). On the other hand, the lowest S concentration in grain (0.025%) was found from C_0(0 g modified chitosan/pot).

4.11.12 Combined effects of salinity and modified chitosan on the S concentration of rice grain

The significant variation was observed on the combined effect of salinity and modified chitosan on the S concentration of rice grain due to the different levels of salinity and different doses of chitosan presented in (Table 4.18). The highest S concentration in boro rice grain (0.092%) was recorded with the treatment combination of S_0C_2 (seedling transplanted in normal soil +40 g modified chitosan/pot). On the other hand, the lowest S concentration in grain of rice (0.031%) was found in S_1C_2 (seedling transplanted in 4 dSm^{-1} saline soil + 40 g modified chitosan/pot) treatment combination.

4.12 pH, organic matter and NPKS status in post harvest soil

4.12.1 Effect of salinity on pH in post harvest soil

There was significant change of pH in post harvest soil (Table 4.19). S_0 (seedling transplanted in normal soil) showed the highest pH (6.911) in post harvest soil and S_3 (seedling transplanted in 12 dSm^{-1} saline soil) showed the lowest pH (6.400) in post harvest soil.

Table 4.19 Effect of salinity on the pH, organic matter and NPKS concentration in post harvest soil

Treatment	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Available K (meq/100g soil)	Available S (ppm)
S_0	6.911 a	1.540 a	0.197 b	49.293 a	0.186 c	60.53 d
S_1	6.633 b	1.671 a	0.226 a	50.077 a	0.219 b	100.77 a
S_2	6.600 b	1.565 a	0.167 d	32.292 b	0.262 a	74.05 b
S_3	6.400 c	1.595 a	0.177 c	49.933 a	0.260 a	70.67 c
CV%	1.01	8.82	0.29	2.19	6.31	0.50
LSD (0.05)	0.06	0.13	5.49	0.97	0.01	0.37

4.12.2 Effect of modified chitosan on pH in post harvest soil

pH of post harvest soil showed significant variation due to the application of different doses of modified chitosan (Table 4.20). The highest pH of post harvest soil (6.67) was recorded from C_0 (0 g modified chitosan/pot) which is similar to C_1 (20 g modified chitosan/pot). On the other hand, the lowest pH of post harvest soil (6.56) was recorded from C_2 (40 g modified chitosan/pot).

Table 4.20 Effect of modified chitosan on the pH, organic matter and NPKS concentration in post harvest soil

Treatment	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Available K (meq/100g soil)	Available S (ppm)
C_0	6.675 a	1.121 b	0.185 b	48.724 a	0.255 a	88.908 a
C_1	6.666 a	1.788 a	0.208 a	44.237 b	0.220 b	71.160 b
C_2	6.566b	1.869 a	0.183 c	43.236 c	0.220 b	69.440 c
CV%	1.01	8.82	0.29	2.19	6.31	0.50
LSD (0.05)	**0.05**	**0.11**	**4.75**	**0.84**	**0.01**	**0.32**

4.12.3 Combined effects of salinity and modified chitosan on pH in post harvest soil

The significant variation was observed on the combined effect of salinity and modified chitosan on pH of post harvest soil due to the different levels of salinity and different doses of chitosan presented in (Table 4.21). The highest pH of post harvest soil (7.16) was recorded with the treatment combination S_0C_1 (seedling transplanted in normal soil + 20 g modified chitosan/pot). On the other hand, the lowest pH of post harvest soil (6.4) was recorded with the treatment combination of S_2C_2 (seedling transplanted in 8 dSm^{-1} saline soil + 40 g modified chitosan/pot).

Table 4.21 Combined effects of salinity and modified chitosan on the the pH, organic matter and NPKS content in post harvest soil

Treatment	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Available K (meq/100g soil)	Available S (ppm)
S_0C_0	6.800bc	1.050c	0.178h	45.253d	0.206def	90.30d
S_0C_1	7.166a	1.770a	0.182g	50.937b	0.191ef	56.60j
S_0C_2	6.766c	1.800a	0.231b	51.690ab	0.162g	34.68 l
S_1C_0	6.600de	1.326b	0.188e	52.943a	0.230cd	106.00b
S_1C_1	6.600de	1.800a	0.318a	52.023ab	0.184fg	110.26a
S_1C_2	6.700cd	1.886a	0.172i	45.263d	0.243c	86.04e
S_2C_0	6.900b	1.056c	0.187e	48.600c	0.300a	81.79f
S_2C_1	6.500ef	1.786a	0.116k	25.397 e	0.212de	41.22k
S_2C_2	6.400f	1.853a	0.200d	22.880f	0.275a	99.13c
S_3C_0	6.400f	1.053c	0.186f	48.100c	0.285ab	77.54g
S_3C_1	6.400f	1.796a	0.217c	48.590c	0.293ab	76.56h
S_3C_2	6.400f	1.936a	0.130j	53.110a	0.203ef	57.91i
CV%	1.01	8.82	0.23	2.19	6.31	0.50
LSD (0.05)	0.11	0.23	9.51	1.68	0.02	0.65

4.12.4 Effect of salinity on organic matter in post harvest soil

Statistically insignificant variation was recorded for organic matter in post harvest soil (Table 4.19). S_1 (seedling transplanting in 4 dSm^{-1} saline soil) showed the highest organic matter (1.67%) in post harvest soil which was similar to S_0 (seedling transplanted

in normal soil), S_2 (seedling transplanted in 8 dSm^{-1} saline soil) and S_3 (seedling transplanted in 12 dSm^{-1} saline soil).

4.12.5 Effect of modified chitosan on organic matter in post harvest soil

The organic matter of post harvest soil showed significant variation due to the application of different doses of modified chitosan (Table 4.20). The highest value of organic matter in post harvest soil (1.869) was recorded from C_2 (40 g modified chitosan/pot) which is similar to C_1 (20 g modified chitosan/pot).On the other hand, the lowest value of organic matter in post harvest soil (1.121) was recorded from C_0 (0 g modified chitosan/pot).

4.12.6 Combined effects of salinity and modified chitosan on organic matter in post harvest soil

The significant variation was observed on the combined effect of salinity and modified chitosan on organic matter in post harvest soil due to the different levels of salinity and different doses of chitosan presented in (Table 4.21).The highest value of organic matter in post harvest soil (1.93) was recorded with the treatment combination S_3C_2 (seedling transplanted in 12 dSm^{-1} saline l soil + 40 g modified chitosan/pot). On the other hand, the lowest value of organic matter in post harvest soil (1.050) was recorded with the treatment combination of S_0C_0 (seedling transplanted in normal soil + 0 g modified chitosan/pot).

4.12.7 Effect of salinity on N concentration in post harvest soil

There was significant change of N concentration in post harvest soil (Table 4.19). S_1 (seedling transplanted in 4 dSm^{-1} saline soil) showed the highest N concentration in post harvest soil (0.226) and S_3 (seedling transplanted in 12 dSm^{-1} saline soil) showed the lowest N concentration in post harvest soil (0.177).

4.12.8 Effect of modified chitosan on N concentration in post harvest soil

Nitrogen concentrations of post harvest soil showed significant variation due to the application of different doses of modified chitosan are presented in (Table 4.20). The highest N concentration in post harvest soil (0.208) was recorded from C_1 (20 g modified chitosan/pot). On the other hand, the lowest N concentration of post harvest soil (0.18) was found from C_2 (40 g modified chitosan/pot).

4.12.9 Combined effects of salinity and modified chitosan on the N concentration in post harvest soil

The significant variation was observed on the combined effect of salinity and modified chitosan on N concentration in post harvest soil due to the different levels of salinity and different doses of chitosan presented in (Table 4.21). The highest N concentration of post harvest soil (0.318) was recorded with the treatment combination of S_1C_1 (seedling transplanting in 4 dSm^{-1} saline soil + 20 g modified chitosan/pot). On the other hand, the lowest N concentration of post harvest soil (0.130) was found in S_3C_2 (seedling transplanting in 12 dSm^{-1} saline soil + 40 g modified chitosan/pot) treatment combination.

4.12.10 Effect of salinity on P concentration in post harvest soil

There wassignificant change of P in post harvest soil (Table 4.19). S_1 (seedling transplanted in 4 dSm^{-1} saline soil) showed the highest P concentration in post harvest soil (50.077) and S_2 (seedling transplanted in 8 dSm^{-1} saline soil) showed the lowest P concentration in post harvest soil(32.292).

4.12.11 Effect of modified chitosan on P concentration in post harvest soil

The P concentrations of post harvest soil showed significant variation due to the application of different doses of modified chitosan are presented in (Table 4.20). The highest P concentration in post harvest soil (48.724) was recorded from C_0 (0 g modified

chitosan/pot). On the other hand, the lowest P concentration of post harvest soil (43.236) was found from C_2 (40 g modified chitosan/pot).

4.12.12 Combined effects of salinity and modified chitosan on the P concentration in post harvest soil

The significant variation was observed on the combined effect of salinity and modified chitosan on P concentration in post harvest soil due to the different levels of salinity and different doses of chitosan presented in (Table 4.21).The highest P concentration of post harvest soil (53.110) was recorded with the treatment combination of S_3C_2 (seedling transplanted in 12 dSm^{-1} saline soil + 40 g modified chitosan/pot). On the other hand, the lowest P concentration of post harvest soil (22.880) was found in S_2C_2 (seedling transplanted in 8 dSm^{-1} saline soil + 40 g modified chitosan/pot) treatment combination.

4.12.13 Effect of salinity on K concentration in post harvest soil

There wassignificant change of K in post harvest soil (Table 4.22). S_2 (seedling transplanted in 8 dSm^{-1} saline soil) showed the highest K concentration in post harvest soil (0.262) is closed to S_3. On the other hand, S_0 (seedling transplanted in normal soil) showed the lowest K concentration in post harvest soil (0.186).

4.12.14 Effect of modified chitosan on K concentration in post harvest soil

The K concentrations of post harvest soil showed significant variation due to the application of different doses of modified chitosan are presented in (Table 4.20). The highest P concentration in post harvest soil (0.255) was recorded from C_0 (0 g modified chitosan/pot). On the other hand, the lowest P concentration of post harvest soil (0.221) was found from C_2 (40 g modified chitosan/pot).

4.12.15 Combined effects of salinity and modified chitosan on the K concentration in post harvest soil

The significant variation was observed on the combined effect of salinity and modified chitosan on K concentration in post harvest soil due to the different levels of salinity and different doses of chitosan presented in (Table 4.21). The highest K concentration of post harvest soil (0.300) was recorded with the treatment combination of S_2C_0 (seedling transplanted in 8 dSm^{-1} saline soil + 0 g modified chitosan/pot). On the other hand, the lowest K concentration of post harvest soil (0.162) was found in S_0C_2 (seedling transplanted in normal soil + 40 g modified chitosan/pot) treatment combination.

4.12.16 Effect of salinity on S concentration in post harvest soil

There was significant change of S in post harvest soil (Table 4.19). S_1 (seedling transplanted in 4 dSm^{-1} saline soil) showed the highest concentration in post harvest soil (100.77) and S_0 (seedling transplanted in normal soil) showed the lowest concentration in post harvest soil (60.53).

4.12.17 Effect of modified chitosan on S concentration in post harvest soil

The S concentrations in post harvest soil showed significant variation due to the application of different doses of modified chitosan are presented in (Table 4.20). The highest S concentration in post harvest soil (88.908) was recorded from C_0 (0 g modified chitosan/pot). On the other hand, the lowest S concentration of post harvest soil (69.44) was found from C_2 (40 g modified chitosan/pot).

4.12.18 Combined effects of salinity and modified chitosan on the S concentration in post harvest soil

The significant variation was observed on the combined effect of salinity and modified chitosan on S concentration in post harvest soil due to the different levels of salinity and different doses of chitosan presented in (Table 4.21). The highest S concentration of post harvest soil (110.26) was recorded with the treatment combination of S_1C_1 (seedling transplanted in 4 dSm^{-1} saline soil + 20 g modified chitosan/pot). On the other hand, the lowest S concentration of post harvest soil (34.68) was found in S_0C_2 (seedling transplanted in normal soil + 40 g modified chitosan/pot) treatment combination.

SUMMARY AND CONCLUSION

The experiment was conducted in the net house of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from December 2015 to April 2016 to study the role of modified chitosan on rice (BRRI dhan29) cultivation in saline soil. BRRI dhan29 was used as the test crop in this experiment. The experiment consists of 2 factors i.e. salinity and modified chitosan. Different doses of modified chitosan (C_0-0 g modified chitosan/pot, C_1-20 g modified chitosan/pot and C_2-40 g modified chitosan/pot). Different levels of salinity (S_0- seedling transplanting in normal soil, S_1-seedling transplanting in 4 dSm^{-1} saline soil, S_2-seedling transplanting in 8 dSm^{-1} saline soil, S_3-seedling transplanting in 12 dSm^{-1} saline soil). The treatment combinations were C_0S_0 (0 g modified chitosan/pot + seedling transplanting in normal soil), C_0S_1 (0 g modified chitosan/pot + seedling transplanting in 4 dSm^{-1} saline soil), C_0S_2 (0 g modified chitosan/pot + seedling transplanting in 8 dSm^{-1} saline soil), C_0S_3 (0 g modified chitosan/pot + seedling transplanting in 12 dSm^{-1} saline soil), C_1S_0 (20 g modified chitosan/pot + seedling transplanting in normal soil), C_1S_1 (20g modified chitosan/pot + seedling transplanting in 4 dSm^{-1} saline soil), C_1S_2 (20g modified chitosan/pot + seedling transplanting in 8 dSm^{-1} saline soil), C_1S_3 (20g modified chitosan/pot + seedling transplanting in 12 dSm^{-1} saline soil), C_2S_0 (40g modified chitosan/pot + seedling transplanting in normal soil), C_2S_1 (40g modified chitosan/pot + seedling transplanting in 4 dSm^{-1} saline soil), C_2S_2 (40g modified chitosan/pot + seedling transplanting in 8 dSm^{-1} saline soil), C_2S_3 (40g modified chitosan/pot + seedling transplanting in 12 dSm^{-1} saline soil). The experiments was laid out in randomized complete block design (RCBD) with 3 replications. The total number of effective tillers/hill, plant height, panicle length, number of filled grain/panicle, 1000 grain weight, grain yield and straw yield were significantly

affected by effect of salinity. The highest value of effective tillers/hill, plant height, panicle length, number of filled grain/panicle, 1000 grain weight, grain yield and straw yield were observed when the levels of salinity was S_0 (seedling transplanting in normal soil) and the variation were significant. The lowest value was observed when the level of salinity was S_3 (seedling transplanting in 12 dSm^{-1} saline soil).

Yield contributing characters and yields were significantly affected by modified chitosan. The higher values of yield parameters and yields were recorded in the treatments where modified chitosan was used. The highest effective tillers/hill (23.91), plant height (60.24 cm), panicle length (19.37cm), 1000 grain wt. (14.83g), grain yield (38.08g) and straw yield (47.08g) were found from C_1 (20g modified chitosan/pot). On the other hand in most cases lowest values were obtained from C_2 (40g modified chitosan/pot).The highest values of effective tillers/hill (49.00), plant height (78.68), panicle length (27.87), 1000 seed wt. (21.33), and grain yield (85.00) were recorded from S_0C_1 (seedling transplanting in normal soil + 20g modified chitosan/pot). The lowest values of effective tillers/hill (0.00), plant height (30.14cm), panicle length (0.00 cm), 1000 grain wt. (0.00g) grain yield (0.00g) and straw yield (0.00g) were observed from S_3C_2 (seedling transplanting in 12 dSm^{-1} saline soil + 40g modified chitosan/pot).

Nutrient concentration in grain and straw of rice plant was significantly affected by application of salinity and modified chitosan. In case of salinity, the highest concentrations of straw N (1.744%) recorded from S_2, P (0.153%) & S (0.460%) from S_0, K (0.344%) from S_1, and in all cases lowest value was observed in S_3treatment. Similarly the highest concentrations of grain N (2.312%) and P (0.145%) were recorded from S_1 , K(0.318%) & S(0.059%) were recorded from S_0 and in all cases lowest value was observed in

S_3treatment. In case of application of modified chitosan the highest concentrations of straw N(1.503%) & S (0.294%) were recorded from C_2, P(0.13%) & K(0.33%) were recorded from $C_0$and in all cases lowest value was observed in C_1. Similarly the highest concentrations of grain N (1.589%), P (0.110 %), K (0.232 %) & S (0.048 %) were recorded from C_2 and in all cases lowest value was observed in C_0.

The pH, organic matter and levels of N, P, K and S of post harvest soil were significantly affected by salinity and chitosan. In case of salinity, the highest pH (6.91) was recorded from S_0, organic matter (1.67%), total N (0.226%), available P (50.07ppm), and S (100.77 ppm) were recorded fromS_1, K (0.262meq/100g soil) was recorded from S_2. the lowest pH (6.400), total N (0.177 %), S (70.67 ppm) were recorded from S_3, P (32.29ppm) was recorded from S_2. In case of application of modified chitosan, the highest pH (6.66),organic matter (1.788%), total N (0.208) were recorded from C_1, available P (48.724ppm), K(0.25 meq/100g soil), S (88.90ppm) were recorded from C_0.The lowest pH (6.56), total N (0.18 %), P (43.236ppm), K (0.220meq/100g soil), S (69.44%) were recorded from C_2 & organic matter (1.12%) was recorded from C_0. In case of combined application of salinity and modified chitosan the highest pH (7.16), organic matter (1.77%) recorded from S_0C_1, N (0.31%) & S (110.2ppm) were from S_1C_1, P (52.94 ppm) from S_1C_0, K (0.300meq/100g soil) from S_2C_0. The lowest pH (6.40), organic matter (1.05%) from S_3C_0, N (0.11%) from S_2C_1, P (22.88) from S_2C_2, K (0.16 meq/100g soil) & S (34.68) from S_0C_2.

From the above discussion it can be concluded that application of modified chitosan could play significant role to increase the grain yield of rice and could improve the salt tolerance in rice. Application of 20g modified chitosan/pot is most favorable for improving yield and

yield contributing characters of rice (BRRI dhan29) in Boro season. Seedling transplanting in normal soil is preferable.

Before recommend the findings of the present study, the following recommendations and suggestions may be made:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.
2. The study is needed to conduct in saline prone area.

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APPENDICES

Appendix I. Monthly average of air temperature, Relative Humidity and Total rainfall of the experimental site during the period from October 2015 to April 2016

Month	Air Temperature (^{o}C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
October, 2015	31.6	20.8	63	1
November, 2015	30.3	18	70	1
December, 2015	26.7	13	73	0
January, 2016	26.0	13.2	72	1
February, 2016	32.9	19.2	61	1
March, 2016	35.8	22.5	65	60
April, 2016	37.9	23.1	62	67

Source: Bangladesh Metrological Department (Climate division), Agargaon. Dhaka-1212.