AMELIORATION OF SALT STRESS IN AROMATIC RICE BY APPLICATION OF DIFFERENT ORGANIC MANURES

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JUNE, 2021

AMELIORATION OF SALT STRESS IN AROMATIC RICE BY APPLICATION OF DIFFERENT ORGANIC MANURES

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REGISTRATION NO.: 13-05252

A Thesis

Submitted to the Faculty of Agriculture,

Sher-e-Bangla Agricultural University, Dhaka,

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

IN

AGRONOMY

SEMESTER: JANUARY-JUNE, 2021

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CERTIFICATE

*This is to certify that thesis entitled, "**AMELIORATION OF SALT STRESS IN AROMATIC RICE BY APPLICATION OF DIFFERENT ORGANIC MANURES**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **S.M. SHIHAB SHAHRIAR, Registration no. 13-05252** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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DEDICATED TO MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises are putting forward to Allah (SWT) Who is the Supreme Planner and has blessed the author to complete this piece of study as required for the degree Master of Science.

It is a great pleasure for the author to make delighted his respected parents, who had been shouldering all kinds of hardship to establish a favourable platform thereby receiving proper education until today.

The author is happy to express his sincere appreciation and profound gratitude to his respected ***Supervisor Assoc. Prof. Anisur Rahman, Ph.D****, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his dynamic guidance, constant encouragement, constructive criticism and valuable suggestions encompassed the research work and thesis writing times.*

It is a great pleasure for the author to express his deep sense of gratitude and sincere regards to his Co-Supervisor ***Prof. Dr. Md. Fazlul Karim****, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his adept guidance, supervision, kind cooperation, and valuable suggestions in preparation of the thesis.*

It is highly appreciating words for ***Prof. Dr. Tuhin Suvra Roy,*** *Chairman, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka along with faculties of the Department of Agronomy, Sher-e-Bangla Agricultural University for their rendered novel services towards me as their student.*

The author also expresses heartfelt thanks to the staff of Department of Agronomy and central farm, SAU, for their valuable suggestions, instructions cordial help and encouragement during the period of research work.

The author wish to extend his special thanks to his classmates and friends for their keen help as well as heartfelt co-operation and encouragement.

The author express his thanks to his family and friends who continuously prayed for his success and without whose love, affection, inspiration and sacrifice this work would not have been completed.

May Allah (SWT) bless and protect them all.

The Author

AMELIORATION OF SALT STRESS IN AROMATIC RICE BY APPLICATION OF DIFFERENT ORGANIC MANURES

ABSTRACT

A pot experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from July to December 2020 to ameliorate the salt stress in aromatic rice by application of different organic manures. The two factor experiment was conducted by following RCBD design with four replications. Factor A consisted three NaCl levels *viz;* S_0 = 0 ppm pot^{-1} (Control), S_1= 1200 ppm pot^{-1} and S_2 = 2400 ppm pot^{-1} and Factor B consisted five types of organic manures *viz* M_0 = No organic manure (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}. Result revealed that salinity decreased plant height, leaf number, tiller number, LAI, SPAD value, RWC, grain yield and other yield attributes. Exposer of 1200 ppm and 2400 ppm NaCl decreased grain yield by 7 and 16% in Binadhan-13 compared to control by decreasing effective tillers. Application of different organic manures such as Biochar, Vermicompost, Azolla and Cowdung significantly influences growth and yield of aromatic rice. Vermicompost application (6 t ha^{-1}) recorded the highest number of effective tillers hill^{-1} (10.40), filled grains panicle^{-1} (98.83), grain yield (25.25 g pot^{-1}), straw yield (94.09 g pot^{-1}), biological yield (119.35 g pot^{-1}) and harvest index (21.12 %). Different types of organic manures application under NaCl stress condition recovered growth and yield loss of aromatic rice. Among the organic manures Vermicompst gave highest grain yield in all stresses *viz* S_0M_2 (28.15 g pot^{-1}), S_1M_2 (24.45 g pot^{-1}) and S_2M_2 (23.15 g pot^{-1}) comparable to others treatment combinations. So, it might be concluded that, the growth and yield of rice decreased with the increasing dose of salt and application of different organic manures recovered growth and yield of rice by ameliorating salt stress. However, application of Vermicompost might be the best approach to reduce salt-induced damages in rice.

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ABBREVIATIONS

Full word	Abbreviations
Agriculture	Agric.
Agro-Ecological Zone	AEZ
And others	*et al.*
Applied	App.
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotechnol.
Botany	Bot.
Centimeter	Cm
Cultivar	Cv.
Degree Celsius	°C
Dry weight	DW
Editors	Eds.
Emulsifiable concentrate	EC
Entomology	Entomol.
Environments	Environ.
Food and Agriculture Organization	FAO
Fresh weight	FW
Gram	g
International	Intl.
Journal	J.
Kilogram	kg
Least Significant Difference	LSD
Liter	L
Triple super phosphate	TSP
Science	Sci.
Soil Resource Development Institute	SRDI
Technology	Technol.
Serial	Sl.
Percentage	%

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop and a primary food source for more than one-third of world's population (Sarkar *et al.,* 2017). Worldwide, rice provides 27% of dietary energy supply and 20% dietary protein (Kueneman, 2006). It constitutes 95% of the cereal consumed and supplies more than 80% of the calories and about 50% of the protein in the diet of the general people of Bangladesh (Hossain *et al*., 2008). In Bangladesh, majority of food grains comes from rice. Rice has tremendous influence on agrarian economy of the country. Annual production of rice in Bangladesh is about 36.28 million tons from 11.52 million ha of land (BBS, 2018). According to the U. S. Department of Agriculture (USDA) report in 2021 rice production for the 2020-21 marketing year is expected to rise to 36.3 million tonnes in Bangladesh as further cultivation of hybrid and high yield variety plantings increase. The country is expected to import 200,000 tonnes of rice in the 2020-21 marketing year to ease food security tensions brought on by the COVID-19 pandemic situation (USDA, 2021).

There are three distinct growing seasons of rice in Bangladesh, according to changes in seasonal conditions such as *aus, aman* and *boro*. More than half of the total production (55.50 %) is obtained in *boro* season occurring in December–May, second largest production in *aman* season (37.90 %) occurring in July-November and little contribution from *aus* season (6.60 %) occurring in April-June (APCAS, 2016).

Among three growing seasons (aus, aman and boro) aman rice occupies the highest area coverage. The aman rice crop occupies 67 per cent of the cropped area of 85.77 ha. In 2020, the amount of land used for high yielding varieties (HYV) is 44.47 lakh (4.44 million) ha, hybrid 2.40 lakh (0.24 million) ha, local varieties 7.15 lakh (0.75 million) hectares and for broadcast aman 3.12 lakh (0.31 million) ha of cultivable land. The total land under the aman crop was 57.14 lakh (5.71 million) ha (Magzter, 2021). Almost 78 % of the land is occupied by the HYV varieties supported by the Department of Agricultural Extension with fertilizers, pesticides and laboratory seeds, while only 12.5 per cent are local/traditional varieties cultivated by the farmers on their own initiatives in low lands (BBS, 2017). There are two type of transplant aman rice *viz*. coarse and fine rice and some of the fine rices are aromatic. Aromatic rice is a special type of rice containing natural ingredient named 2-acetyl-1-pyrroline, which is responsible for their fragrant, taste and aroma (Gnanavel and Anbhazhagan, 2010) and had 15 times more 2-acetyl-1- pyrroline content than non - aromatic rice, ranges 0.14 -0.009 ppm respectively (Singh, 2000). In addition, there are about 100 other volatile compounds, including 13 hydrocarbons, 14 acids, 13 alcohols, 16 aldehydes, 14 ketones, 8 esters, 5 phenols and some other compounds, which are associated with the aroma development in rice (Hinge *et al*., 2016).

Most of the aromatic rice varieties in Bangladesh are traditional photo-period sensitive types and are grown during *aman* season (Chowdhury *et al.,* 2017). Cultivation of aromatic rice has been gaining popularity in Bangladesh over the recent years, because of its huge demand both for internal consumption and export (Das and Baqui, 2000).

In Bangladesh the average yield of rice is almost less than 50% of the world average rice grain yield. The national average yield (2.60 t ha^{-1}) of rice in Bangladesh is lower than the potential national yield (5.40 t ha^{-1}) and world average yield (3.70 t ha^{-1}) (Jahan *et al.,* 2015).

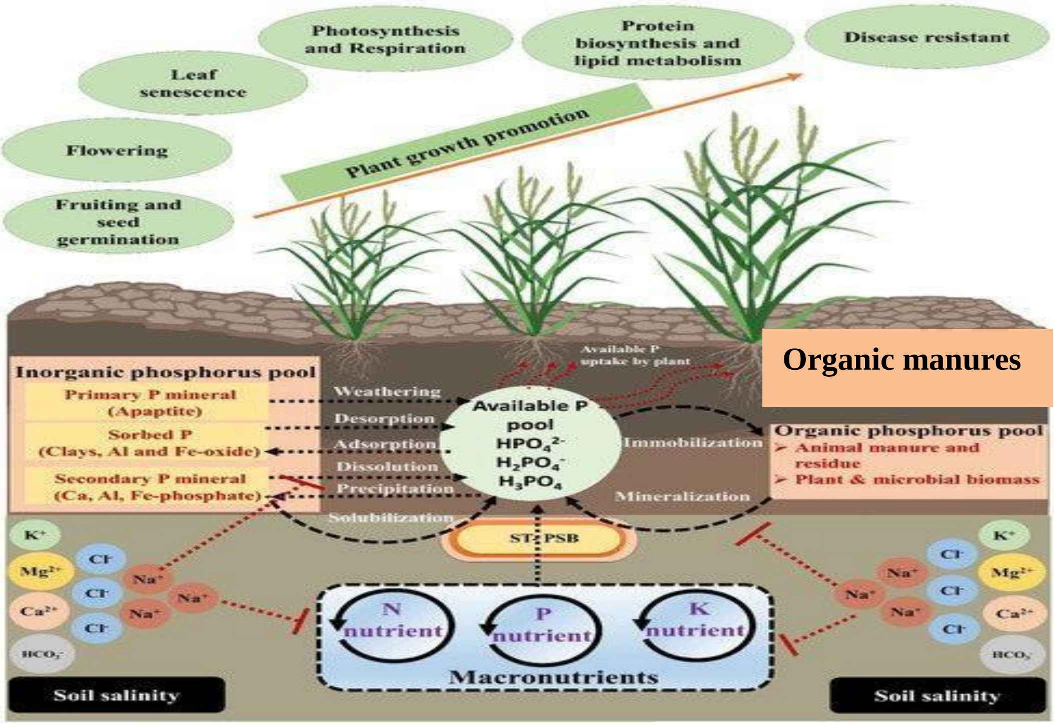
The lower yield of aromatic rice has been attributed to several reasons such as lack of high yielding cultivars, soil salinization, fluctuation of the market prices, lack of knowledge of the handling of agronomic management practices etc.

Aromatic rice is very sensitive to salinity. Salinity is one of the most brutal environmental factors limiting productivity of crop plants because most of the crop plants are sensitive to salinity (Haque *et al.,* 2014). Usually 30-50% yield losses occur depending on the level of soil salinity. Over 30% of the cultivable area of Bangladesh lies in the coastal and offshore zones. Out of 2.86 million ha of coastal and offshore lands, about 1.06 million ha are affected by soil salinity (SRDI, 2010). The area under salinity is increasing with time (from 0.83 m ha to 1.056 m ha in 36 years; SRDI, 2010) due to rise in sea water level with increased global temperature. According to the IPCC (2007), crop production may fall by 10-30% by 2050 in Bangladesh due to climate change.

Salinity stress causes osmotic stress and ion toxicity, through increasing the assimilation of Na^+ ion and decreasing the Na^+/K^+ ratio due to lower osmotic potential within the plant roots. Further, these ionic imbalance affects the uptake, and transport of other important essential ions in target cells and hamper the crucial plant processes and functions (Arif *et al*., 2020).

Salinity impairs the seedling establishment, stunted plant growth, poor reproductive development, and ultimately declines the crop yield (Turan *et al*., 2009). Salinity also alters the ultra-structural cell components, disturbs the photosynthesis machinery, damages the membranous structure, increases the reactive oxygen species production, reduce the enzymatic activity, which limit the growth and yield of crops (Hasanuzzaman *et al*., 2014).

Soil salinity must be reclaimed to restore soil productivity for increasing food production. The approaches for the management of soil salinity include leaching, incorporation of different organic and inorganic amendments, mulching, and development of salt-tolerant crops. The suitability of approaches depends on several considerations such as cost of reclamation, the time required, the extent of the salt stress, soil properties, availability of technology, and other environmental factors.



(Source: Dey *et al*., 2021)

Figure 1. Improve salt stress condition by using organic manures

Among different strategies, the application of different organic manures like Azolla, Vermicompost, Biochar and cowdung etc are beneficial, cost effective, environment friendly, and sustainable for amelioration of salt stress and enhancement of crop production due to the extensive roles of organic manures in improving the soil's physical, chemical, and biological and/or biochemical, properties of soil (Idrees *et al*., 2004; Abou El-Magd *et al*., 2008; Leithy *et al.*, 2010; Raafat and Thawrat, 2011). Organic manure help to flocculate mineral particles to organic polymers because of their bonding or adhesion properties (Diacono and Montemurro, 2015) resulting in a good structural stability, which is a precondition to maintain an appropriate soil structure. The application of organic manure to salinity affected soil can improve the aggregate stability and porosity, resulting in increased Na leaching and decreased exchangeable sodium percentage (ESP) and electrical conductivity (EC) values (Wang *et al*., 2014).

Keeping in mind of the above consideration, the present study was undertaken to achieve the following objectives

i. To know the effect of salinity on the performance of aromatic rice plant
ii. To find out the role of organic manure on aromatic rice under salinity stress condition

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding to amelioration of salinity stress in aromatic rice by application of organic manures, to gather knowledge helpful in conducting the present piece of work.

2.1 Plant stress

Stress in plants refers to external conditions that adversely affect growth, development or productivity of plants (Verma *et al*., 2013). Stresses trigger a wide range of plant responses like altered gene expression, cellular metabolism, changes in growth rates, crop yields, etc. A plant stress usually reflects some sudden changes in environmental condition. However in stress tolerant plant species, exposure to a particular stress leads to acclimation to that specific stress in a time time-dependent manner (Verma *et al*., 2013). Plant stress can be divided into two primary categories namely

i. Abiotic stress and

ii. Biotic stress.

2.2 Abiotic stress

Abiotic stresses such as drought (water stress), excessive watering (water logging), extreme temperatures (cold, frost and heat), salinity and mineral toxicity negatively impact growth, development, yield and seed quality of crop and other plants. In future it is predicted that fresh water scarcity will increase and ultimately intensity of abiotic stresses will increase. Hence there is an urgency to develop crop varieties that are resilient to abiotic stresses to ensure food security and safety in coming years. A plants first line of defense against abiotic stress is in its roots. The chances of surviving stressful conditions will be high if the soil holding the plant is healthy and biologically diverse. One of the primary responses to abiotic stress such as high salinity is the disruption of the Na^+/K^+ ratio in the cytoplasm of the plant cell. (Seki *et al*., 2007).

2.3 Crop plants and abiotic stresses

Plants are encountered by number of abiotic stresses which impact on the crop productivity worldwide. These abiotic stresses are interconnected with each other and may occur in form of osmotic stress, malfunction of ion distribution and plant cell homeostasis. The growth rate and productivity is affected by a response caused by group of genes by changing their expression patterns. So, the identification of responsive genes against abiotic stresses is necessary in order to understand the abiotic stress response mechanisms in crop plants. The abiotic stresses occurring in plants include cold, salt, drought, heat and toxicity stress. (He *et al*., 2018).

2.4 Salt stress

The condition of soil characterized by high concentrations of soluble salt is called salinity. Salt stress is one of the most decisive environmental factors and harms the plant growth via osmotic stress, ion toxicity, nutrient imbalances, and water deficit (Zörb *et al*., 2018). About 6% of world's total land area and one-third of world's irrigated land area are affected by salinity directly or by secondary salinity. Among the cultivable area, 20% of irrigated land and 2% of the dry land area are affected by salinity directly or by secondary salinity (Munns and Tester, 2008). The problem of salinization is increasing day by day, often due to bad agricultural practices and climate changes. It is assumed that 50% of the cultivable land will be salt affected by the middle of the twenty-first century (Mahajan and Tuteja, 2005). Excess salinity in soil is one of the major environmental factors that limit growth and yield of a wide variety of crops including rice (Hasanuzzaman *et al*., 2013a; Hasanuzzaman *et al*., 2013b and Tester and Davenport, 2003). Many studies revealed the negative effect of salinity on plant growth, development and yield (Hasanuzzaman *et al*., 2009; Peng *et al*., 2008). The damages by higher salinity in plant start from germination and exist till death of plant (Peng *et al*., 2008). It is evident that salt stress has negative correlation with seed germination and vigor of wide variety of crops (Hasanuzzaman *et al*., 2013). In the seedling stage, salt stress affects plant growth by osmotic and ionic stress. Salinity-induced ionic and osmotic stresses reduce rate of photosynthesis and consequently cause oxidative stress, which is also responsible for growth reduction. The negative effects of salt stress that mentioned ultimately reduced yield of most crops including rice, except some halophytes. On the basis of tolerance ability toward salinity, rice is considered as salt-sensitive crop, and growth and yield of rice are greatly affected by salinity (Mishra *et al*., 2013). Salinity-induced yield reduction of rice is alarming for the food security of ever-growing population of the world, especially in Asia, because 90% of the world's rice is produced and consumed in Asia and more than 3 billion of Asian intake their 50–80% daily calorie from rice (Khush, 2005).

2.5 Effect of salinity on rice plants

Das *et al.* (2015) carried out a study to understanding salinity responses and adopting 'omics-based' approaches to generate salinity tolerant cultivars of rice and reported that at early stage of growth, rice is grouped as salinity susceptible cereal and confines its efficiency of production at mature stage.

Horie *et al.* (2012) carried out an experiment on salinity tolerance mechanisms in glycophytes and reported that due to the excess accumulation of Na^+ in the cytoplasm during NaCl salinity, cellular metabolisms such as protein synthesis and enzyme activities are hampered, and therefore, source-sink relationship and photosynthesis are disrupted. Thay also noticed that Na^+ accumulation in shoots is relatively well correlated with the survival of rice plants under salinity stress and hence, keeping a lower cytosolic Na^+ is considered as one of the vital strategies for salt tolerance in glycophytes. As a result of salinity-induced osmotic stress, water uptake by plant is hampered and plant suffers from physiological drought. This also led to the interruption of nutrient uptake. Under osmotic stress, regulation of water transport becomes a vital adaptive strategy of rice plants because a sufficient amount of water is indispensable for the cells to maintain their growth and vital cellular functions such as photosynthesis and metabolisms. This situation also induces stomatal closure, which results in the reduction of evaporation and water transport. A set of hormonal regulations also associated with these processes is upregulated many-fold under salt stress.

According to IRRI (2006), soil salinity beyond EC ~4 dS m^{-1} is considered as moderate salinity for rice, while more than 8 dS m^{-1} is high. However, it is not absolute measure, and it depends on other soil factors because they are interacted with each other. Excess salt caused both ionic toxicity and osmotic stress in rice plants. Under high salinity, rice plants show various morphological, physiological or biochemical alterations and symptoms and even may die when the salt stress becomes very high. Lee *et al.* (2003) reported that the tolerance level of indica is higher than that of japonica at seedlings stage.

Xiong and Zhu (2002) reported that sodium ion itself causes direct cellular injury to plants, and additionally, higher amount of Na^+ in root zone inhibits K^+ uptake because of their antagonistic effect. This shortage of K^+ inside the cell unavoidably leads to decrease in plant growth because K^+ has vital role in preserving membrane potential, enzyme activities and cell turgor.

2.5.1 Plant growth

Rahman *et al.* (2016) reported that salt stress (200 mM NaCl) reduced plant growth by creating ionic and water imbalance, and oxidative stress.

Ologundudu *et al.* (2014) conducted experiment with eight rice cultivars under different level of salinity (0–15 dS m^{-1}) and reported that root and shoot length, root and shoot dry weight, and total dry matter production decreased with increasing the level of salinity. Özdemir *et al*. (2014) reported that salt-induced growth reduction by oxidative stress in rice seedlings.

Aref (2013) reported that rice plant subjected to salinity at tillering, panicle initiation, panicle emergence and ripening stage where salt-induced damages were higher at tillering and panicle initiation stages compared with other two stages.

Hasanuzzaman *et al.* (2013) carried out a study to know the plant response to salt stress and role of exogenous protectants to mitigate salt-induced damages and noticed that seedling and early vegetative growth stages are most susceptible to salinity during the entire life cycle of plant.

Kazemi and Eskandari (2011) carried out an experiment to study the effects of salt stress on germination and early seedling growth of rice (*Oryza sativa*) cultivars in Iran and found that growth of rice seedlings decreased with increasing the level of salinity.

Munns and Tester (2008) reported that the presence of high concentration of salt (NaCl) around the root zone also reduces plant growth by ionic toxicity through over accumulation of Na+ and Cl−. In addition, Na+ influx causes chlorosis, necrosis and premature senescence of adult leaves and thus limits the photosynthetic area available to support continued growth of salt-affected plants.

Makihara *et al.* (1999) carried out an experiment to understand the effect of salinity on the growth and development of rice (*Oryza sativa* L.) varieties and reported that on the basis of tolerance ability, rice is salt sensitive crop and the sensitivity to salinity varies with the growth stages. Among the growth stages, early seedling stages of rice are also considered as most sensitive to salinity compared with other stages.

2.5.2 Physiological attributes

Rahman *et al.* (2016) reported that 12-day-old rice seedlings exposed to 150 mM NaCl for 3 days caused 23 and 19% reduction in chl a and chl b, respectively, compared to control. As the duration of salt stress extended for further 3 days, chl a and chl b reduced by 46 and 48%, compared to control.

Ashraf and Harris (2013) reported that photosynthetic pigments, chl a and chl b, are greatly affected by different abiotic stresses including salinity. Accumulation of toxic Na+ reduces the content of precursor of chl biosynthesis (such as glutamate and 5-aminolevullinic acid) and thus interrupts chl biosynthesis under saline condition.

Amirjani (2010) found a dose-dependent reduction of chl content against salt stress (0, 25, 50, 100 and 200 mM NaCl). At 200 mM NaCl, chl a and chl b reduced by 44 and 27%, respectively, compared to control.

Cha-Um and Kirdmanee (2010) reported that in dark reaction, net photosynthetic rate (NPR), gs and transpiration rate (E) decreased in both varieties, Homjan (HJ) and Pathumthani 1 (PT1) varieties, under salt-stressed condition.

Romero-Aranda *et al.* (2006) reported that increase of salt in the root medium can lead to a decrease in leaf water potential and, hence, may affect many plant processes. Osmotic effects of salt on plants are the result of lowering of the soil water potential due to increase in solute concentration in the root zone. At very low soil water potentials, this condition interferes with plants' ability to extract water from the soil and maintain turgor. However, at low or moderate salt concentration (higher soil water potential), plants adjust osmotically (accumulate solutes) and maintain a potential gradient for the influx of water.

Ghoulam *et al.* (2002) carried out an experiment to study the effects of salt stress on growth, inorganic ions and proline accumulation in relation to osmotic adjustment in five sugar beet cultivars and reported that salt treatment caused a significant decrease in relative water content (RWC) in sugar beet varieties.

Katerji *et al.* (1997) reported that a decrease in RWC indicates a loss of turgor that results in limited water availability for cell extension processes.

2.5.3 Yield and yield contributing characters

Arsa *et al.* (2016) reported that salt stress (2.5% NaCl) along with drought stress reduced grain yield and aroma of rice grain. The level of yield reduction increased with increasing the level of salinity. Yield reduction also depends on stages of plant growth when it is affected by salinity.

Kumar and Khare (2016) carried out an experiment on differential growth and yield responses of salt-tolerant and susceptible rice cultivars to individual (Na^+ and Cl^-) and additive stress effects of NaCl and noted that salinity reduced number of grain per panicle, filled grain percentage, 1000-grain weight and grain yield both in sensitive and in tolerant cultivar where yield reduction was higher in sensitive cultivar.

Chunthaburee *et al.* (2015) conducted experiment with four different cultivars and found that salt stress (25 mM NaCl) reduced yield and harvest index by decreasing 1000-grain weight, filled grain percentage and panicle fertility.

A greenhouse experiment was conducted by Aref (2013) with different levels of salinity (2–8 dS m^{-1}) where salt stress exposed at different stages (tillering, panicle initiation, panicle emergence and ripening) of plant. He reported that salinity decreased grain yield, biomass yield and harvest index when salt stress was exposed at tillering and panicle initiation stage and yield reduction increased with increasing the level of salinity.

Saleethong *et al.* (2013) reported that salt stress reduced grain yield both in tolerant (32%) and in sensitive cultivars (56%) by affecting yield contributing parameters where yield reduction is higher in sensitive cultivar. They also reported that salt stress decreased grain quality by reducing N, P, K and Mg content in rice grain.

Ali *et al.* (2004) reported that salinity (8.5 dS m^{-1}) reduced grain yield of rice by reducing photosynthesis, leaf area index (LAI) and productive tiller.

Zeng and Shannon (2000) carried out an experiment to study the salinity effects on seedling growth and yield components of rice and reported that salt stress affected reproductive stage of rice due to lower growth and lower survival percentage of seedlings under different levels of salinity (19–11.7 dS m^{-1}). They noticed that salinity decreased grain yield by decreasing tiller number, pollen viability, fertility percentage and 1000-grain weight where the level of yield reduction increased with increasing the level of salinity.

2.6 Organic manure

Organic manures are natural products used by farmers to provide food for the crop plants. Organic manures are beneficial in the cultivation of crops. They increase the organic matter in the soil which in turn releases the plant food in available from the use of crops. Organic manures enable a soil to hold more water and also help to improve the drainage in clay soils. They even provide organic acids that help to dissolve soil nutrients and make them available for plants. Organic manure is being increasingly popular for organic farming (Christians *et al*., 2016).

2.7 Benefits of organic manure

Organic manure increases ph of acidic soils. Soil enhancing benefits from manures are related to the organic matter that improves soil structure, moisture retention and increase mobility of phosphorous, potassium and other micro nutrients and also stimulate microbial activity (Maerere *et al*., 2001 and Garg and Bahla, 2008). Under organic management the ph of soil is increased and the concentrations of plant available nutrients are increased, also total active microbial populations are increased (Lee, 2010).

2.8 Description of some organic manures

Biochar

Biochar is a charcoal-like substance that’s made by burning organic material from agricultural and forestry wastes (also called biomass) in a controlled process called pyrolysis. Biochar enhancing soil structure, increasing water retention and aggregation, decreasing acidity, reducing nitrous oxide emissions, improving porosity, regulating nitrogen leaching, improving electrical conductivity and improving microbial properties of soil (Tomczyk *et al*., 2020).

Vermicompost

Vermicompost (vermi-compost) is the product of the decomposition process using various species of worms, usually red wigglers, white worms, and other earthworms, to create a mixture of decomposing vegetable or food waste, bedding materials, and vermicast. This process is called vermicomposting, while the rearing of worms for this purpose is called vermiculture. Vermicompost contains water-soluble nutrients and is an excellent, nutrient-rich organic fertilizer and soil conditioner. It is used in gardening and sustainable, organic farming (Adhikary, 2022).

Azolla

Azolla is a floating pteridophyte, which contains as endosymbiont the nitrogen-fixing cyanobacterium Anabaena azollae (Nostocaceae family). Widely cultivated in the Asian regions, Azolla is either incorporated into the soil before rice transplanting or grown as a dual crop along with rice. While azolla is growing in the paddy, it fixes nitrogen and also absorbs nutrients out of the water that might otherwise be washed away (Bocchi and Malgioglio, 2010).

Cowdung

Cow dung, which is usually a dark brown color, is often used as manure (agricultural fertilizer). The use of cattle manure, or cow dung, in the garden is a popular practice in many rural areas. This type of manure is not as rich in nitrogen as many other types; however, the high ammonia levels can burn plants when the fresh manure is directly applied. Composting cow manure has several benefits. In addition to eliminating harmful ammonia gas and pathogens (like E. coli), as well as weed seeds, composted cow manure will add generous amounts of organic matter to soil. By mixing this compost into the soil, improve soil moisture-holding capacity. This allows us to water less frequently, as the roots of plants can use the additional water and nutrients when needed. Additionally, it will improve aeration, helping to break up compacted soils. Composted cow manure also contains beneficial bacteria, which convert nutrients into easily accessible forms so they can be slowly released without burning tender plant roots. Composting cow manure also produces about a third less greenhouse gases, making it environmentally friendly (Gupta *et al*., 2016)

2.9 Effect of different organic manure

2.9.1 Growth characters

Tharmaraj *et al*. (2011) carried out an experiment to study the effect of vermicompost on soil chemical and physical properties. The vermiproduct treated plants display quicker and higher growth rate and productivity than the control plots. Among the treated group, the development rate was high in the combination of vermicompost and vermiwash treated plants, than the vermicompost and vermiwash un-treated plants.

Morteza (2010) carried an experiment in 2008 and 2009, in randomized block design based on 4 replications. Highest total number of tillers were observed in plots treated with 2 t/ha organic fertilizer (11.19), it was followed by organic fertilizer $^{+}$NPK (11.03) and NPK alone (10.66) and minimum of that was for 0.5 ton/ha organic fertilizer (9.75) against untreated control (9.63).

Amitava *et al*. (2008) reported that organic sources offer more balanced nutrition to the plants, especially micro nutrients which has caused better tillering in plants grown with Vermicompost and FYM.

Bala and Hossain (2008) suggested application of Mo with organic matter to produce highest number of panicle / hill, spikelets / panicle and grains.

Muhammad *et al.* (2008) reported that the variation in plant height due to different nutrient sources and their variation in the availability of major nutrients. The available nutrients might have helped in enhancing leaf area, which thereby resulted in higher photo-assimilates and more dry matter accumulation impact on plant height of rice.

Ebaid and El-Peface (2007) reported that the increase in grain yield components can be due to the fact that available more water enhanced nutrient availability which improved nitrogen and other macro- and micro-elements absorption as well as enhancing the production and translocation of the dry matter content from source to sink.

Miller (2007) reported that organic sources offer more balanced nutrition to the plants, especially micro nutrients which positively affect number of tiller in plants

Sudhakar *et al.* (2002) studied that Earthworms can live in decaying organic wastes and can degrade it into fine particulate materials, which are rich in nutrients. Vermicomposting is the application of earthworms in producing vermifertilizer, which helps in the maintenance of a better environment and results in sustainable agriculture. Earthworms make the soil porous and help in better aeration and water infiltration. Vermicompost can be prepared from different organic materials like sugarcane trash, coir pith, pressmud, weeds, cattle dung, bio digested slurry etc. Increased availability of nutrients in vermicompost compared to non-ingested soil resulted in significantly better growth and yield of rice has been reported by several workers.

2.9.2 Physiological attributes

Verma *et al*. (2013) carried out an experiment to know the influence of vermi-products and pusa hydrogel on growth and flowering of landscape gerbera under greenhouse condition and found that leaf relative water content (LRWC) was significantly enhanced by vermicompost application. Jain *et al.* (2012) reported LRWC could not be affected significantly by vermicompost addition. Berova and Karanatsidis (2009) reported that chlorophyll contents increased significantly with vermicompost application. Khan *et al.* (2000) reported that soil salinity caused significant reduction in LRWC.

2.9.3 Yield and yield contributing characters

Shaikh *et al.* (2017) conducted an experiment to know the effect of substitution of organic resources on yield paddy (*Oryza sativa* L.) at Agricultural Research Station, Vadgaon Maval Dist. Pune. It was observed that expression of yield attributes ultimately reflected on higher grain (51.00 q ha^{-1}) and straw yields (62.71 q ha^{-1}) with the use of (2.5 t FYM ha^{-1} + 0.750 t vermicompost ha^{-1} + 0.375 t green leaves of glyricidia ha^{-1} + 0.250 t neem cake ha^{-1}) “T8”, as compared to other treatments.

Tazmin *et al.* (2015) reported that application of manure and fertilizers enhanced the yield contributing the character of rice.

Davari and Sharma (2015) reported that permutation of FYM + wheat residues + bio-fertilizers and vermicompost + wheat residues + bio-fertilizers brought about greater increase in grain yield (51-58%) over control, 18-22% over FYM and vermicompost alone and 6-10% over FYM + wheat residues and vermicompost + wheat residues.

Urkurkar *et al.* (2010) reported rice yield of 3.66 t/ha when 100% N was given through cowdung manure, neem cake and composted crop residues. This was exceptionally near to that of 100% N through chemical fertilizer.

Manivannan and Sriramachandrasekharan (2009) reported that Combined application of vermicompost (50% N) and urea (50% N) resulted in the highest number of panicles m^{-2}, a number of grains $panicle^{-1}$, panicle length and 1000 grain weight which was on a par with that of poultry manure (50% N) and urea (50% N). Improved growth coupled with the transport of photosynthates towards reproductive structure might have increased the yield attributes and yield due to organic addition.

Singh (2008) reported that the available nutrients might have helped in enhancing leaf area, which resulted in higher photo-assimilates and more dry matter accumulation.

Nayak *et al*. (2007) reported a significant increase in effective tillers hill^{-1} due to application of chemical fertilizer with organic manure.

Barik and Chattopadhyay (2006) reported that application of vermicompost alone or in combination with 75% or 50% of recommended NPK fertilisers resulted in higher number of effective tillers plant^{-1} as compared to farm yard manure treated plots alone or in combination with respective levels of NPK fertilizers and attributed this to the higher availability of NPK and also to other nutrients, higher occurrence of different beneficial microorganisms, production of growth promoting hormones antibiotics, enzymes etc., which helps in improvement of soil health compared to farmyard manure in chromium contaminated soil.

Salem (2006) reported that application of FYM along with nitrogen fertilizer significantly increased number of panicles per square meter, panicle length, panicle weight, number of filled grains/panicle, 1000-grain weight and grain yield in rice.

Yang *et al.* (2004) recorded that 1000-grain weight was increased by the application of chemical fertilizer along with organic manure.

Sudha and Chandini (2003) reported that unlike in other organic manures, the increase in panicle number, tiller production m^{-2} better dry matter accumulation observed with the addition of vermicompost was attributed to the quick nutrient absorption by plants compared to FYM.

Sheeba and Kumarasamy (2001) reported that the organic carbon and cation exchange capacity increased significantly in the manured treatments and in the treatments that received N with or without P and K. Nitrogen turnover was increased by *Rhizobium* inoculation or N application to sunnhemp. Green manuring significantly increased soil organic C, total and available N, available P and K and water-holding capacity.

Murali and Setty (2001) conducted an experiment and found that application of vermicompost @ 5.0 t/ha recorded significantly higher yield (4.89 t ha^{-1}) as compared to no vermicompost application (4.07 t ha^{-1}), due to the significantly higher number of panicle/hill and number of filled grains $panicle^{-1}$ (187) resulting from the availability of more nutrients with vermicompost application.

Hoque (1999) reported significantly increased grain and straw yields due to application of organic manure and chemical fertilizers.

Kandasamy and Ramasamy (1998) reported a significant increase in plant height, LAI, tiller production and DMP was observed due to the application of FYM @ 10 t ha^{-1} than other manures.

Ravi and Srivastava (1997) reported that application of vermicompost recorded significantly higher plant height, effective tillers $hill^{-1}$, grain and straw yield of rice, compared to the application of inorganic fertilizer.

2.10 Effects of organic manure under salt stressed condition

Benazzouk *et al.* (2019) observed a reduction in sodium accumulation by the use of vermicompost. Wang *et al.* (2014) found that a mixture of organic wastes decreased bulk density, EC, and ESP by 11%, 87%, and 71%, respectively, and increased total porosity and organic carbon by 25% and 96% respectively, than the control. These results suggest the effectiveness of combination of different amendments for reclaiming salt-affected soil.

Diacono and Montemurro (2010) carried out an experiment to study long-term effects of organic amendments on soil fertility and reported that several organic materials, such as farmyard manures, agro-industrial by products and composts can be used as amendments to enhance and sustain the overall soil fertility. This amendments could likely be considered for soil remediation in the salt-affected areas due to their high organic matter content.

Khan *et al.* (2010) that applying FYM lessened the destructive effects of salinity and improved the characteristics of soil like EC, pH and SAR.

Pang *et al.* (2010) reported that adding organic matter like FYM and solid municipal waste is also an effective approach for ameliorating soils affected by salts and excessive sodium on exchange complex.

Lakhdar *et al.* (2009) reported that amendment incorporation under high soil salinity or sodicity may also provide a buffer of pH in saline and alkaline soils, influencing the activity of microorganisms.

Lakhdar *et al.* (2008) depicted that using saline water for irrigating crop lowers the potassium level of soil which can be maintained by adding various organic materials.

Walker and Bernal (2008) reported that under saline soils the available fraction of K can increase through the increase of CEC linked to organic matter content. In particular, the application of poultry manure and compost to soil can increase both the CEC (Cations exchange capacity) and the soluble and exchangeable-K^+, which is a competitor of Na^+ under sodicity conditions, thus, limiting the entry of Na^+ into the exchange complex.

Clark *et al.* (2007) reported that the application of organic matter improves soil properties which are affected by salts, resulting in an improvement in growth through accelerating the leaching of toxic salts and cation exchange.

Haq *et al.* (2007) that incorporating FYM reduced soil EC considerably. Saeed *et al.* (2007) who explained that using saline water enhanced the SAR (Sodium Adsorption Ratio) but adding of organic matter lessened soil SAR.

Roy *et al.* (2006) reported that organic matter has several beneficial effects on agricultural fields, such as the slow release of nutrients, soil structure improvement, and the protection of soils against erosion.

Hu and Schmidhalter (2005) highlighted, the uptake of phosphorous (P) by crops is reduced in dry-soil conditions and the availability of this macronutrient can be reduced in saline soils. Conversely, during the mineralization process, organic matter releases humic substances, which may convert soil phosphates into available forms, improving release from hardly soluble rock minerals due to high total acidity.

Crecchio *et al*. (2004) reported that adding compost in soil improves the chemical and physical properties under salinity environment and applying solid municipal waste compost continuously for extended periods increases the content of organic matter in soil as well as C/N ratio when compared to soil with no organic matter additions.

Hanay *et al.* (2004) depicted that concentration of potassium enhances by adding various organic materials. Turner (2004) who stated that organic manure augmented the concentration of phosphorus in soil under the conditions of salinity.

Hao and Chang (2003) showed that the soluble ions and the adsorption ratios of Na^+ and K^+ increased with 25 years of high rates of cattle manure application, particularly under non-irrigated conditions. Banaras *et al*. (2002) reported that saline soil productivity can be improved by applying organic amendments in different crops.

Chandra *et al.* (2002) pointed out that, at low concentration, salts had a stimulating effect on carbon mineralization, but they can become toxic to microorganisms with increasing concentrations. Hussain *et al.* (2001) observed that adding FYM and gypsum lowers the SAR value thereby reducing the hazard of salinity.

Atiyeh *et al.* (2000) carried out an experiment to study the biochemical changes in cow manure processed by earthworms (Eisenia andrei) and their effects on plant growth and found that vermicomposts, which are stabilized organic materials produced by earthworms and microorganisms, have been reported to improve plant germination growth and yields in greenhouse crops. Vermicompost has large particulate surface areas that provide many micro sites for microbial activity, strong retention of nutrients, high nutrients content and rich microbial populations.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to investigate the amelioration of salt stress in aromatic rice by application of different organic manures. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from July to December 2020 in Aman season.

3.2.1 Geographical location

The experiment was conducted in the Agronomy field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.2.2 Agro-Ecological Zone

The experimental site belongs to the Agro-ecological zone (AEZ) of “The Modhupur Tract”, AEZ-28 (Anon., 1988 a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon., 1988 b). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2.3 Soil

The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.4–5.6 (Anon., 1989). The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0–15 cm depths were collected from the Sher-e-Bangla Agricultural University (SAU) Farm, field. The soil analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The morphological and physicochemical properties of the soil are presented in below table.

Table 1. Morphological characteristics of the experimental area

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University soil research field, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

Table 2. The initial physical and chemical characteristics of soil use in this experiment

Physical characteristics	
Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	Value
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10

3.3 Experimental materials

3.3.1 Plant material

Binadhan-13 was used as experimental materials for this experiment. The important characteristics of these are mentioned below:

Binadhan-13 developed by Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh. It has been developed from local fine grain aromatic rice cultivar Kalizira with the application of gamma radiation and Datura extract. The mutant KD5-18-150 has been released as Binadhan-13, a fine grain aromatic rice variety suitable for cultivation in T. aman season of Bangladesh. The mutant contains most of the characters of Kalizira. The main characteristics of Binadhan-13 are as follows: Leaves remain green till maturity. Crop duration 138-142 days. Moderately lodging resistant. Grain yield 3.2-3.6 t ha^{-1} and 1000 grains weight is 13.2 g.

3.3.2 Earthen pot

Earthen pots of having 12 inches diameter, 12 inches height with a hole at the centre of the bottom were used. Silt soil was used in the experiment. Twelve kilogram sun-dried soils were put in each pot. After that, pots were prepared for seed sowing.

3.4 Salinity treatment

The salinity treatments were applied from 20 to 40 DAT. There were three salinity levels including control which was developed by adding respected amount of commercial NaCl salt to the soil/pot as water dissolved solution. The salinity levels were S_0 (control), S_1 (1200 ppm pot^{-1}) and S_2 (2400 ppm pot^{-1}). In order to spreading homogenously in each pot the salts were dissolved in 60 liter water and were added to pots for proper salinity imposition.

3.5 Experimental treatment

There were two factors in the experiment namely different salt stress and application of different organic manures as mentioned below:

Factor A: Different salt stress (3) *viz;*

S_0 = 0 ppm pot^{-1} (Control),
S_1= 1200 ppm pot^{-1} and
S_2 = 2400 ppm pot^{-1}

Factor B: Application of different organic manures (5) *viz;*

M_0 = 0.0 kg ha^{-1} (Control),
M_1 = Biochar 4 t ha^{-1},
M_2 = Vermicompost 6 t ha^{-1},
M_3 = Azolla 0.5 t ha^{-1} and
M_4 = Cowdung 10 t ha^{-1}.

3.6 Experimental design

The experiment was laid out in Randomized Completely Block Design (RCBD) with 2 factor and four replications. Total 60 unit pots were made for the experiment with 15 treatments having 4 replications.

3.7 Detail of experimental preparation

3.7.1 Seed collection and sprouting

Binadhan-13 rice variety seed was collected from BINA (Bangladesh Institute of Nuclear Agriculture), BAU Campus, Mymensingh-2202. Healthy and disease free seeds were selected, following standard technique. Seeds were immersed in water in a bucket for 24 hrs. These were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hrs which were suitable for sowing in 72 hrs.

3.7.2 Raising of aman seedlings

A typical system was followed in raising of seedlings in the seedbed. The nursery bed was set up by puddling with continued ploughing followed by laddering. The sprouted seeds were planted as uniformly as possible. Irrigation was delicately given to the bed as and when required.

3.7.3 Preparation of the pot

The upper edge diameter of the pots was 30 cm (r= 15 cm). While filling with soil, the upper one inch of the pot was kept vacant so that irrigation can be provided using a hose pipe. The preparation of the pot was done in 6 November 2020.

3.7.4 Fertilizer application

Chemical

Plant nutrients *viz*. N, P, K, S, and Zn for rice were given through urea, triple superphosphate, muriate of potash, gypsum, and zinc sulphate, respectively.

Chemical fertilizers	Rrate (kg ha^{-1})	Nutrients elements
Urea	150	N
Triple superphosphate	100	P_2O_5
Muriate of potash	70	K_2O
Gypsum and	60	S
Zinc sulphate	10	Zn

All of the fertilizers except urea were applied as basal dose at the time filling pot with soil. Urea (150 kg ha^{-1}) was applied in equal three splits. The first dose of urea was applied at 21 days after transplanting (DAT). The second dose of urea was added as top dressing at 45 days (active vegetative stage) after transplanting and third dose was applied at 60 days (panicle initiation stage) after transplanting recommended by fertilizer recommendation guide, 2012.

Organic manures

Different manures and fertilizers were applied according with per treatment requirement and mixing with soil properly before filling pot with soil.

Organic manures	Rate (t/kg ha^{-1})
Biochar	4 t
Vermicompost	6 t
Cowdung	10 t
Azolla	500 kg

3.8 Seedling uprooting and transplanting in the pot

Seedlings of thirty days old were uprooted carefully from the seedbed and transplanted in the pots. There were 3 hill pot^{-1} and one seedling was used $hill^{-1}$.

3.9 General observations of the experimental field

Regular observations were made to see the growth and visual differences of the crops, due to application of different treatment were applied in the experimental pot. In general, the plant looked nice with normal green plants. Incidence of stem borer, green leaf hopper, leaf roller was observed during tillering stage and there were also some rice bug were present in the experimental pot. But any bacterial and fungal disease was not observed. The flowering was not uniform.

3.10 Crop sampling and data collection

Pot from each replication were selected and marked with sample card. Different data were recorded from selected plants at various growth stages.

3.11 Harvesting, threshing and cleaning

The rice plant was harvested depending upon the maturity of grains and harvesting was done manually from each plot. Maturity of crop was determined when 80–90% of the grains become golden yellow in color. Harvesting date was 02/12/2020. Harvesting was done in the morning to avoid shattering. Prior to harvesting, randomly selected plant from each replication pot were separately harvested for recording yield attributes and other data. The harvested plants were tied into bundles and carried to the threshing floor of the Soil Field Laboratory. Threshing was done by pedal thresher. The grains were cleaned and sun dried to moisture content of 12%. Straw was also sun dried properly. Finally grain and straw yields pot^{-1} were recorded.

3.12 Field operation

The different field operations performed during the course of present investigation are given below in chronological order in list form

Table 3. List of schedule of field operations were done during the course of experimentation

Operations	Working Dates
Seedbed preparation	8 th July 2020
Sowing seeds in the seedbed	11 th July 2020
Filling pot with soil	4 th August 2020
Application of different organic manures	5 th August 2020
Application of fertilizers (1/3rd Urea, TSP, MoP, Gypsum and Zinc sulphate	9 th August 2020
Transplanting of seedlings	10 th August 2020
Intercultural Operations	**Working Dates**
Weeding	25 August and 25 September 2020
2nd split application of urea	24 th August 2020
3rd split application of urea	10 th October 2020
Insecticide application	23 th October 2020
Harvesting and threshing	2 nd December 2020

3.13 Data collection

The data were recorded on the following parameters

a. Crop growth parameters:

i. Plant height (cm)
ii. Number of tillers hill^{-1}
iii. Leaf area index (LAI)

b. Physiological parameters:

iv. Chlorophyll content

v. Leaf relative water content (LRWC)

c. Yield contributing parameter:

vi. Number of effective tillers hill^{-1}

vii. Number of non-effective tillers hill^{-1}

viii. Panicle length (cm)

ix. Filled grains panicle^{-1}

x. Unfilled grains panicle^{-1}

xi. Total grains panicle^{-1}

xii. 1000 grain weight (g)

d. Yield contributing parameter

xiii. Grain yield pot^{-1} (g)

xiv. Straw yield pot^{-1} (g)

xv. Biological yield pot^{-1} (g) and

xvi. Harvest index

3.14 Procedure of data collection

i. Plant height (cm)

The height of rice plant from each pot was determined by measuring the distance from the soil surface to the tip of the leaf at 20 days interval upto harvest from each hill^{-1} and finally averaged. Mean plant height of rice plant were calculated and expressed in cm.

ii. Number of tillers hill^{-1}

Number of tillers hill^{-1} were counted at 20 days interval up to harvest from each hills and finally averaged as their number hill^{-1}. Only those tillers having three or more leaves were considered for counting.

iii. Leaf area index (LAI)

Leaf area index were estimated manually by counting the total number of leaves per plant and measuring the length and average width of leaf and multiplying by a factor of 0.75 (Kluen and Wolf, 1986). It was done at 20, 40, 60 and 80 DAT.

$$\text{Leaf area index} = \frac{\text{Surface area of leaf sample (cm}^2\text{)} \times \text{Correction factor}}{\text{Ground area from where the leaves were collected}}$$

iv. Chlorophyll content

Three leaf blades were randomly selected from each pot. The top and bottom of each leaflet were measured with atLEAF as atLEAF value. Then it was averaged and total chlorophyll content was measured by the conversion of atLEAF value from SPAD units and then totals chl content. Chlorophyll content was measured at 40 DAT.

v. Relative water content (RWC)

Three leafblades were randomly selected from each pot and cut with scissors. Relative water content (RWC) was measured. Relative water content was measured at 50 DAT. Leaf laminas were weighed (fresh weight, FW) and then immediately dipped into distilled water in a petridish for 24 h in the dark. Turgid weights (TW) were obtained after drying excess surface water with paper towels. Dry weights (DW) were measured after drying at 80^{0}C for 48 h. Then calculation was done using the following formula:

$$\text{RWC (\%)} = \frac{\text{FW- DW}}{\text{TW-DW}} \times 100$$

vi. Number of effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tillers per hill. Data on effective tiller per hill were recorded from each hill at harvesting time and average value was recorded.

vii. Number of non-effective tillers hill^{-1}

The total number of non-effective tillers hill^{-1} was counted as the tillers, which have no panicle on the head. Data on non-effective tiller per hill were counted from each hill at harvesting time and average value was recorded.

viii. Panicle length

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Panicle length was measured with a meter scale and average value was recorded.

ix. Number of filled grains panicle^{-1}

The total number of filled grains was collected from each panicle of each replication and then average number of filled grains per panicle was recorded.

x. Number of unfilled grains panicle^{-1}

The total number of unfilled grains was collected each panicle then average number of unfilled grains per panicle was recorded.

xi. Number of total grains panicle^{-1}

The number of filled grains panicle^{-1} along with the number of unfilled grains panicle^{-1} gave the total number of grains panicle^{-1}.

xii. Weight of 1000-grain

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained 12% moisture and the mean weight were expressed in gram.

xiii. Grain yield pot^{-1}

Grain from panicle from each pot were collected, dried for some days and then weighted.

xiv. Straw yield pot^{-1}

Straw obtained from each pot were sun dried and weighted carefully and finally converted to g pot^{-1}.

xv. Biological yield pot^{-1}

The summation of grain yield and above ground straw yield was the biological yield. Biological yield g pot^{-1} = (Grain yield g pot^{-1} + Stover yield g pot^{-1})

xvi. Harvest index (%)

Harvest index was calculated on dry weight basis with the help of following formula.

Harvest index (HI %) = $\frac{\text{Grain yield}}{\text{Biological yield}} \times 100$

Here, Biological yield = Grain yield + straw yield

3.15 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistix 10 Data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

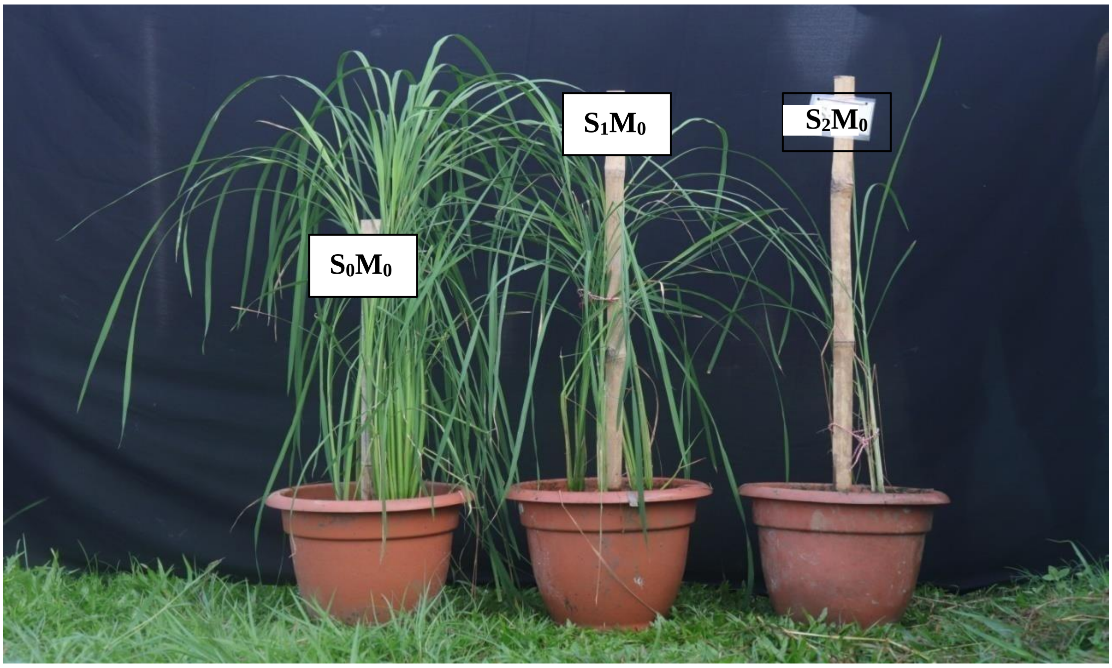
RESULTS AND DISCUSSION

Results obtained from the present study have been presented and discussed in this chapter with a view to study the amelioration of salinity stress in aromatic rice by application of organic manures. The data are given in different tables and figures. The results have been discussed, and possible interpretations are given under the following headings.

4.1 Phenotypic appearance

Effect of salt stress

Salinity drastically effects on rice plant. Increasing salinity level gradually decreased plant growth and development. At moderate salinity level plant withstand some degree of salt stress but increasing stress level reduce plant height, leaf numbers, tillers hill^{-1} and cause shrinkage of leaf and burning of leaf tip due to the adverse effect of salinity.

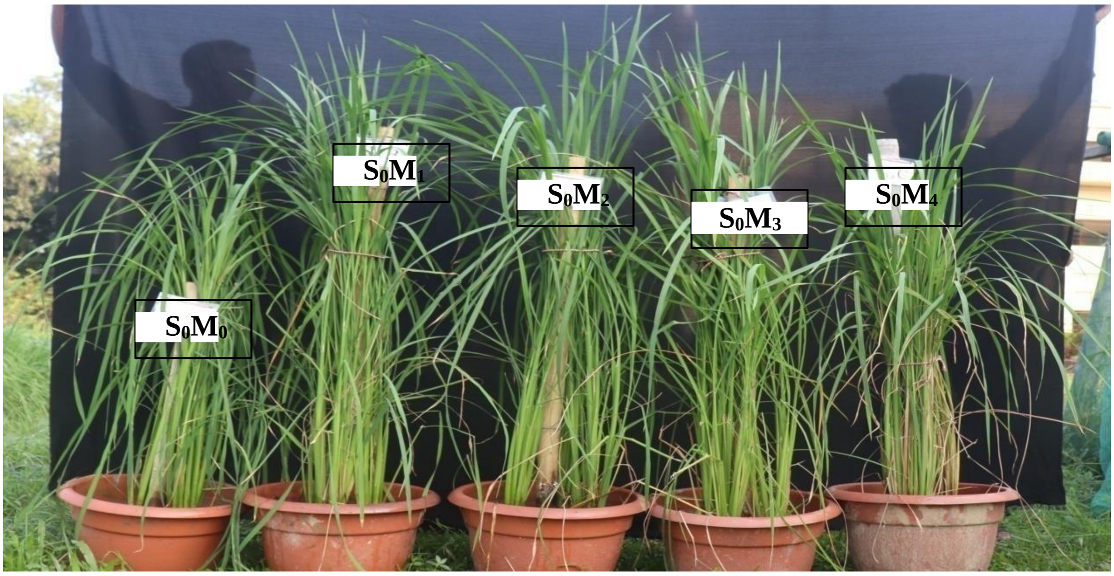


Here, S_0: 0 ppm (Control), S_1: 1200 ppm, S_2: 2400 ppm and M_0 : Without organic manures (Control).

Figure 2. Phenotypic appearance of Binadhan-13 under the effect of different salinity level at 50 DAT

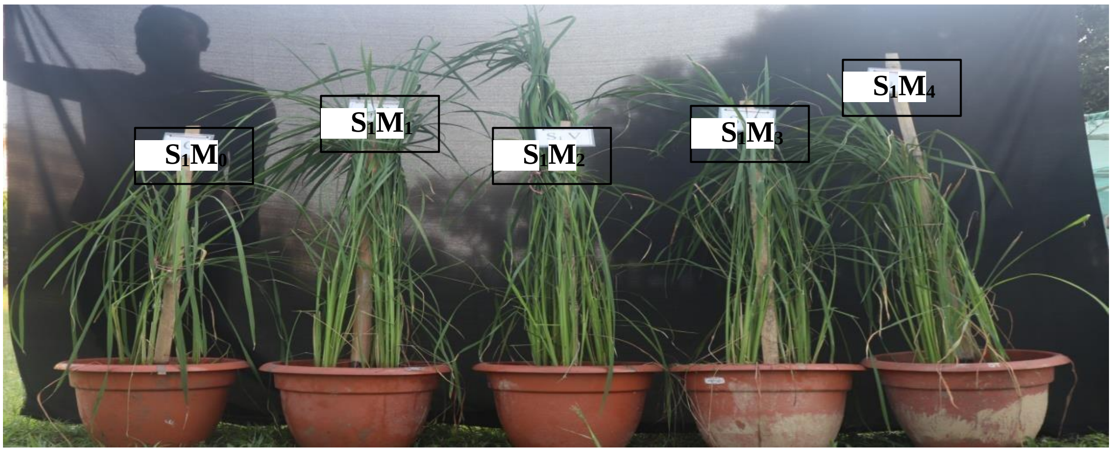
Effect of organic manures

Organic manure influences the plant growth by increasing leaf number, tiller number and plant height.



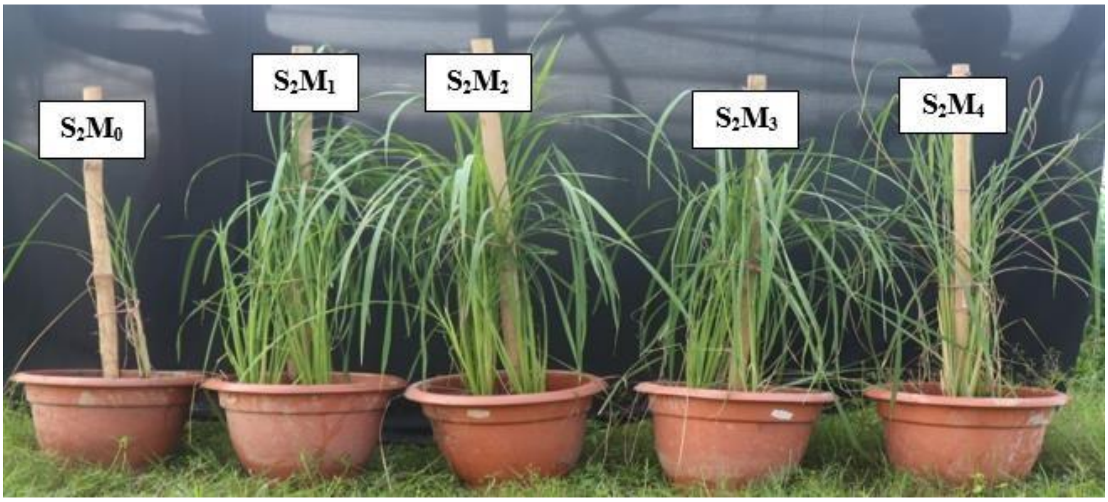
Here, S_0 : 0 ppm (Control), M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 3. Phenotypic appearance of Binadhan-13 under the effect of different organic manures application at 50 DAT



Here, S_1 : 1200 ppm, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 4. Phenotypic appearance of Binadhan-13 under the combined effect of salt levels and different organic manures application at 50 DAT



Here, S_2 : 2400 ppm, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 5. **Phenotypic appearance of Binadhan-13 under the combined effect of salt levels and different organic manures application at 50 DAT**

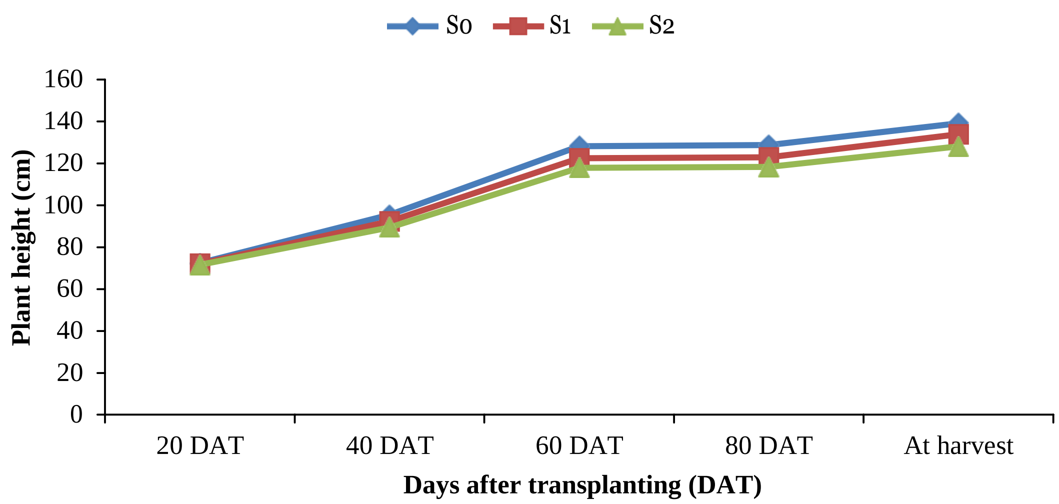
The application of manure is well-known for its ability to improve and preserve the biological, chemical, and physical properties of soil, as well as provide various nutrients, such as N. As a soil enhancer and fertilizer, manure is a highly valuable resource (Irshad *et al*, 2002). Baddour *et al* (2017) suggested that organic manures could be the safest way to preserve soil fertility, sustainability and salt resistance. Results reveled that organic manure application improve phenotypic appearance of Binadhan-13 such as plant height tiller number and leaf number under salt stress condition.

4.2 Plant growth parameters

4.2.1 Plant height

Effect of salt stress

Plant height is an important morphological character that acts as a potential indicator of availability of growth resources in its approach. Plant height was recorded at 20, 40, 60 and 80 DAT and at harvest. Different salinity level significantly effect on plant height of Binadhan-13 at 40, 60 and 80 DAT and at harvest (Figure 6). The maximum plant height (72.36, 95.42, 128.26, 128.87 and 139.23 cm) at 20, 40, 60 and 80 DAT and at harvest, respectively, were recorded in S_0 (Control) treatment. Increasing salinity level decreased plant height and the minimum plant height (71.63, 89.57, 117.96, 118.36 and 128.16 cm) at 20, 40, 60 and 80 DAT and at harvest respectively were recorded in S_2 (2400 ppm pot^{-1}) treatment which was (1.01 %, 6.13%, 8.03%, 8.15% and 7.95%) lower compared to control treatment. Gradual decrease in plant height might be due to the nutrient unavailability caused by increased salinity or the inhibition of cell division or cell enlargement. The result obtained from the present study was similar with the findings of Horie *et al.* (2012) and reported that salinity-induced osmotic stress, as a result water uptake by plant is hampered and plant suffers from physiological drought. This also led to the interruption of nutrient uptake. Under osmotic stress, regulation of water transport becomes a vital adaptive strategy of rice plants because a sufficient amount of water is indispensable for the cells to maintain their growth and vital cellular functions such as photosynthesis and metabolisms. This situation also induces stomatal closure, which results in the reduction of evaporation and water transport. A set of hormonal regulations also associated with these processes is upregulated many-fold under salt stress.



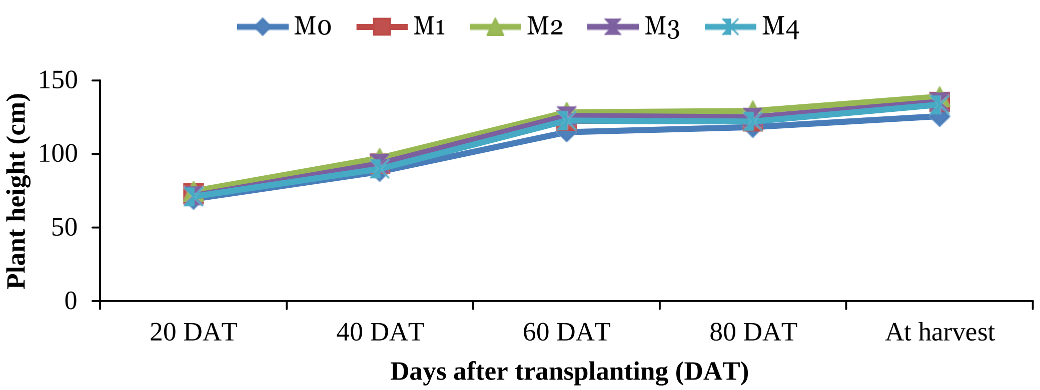
Note: Here, S_0: 0 ppm (Control), S_1 : 1200 ppm, S_2 : 2400 ppm.

Figure 6. Effect of salt stress on plant height of aromatic rice at different DAT [LSD $_{(0.05)}$ = NS, 0.71, 1.26, 1.49, 2.56 at 20, 40, 60 and 80 DAT and at harvest, respectively].

Effect of different organic manures

Application of different types of organic manure significantly influenced the plant height at different days after transplanting (Figure 7). Experimental result showed that the largest height (74.68, 97.17, 128.28, 129.28 and 138.90 cm) at 20, 40, 60 and 80 DAT and at harvest respectively were recorded by the application of Vermicompost @ 6 t ha^{-1} (M_2 treatment) which was 7.65, 10.23, 11.61, 9.29 and 10.57% higher compared

to control treatment. Whereas the minimum plant height (69.37, 88.15, 114.93, 118.29 and 125.62 cm) at 20, 40, 60 and 80 DAT and at harvest, respectively, were recorded in control treatment. Nutrient availability from organic sources is due to microbial action and improved physical condition of soil (Mahajan *et al.*, 2016) the increase in plant height in response to application of organic along with chemical fertilizers is probably due to enhanced availability of nutrients. In this experiment vermicompost has a positive effect on plant growth and development due to proper supply of nutrients to the plant which influences growth and development. Tharmaraj *et al.* (2011) also found similar result which supported the present finding reported that vermiproduct treated plants display quicker and higher growth rate and productivity than the control plots. Among the treated group, the development rate was high in the combination of vermicompost treated plants, than the vermicompost and vermiwash un-treated plants.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 7. Effect of organic manures on plant height of aromatic rice at different DAT [LSD $_{(0.05)}$ = 1.14, 0.91, 1.62, 1.93 and 3.30 at 20, 40, 60 and 80 DAT and at harvest, respectively].

Combined effect of salt stress and organic manure

Combined effect of salt stress and organic manure significantly affected on plant height of Binadhan-13 only at 40, 60 and 80 DAT and at harvest, respectively. (Table 4). The largest plant (75.42, 101.30, 133.13, 133.09 and 145.00 cm) at 20, 40, 60 and 80 DAT and at harvest, respectively, was recorded in S_0M_2 treatment combination which was 7.85, 7.05, 9.72, 6.76 and 8.59 % higher comparable to control treatment and it was statistically similar with S_0M_1 (130.55 cm) treatment combination at 60 DAT and with S_0M_3 (131.86 and 143.10 cm) treatment combination at 80 DAT and at harvest respectively. Whereas the minimum plant height (68.16, 82.25, 108.07, 110.16 and 112.40 cm) at 20, 40, 60, and 80 DAT and at harvest, respectively, was recorded in S_2M_0 treatment combination which was 2.53, 13.08, 10.93, 11.63 and 15.82 % lower comparable to control treatment. Wang *et al.* (2014) reported that a mixture of organic wastes decreased bulk density, EC, and ESP by 11, 87, and 71, respectively, and increased total porosity and organic carbon by 25 and 96% respectively, than the control. These results suggest the effectiveness of combination of different amendments for reclaiming salt-affected soil.

Table 4. Combined effect of salt stress and different organic manures on plant height of aromatic rice at different DAT and at harvest

Treatment Combinations	Plant height (cm)				
	20 DAT	40 DAT	60 DAT	80 DAT	At harvest
S_0M_0	69.93	94.63 c	121.34 g	124.66 d-f	133.53 c-g
S_0M_1	74.01	96.37 b	130.55 ab	127.96 cd	135.90 c-f
S_0M_2	75.42	101.30 a	133.13 a	133.09 a	145.00 a
S_0M_3	71.18	93.78 cd	128.54 bc	131.86 ab	143.10 ab
S_0M_4	70.14	91.01 f	127.74 cd	126.76 cd	138.63 bc
S_1M_0	70.01	87.57 g	115.38 h	120.06 g-i	130.93 e-g
S_1M_1	72.93	92.72 de	121.84 fg	121.36 f-h	136.80 cd
S_1M_2	74.94	96.36 b	127.32 cd	129.08 bc	136.50 c-e
S_1M_3	72.29	94.96 bc	125.52 de	123.16 e-g	133.00 c-g
S_1M_4	71.64	90.43 f	122.22 fg	121.06 gh	132.73 d-g
S_2M_0	68.16	82.25 h	108.07 i	110.16 j	112.40 h
S_2M_1	73.07	91.39 ef	115.74 h	117.66 i	133.60 c-g
S_2M_2	73.69	93.84 cd	124.40 ef	125.66 de	135.20 c-f
S_2M_3	71.76	92.00 ef	123.44 e-g	120.06 g-i	130.50 fg
S_2M_4	71.45	88.39 g	118.14 h	118.26 hi	129.10 g
$LSD_{(0.05)}$	Ns	1.58	2.80	3.34	5.71
CV (%)	1.97	1.20	1.60	1.90	2.99

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Note: Here,

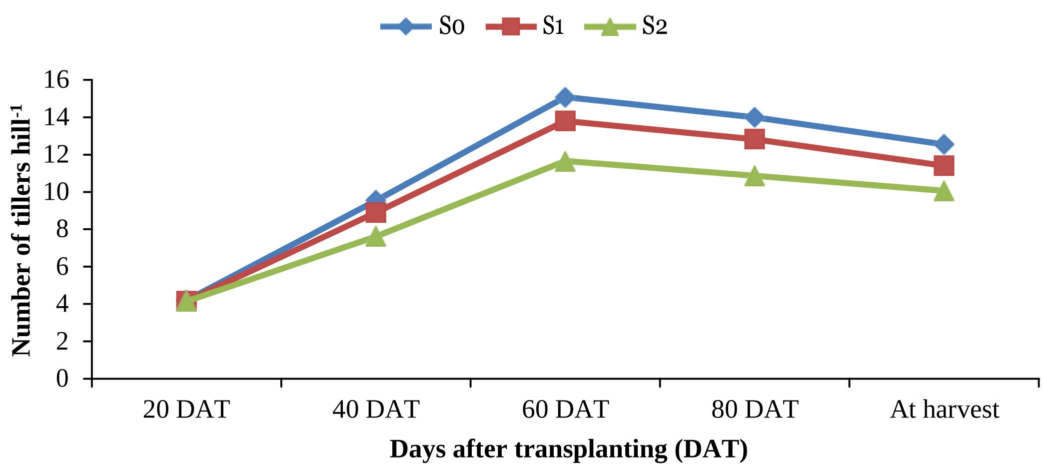
S_0 = 0 ppm pot^{-1} (Control)
S_1= 1200 ppm pot^{-1}
S_2 = 2400 ppm pot^{-1}

M_0 = 0.0 kg ha^{-1} (Control)
M_1 = Biochar 4 t ha^{-1}
M_2 = Vermicompost 6 t ha^{-1}
M_3 = Azolla 0.5 t ha^{-1}

4.2.2 Number of tillers hill^{-1}

Effect of salt stress

Different salt stress conditions have significant effect on number of tillers hill^{-1} of Binadhan-13 at 40, 60 and 80 DAT and at harvest respectively (Figure 8). Experimental result showed that the highest number of tillers hill^{-1} (4.20, 9.54 , 15.08 and 14.00 and 12.56) at 20, 40, 60 and 80 DAT and at harvest respectively was recorded in S_0 (Control) treatment. With the increasing salinity levels the number of tillers hill^{-1} drastically reduced. So the minimum number of tillers hill^{-1} (4.14, 7.63, 11.66, 10.87 and 10.07) at 20, 40, 60 and 80 DAT and at harvest respectively were recorded in S_2 (1.88 g pot^{-1}) treatment which was 20.02 , 22.68, 22.36 and 19.82 % lower comparable to control treatment. Results were similar with the findings of Aref (2013) who reported that rice plant subjected to salinity at tillering, panicle initiation, panicle emergence and ripening stage where salt-induced damages were higher at tillering and panicle initiation stages compared with other two stages.

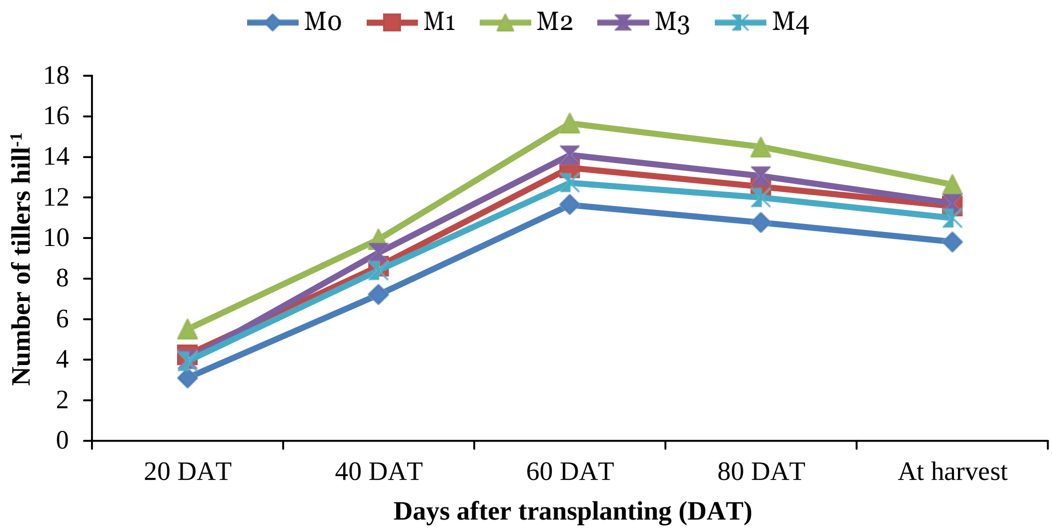


Note: Here, S_0: 0 ppm (Control), S_1: 1200 ppm, S_2: 2400 ppm.

Figure 8. Effect of salt stress on number of tillers hill^{-1}of aromatic rice at different DAT [LSD $_{(0.05)}$ = NS, 0.45, 0.54, 0.49 and 0.20 at 20, 40, 60 and 80 DAT and at harvest, respectively].

Effect of different organic manures

Different types of organic manures have significant effect on number of tillers hill^{-1} of Binadhan-13 at different stages of rice (Figure 9). Experimental results revealed that the highest number of tillers hill^{-1} (5.52, 9.94, 15.66, 14.50 and 12.65) at 20, 40, 60 and 80 DAT and at harvest, respectively, was recorded by the application of Vermicompost @ 6 t ha^{-1} (M_2 treatment) which was 77.49 , 37.68 , 34.54, 34.76 and 28.82 % higher over control treatment. Whereas the lowest number of tillers hill^{-1} (3.11, 7.22, 11.64, 10.76 and 9.82) at 20, 40, 60 and 80 DAT and at harvest respectively were recorded in control treatment. Different organic manure application showed different number of tillers hill^{-1} because of the variation of N availability, which plays a vital role in cell division. Organic sources offered more balanced nutrition to the plants, especially micro nutrients which positively affected number of tiller in plants. Results in agreement with Amitava *et al*. (2008) who reported that vermicompost and FYM offered balanced nutrition to the plants, which resulted better tillering in rice plants.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 9. Effect of organic manures on number of tillers hill^{-1}of aromatic rice at different DAT [LSD $_{(0.05)}$= 0.19, 0.58, 0.69, 0.64 and 0.27at 20, 40, 60 and 80 DAT and at harvest, respectively].

Combined effect of salt stress and organic manure

Combined effect of salt stress and organic manure significantly influenced the number of tillers hill^{-1} of Binadhan-13 at 40, 60, and 80 DAT and at harvest (Table 5). Experimental result revealed that the maximum number of tillers hill^{-1} (5.67, 12.00, 19.17, 17.67 and 13.70) at 20, 40, 60 and 80 DAT and at harvest, respectively, were recorded in S_0M_2 treatment combination which was 89, 63.93, 58.69, 56.09 and 16.10 % higher comparable to control treatment and it was statistically similar with S_0M_3 (11.06) treatment combination at 40 DAT. The lowest number of tillers hill^{-1} (3.00, 6.27, 9.69, 9.14, 8.67) were recorded in S_2M_0 treatment combination which was 14.34, 19.78, 19.26 and 26.53 lower comparable to control treatment and it was statistically similar with S_1M_0 (9.0) and S_2M_4 (9.10) treatment combination at harvest respectively. Clark *et al.* (2007) reported that the application of organic matter improves soil properties which are affected by salts, resulting in an improvement in growth through accelerating the leaching of toxic salts and cation exchange.

Table 5. Combined effect of salt stress and different organic manures on number of tillers hill^{-1} of aromatic rice at different DAT and at harvest

Treatment Combinations	Number of tillers hill^{-1}				
	20 DAT	40 DAT	60 DAT	80 DAT	At harvest
S_0M_0	3.00	7.32 e	12.08 gh	11.32 gh	11.80 e
S_0M_1	4.33	8.60 b-d	13.86 c-e	12.93 c-e	12.30 cd
S_0M_2	5.67	12.00 a	19.17 a	17.67 a	13.70 a
S_0M_3	4.00	11.06 a	16.73 b	15.39 b	13.00 b
S_0M_4	4.00	8.70 b-d	13.58 d-f	12.70 d-f	12.00 de
S_1M_0	3.33	8.06 c-e	13.16 e-g	11.82 fg	9.00 g
S_1M_1	4.10	8.90 bc	13.98 c-e	13.00 c-e	11.93 de
S_1M_2	5.45	9.50 b	14.91 c	13.83 c	12.67 bc
S_1M_3	4.00	9.40 b	14.47 cd	13.40 cd	11.60 e
S_1M_4	3.90	8.64 b-d	12.54 fg	12.11 e-g	11.87 de
S_2M_0	3.00	6.27 f	9.69 i	9.14 i	8.67 g
S_2M_1	4.33	8.33 c-e	12.55 fg	11.66 fg	10.50 f
S_2M_2	5.45	8.33 c-e	12.89 e-g	12.00 e-g	11.57 e
S_2M_3	4.00	7.38 e	11.07 h	10.38 h	10.53 f
S_2M_4	3.90	7.86 de	12.08 gh	11.19 gh	9.10 g
LSD(0.05)	NS	1.02	1.21	1.11	0.46
CV (%)	5.57	8.22	6.28	6.17	2.86

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Note: Here,

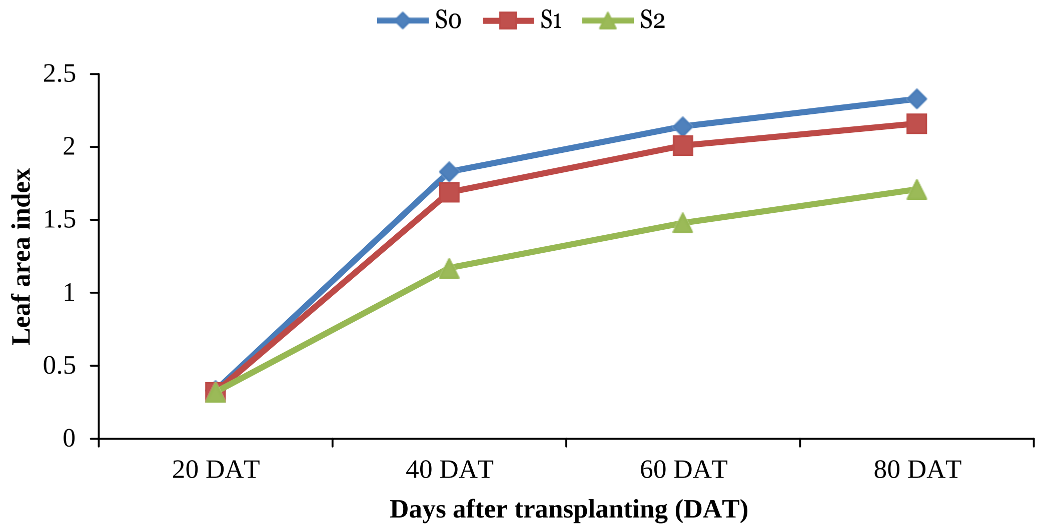
S_0 = 0 ppm pot^{-1} (Control)
S_1= 1200 ppm pot^{-1}
S_2 = 2400 ppm pot^{-1}

M_0 = 0.0 kg ha^{-1} (Control)
M_1 = Biochar 4 t ha^{-1}
M_2 = Vermicompost 6 t ha^{-1}
M_3 = Azolla 0.5 t ha^{-1}

4.2.3 Leaf area index (LAI)

Effect of salt stress

The LAI of rice vary with the canopy architecture, which depends on the cultivars, geography, and different field management practices. Due to different dose of salt application leaf area index of Binadhan-13 significantly influenced at 40, 60 and 80 DAT (Figure 10). Experimental result revealed that, the highest leaf area index (0.33, 1.83, 2.14 and 2.33) at 20, 40, 60 and 80 DAT respectively was recorded in S_0 or control treatment. With the increasing salinity levels leaf area index drastically reduced. So the minimum leaf area index (1.17, 1.48 and 1.71) at 40, 60 and 80 DAT was recorded in S_2 treatment which was (3.03, 36.07, 30.84 and 26.61 %) lower comparable to control treatment.

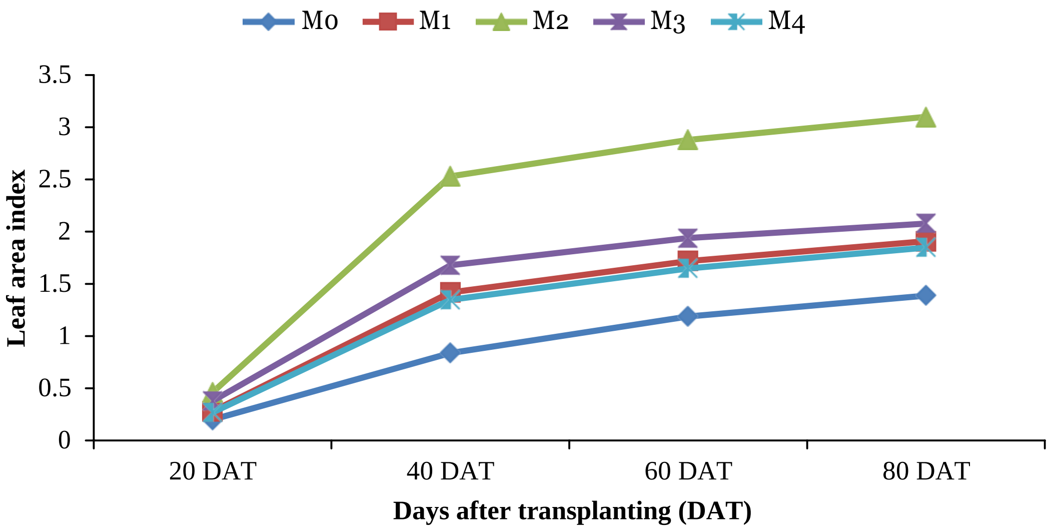


Note: Here, S_0: 0 ppm (Control), S_1: 1200 ppm, S_2: 2400 ppm.

Figure 10. Effect of salt stress on leaf area index aromatic rice at different DAT [LSD $_{(0.05)}$ = NS, 0.05, 0.03 and 0.06 at 20, 40, 60 and 80 DAT respectively].

Effect of different organic manures

Different types of organic manures have significant effect on leaf area index of Binadhan-13 at different days after transplanting (Figure 11). Experimental results revealed that the leaf area index (0.46, 2.53, 2.88 and 3.10) at 20, 40, 60, and 80 DAT were recorded by the application of Vermicompost @ 6 t ha^{-1} (M_2 treatment) which was 130 , 201.19, 142.02 and 123.02 % higher over control treatment. Whereas the minimum leaf area index (0.20, 0.84, 1.19 and 1.39) at 20, 40, 60 and 80 DAT and were recorded in control treatment (M_0). Muhammad *et al.* (2008) reported that the variations in leaf area index were observed due to different nutrient sources and their variation in the availability of major nutrients.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 11. Effect of organic manures on leaf area index aromatic rice at different DAT [LSD $_{(0.05)}$ = 0.01, 0.06, 0.05 and 0.08 at 20, 40, 60 and 80 DAT respectively].

Combined effect of salt stress and organic manure

Combined effect of salt stress and organic manure significantly influenced leaf area index of Binadhan-13 at 40, 60 and 80 DAT (Table 6). The highest leaf area index (0.47, 2.95, 3.22 and 3.57) at 20, 40, 60, and 80 DAT were recorded in S_0M_2 treatment combination which was 135, 189.22, 123.61 and 142.86 % higher compared to control treatment. The lowest leaf area index (0.20, 0.56, 0.91 and 1.14) at 20 DAT, 40, 60 and 80 DAT respectively was recorded in S_2M_0 treatment combination which was (45.09, 36.81 and 22.45 %) lower comparable to control treatment. Singh (2008) reported that the available nutrients might have helped in enhancing leaf area, which resulted in higher photo-assimilates and more dry matter accumulation. Clark *et al.* (2007) reported that the application of organic matter improves soil properties which are affected by salts, resulting in an improvement in growth through accelerating the leaching of toxic salts and cation exchange.

Table 6. Combined effect of salt stress and different organic manures on n leaf area index of aromatic rice at different DAT

Treatment Combinations	Leaf area index			
	20 DAT	40 DAT	60 DAT	80 DAT
S_0M_0	0.20	1.02 gh	1.44 g	1.47 h
S_0M_1	0.29	1.62 e	1.92 e	2.14 e
S_0M_2	0.47	2.95 a	3.22 a	3.57 a
S_0M_3	0.39	2.01 d	2.25 d	2.34 d
S_0M_4	0.28	1.55 ef	1.85 ef	2.11 e
S_1M_0	0.20	0.93 h	1.23 i	1.55 gh
S_1M_1	0.29	1.56 ef	1.86 ef	1.96 f
S_1M_2	0.46	2.52 b	2.99 b	3.09 b
S_1M_3	0.38	1.95 d	2.19 d	2.29 d
S_1M_4	0.27	1.49 f	1.79 f	1.89 f
S_2M_0	0.20	0.56 i	0.91 j	1.14 i
S_2M_1	0.27	1.09 g	1.39 gh	1.62 g
S_2M_2	0.45	2.12 c	2.42 c	2.65 c
S_2M_3	0.38	1.08 g	1.38 gh	1.61 gh
S_2M_4	0.27	1.02 gh	1.32 h	1.55 gh
$LSD_{(0.05)}$	NS	0.10	0.08	0.14
CV (%)	5.39	4.70	3.15	4.93

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Note: Here,

S_0 = 0 ppm pot^{-1} (Control)
S_1= 1200 ppm pot^{-1}
S_2 = 2400 ppm pot^{-1}

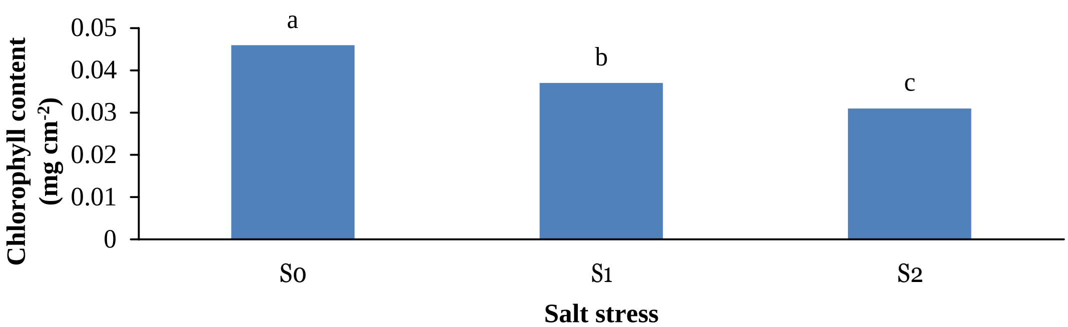
M_0 = 0.0 kg ha^{-1} (Control)
M_1 = Biochar 4 t ha^{-1}
M_2 = Vermicompost 6 t ha^{-1}
M_3 = Azolla 0.5 t ha^{-1}

4.3 Physiological parameters

4.3.1 Chlorophyll content

Effect of salt stress

Chlorophyll is the natural compound present in green plants that gives them their color. It helps plants to absorb energy from the sun as they undergo the process of photosynthesis. (Zhao *et al*., 2014). In this experiment, different salt stress condition significantly affected chlorophyll content at 40 DAT (Figure 12). Experimental result revealed that the maximum chlorophyll content (0.046) was recorded in Control (S_0) treatment which was gradually decreasing with increasing salt concentration. The minimum chlorophyll content (0.031) was recorded in S_2 treatment and it was (32.61 %) lower comparable to control treatment. 12-day-old rice seedlings exposed to 150 mM NaCl for 3 days caused 23 and 19% reduction in chl a and chl b, respectively, compared to control. As the duration of salt stress extended for further 3 days, chl a and chl b reduced by 46 and 48%, compared to control (Rahman *et al.* 2016). Ashraf and Harris (2013) reported that photosynthetic pigments, chl a and chl b, are greatly affected by different abiotic stresses including salinity. Accumulation of toxic Na^+ reduces the content of precursor of chl biosynthesis (such as glutamate and 5-aminolevullinic acid) and thus interrupts chl biosynthesis under saline condition. Amirjani (2010) found a dose-dependent reduction of chl content against salt stress (0, 25, 50, 100 and 200 mM NaCl). Under salt stress conditions (200 mM NaCl), chl a and chl b reduced by 44 and 27 %, respectively, compared to control.

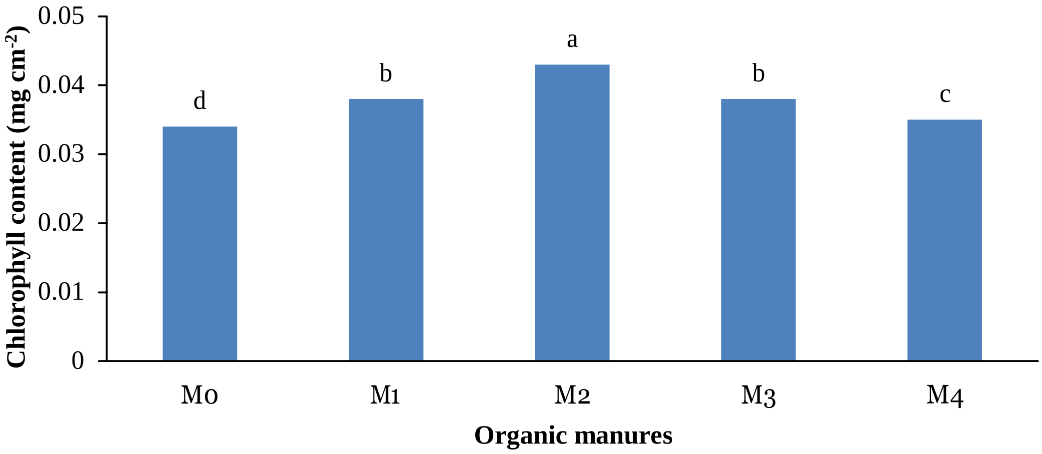


Note: Here, S_0: 0 ppm (Control), S_1: 1200 ppm, S_2 : 2400 ppm.

Figure 12. Effect of salt stress on chlorophyll content aromatic rice at 40 DAT [LSD $_{(0.05)}$ = 0.0005]

Effect of different organic manures

Different types of organic manure application significantly influenced chlorophyll content at 40 DAT (Figure 13). Experimental result revealed that the maximum chlorophyll content (0.043) was recorded in M_2 treatment which was (26.47 %) higher comparable to control treatment. Whereas the minimum chlorophyll content (0.034) was recorded in M_0 treatment. The result obtained from the present study was similar with the findings of Berova and Karanatsidis (2009) who reported that chlorophyll contents increased significantly with vermicompost application.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 13. Effect of organic manures on chlorophyll content of aromatic rice at 40 DAT [LSD $_{(0.05)}$ = 0.0007]

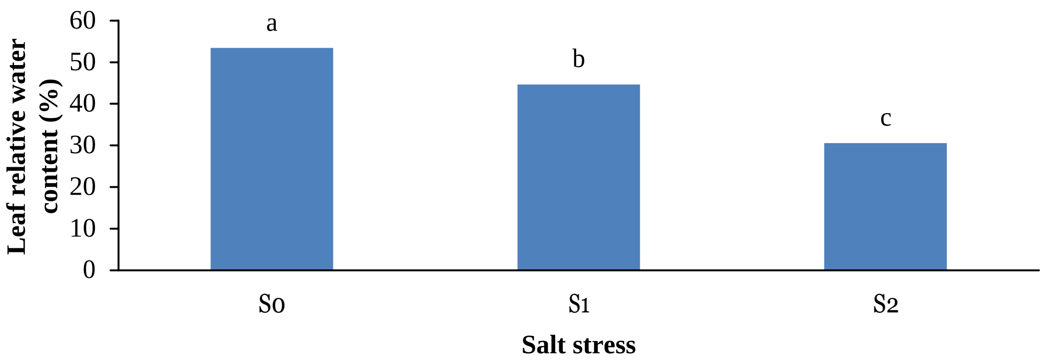
Combined effect of salt stress and organic manure

Combined effect of salt stress and organic manures have significant effect on chlorophyll content at 40 DAT (Table 7). Experimental result revealed that the maximum chlorophyll content (0.054) was recorded in S_0M_2 treatment combination which was (31.71 %) higher comparable to control treatment. Whereas the minimum chlorophyll content (0.028) was recorded in S_2M_0 treatment which was (31.71 %) lower comparable to control treatment.

4.3.2 Leaf relative water content (LRWC)

Effect of salt stress

Relative water content is described as the amount of water in a leaf at the time of sampling relative to the maximal water a leaf can hold. It is an important parameter in water relation studies, e.g. it allows the calculation of the osmotic potential at full turgor (Browne *et al*., 2020). In this experiment, different salt stress condition significantly influenced the leaf relative water content of Binadhan-13 at 50 DAT (Figure 14). Experimental results revealed that the maximum leaf relative water content (53.43) was recorded in control (S_0) treatment which was gradually decreasing with increasing salt concentration. The minimum leaf relative water content (30.52) was recorded in S_2 treatment and it was (42.88 %) lower comparable to control treatment. Romero-Aranda *et al.* (2006) reported that increase of salt in the root medium can lead to a decrease in leaf water potential and, hence, may affect many plant processes. Osmotic effects of salt on plants are the result of lowering of the soil water potential due to increase in solute concentration in the root zone. At very low soil water potentials, this condition interferes with plants' ability to extract water from the soil and maintain turgor. However, at low or moderate salt concentration (higher soil water potential), plants adjust osmotically (accumulate solutes) and maintain a potential gradient for the influx of water. Ghoulam *et al.* (2002) and Katerji *et al.* (1997) also reported that a decrease in RWC indicates a loss of turgor that results in limited water availability for cell extension processes.

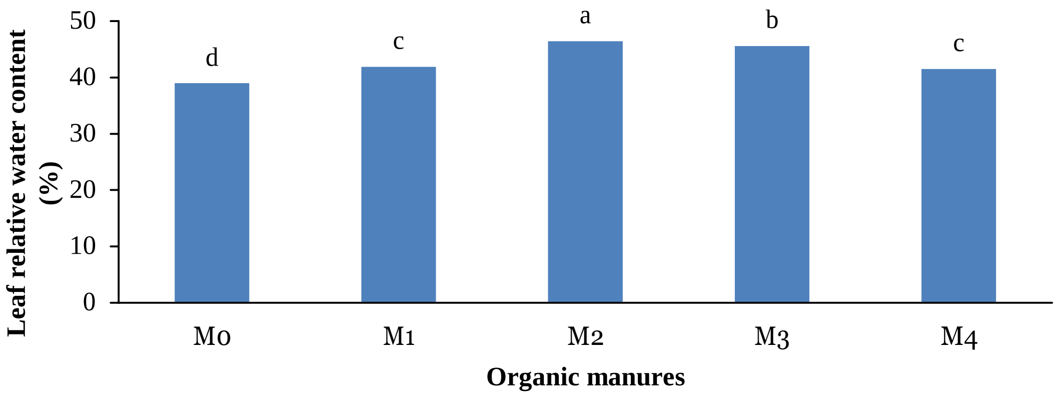


Note: Here, S_0 : 0 ppm (Control), S_1 : 1200 ppm, S_2 : 2400 ppm.

Figure 14. Effect of salt stress on leaf relative water content of aromatic rice at 50 DAT [LSD $_{(0.05)}$ = 0.63]

Effect of different organic manures

Application of different organic manures significantly influenced leaf relative water content of aromatic rice at 50 DAT (Figure 15). Experimental results revealed that the maximum leaf relative water content (46.43) was recorded in M_2 treatment which was 19.17 % higher comparable to control treatment. The minimum leaf relative water content (38.96) was recorded in M_0 treatment. The result obtained from the present study was similar with the findings of Verma *et al*. (2013) who reported that leaf relative water content (LRWC) was significantly enhanced by vermicompost application.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 15. Effect of organic manures on leaf relative water content of aromatic rice at 50 DAT [LSD $_{(0.05)}$ = 0.81]

Combined effect of salt stress and organic manure

Combined effect of salt stress and organic manure significantly affected leaf relative water content of binadhan-13 at 50 DAT (Table 7). The maximum leaf relative water content (54.71) was recorded in S_0M_2 treatment combination which was (3.81 %) higher comparable to control (S_0M_0) treatment which was statistically similar with S_0M_3 treatment combination recorded leaf relative water (54.05) at 50 DAT. Whereas the minimum leaf relative water content (24.07) was recorded in S_2M_0 treatment which was (54.33 %) lower comparable to control treatment. Clark *et al.* (2007) reported that the application of organic matter improves soil properties which are affected by salts, resulting in an improvement in growth through accelerating the leaching of toxic salts and cation exchange.

Table 7. Combined effect of salt stress and different organic manures on leaf relative water content and chlorophyll contents of aromatic rice

Treatment Combinations	Chlorophyll contents	Leaf relative water content (%)
S_0M_0	0.041 c	52.70 b
S_0M_1	0.046 b	52.90 b
S_0M_2	0.054 a	54.71 a
S_0M_3	0.046 b	54.05 ab
S_0M_4	0.041 c	52.80 b
S_1M_0	0.034 e	40.12 e
S_1M_1	0.037 d	42.68 d
S_1M_2	0.041 c	49.20 c
S_1M_3	0.037 d	48.90 c
S_1M_4	0.035 e	42.33 d
S_2M_0	0.028 h	24.07 i
S_2M_1	0.032 f	30.08 h
S_2M_2	0.034 e	35.37 f
S_2M_3	0.032 f	33.78 g
S_2M_4	0.030 g	29.32 h
$LSD_{(0.05)}$	0.001	1.41
CV (%)	2.26	2.31

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Note: Here,

S_0 = 0 ppm pot^{-1} (Control), S_1= 1200 ppm pot^{-1}, S_2 = 2400 ppm pot^{-1}

M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1},

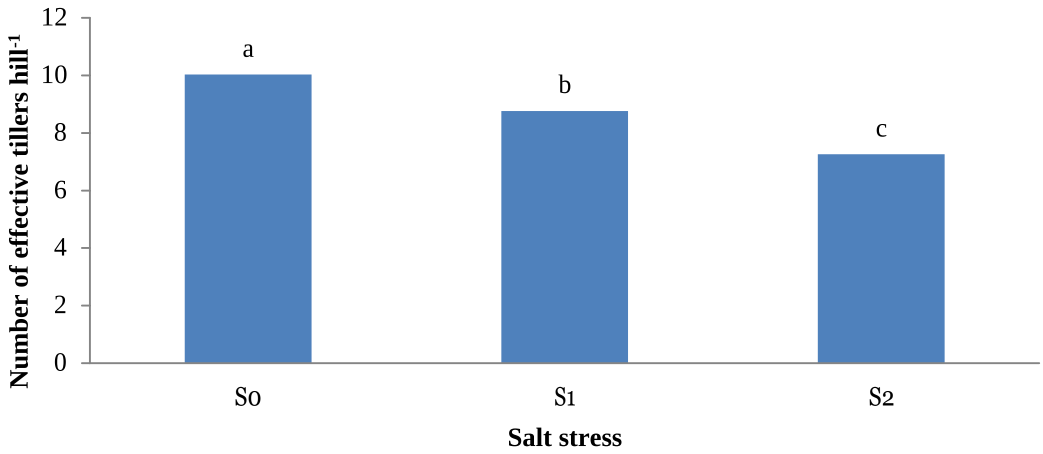
M_3 = Azolla 0.5 t ha^{-1}, M_4 = Cowdung 10 t ha^{-1}

4.4 Yield contributing characters

4.4.1 Number of effective tillers hill^{-1}

Effect of salt stress

It is obvious from the data that number of effective tillers hill^{-1} varied significantly under different salt stress condition (Figure 16). Among all the treatments, the highest number of effective tillers hill^{-1} (10.03) was recorded in control (S_0) treatment and the number of tillers hill^{-1} decreased with increasing salinity levels in rice. The minimum number of effective tillers hill^{-1} (7.26) was recorded in (S_2) treatment which was (27.62 %) lower over control treatment. Extreme salt stress showed negative impact on growth and development of the plant. The reduction of a number of effective tillers is common during salt stress in the plant. A number of effective tillers significantly reduced in Binadhan-13 under all salt stress levels. This difference is directly linked with chlorophyll contents (SPAD values), and photosynthesis activities in rice leaves. The results in a reduction of the C assimilation and biomass production due to osmotic stress and ion imbalance high Na^+ and Cl^- in soil and plant tissues under salt stress condition. Aref (2013) reported that rice plant subjected to salinity at tillering, panicle initiation, panicle emergence and ripening stage where salt-induced damages were higher at tillering and panicle initiation stages compared with other two stages.

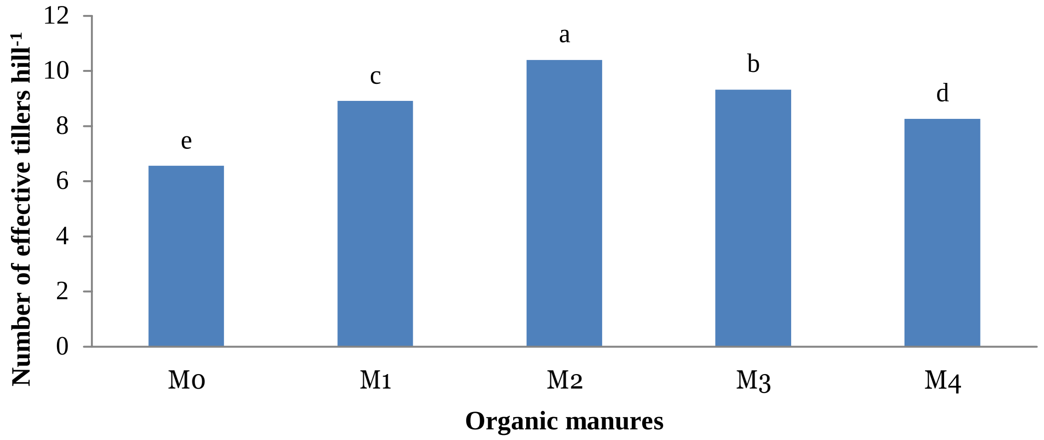


Note: Here, S_0: 0 ppm (Control), S_1: 1200 ppm, S_2: 2400 ppm.

Figure 16. Effect of salt stress on number of effective tillers hill^{-1} of aromatic rice at harvest [LSD $_{(0.05)}$ = 0.20]

Effect of different organic manures

Different types of organic manure application significantly influenced the number of effective tillers $hill^{-1}$ of Binadhan-13 (Figure 17). The highest number of effective tillers $hill^{-1}$ (10.40) was recorded in M_2 treatment which was (58.53 %) higher comparable to control treatment. Whereas the minimum effective tillers $hill^{-1}$ (6.56) was recorded in M_0 treatment. The higher effective tiller $hill^{-1}$ organic matter treated pot comparable to control one due to better availability of nutrients applied either through fertilizers or in combination with organic sources increased growth and development of the crop. The result obtained from the present study was similar with the findings of Tazmin *et al.* (2015) who reported that application of manure and fertilizers enhanced the yield contributing the character of rice. Nayak *et al*. (2007) reported a significant increase in effective tillers/hill due to application of chemical fertilizer with organic manure.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 17. Effect of organic manures on number of effective tillers $hill^{-1}$ of aromatic rice at harvest [LSD $_{(0.05)}$ = 0.25].

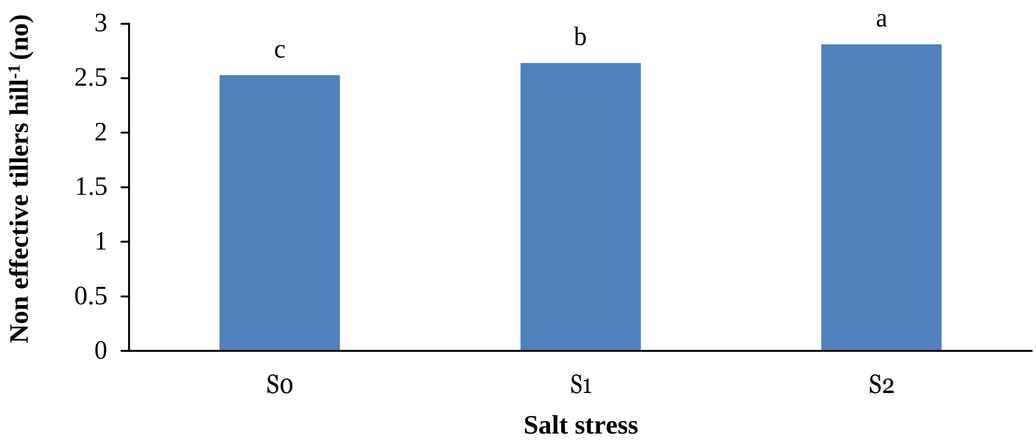
Combined effect of salt stress and organic manure

Combined effect of salt stress and organic manures has significant effect on number of effective tillers $hill^{-1}$ of Binadhan-13 (Table 8). The maximum number of effective tillers $hill^{-1}$ (11.51) was recorded in S_0M_2 treatment combination which was (27.89 %) higher comparable to control treatment. Whereas the minimum number of effective tillers $hill^{-1}$ (5.00) was recorded in S_2M_0 treatment combination which was (44.44 %) lower comparable to control (S_0M_0) treatment combination. Roy *et al.* (2006) reported that organic matter has several beneficial effects on agricultural fields, such as the slow release of nutrients, soil structure improvement, and the protection of soils against erosion. Hu and Schmidhalter (2005) highlighted, the uptake of phosphorous (P) by crops is reduced in dry-soil conditions and the availability of this macronutrient can be reduced in saline soils. Conversely, during the mineralization process, organic matter releases humic substances, which may convert soil phosphates into available forms, improving release from hardly soluble rock minerals due to high total acidity.

4.4.2 Number of non-effective tillers $hill^{-1}$

Effect of salt stress

Salt stress condition significantly influenced the number of non-effective tillers $hill^{-1}$ of Binadhan-13 (Figure 18). Experimental result showed that the maximum number of non-effective tillers $hill^{-1}$ (2.81) was recorded in S_2 treatment which was (11.07 %) higher over control treatment. Whereas the minimum number of non-effective tillers $hill^{-1}$ (2.53) was recorded in control (S_0) treatment. Salinity causes toxicity to plant and among different parts of the plant roots are usually the first tissue to be exposed to salinity, where the salt ions inhibit root extension and proliferation. Upon translocation to the shoot, salt ions can severely inhibit plant growth by slowing or arresting expansion and biomass accumulation result in slow crop growth rate as well as compromising plant reproductive capacity through losses in fertility, yield, and seed production. As a result the number of non-effective tillers $hill^{-1}$ increased with increasing the level of salinity. Aref (2013) reported that rice plant subjected to salinity at tillering, panicle initiation, panicle emergence and ripening stage where salt-induced damages were higher at tillering and panicle initiation stages compared with other two stages.

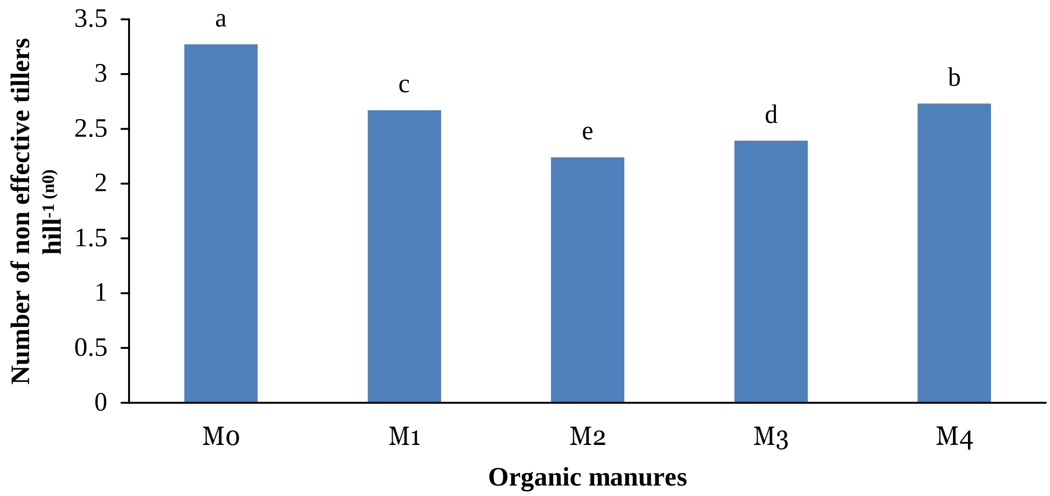


Note: Here, S_0: 0 ppm (Control), S_1: 1200 ppm, S_2: 2400 ppm.

Figure 18. Effect of salt stress on number of non-effective tillers hill^{-1} of aromatic rice at harvest [LSD $_{(0.05)}$ = 0.03].

Effect of different organic manures

Application of different organic manures has significantly effect on number of non-effective tillers hill^{-1} of Binadhan-13 (Figure 19). Experimental result showed that the maximum number of non-effective tillers hill^{-1} (3.27) was recorded in M_0 treatment. Whereas the minimum number of non-effective tillers hill^{-1} (2.24) was recorded in (M_2) treatment which was (31.49 %) lower over control treatment. Tazmin *et al.* (2015) reported that application of manure and fertilizers enhanced the yield contributing the character of rice. As a result in this experiment due to lack of proper nutrients supply number of non-effective tillers hill^{-1} was higher in control treatment comparatively to other organic manure treated plots.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}

Figure 19. Effect of organic manures on number of non-effective tillers hill^{-1} of aromatic rice [LSD $_{(0.05)}$ = 0.03].

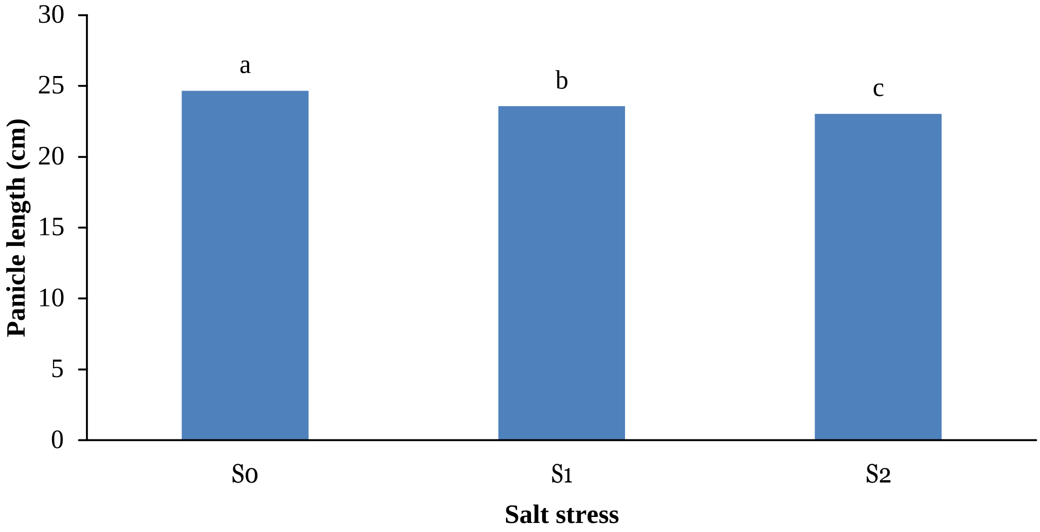
Combined effect of salt stress and organic manure

Combination of salt stress and organic manures has significantly effect on number of non-effective tillers hill^{-1} of Binadhan-13 (Table 8). Experimental result revealed the maximum number of non-effective tillers hill^{-1} (3.67) was recorded in S_2M_0 treatment combination which was 31.07 % higher comparable to control treatment. Whereas the minimum number of non-effective tillers hill^{-1} (2.18) was recorded in S_0M_2 treatment combination which was 22.14 % lower comparable to control treatment combination.

4.4.3 Panicle length

Effect of salt stress

Binadhan-13 rice variety showed significant variation in respect of panicle length due to the effect of different salt stress condition (Figure 20). Experimental results showed that the maximum panicle length (24.66 cm) was recorded in S_0 treatment. Increasing salt stress gradually decreasing panicle length growth and seedling survival rates decreased by salinity. The minimum panicle length (23.03 cm) was recorded in S_2 treatment which was (6.61 %) lower over control treatment. It is possible that the decrease of panicle length in salinized plants were due to several reasons. One possibility is that salinity reduced photosynthesis, which in turn limited the supply of carbohydrate needed for growth.

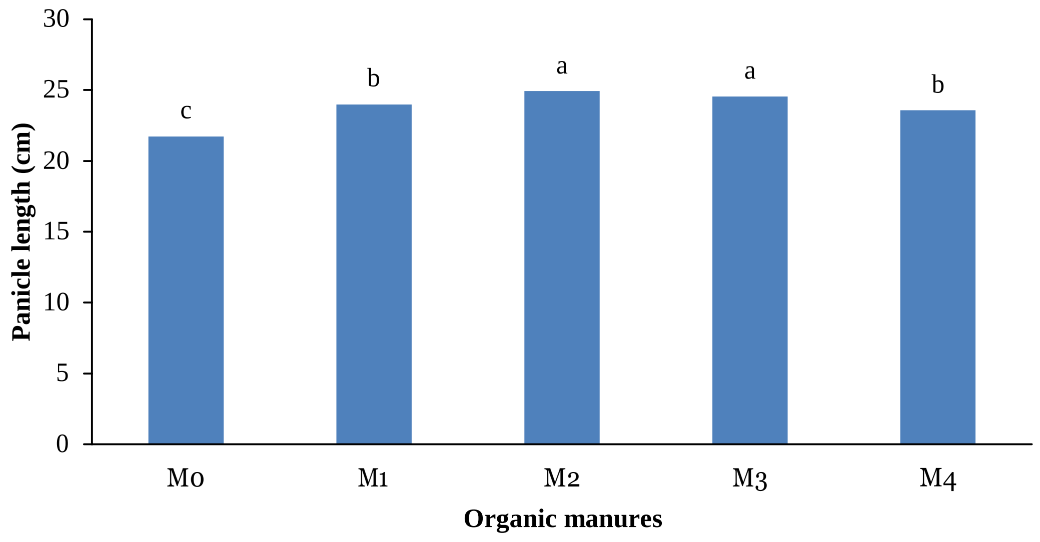


Note: Here, S_0: 0 ppm (Control), S_1: 1200 ppm, S_2: 2400 ppm.

Figure 20. Effect of salt stress on panicle length of aromatic rice at harvest [LSD $_{(0.05)}$ = 0.34].

Effect of different organic manures

Application of different organic manure significantly influenced panicle length of Binadhan-13 (Figure 21). Experimental result showed that the maximum panicle length (24.93 cm) was recorded in M_2 treatment which was (14.67 %) higher over control treatment and it was statistically similar with M_3 treatment (24.55 cm). Whereas, the minimum panicle length (21.74 cm) was recorded in control (M_0) treatment. Tazmin *et al.* (2015) reported that application of manure and fertilizers enhanced the yield contributing character of rice. As a result in this experiment due to lack of proper nutrients supply panicle length was minimum in control treatment comparatively to other organic manure treated pots.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 21. Effect of organic manures on panicle length of aromatic rice at harvest [LSD $_{(0.05)}$ = 0.44]

Combined effect of salt stress and organic manure

Different salt stress condition along with different organic manures has significantly effect on panicle length of Binadhan-13 (Table 8). The maximum panicle length (25.87) was recorded in S_0M_2 treatment combination which was (11.56 %) higher comparable to control treatment (S_0M_0). Whereas the minimum panicle length (20.33 cm) was recorded in S_2M_0 treatment combination which was (12.33 %) lower comparable to control treatment combination. Clark *et al.* (2007) reported that the application of organic matter improves soil properties which were affected by salts, resulting in an improvement in growth through accelerating the leaching of toxic salts and cation exchange.

Table 8. Combined effect of salt stress and different organic manures on effective, non-effective tillers hill^{-1} and panicle length of aromatic rice

Treatment Combinations	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)
S_0M_0	9.00 d	2.80 d	23.19 ef
S_0M_1	9.50 c	2.80 d	24.57 b
S_0M_2	11.51 a	2.18 i	25.87 a
S_0M_3	10.75 b	2.25 h	25.60 a
S_0M_4	9.40 cd	2.60 e	24.07 b-d
S_1M_0	5.67 g	3.33 b	21.69 g
S_1M_1	9.53 c	2.40 f	23.93 b-e
S_1M_2	10.40 b	2.27 h	24.67 b
S_1M_3	9.00 d	2.60 e	23.90 b-e
S_1M_4	9.27 cd	2.60 e	23.70 c-f
S_2M_0	5.00 h	3.67 a	20.33 h
S_2M_1	7.70 f	2.80 d	23.46 d-f
S_2M_2	9.30 cd	2.27 h	24.25 bc
S_2M_3	8.20 e	2.33 g	24.15 b-d
S_2M_4	6.10 g	3.00 c	22.96 f
$LSD_{(0.05)}$	0.44	0.06	0.77
CV (%)	3.55	1.53	2.27

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Note: Here,

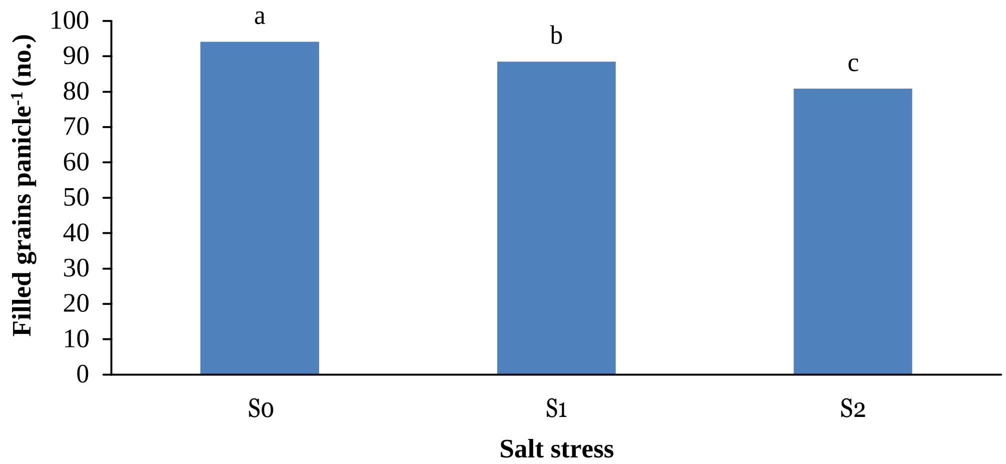
S_0 = 0 ppm pot^{-1} (Control)
S_1= 1200 ppm pot^{-1}
S_2 = 2400 ppm pot^{-1}

M_0 = 0.0 kg ha^{-1} (Control)
M_1 = Biochar 4 t ha^{-1}
M_2 = Vermicompost 6 t ha^{-1}
M_3 = Azolla 0.5 t ha^{-1}

4.4.4 Number of filled grains panicle^{-1}

Effect of salt stress

Binadhan-13 showed significant variation in respect of number of filled grains panicle^{-1} due to the effect of different salt stress condition (Figure 22). Experiment result showed that the maximum number of filled grains panicle^{-1} (94.12) was recorded in S_0 treatment. Increasing salt stress gradually decreasing number of filled grains panicle^{-1} due to that salinity affects plants with nitrogen uptake, reducing growth and stopping plant reproduction. Some ions (particularly chloride) are toxic to plants and as the concentration of these ions increases, the plant is poisoned and dies. The minimum number of filled grains panicle^{-1} (80.85) was recorded in S_2 treatment which was (14.09 %) lower over control treatment. The result obtained from the present study was similar with the findings of Aref (2013) who reported that rice plant subjected to salinity at tillering, panicle initiation, panicle emergence and ripening stage where salt-induced damages were higher at tillering and panicle initiation stages compared with other two stages.

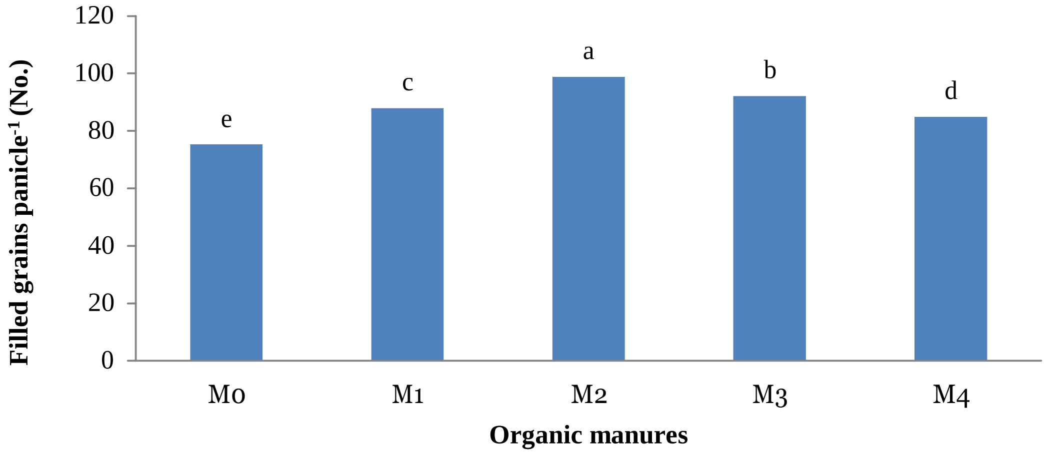


Note: Here, S_0: 0 ppm (Control), S_1: 1200 ppm, S_2: 2400 ppm.

Figure 22. Effect of salt stress on number of filled grains panicle^{-1}of aromatic rice at harvest [LSD $_{(0.05)}$= 1.63].

Effect of different organic manures

Different types of organic manure application have significant influenced on number of filled grains panicle^{-1} of Binadhan-13 (Figure 23). Experimental result revealed that the maximum number of filled grains panicle^{-1} (98.83) was recorded in M_2 treatment which was (31.20 %) higher comparable to control treatment. Whereas the minimum number of filled grains panicle^{-1} (75.33) was recorded in M_0 treatment. The result obtained from the present study was similar with the findings of Tazmin *et al.* (2015) who reported that application of manure and fertilizers enhanced the yield contributing characters of rice.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 23. Effect of organic manures on number of filled grains panicle^{-1}of aromatic rice at harvest [LSD $_{(0.05)}$ = 2.11].

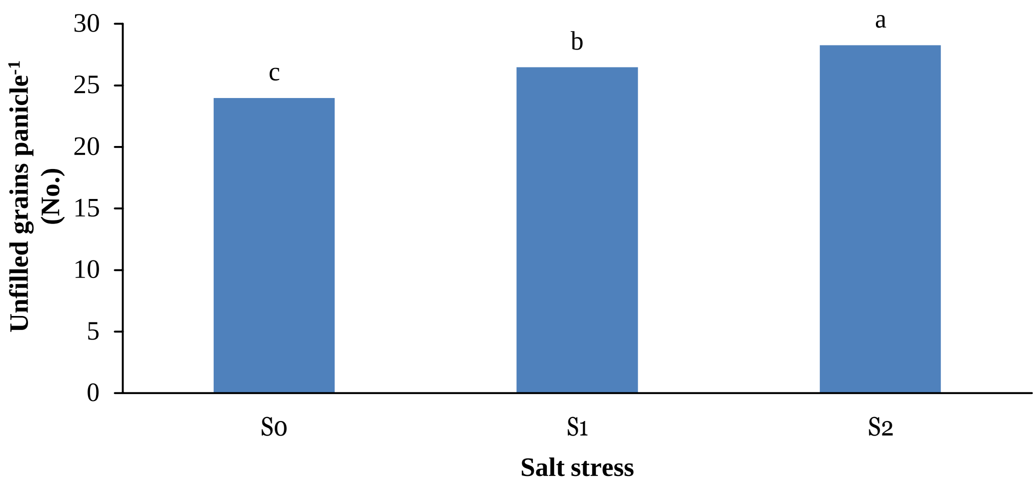
Combined effect of salt stress and organic manure

Different salt stress condition along with different organic manure significantly affected the number of filled grains panicle^{-1} of Binadhan-13 (Table 9). The maximum number of filled grains panicle^{-1} (107.00) was recorded in S_0M_2 treatment combination which was (28.41 %) higher comparable to control treatment combination. Whereas the minimum number of filled grains panicle^{-1} (66.67) was recorded in S_2M_0 treatment combination which was (19.99 %) lower comparable to control treatment combination. Clark *et al.* (2007) reported that the application of organic matter improves soil properties which are affected by salts, resulting in an improvement in growth through accelerating the leaching of toxic salts and cation exchange. Crecchio *et al*. (2004) also reported that adding compost in soil improves the chemical and physical properties under salinity environment and applying solid municipal waste compost continuously for extended periods increases the content of organic matter in soil as well as C/N ratio when compared to soil with no organic matter additions.

4.4.5 Number of unfilled grains panicle^{-1}

Effect of salt stress

Number of unfilled grains panicle^{-1} of Binadhan-13 varied significantly due to the effect of different salt stress condition (Figure 24). Experimental result showed that the maximum number of unfilled grains panicle^{-1} (28.26) was recorded in S_2 treatment which was 17.89 % higher over control treatment. The minimum number of unfilled grains panicle^{-1} (23.97) was recorded in S_0 treatment. Plants when exposed to excess salt condition either in soil or in solution culture, they exhibited toxicity symptoms such as: inhibition of seed germination, decrease in plant height, lower filled grains panicle^{-1}, seed yield and sometimes leads to death.



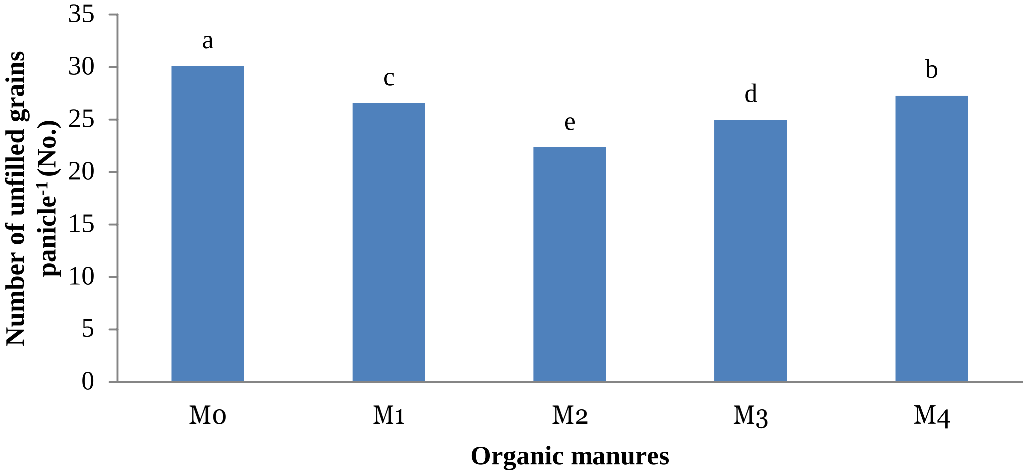
Note: Here, S_0: 0 ppm (Control), S_1: 1200 ppm, S_2: 2400 ppm.

Figure 24. Effect of salt stress on number of unfilled grains panicle^{-1}of aromatic rice at harvest [LSD $_{(0.05)}$ = 0.38].

Effect of different organic manures

Application of different types of organic manure significantly influenced the number of unfilled grains panicle^{-1} of Binadhan-13 (Figure 25). Experimental result revealed that the maximum number of unfilled grains panicle^{-1} (30.09) was recorded in M_0

treatment. Whereas the minimum number of unfilled grains panicle^{-1} (22.34) was recorded in M_2 treatment which was (25.75 %) lower over control treatment.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 25. Effect of organic manures on number of unfilled grains panicle^{-1}of aromatic rice at harvest [LSD $_{(0.05)}$= 0.49].

Combined effect of salt stress and organic manure

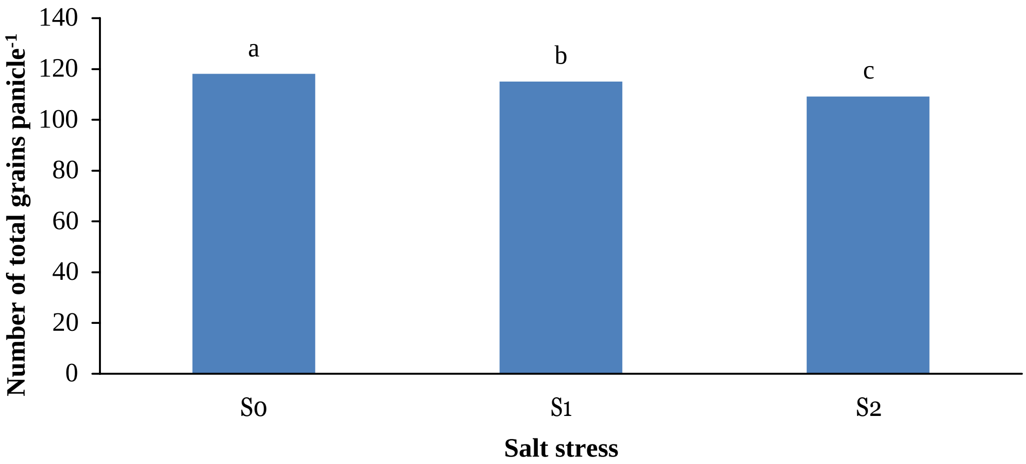
Different salt stress condition along with different organic manures significantly affected on number of unfilled grains panicle^{-1} of Binadhan-13 (Table 9). Experimental result revealed the maximum number of unfilled grains panicle^{-1} (33.07) was recorded in S_2M_0 treatment combination which was (21.58 %) higher comparable to control treatment combination. Whereas the minimum number of unfilled grains panicle^{-1} (19.21) was recorded in S_0M_2 treatment combination which was (29.38 %) lower comparable to control treatment combination.

4.4.6 Number of total grains panicle^{-1}

Effect of salt stress

Binadhan-13 rice variety showed significant variation in respect of number of total grains panicle^{-1} due to the effect of different salt stress condition (Figure 26).

Experimental result showed that the maximum number of total grains panicle^{-1} (118.09) was recorded in S_0 treatment. Increasing salt stress gradually decreasing number of total grains panicle^{-1} due to that salinity affects plants with nitrogen uptake, reducing growth and stopping plant reproduction. Some ions (particularly chloride) are toxic to plants and as the concentration of these ions increases, the plant is poisoned and dies. The minimum number of total grains panicle^{-1} (109.11) was recorded in S_2 treatment which was (7.60 %) lowers over control treatment.

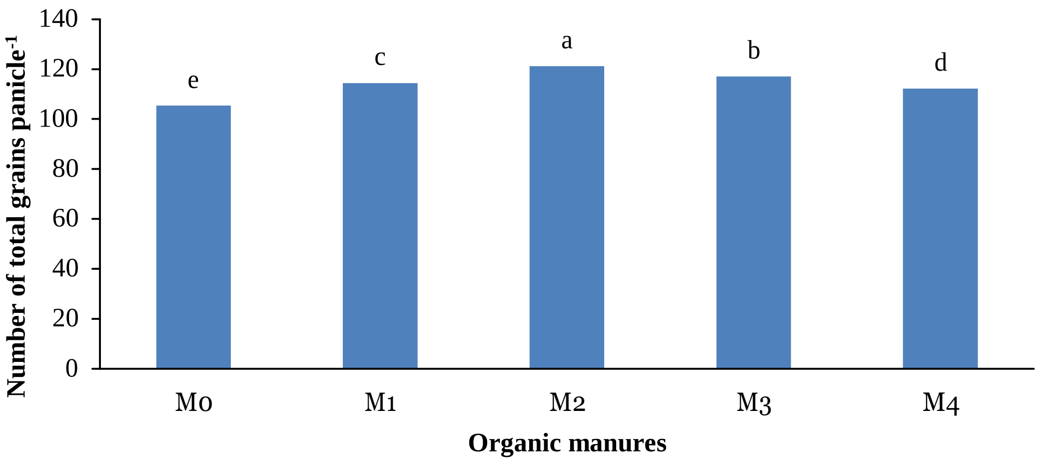


Note: Here, S_0 : 0 ppm (Control), S_1 : 1200 ppm, S_2 : 2400 ppm.

Figure 26. Effect of salt stress on number of total grains panicle^{-1}of aromatic rice at harvest [LSD $_{(0.05)}$= 1.07].

Effect of different organic manures

Different types of organic manure application significantly affected on number of total grains panicle^{-1} of Binadhan-13 (Figure 27). Experimental result revealed that the maximum number of total grains panicle^{-1} (121.17) was recorded in M_2 treatment which was (14.94 %) higher comparable to control treatment. Whereas the minimum number of filled grains panicle^{-1} (105.42) was recorded in M_0 treatment. The higher number of total grains panicle^{-1} in organic matter treated plot comparable to control one due to better availability of nutrients applied either through fertilizers or in combination with organic sources increased growth and development of the crop. The result obtained from the present study was similar with the findings of Tazmin *et al.* (2015) who reported that application of manure and fertilizers enhanced the yield contributing characters of rice.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 27. Effect of organic manures on number of total grains panicle^{-1}of aromatic rice at harvest [LSD $_{(0.05)}$= 1.39].

Combined effect of salt stress and organic manure

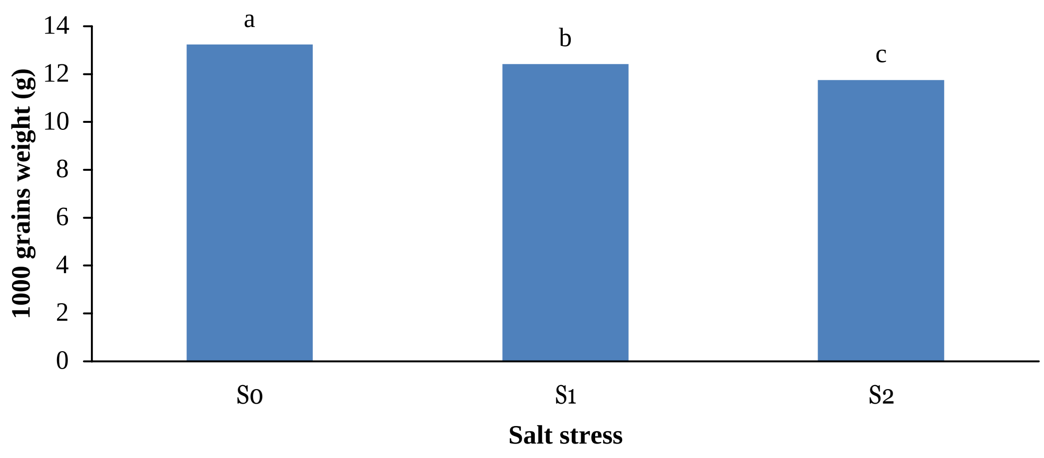
Combination of salt stress and with different organic manures have significantly affected on number of total grains panicle^{-1} of Binadhan-13 (Table 9). The maximum number of total grains panicle^{-1} (126.21) was recorded in S_0M_2 treatment combination which was (14.19 %) higher comparable to control treatment combination. Whereas the minimum number of total grains panicle^{-1} (99.74) was recorded in S_2M_0 treatment combination which was (9.76 %) lower comparable to control treatment combination.

4.4.7 1000 grains weight

Effect of salt stress

Different salt level significantly influenced 1000 grains weight of Binadhan-13 (Figure 28). Experimental result showed that the maximum 1000 grains weight (13.24 g) was recorded in S_0 treatment. Whereas the minimum 1000 grains weight (11.75 g) was recorded in S_2 treatment which was (11.25 %) lower over control treatment. The variation of 1000 grains weight among different treatment due to reason that salt availability in soil can disturb normal functioning of plant metabolism, consequently leading to stunted growth and low crop productivity. Kumar and Khare

(2016) also found similar result which supported the present finding and reported that salinity reduced number of grain per panicle, filled grain percentage, 1000-grain weight and grain yield both in sensitive and in tolerant cultivar.

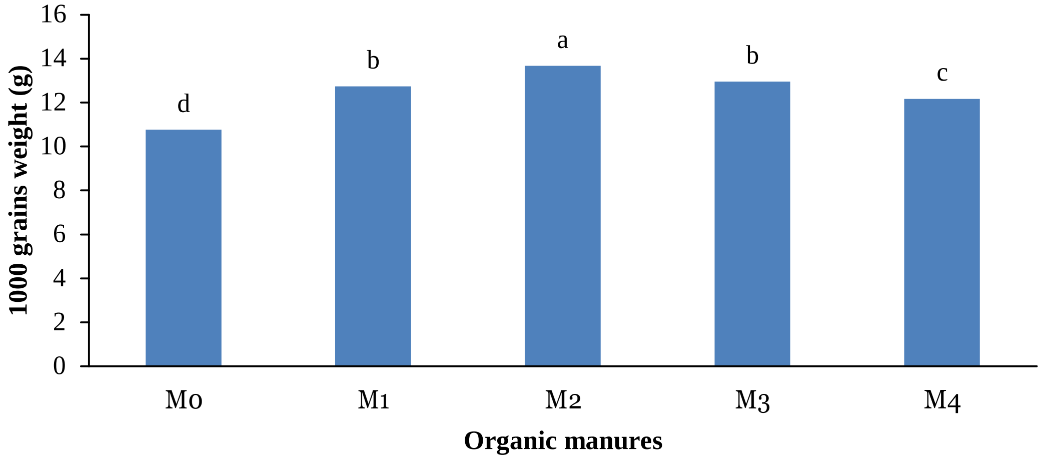


Note: Here, S_0 : 0 ppm (Control), S_1 : 1200 ppm, S_2 : 2400 ppm.

Figure 28. Effect of salt stress on 1000 grains weight of aromatic rice at harvest [LSD $_{(0.05)}$= 0.27].

Effect of different organic manures

Binadhan-13 showed significant variation on 1000 grains weight, for the application of different organic manure (Figure 29). Experimental result showed that the maximum 1000 grains weight (13.67 g) was recorded in M_2 treatment which was (26.81 %) higher over control treatment, while minimum 1000 grains weight (10.78 g) was recorded in M_0 treatment. The possible reason behind may be due to production of higher number of filled grain per panicle in the plants due to proper organic manures. This caused the high sink capacity as compared to limited respective source, therefore, the grain filling was more and consequently the grain of weight was high. Manivannan and Sriramachandrasekharan (2009) reported that combined application of vermicompost (50% N) and urea (50% N) resulted in the highest number of panicles m^{-2}, a number of grains panicle^{-1}, panicle length and 1000 grain weight. Improved growth coupled with the transport of photosynthates towards reproductive structure might have increased the yield attributes and yield due to organic addition.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 29. Effect of organic manures on 1000 grains weight of aromatic rice at harvest [LSD $_{(0.05)}$= 0.35].

Combined effect of salt stress and organic manure

Interaction of salt stress and organic manure significantly influenced 1000 grains weight of Binadhan-13 (Table 9). The highest 1000 grains weight (14.39 g) was recorded in S_0M_2 treatment combination which was (20.42 %) higher comparable to control treatment combination (S_0M_0). The minimum 1000 grains weight (9.78 g) was recorded in S_2M_0 treatment combination which was (18.15 %) lower comparable to control treatment combination.

Table 9. Combined effect of salt stress and different organic manures on number of filled, unfilled, total grains panicle^{-1} and 1000 grains weight of aromatic rice

Treatment Combinations	No. filled grains panicle^{-1}	No. unfilled grains panicle^{-1}	No. total grains panicle^{-1}	1000 grains weight (g)
S_0M_0	83.33 gh	27.20 de	110.53 ef	11.95 e
S_0M_1	93.00 c	24.86 f	117.86 c	13.35 b
S_0M_2	107.00 a	19.21 i	126.21 a	14.39 a
S_0M_3	98.50 b	23.57 g	122.07 b	13.28 b
S_0M_4	88.79 de	25.00 f	113.79 d	13.21 bc
S_1M_0	76.00 i	30.00 b	106.00 g	10.61 g
S_1M_1	88.00 d-f	26.99 de	114.99 d	12.98 bc
S_1M_2	99.48 b	22.32 h	121.80 b	13.38 b
S_1M_3	93.13 c	24.76 f	117.89 c	13.00 bc
S_1M_4	86.00 e-g	28.36 c	114.36 d	12.11 de
S_2M_0	66.67 j	33.07 a	99.74 h	9.78 h
S_2M_1	82.80 gh	27.76 cd	110.56 ef	11.89 e
S_2M_2	90.00 cd	25.49 f	115.49 cd	13.25 b
S_2M_3	84.80 fg	26.53 e	111.33 e	12.61 cd
S_2M_4	80.00 h	28.44 c	108.44 f	11.23 f
$LSD_{(0.05)}$	3.65	0.85	2.41	0.61
CV (%)	2.92	2.27	1.48	3.45

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Note: Here,

S_0 = 0 ppm pot^{-1} (Control)

S_1= 1200 ppm pot^{-1}

S_2 = 2400 ppm pot^{-1}

M_0 = 0.0 kg ha^{-1} (Control)

M_1 = Biochar 4 t ha^{-1}

M_2 = Vermicompost 6 t ha^{-1}

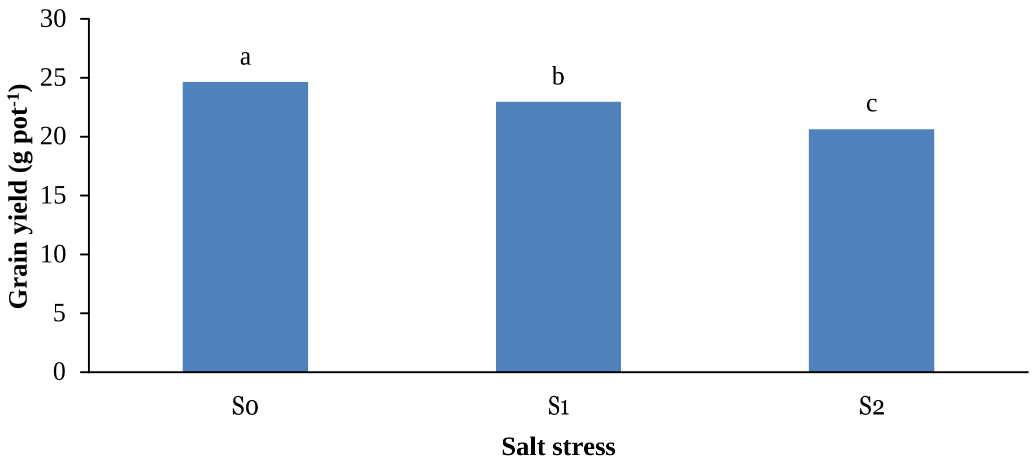
M_3 = Azolla 0.5 t ha^{-1}

4.5 Yield characters

4.5.1 Grain yield

Effect of salt stress

Exposure of salinity significantly influenced the grain yield of Binadhan-13 (Figure 30). Experimental result revealed that the maximum grain yield (24.66 g pot^{-1}) was recorded in S_0 treatment whereas the minimum grain yield (20.64 g pot^{-1}) was recorded in S_2 treatment which was (16.30 %) lower over control treatment. The reduction of seed yield under salt stress was due to salt inhibit the rate of photosynthesis in plants which ultimately impact on plant growth, yield and yield contributing attributes. Arsa *et al.* (2016) also found similar result which supported the present finding who reported that salt stress (2.5% NaCl) along with drought stress reduced grain yield and aroma of rice grain. The level of yield reduction increased with increasing the level of salinity. Yield reduction also depends on stages of plant growth when it is affected by salinity. Ali *et al.* (2004) reported that salinity (8.5 dS m^{-1}) reduced grain yield of rice by reducing photosynthesis, leaf area index (LAI) and productive tiller.

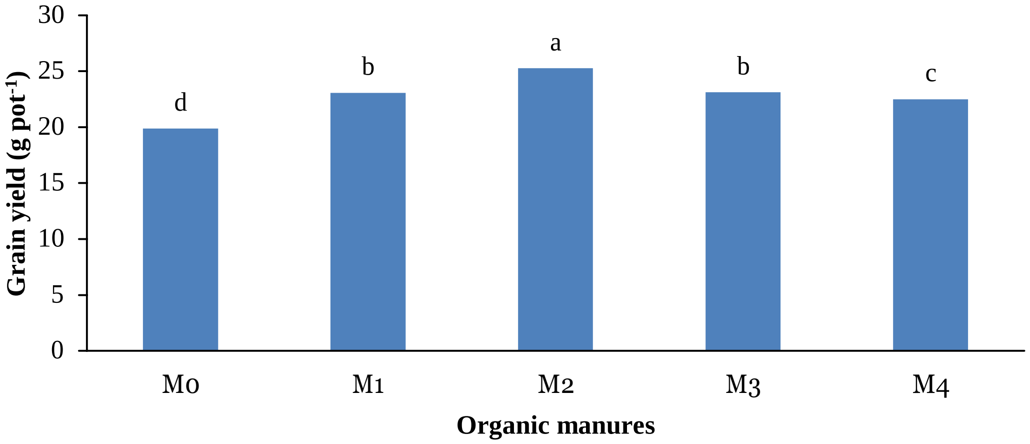


Note: Here, S_0 : 0 ppm (Control), S_1 : 1200 ppm, S_2 : 2400 ppm.

Figure 30. Effect of salt stress on grain yield pot^{-1} of aromatic rice at harvest [LSD $_{(0.05)}$= 0.37].

Effect of different organic manures

Application of different organic manures significantly affected grain yield of Binadhan- 13 (Figure 31). Experimental results showed that the maximum grain yield (25.25 g pot^{-1}) was recorded in M2 treatment which was 27.08 % higher over control treatment. Whereas the minimum grain yield (19.87 g pot^{-1}) was recorded in M_0 treatment. The increase in grain yield over control treatment might be due to application organic manures enhancing the dry matter production, effective tillers number hill^{-1}, filled grains panicle^{-1} and 1000 grains weight. The result obtained from the present study was similar with the findings of Mirza *et al.* (2010) and reported that among the manures i.e., poultry manure, green manure, cow dung and vermicompost, application of vermicompost @8 t ha^{-1} produced better grain yield compared to other organic manures.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 31. Effect of organic manures on grain yield pot^{-1} of aromatic rice at harvest [LSD $_{(0.05)}$= 0.47].

Combined effect of salt stress and organic manure

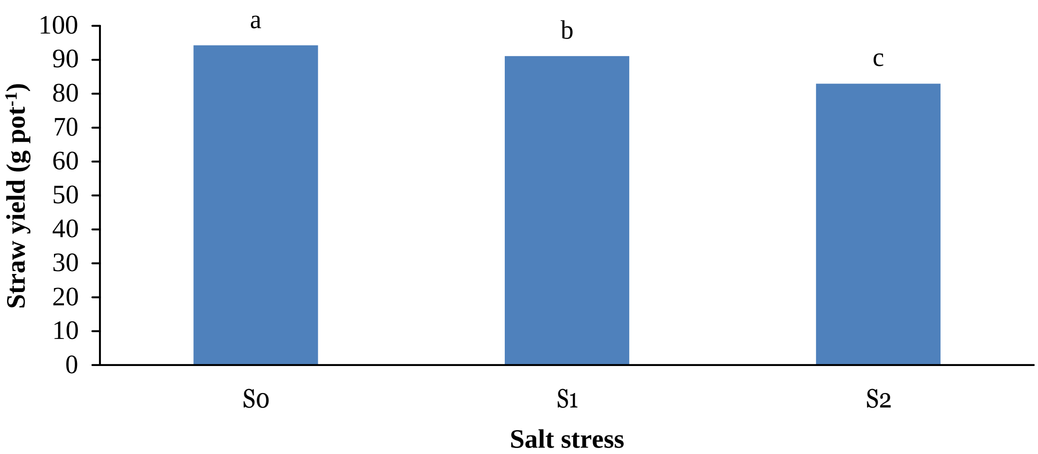
Combined effect of salt stress and organic manure significantly affected on grain yield of Binadhan-13 (Table 10). Experimental result revealed the maximum grain yield (28.15 g pot^{-1}) was recorded in S_0M_2 treatment combination which was (25.33 %) higher comparable to control treatment combination (S_0M_0). Whereas the minimum grain yield (15.67 g pot^{-1}) was recorded in S_2M_0 treatment combination which was

(30.23 %) lower comparable to control treatment combination. Benazzouk *et al.* (2019) also found similar result which supported the present finding and observed a reduction in sodium accumulation by the use of vermicompost. Roy *et al.* (2006) reported that organic matter has several beneficial effects on agricultural fields, such as the slow release of nutrients, soil structure improvement, and the protection of soils against erosion. Banaras *et al.* (2002) reported that saline soil productivity can be improved by applying organic amendments in different crops.

4.5.2 Straw yield

Effect of salt stress

Straw yield of binadhan-13 varied with the variation of different levels of salinity (Figure 32). The height straw yield (94.21 g pot^{-1}) was recorded in control (S_0) treatment whereas the minimum straw yield (82.92 g pot^{-1}) was recorded in S_2 treatment which was 11.98 % lower compared to control treatment. Higher concentration of salt is toxic to plant and its can disrupt normal functioning of plant metabolism, consequently leading to stunted growth and low crop productivity.

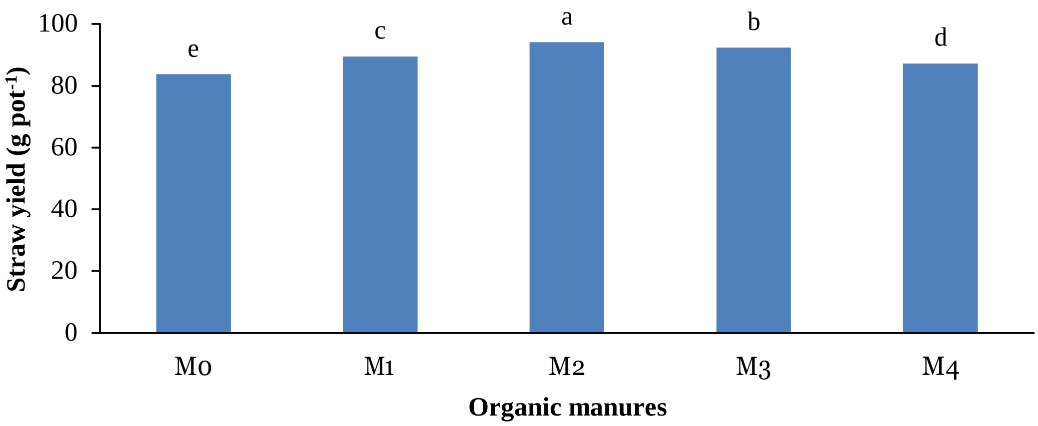


Note: Here, S_0 : 0 ppm (Control), S_1 : 1200 ppm, S_2 : 2400 ppm.

Figure 32. Effect of salt stress on straw yield pot^{-1} of aromatic rice at harvest [LSD $_{(0.05)}$= 1.28].

Effect of different organic manures

Application of different organic manures significantly influenced on straw yield of Binadhan-13 (Figure 33). The highest straw yield (94.09 g pot^{-1}) was recorded for the application of vermicompost (M_2) which was 12.32 % higher over control treatment. Whereas the minimum straw yield (83.77 g pot^{-1}) was recorded in M_0 treatment. Jeyabal and Kuppuswamy (2001) also found similar result which supported the present finding and reported that application of Vermicompost and FYM recorded with higher grain and straw yield of rice in rice - legume cropping system and improved the soil fertility. Hoque *et al.* (1999) reported significantly increased grain and straw yields due to application of organic manure and chemical fertilizers.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 33. Effect of organic manures on straw yield pot^{-1} of aromatic rice at harvest [LSD $_{(0.05)}$= 1.65].

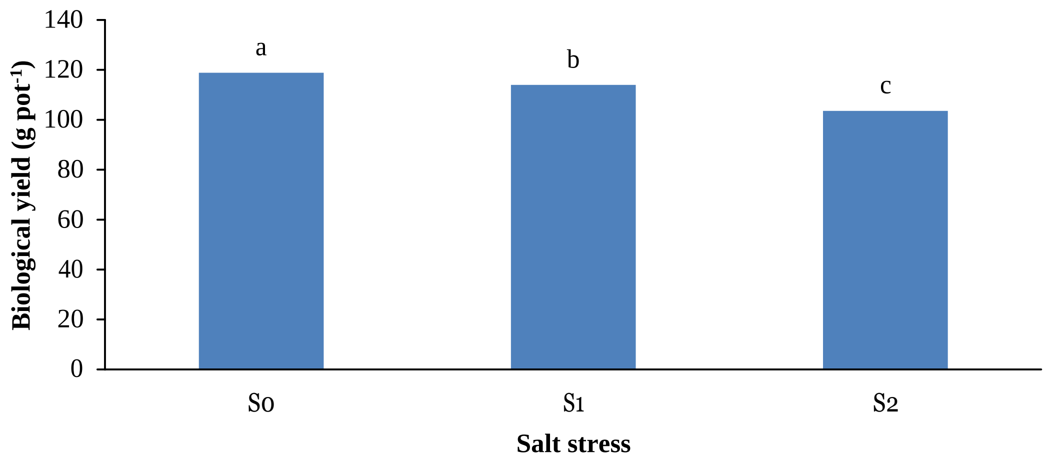
Combined effect of salt stress and organic manures

Combined effect of salt stress and organic manure have significant influenced on straw yield of Binadhan-13 (Table 10). The maximum straw yield (100.17 g pot^{-1}) was recorded in S_0M_2 treatment combination which was 9.88 % higher comparable to control treatment combination and it was statistically similar with S_0M_3 treatment combination recorded straw yield (99.78 g pot^{-1}). Whereas the minimum straw yield (73.32 g pot^{-1}) was recorded in S_2M_0 treatment combination which was 19.57 % lower comparable to control treatment combination.

4.5.3 Biological yield

Effect of salt stress

Different level of salt application significantly affected biological yield of Binadhan-13 (Figure 34). The maximum biological yield (118.87 g pot^{-1}) was recorded in S_0 treatment whereas the minimum biological yield (103.56 g pot^{-1}) was recorded in S_2 treatment which was 12.88 % lower over control treatment. Higher concentration of salt is toxic to plant and its can disturb normal functioning of plant metabolism, consequently leading to stunted growth and low crop productivity. The result obtained from the present study was similar with the findings of Chunthaburee *et al.* (2015) and found that salt stress (25 mM NaCl) reduced yield and harvest index by decreasing 1000-grain weight, filled grain percentage and panicle fertility. Aref (2013) also reported that salinity decreased grain yield, biomass yield and harvest index when salt stress was exposed at tillering and panicle initiation stage and yield reduction increased with increasing the level of salinity.

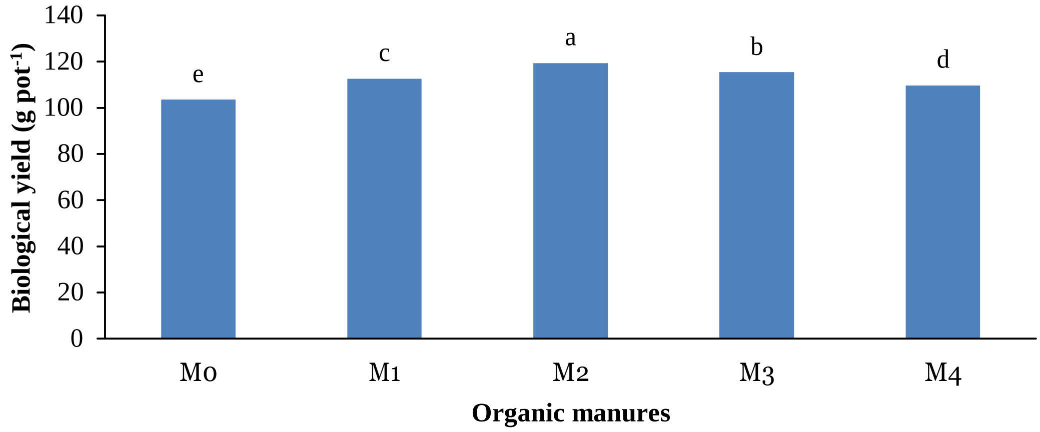


Note: Here, S_0 : 0 ppm (Control), S_1 : 1200 ppm, S_2 : 2400 ppm.

Figure 34. Effect of salt stress on biological yield pot^{-1} of aromatic rice at harvest [LSD $_{(0.05)}$= 1.26].

Effect of different organic manures

Application of different organic manures significantly influenced on biological yield of Binadhan-13 (Figure 35). The maximum biological yield (119.35 g pot^{-1}) was recorded in M_2 treatment which was 15.16 % higher over control treatment. Whereas the minimum biological yield (103.64 g pot^{-1}) was recorded in M_0 treatment. Manivannan and Sriramachandrasekharan (2009) also found similar result which supported the present finding and reported that combined application of vermicompost (50% N) and urea (50% N) resulted in the highest number of panicles m^{-2}, a number of grains panicle^{-1}, panicle length and 1000 grain weight which was on a par with that of poultry manure (50% N) and urea (50% N). Improved growth coupled with the transport of photosynthates towards reproductive structure might have increased the yield attributes and yield due to organic addition.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 35. Effect of organic manures on biological yield pot^{-1} of aromatic rice at harvest [LSD $_{(0.05)}$= 1.62].

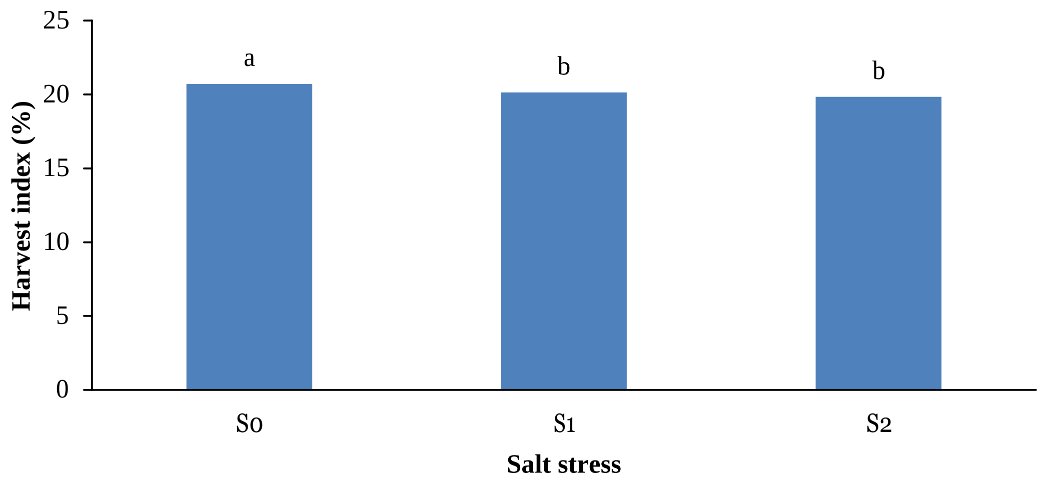
Combined effect of salt stress and organic manure

Interaction of salt stress and organic manures has significant effect on biological yield of Binadhan-13 (Table 10). The present study revealed that the maximum biological yield (128.32 g pot^{-1}) was recorded in S_0M_2 treatment combination which was 12.94 % higher compared to control treatment combination. Whereas the minimum biological yield (88.99 g pot^{-1}) was recorded in S_2M_0 treatment combination which was 21.68 % lower comparable to control treatment combination.

4.5.4 Harvest index

Effect of salt stress

Application of different levels of salt significantly affected harvest index of Binadhan-13 (Figure 36). Our results revealed that the maximum harvest index (20.73 %) was recorded in S_0 treatment whereas the minimum harvest index (19.86 %) was recorded in S_2 treatment which was (4.20 %) lower over control treatment. The differences of harvest index at different salt level due to reason that increasing the level of salt decreased yield contributing characters of plant which ultimately impact on harvest index. The result obtained from the present study was similar with the findings of Chunthaburee *et al.* (2015) and found that salt stress (25 mM NaCl) reduced yield and harvest index by decreasing 1000-grain weight, filled grain percentage and panicle fertility. Aref (2013) also reported that salinity decreased grain yield, biomass yield and harvest index when salt stress was exposed at tillering and panicle initiation stage and yield reduction increased with increasing the level of salinity.

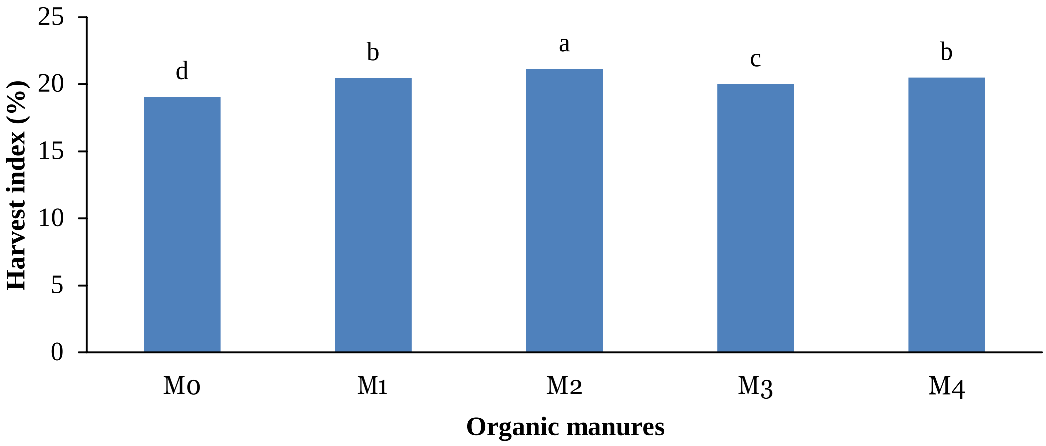


Note: Here, S_0 : 0 ppm (Control), S_1 : 1200 ppm, S_2 : 2400 ppm.

Figure 36. Effect of salt stress on harvest index of aromatic rice at harvest [LSD $_{(0.05)}$= 0.36].

Effect of different organic manures

Harvest index varied in Binadhan-13 for the application of different types of organic manures (Figure 37). The maximum harvest index (21.12 %) was recorded in M_2 treatment which was (10.69 %) higher over control treatment. Whereas the minimum harvest index (19.08 %) was recorded in M_0 treatment. Organic manures provided favorable environment for microorganisms like *Azospirillium* which fixes atmospheric nitrogen available to plant and PSB (Phosphate Solubilizing Biofertilizers) which converts insoluble phosphate into soluble forms result in proper nutrients absorption as well as enhancing the production and translocation of the dry matter content from source to sink which impact on harvest index as its depends on grain yield and biological yield of the plant.



Note: Here, M_0 = 0.0 kg ha^{-1} (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}.

Figure 37. Effect of organic manures on harvest index of aromatic rice at harvest [LSD $_{(0.05)}$= 0.48].

Combined effect of salt stress and organic manure

Combined effect of salt stress and organic manure significantly promoted on harvest index of Binadhan-13 (Table 10). Experimental result revealed the maximum harvest index (21.92 %) was recorded in S_0M_2 treatment combination which was (10.65 %) higher comparable to control treatment combination. Whereas the minimum harvest index (17.61 %) was recorded in S_2M_0 treatment combination which was (11.11 %) lower comparable to control treatment combination.

Table 10. Combined effect of salt stress and different organic manures on grain, straw, biological yield and harvest index of aromatic rice

Treatment Combinations	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})	Biological yield (g pot^{-1})	Harvest index (%)
S_0M_0	22.46 gh	91.16 cd	113.62 d-f	19.81 d
S_0M_1	23.97 cd	90.96 cd	114.93 de	20.85 bc
S_0M_2	28.15 a	100.17 a	128.32 a	21.92 a
S_0M_3	25.05 b	99.78 a	124.83 b	20.07 cd
S_0M_4	23.65 c-e	89.00 de	112.65 ef	20.99 b
S_1M_0	21.48 i	86.84 e-g	108.32 gh	19.83 d
S_1M_1	23.30 d-f	92.92 bc	116.22 cd	20.05 cd
S_1M_2	24.45 c	94.29 b	118.74 c	20.59 b-d
S_1M_3	23.09 e-g	91.55 b-d	114.64 de	20.14 cd
S_1M_4	22.60 f-h	89.59 de	112.19 ef	20.15 cd
S_2M_0	15.67 j	73.32 i	88.99 j	17.61 e
S_2M_1	21.95 hi	84.69 gh	106.64 hi	20.58 b-d
S_2M_2	23.15 d-g	87.82 ef	110.97 fg	20.86 bc
S_2M_3	21.18 i	85.67 f-h	106.85 hi	19.82 d
S_2M_4	21.25 i	83.12 h	104.37 i	20.41 b-d
$LSD_{(0.05)}$	0.83	2.86	2.81	0.83
CV (%)	2.55	2.25	1.76	2.86

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Note: Here,

S_0 = 0 ppm pot^{-1} (Control)
S_1= 1200 ppm pot^{-1}
S_2 = 2400 ppm pot^{-1}

M_0 = 0.0 kg ha^{-1} (Control)
M_1 = Biochar 4 t ha^{-1}
M_2 = Vermicompost 6 t ha^{-1}
M_3 = Azolla 0.5 t ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

A pot experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during, July to December 2020 to know the amelioration of the effect of different organic manures under salt stress condition in aromatic rice. The experiment consisted of two factors, and followed RCBD with four replications. Factor A: Different salt stress (3) *viz;* S_0 = 0 ppm pot^{-1} (Control), S_1= 1200 ppm pot^{-1} and S_2 = 2400 ppm pot^{-1} and Factor B: Application of different organic manures (5) *viz* M_0 = No organic manure (Control), M_1 = Biochar 4 t ha^{-1}, M_2 = Vermicompost 6 t ha^{-1}, M_3 = Azolla 0.5 t ha^{-1} and M_4 = Cowdung 10 t ha^{-1}. Data on different parameters were collected for assessing results for this experiment and showed significant variation in respect of growth, yield and yield contributing characteristics of Binadhan-13 due to the effect of different salt stress condition, organic manures and their combinations.

In case of different salt stress condition, plant growth deceasing with increasing salt level. The minimum plant height (71.63, 89.57, 117.96, 118.36 and 128.16 cm) at 20 DAT, 40 DAT, 60 DAT, 80 DAT and at harvest respectively was recorded in S_2 (1.88 g pot^{-1}) treatment. In similar way, the minimum number of tillers hill^{-1}, leaf area index, chlorophyll content and relative water content were recorded in S_2 (1.88 g pot^{-1}) treatment.

Exposure of salt greatly reduced the yield and yield contributing parameters of rice. The minimum number of effective tillers hill^{-1} (7.26), panicle length (23.03 cm), filled grains panicle^{-1} (80.85), total grains panicle^{-1} (109.11), 1000 seed weight (11.75 g), grain yield (20.64 g pot^{-1}), straw yield (82.92 g pot^{-1}), biological yield (103.56 g pot^{-1}) and harvest index (19.86 %) were recorded in S_2 treatment.

Organic manure helps to develop plant growth. The maximum plant height (74.68, 97.17, 128.28, 129.28 and 138.90 cm) at 20 DAT, 40 DAT, 60 DAT, 80 DAT and at harvest respectively was recorded by the application of Vermicompost @ 6 t ha^{-1} (M_2 treatment). In similar way, the maximum number of tillers hill^{-1}, leaf area index, chlorophyll content and relative water content were recorded in M_2 treated pot.

All organic manures don't have same ability to contribute to yield development of rice plant. In this experiment vermicompost (M_2) played a major role for the improvement of yield of rice. The maximum effective tillers hill^{-1} (10.40), panicle length (24.93 cm), filled grains panicle^{-1} (98.83), total grains panicle^{-1} (121.17), grain yield (25.25 g pot^{-1}), straw yield (94.09 g pot^{-1}), biological yield (119.35 g pot^{-1}) and harvest index (21.12 %) was recorded in M_2 treatment.

In case of combined effect, the highest plant growth and development was seen with the absence of salt stress condition along with the application of vermicompost. The minimum plant height (68.16, 82.25, 108.07, 110.16 and 112.40 cm) at 20 DAT, 40 DAT, 60 DAT, 80 DAT and at harvest respectively was recorded in S2M0 treatment combination. In similar way, the minimum number of tillers hill^{-1}, leaf area index, chlorophyll content and relative water content were recorded in S2M0 treatment combination.

The minimum number of effective tillers hill^{-1} (5.00), panicle length (20.33 cm), filled grains panicle^{-1} (66.67), total grains panicle^{-1} (99.74), 1000 grains weight (9.78 g), grain yield (15.67 g pot^{-1}), straw yield (73.32 g pot^{-1}), biological yield (88.99 g pot^{-1}) and harvest index (17.61 %) were recorded in S_2M_0 treatment combination.

Recommendation

The experiment was conducted with only four organic manures and single aromatic rice variety; it is difficult to recommend the appropriate organic manures for the amelioration of salt stress condition. However, according to the findings of the study the following recommendations can be suggested:

i. Among the four organic manures (Biochar, Vermicompost, Azolla, and Cowdung) vermicompost is the best to ameliorate salt stress condition in aromatic rice.
ii. However, more experiment should be conducted at different location of salt prone areas with more varieties of aromatic rice and different amendments.

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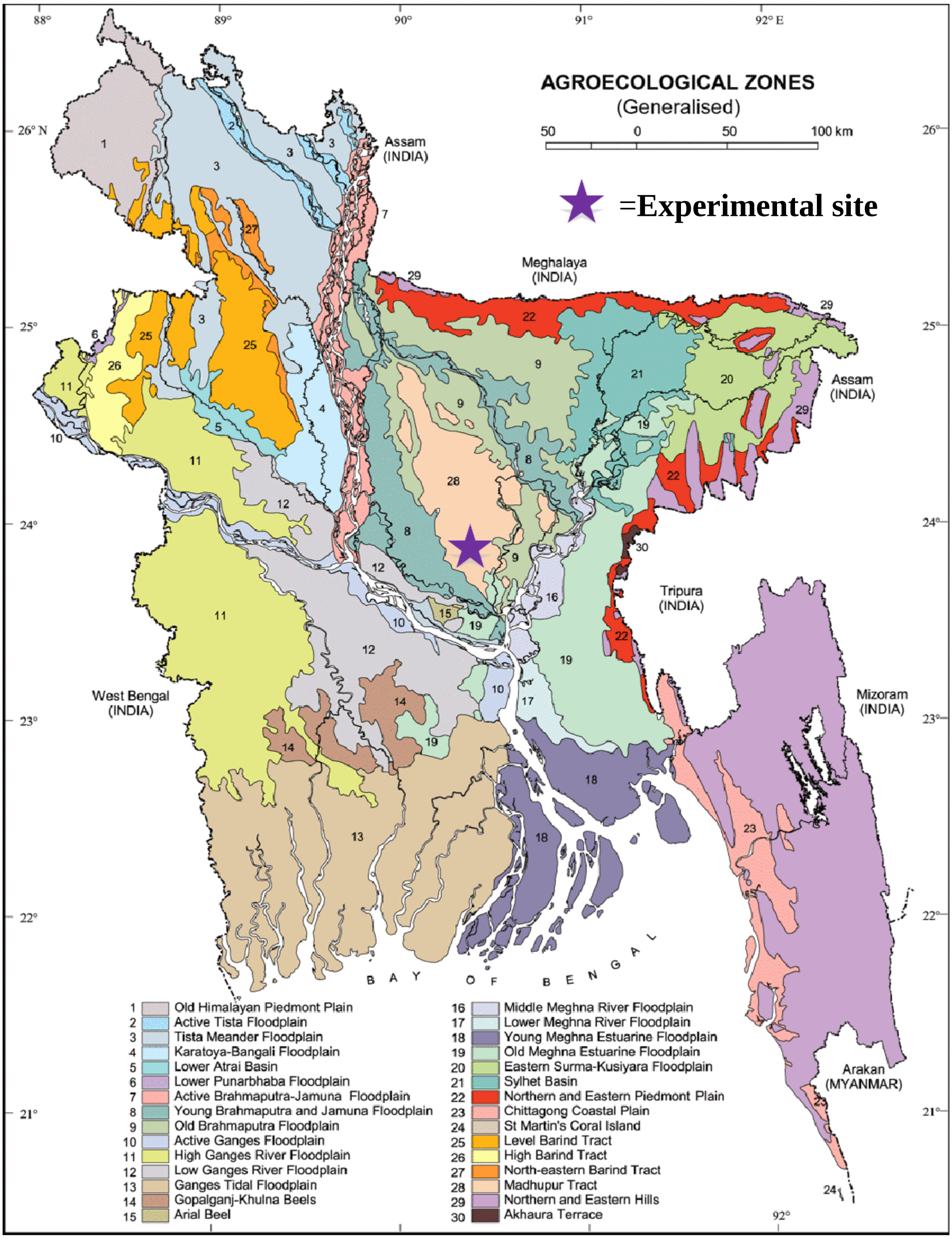
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Monthly meteorological information during the period from July to December-2020.

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2020	July	32.6°C	26.8°C	81%	114
	August	32.6°C	25.5°C	80%	106
	September	32.4°C	25.7°C	80%.	86
	October	31.2°C	23.9°C	76%.	52
	November	29.6	19.8	53	00
	December	28.8	19.1	47	00

(Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix III. Analysis of variance of the data of plant height of aromatic rice different DAT

Sources of variation	**DF**	Mean square of plant height at				
		20 DAT	40 DAT	60 DAT	80 DAT	At harvest
Replication	3	26.7778	4.994	6.017	5.400	9.800
Salt stress (S)	2	2.84^{Ns}	170.813*	533.499*	554.930*	613.530*
Manures (M)	4	50.49*	148.153*	303.544*	198.926*	296.078*
S× M	8	2.50^{Ns}	21.029*	15.740*	13.423*	78.075*
Error	42	2.0183	1.233	3.874	5.495	16.038
Total	59					

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data of number of tillers hill^{-1} of aromatic rice different DAT

Sources of variation	DF	Mean square of number of tillers hill^{-1}				
		30 DAT	45 DAT	60 DAT	75 DAT	At harvest
Replication	3	0.05157	0.3111	0.1778	0.5333	0.0010
Salt stress (S)	2	0.0220^{Ns}	20.7015*	63.5363*	53.1348*	30.9637*
Manures (M)	4	9.119*	10.2997*	24.5480*	19.6889*	12.9679*
S× M	8	0.068 ^{Ns}	5.2348*	9.7850*	7.4670*	1.4726*
Error	42	0.05377	0.2159	0.4024	0.3429	0.1053
Total	59					

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data of leaf area index of aromatic rice different DAT

Sources of variation	DF	Mean square of leaf area index at			
		20 DAT	40 DAT	60 DAT	80 DAT
Replication	3	0.00030	0.00608	0.01111	0.02178
Salt stress (S)	2	0.00072 ^{Ns}	2.38731*	2.39755*	1.99603*
Manures (M)	4	0.12460	4.61937*	4.63303*	4.82937*
S× M	8	0.00012 ^{Ns}	0.07427*	0.04605*	0.07559*
Error	42	0.00030	0.00542	0.00349	0.01035
Total	59				

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data of leaf relative water and chlorophyll contents of aromatic rice

Sources of variation	DF	Mean square of	
		Leaf relative water content	Chlorophyll contents
Replication	3	0.31	1.111E-06
Salt stress (S)	2	2671.34*	1.054E-03*
Manures (M)	4	114.38*	1.371E-04*
S× M	8	17.39*	1.287E-05*
Error	42	0.98	7.302E-07
Total	59		

*: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data of number of effective and non-effective tillers hill^{-1} and panicle length of aromatic rice at harvest

Sources of variation	**DF**	Mean square of		
		No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length
Replication	3	7.730E-29	0.00100	0.4222
Salt stress (S)	2	38.5291*	0.41539*	13.7598*
Manures (M)	4	24.3465*	1.85456*	18.5154*
S× M	8	2.47015*	0.23082*	0.7858*
Error	42	0.09524	0.00052	0.2913
Total	59			

*: Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data of number of filled grains, unfilled grains, total grains panicle^{-1} and 1000 grains weight of aromatic rice at harvest

Sources of variation	**DF**	Mean square of			
		No. of filled grains panicle^{-1}	No. of unfilled grains panicle^{-1}	No. of total grains panicle^{-1}	1000 grains weight
Replication	3	10.800	0.3556	3.244	0.5778
Salt stress (S)	2	887.578*	92.9480*	416.381*	11.0549*
Manures (M)	4	912.356*	98.4901*	413.873*	14.1064*
S× M	8	14.238*	3.5732*	7.791*	0.5002*
Error	42	6.562	0.3556	3.483	0.1849
Total	59				

*: Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data of grains yield, straw yield, biological yield pot^{-1} and harvest index of aromatic rice at harvest

Source	**DF**	Mean square of			
		Grains yield	Straw yield	Biological yield	Harvest index
Replication	3	5.693	4.444	20.14	0.1737
Salt stress (S)	2	325.652*	345.885*	1335.11*	12.5450*
Manures (M)	4	178.064*	102.560*	534.10*	17.7807*
S× M	8	24.399*	18.774*	78.47*	3.8400*
Error	42	1.348	2.063	2.70	0.6461
Total	59				

*: Significant at 0.05 level of probability

PLATES

Plate 1. Pot filling

Plate 2. Vegetative stage of rice