EFFECTS OF SALINITY ON GROWTH AND YIELD PERFORMANCE OF SOME RICE (*Oryza sativa* L.) CULTIVARS

By

MD. ALAM HOSSAIN
Reg. No.: 05-01558

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Approved By:

(Professor Dr. Md. Abdur Razzaque)	**(Professor Md. Shahjahan Miah)**
Department of Agricultural Chemistry	Department of Agricultural Chemistry
Sher-e-Bangla Agricultural University,	Sher-e-Bangla Agricultural University,
Dhaka-1207	Dhaka-1207
Supervisor	***Co-supervisor***

Professor Dr. Rokeya Begum
Chairman
Examination Committee

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka – 1207
PABX: 9110351 & 9144270-79

CERTIFICATE

This is to certify that the thesis entitled "EFFECTS OF SALINITY ON GROWTH AND YIELD PERFORMANCE OF SOME RICE (*Oryza sativa* L.) CULTIVARS" submitted to the DEPARTMENT OF AGRICULTURAL CHEMISTRY,, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (M.S.) in AGRICULTURAL CHEMISTRY, embodies the results of a piece of bonafide research work carried out by MD. ALAM HOSSAIN, Registration. No. 05-01558, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

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

Dated:
Dhaka, Bangladesh

(Prof. Dr. Md. Abdur Razzaque)
Department of Agricultural Chemistry
Sher-e-Bangla Agricultural University,
Dhaka, Bangladesh
Supervisor

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ABSTRACT

A pot culture experiment was conducted to study the effect of salinity on growth and yield of rice during the Aman season (June- December) of the year 2010 at the Sher-e-Bangla Agricultural University, Dhaka-1207. Four rice cultivars namely Sadamota, BRRI dhan40, Heera and Lalmota and five salinity levels (0, 3, 6, 9 and 12 dS m^{-1}) were imposed in the experiment. During the experiment, plant height, relative root length, relative root dry weight, relative shoot dry weight, relative total dry matter, effective tiller $hill^{-1}$, non-effective tiller $hill^{-1}$, panicle length, number of filled and unfilled grains $panicle^{-1}$, thousand grain weight and yield $hill^{-1}$ of the rice cultivars were measured. The results indicated that all the parameters have significant varietal differences among them. The tallest plants were found in Sadamota and Lalmota cultivars while shortest plants were obtained from Heera. But relative shoot dry weight and relative total dry matter were highest in Heera as it contained maximum effective and non-effective tillers $hill^{-1}$. Panicle length, number of filled grains $panicle^{-1}$, thousand grain weight and grain yield $hill^{-1}$ were highest in Heera and lowest in BRRI dhan40 and Lalmota due to the mean effect of five salinity levels. Plant height was highest at control salinity treatment and lowest in the maximum salinity level (12 dS m^{-1}) for every cultivar. Similar results were observed in case of relative root dry weight, relative shoot dry weight, relative total dry matter, number of effective tillers $hill^{-1}$, panicle length and number of filled grains $panicle^{-1}$ for each of the cultivars. All the parameters decreased with increasing salinity but this decreasing tendency was slower in Heera than other cultivars. On the other hand, number of non-effective tillers $hill^{-1}$ and unfilled grain $panicle^{-1}$ increased with the increasing level of salinity and the highest values were obtained from maximum salinity level in BRRI dhan40. At the highest (12 dS m^{-1}) level of salinity, significantly better performance for thousand grain weight and grain yield $hill^{-1}$ was given by Heera while BRRI dhan40 was the most badly affected one by salinity.

Dedicated to

My

Beloved Parents

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LIST OF ABBREVIATIONS

Abbreviated Form	Elaborated Form
EC	Electrical Conductivity
dS	Deci Siemens
ha^{-1}	Per hectare
m^{-1}	Per meter
$hill^{-1}$	Per hill
L^{-1}	Per Litre
$panicle^{-1}$	Per panicle
g	Gram
kg	Kilogram
et al.	and others
mmol	Milli mole
BRRI	Bangladesh Rice Research Institute
LSD	Least Significant Difference

Chapter 1
Introduction

CHAPTER 1

INTRODUCTION

Salinity in soil or water is one of the major stresses that severely limit crop production. The deleterious effects of salinity on plant growth are associated with (i) low osmotic potential of soil solution (water stress), (ii) nutritional imbalance, (iii) specific ion effect, or (iv) a combination of these factors (Asch *et al.*, 2000, Juan *et al.*, 2005, Hu *et al.*, 2005). This soil salinity stress varies in magnitude and interactions over time and place, making long-term adaptability of a variety dependent on its level of tolerance to all the stresses that occur in its growing environment. In general, the term salinity includes all the problems due to salts present in the soil while in strict terms, these soils are categorized into two types: sodic (or alkali) and saline (a third type can be referred to as saline-sodic soils). Saline soils are again dominated by sodium cations with electrical conductivity (EC) more than 4 dS m^{-1}, but the dominant anions are usually soluble chloride and sulphate. Exchangeable sodium percentage (ESP < 15) and pH values of these soils are much lower than in sodic soils.

Rice (*Oryza sativa*) is the most important crop in the world after wheat, with more than 90% currently grown in Asia. Rice is the grain that has shaped the cultures, diets and economies of billions of Asians. For them, rice is more than food; rice is life. About 120,000 varieties of rice are grown across the world in an extensive range of climatic soil and water condition. It is grown on an area of 149.151 million hectares (ha) yielding 550.193 million tons of paddy with a yield of 3689 kg ha^{-1} (Alam *et al.*, 2001). In Asia, China is the major rice producing country followed by India, Indonesia and Bangladesh. However, yield per hectare is highest (6.1 tons) in Japan followed by China (5.1 tons ha^{-1}). Rice breeders have used genetic variability to produce cultivars that have high yield potential and that resist disease and insect damage and that tolerate cold, drought, and even floods. But apart from some sporadic work in Sri Lanka and India, little has been done until recently to identify any breed/cultivars adaptable to adverse soil conditions such as salinity. Salinity is a major threat to crop productivity in the southern and south-western part of Bangladesh, where it is developed due to frequent flood by sea water of the Bay of Bengal and on the other hand introduction of irrigation with saline waters. In Bangladesh, there are approximately 2.85 million ha of coastal soils (Ponnamperuma, 1977) which occur in the southern parts of the Ganges tidal floodplain, in the young Meghna estuarine floodplain and in tidal areas of the Chittagong coastal plain and offshore islands (Brammer, 1978). About one million ha of land of these coastal and offshore areas are affected by varying degrees of salinity. These coastal saline soils are distributed unevenly in 64 thanas of 13 coastal districts covering 8 agroecological zones (AEZ) of the country. The majority of the saline land (0.65 million ha) exists in the districts of Satkhira, Khulna, Bagerhat, Barguna, Patuakhali, Pirojpur and Bhola on the western coast and a smaller portion (0.18 million ha) in the districts of Chittagong, Cox's Bazar, Noakhali, Lakshmipur, Feni and Chandpur. According to the report of Soil Resource Development Institute (SRDI, 2007) of Bangladesh, about 0.203 million ha of land is very slightly (2-4 dSm^{-1}), 0.492 million ha is slightly (4-8 dSm^{-1}), 0.461 million ha is moderately (8-12 dSm^{-1}) and 0.490 million ha is strongly (>12 dSm^{-1}) salt affected soils in southwestern part of the coastal area of Bangladesh. Large fluctuations in salinity levels over time are also observed at almost all sites in these regions. The common trend is an increase in salinity with time, from November- December to March-April, until the onset of the monsoon rains.

There is a general lacking of suitable salt tolerant modern variety (MV) of rice to suited different AEZ in the coastal areas of Bangladesh. For centuries, farmers have salt-tolerant cultivars on the saline soils of India, Burma, Thailand, Indonesia, the Philippines and Vietnam. But, because of lodging and susceptibility to disease and insect damage, yields are about 1 ton ha^{-1}. Recognition of the potential of saline lands for rice production in the densely populated countries of South and Southeast Asia promoted the inclusion of salt tolerance as a component of the programme of the International Rice Research Institute (IRRI). Among the adverse soil conditions, salinity received most attention, because of its widespread occurrence in current and potential rice lands. Salt tolerance studies are usually conducted in growth chambers and greenhouse, with plants raised in plastic trays or in small pots. The salt tolerance of any crop is usually expressed as decrease in yield associated with a given level of soil salinity as compared with yield under non-saline conditions. The primary salinity factors influencing plant growth are the kind and concentration of salt present in the soil solution. Yeo and Flowers (1982) reported varietal differences in rice for salinity tolerance. Salt seems to affect rice during pollination, decrease seed setting and grain yield (Maloo, 1993).

The rice production system plays a great role in the reduction of hunger and poverty in Bangladesh. In 1975-76 total rice production in Bangladesh was 10.32 million tons when the country's population was 79.90 million and rice area was 10.32 million ha. In 2007-08 the country produced 27.32 million tons in 10.71 million ha of rice area to feed more than 145 million people (BBS, 2007 & DAE, 2007). This indicates the growth of rice production was much faster than the growth of population while the cultivable rice area is not significantly different between these three decades. This increase in rice production has been achieved due to the adoption of modern rice varieties on around 73% of the rice land which contributes to about 85% of the country's total rice production, the use of modern rice cultivation technology, improvement irrigation and the proper use of fertilizer and pesticides (BBS, 2006). Rice breeders have used genetic variability to produce cultivars that have high yield potential and that resist disease and insect damage and that tolerate cold, drought, and even floods. But apart from some sporadic work in Sri Lanka and India, little has been done until recently to identify any breed/cultivars adaptable to adverse soil conditions such as salinity.

The present population of Bangladesh is about 160 million. The alarming growth of population and loss of arable land due to urbanization are main causes of concern for finding ways and means for augmenting food production particularly rice. The possibility of increasing food production by increasing land area is seriously limited in Bangladesh. The only feasible alternative is to increase the cultivated areas by bringing salt affected soils under cultivation with high yielding salt tolerant rice cultivars. Considering the above circumstances, the present study has been designed and planned -

i. to study the different growth parameters of four selected rice cultivars under different salinity levels, and

ii. to observe the yield performances of the selected rice cultivars under different saline conditions.

Chapter 2
Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

In many parts of the world, Rice is the staple food. Various environmental factors *viz*. variety, soil salinity, nutrient availability, temperature, humidity, light intensity and moisture affect the proper growth and yield of rice. Many research works have been conducted on various aspects of rice in different countries. A lot of research works have been conducted about effect of salinity on rice. Available literatures related to the present study are reviewed here.

Considerable improvements in salinity tolerance have been made in crop species in recent times through conventional selection and breeding techniques (Ashraf, 2002; Ashraf, 1994; Shannon, 1998). Most of the selection procedures have been based on differences in agronomic characters, which represent the combined genetic and environmental effects on plant growth and include the integration of the physiological mechanisms conferring salinity tolerance. Typical agronomic selection parameters for salinity tolerance are yield, biomass, plant survivality, plant height, leaf area, leaf injury, relative growth rate and relative growth reduction.

Many scientists have suggested that selection is more convenient and practicable if the plant species possesses distinctive indicators of salt tolerance at the whole plant, tissue or cellular level (Ashraf, 2002; Epstein and Rains, 1987). Physiological criteria are able to supply more objective information than agronomic parameters or visual assessment while screening for component traits of complex characters (Yeo, 1994). There are no well-defined plant indicators for salinity tolerance that could practically be used by plant breeders for improvement of salinity tolerance in a number of important agricultural crops. This is partly due to the fact that the mechanism of salt tolerance is so complex that variation occurs not only among the species but, in many cases, also among cultivars within a single species (Ashraf, 1994; Ashraf, 2002). During the course of plant growth, the form and functions of various organs undergo significant change and the ability of the plant to react to salinity stress depend on those genes that are expressed at the stage of development during which the stress is imposed (Epstein and Rains, 1987). The mechanism of salinity tolerance becomes even more complicated when the response of a plant also varies with the concentration of saline medium and the environmental conditions in which the plant is grown.

Osmotic adjustment in plants subjected to salt stress can occur by the accumulation of high concentration of either inorganic ions or low molecular weight organic solutes. Although both of these play a crucial role in higher plants grown under saline conditions, their relative contribution varies among species, among cultivars and even between different compartments within the same plant (Ashraf, 1994). The compatible osmolytes generally found in higher plants are of low molecular weight sugars, organic acids, amino acids, proteins and quaternary ammonium compounds.

Choi *et al.* (2003) observed that the plant height decreased in the 0.5% saline water in the soil. Khan *et al.* (1997) conducting a pot experiment with three rice cultivars reported that plant height was seriously decreased by salinity. Similar opinion was also postulated by Saleque *et al.* (2005). During vegetative period, the most common salinity effect was stunting of plant growth, whereas leaf withering was less apparent (Alam *et al.*, 2001). The mutant variety maintained its superiority in various characteristics such as plant height, higher number of fertile panicles per plant and high plant yield (Baloch *et al.*, 2003).

Salinity affected rice during pollination, decreased seed setting and grain yield (Maloo, 1993). Finck (1977) suggested that deficiency of K and Ca elements might play a significant role in plant growth depression in many saline soils. Girdhar (1988) observed that salinity delayed germination, but did not affect the final germination up to the EC of 8 dSm^{-1} by evaluating the performance of rice under saline water irrigation.

Abdullah *et al.* (2001) performed an experiment on the effect of salinity stress (50 mM) on floral characteristics, yield components, and biochemical and physiological attributes of the sensitive rice variety IR-28. The results showed significant decrease in panicle weight, panicle length, primary branches per panicle, filled and unfilled grain, total grains and grain weight per panicle, 1000-grain weight and total grain weight per hill. They further observed significant reduction in both chlorophyll a and chlorophyll b content in different parts of the rice leaves at saline condition. In another experiment, Abdullah *et al.* (2002) studied the effect of salinity on photosynthate translocation in panicle branches and developing spikelets, carbohydrate content of different vegetative parts and suggested that reduction in grain number and grain weight in salinized panicles was not merely due to reduction in pollen viability and higher accumulation of Na^+ and less K^+ in different floral parts but also due to higher accumulation of photosynthates (sugar) in primary and secondary panicle branches, panicle main stalk and panicle stem coupled with reduced activity of starch synthetase in developing grains.

Alam *el al.* (2001) stated that the critical EC level of salinity for seedling growth was about 5 dSm^{-1}. They observed that dry matter, seedling height, root length and emergence of new roots of rice decreased significantly at an electrical conductivity value of 5-6 dSm^{-1} and during the early seedling stage, more higher salinity caused rolling and withering of leaves, browning of leaf tips and ultimately death of seedlings. They especulated that both osmotic imbalance and Cl^- was responsible for suppress of the growth. These authors maintained that the shoot growth was more suppressed than that of root and salt injury was more severe at high temperature (35°C) and low humidity (64%) due to increased transpiration and uptake of water and salt by rice plants. At the reproductive stage, salinity depressed grain yield much more than that at the vegetative growth stage (Alam *et al.*, 2001). These authors maintained that at critical salinity levels straw yield was normal but produced little or no grain. The decrease in grain yield was found proportional to the salt concentration and the duration of the saline treatment. When the plants were continuously exposed to saline media, salinity affected the panicle initiation, spikelet formation, fertilization of florets and germination of pollen grains hence caused an increase in number of sterile florets. The greatest injurious effect was on the panicle. Salinity severely reduced the panicle length, number of primary branches per panicle, number of spikelet per panicle, seed setting percentage and panicle weight and reduced the grain yield. The weight of 1000-grain was also reduced. Salt injury resulted in the production of small grains in grain length, width and thickness. Most rice cultivars were severely injured in submerged soil cultures at EC of 8-10 dSm^{-1} at 25° C; sensitive ones were hurt even at 2 dSm^{-1}. At comparable EC's injury was less in sea water than in solutions of common salt, in neutral and alkaline soils than in acid soils, at 20°C than at 35°C and in 2-week old seedling than in 1-week old seedlings. Since rice plant is susceptible to salinity at transplanting and gains tolerance with age, they advised that aged seedlings (6 weeks old) be planted in saline fields.

Chapter 3
Methods and Materials

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted under pot-culture at the net house of the Department of Genetics and Plant Breeding and Laboratory of Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207 to study the effect of salinity on the growth and yield of four selected rice cultivars during Aman season (2010). This chapter of dissertation is an important component that essentially maps out the method that was utilized when researching and writing this work. It describes the key method, use of different parameters to correlate with growth and yield of rice. It further covers the data collection procedure, source of data and way data were analyzed.

The materials and methods followed during entire period of the experiment are described in this chapter.

3.1 Site of the experiment

The experiment was conducted at the nethouse of the Department of Genetics and Plant Breeding and Laboratory of Agricultural Chemistry Department, Sher-e-Bangla Agricultural University, Dhaka-1207.

3.2 Experimental period

The experiment was conducted in pots during Aman rice cropping season (June to November) of the year of 2010.

3.3 Selection of cultivars

There were 4 rice cultivars used for selection of salt tolerant and susceptible lines/ varieties. The seeds of two local cultivars namely Sadamota and Lalmota and another modern cultivar BRRI dhan40 were collected from Bangladesh Rice Research Institute (BRRI). The seeds hybrid rice "Heera" were collected from "Supreme Seed Company".

3.4 Experimental design

The experiment was set in Completely Randomized Design (CRD) having two factors with three replications.

Factor 1: Cultivar- 4 (V_1- Sadamota, V_2- BRRI dhan40, V_3- Heera and V_4- Lalmota)

Factor 2: Salinity level - 5 (0, 3, 6, 9 and 12 dS m^{-1})

Replication: 3

The four cultivars in combination with five salinity levels were randomly assigned to 60 experimental units/ pots.

3.5 Salinity treatments

The five salinity treatments were 0 (control), 3, 6, 9 and 12 dSm^{-1}. The different salinity levels were obtained by dissolving commercial salt (NaCl) at the rate of 640 mg per litre distilled water for 1 dSm^{-1} salinity level. The control *i.e.* 0 was maintained using distilled water only.

3.6 Collection and preparation of soil

The soil of the experiment was collected from Sher-e-Bangla Agricultural University (SAU) farm. The soil was non-calcarious Red Brown Terrace soil with loamy texture belonging to the AEZ Madhupur Tract. The collected soil was pulverized and inert materials, visible insect pest and plant propagules were removed. The soil was dried in the sun, crushed carefully and thoroughly mixed.

3.7 Sterilization of seed

Prior to germination seeds were surface sterilized with 1% sodium hypochlorite solution. The glass vials containing distilled water for seed rinsing was sterilized for 20 minutes.

3.8 Sowing of seeds in seed bed

The sterilized seeds were soaked with water for 24 hours, washed thoroughly in clean water, and incubated for sprouting, which were sown in the wet seed bed. Required amount of fertilizers were applied one day before sowing seeds in the seed bed.

3.9 Raising of seedlings

The seedlings were grown in pots and the soil was used as growth medium. Chemical fertilizers namely urea, triple supper phosphate (TSP) and muriate of potash (MOP) at the rate of 120, 100 and 75 kg/ha, respectively were applied for N, P and K before final preparation of the seed bed. The fertilizers were applied one day before sowing the germinated seeds in the seed bed.

3.10 Seedling transplant in the pots

The chemical fertilizers *i.e.*, urea, triple super phosphate (TSP), muriate of potash (MOP) and gypsum were added for N, P, K and S in all the pot soils at the rate of 100 kg N, 60 kg P_2O_5, 80 kg K_2O and 20 kg S ha^{-1}, respectively. The whole amount of TSP, MOP, gypsum and $1/3^{rd}$ of urea were applied before the final preparation of the pots. Thereafter the pots containing soil were moistened with water. Five weeks old seedlings of selected rice cultivars were transplanted in the respective pots. There were two hills in each pot. Two weeks after transplanting the salt solutions were applied in each pot according to the treatments. To avoid osmotic shock, salt solutions were added in three equal installments on alternate days until the expected conductivity was reached. The electrical conductivity (EC) of each pot was measured everyday with a EC meter and necessary adjustments were made by adding water. The remaining 2/3rd urea were top dressed at two equal divisions after 25 and 50 days of transplanting.

3.11 Collection of data

3.11.1 Plant height

The plant height (cm) was measured from the surface level of the soil to the tip of the longest leaf at 30 days after transplanting (DAT), 45 DAT, at flowering and at harvesting by taking the average value of ten random samples.

3.11.2 Number of effective and non-effective tillers

At the final harvest, number of effective and non-effective tillers hill^{-1} were recorded.

3.11.3 Root length and root dry weight

Roots hill^{-1} were carefully cleaned after final harvest with running tap water and finally washed with distilled water. After measuring the length, the root samples were oven-dried to a constant weight at 70^{0} C and the root dry weight hill^{-1} was recorded.

3.11.4 Shoot dry weight

After separation of roots, the samples of stem, leaf and panicle $hill^{-1}$ were oven-dried to a constant weight at 70^0 C. Then the shoot dry weight was calculated from the summation of leaf, stem and panicle.

3.11.5 Total dry matter

The total dry matter (TDM) $hill^{-1}$ was calculated from the summation of root dry weight and shoot dry weight $hill^{-1}$.

3.11.6 Relative growth data: The relative growth performance of seedlings of different cultivars/ lines was calculated to evaluate the salt tolerance for each genotype by the following formula proposed by Ashraf and Waheed (1990):

$$\text{Relative growth data (\%)} = \frac{\text{The data of salt treated plant of a cultivar}}{\text{The data of control treated plant of that cultivar}} \times 100$$

3.11.7 Panicle length

Average panicle length (cm) was calculated by taking the lengths of all the panicles $hill^{-1}$.

3.11.8 Number of filled grain

Average number of filled grain was calculated by counting the number of filled grain of all panicles $hill^{-1}$.

3.11.9 Number of unfilled grain

Number of unfilled grain panicle^{-1} was also counted.

3.11.10 1000-grain weight

After taking about 10 g of oven dried grain, the number of grains was counted. Thousand grain weight hill^{-1} was calculated by following formula –

1000-grain weight = {(10 ÷ Number of grains) × 1000} g

3.11.11 Yield

After proper drying, the grain yield hill^{-1} was recorded which had effective tillers.

3. 12 Statistical analysis

The collected data were analyzed statistically following CRD design by MSTAT-C computer package programme developed by Russel (1986). The treatment means were compared by Duncan's Multiple Range Test (DMRT) and regression analysis were performed as and where necessary.

Chapter 4
Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

Four rice cultivars (Sadamota, BRRI dhan40, Heera and Lalmota) were selected for this experiment in order to study some growth and yield parameters under salinity. The levels of salinity chosen were 0, 3, 6, 9 and 12 dSm^{-1} in order to get more frequency for having a precise effect of salinity levels. Although salinity starts from 4 dSm^{-1} and above, and there is a probability of increasing trend of salinity in the root zone and surface of the soil which could minimize by choosing more frequent interval of salinity. Relative values were calculated and analysed for root length, root dry weight, shoot dry weight and total dry matter. The results are discussed character wise under the following heads:

4.1 Plant height

The plant height of different rice cultivars differed significantly due to the mean effect of different salinity levels at different growth stages and at harvest. The tallest plants were found in cultivar Sadamota and Lalmota at all growth stages even at harvest and the shortest plants were in Heera at all growth stages followed by BRRI dhan40 (Table 1).

Table 1. Effects of cultivar on plant height of rice at different days after transplantation (mean of 5 salinity levels)

Cultivar	Plant height (cm) at different days after transplanting (DAT)			
	30	45	At flowering	At harvest
Sadamota	89.04 a	124.4 a	137.0 a	140.9 a
BRRI dhan40	54.98 b	66.62 b	75.39 c	81.15 b
Heera	49.36 c	49.92 c	61.83 d	66.24 c
Lalmota	88.39 a	124.3 a	136.5 b	140.4 a
Significant level	**	**	**	**
$LSD_{0.05}$	0.7190	0.7911	0.3854	0.5834
CV (%)	2.10	1.97	0.41	0.91

** 1% level of significance

There was a significant decrease in plant height with increasing the salinity level. At different growth stages {at 30 Days After Transplanting (DAT), 45 DAT, at flowering and at harvesting} of rice plant the highest (76.91, 107.4, 118.9 and 123.5 cm) plant height were observed in 0 dSm^{-1} and the lowest (63.49, 72.90, 87.46 and 90.76 cm) values were found in 12 dSm^{-1} (Table 2).

Table 2. Effect of different salinity levels on plant height of rice at different days after transplantation (mean of 4 cultivars)

Salinity level (dSm^{-1})	Plant height (cm) at different days after transplanting (DAT)			
	30	45	At flowering	At harvest
0	76.91 a	107.4 a	118.9 a	123.5 a
3	74.94 b	101.9 b	114.2 b	118.7 b
6	72.18 c	92.56 c	102.3 c	107.5 c
9	64.69 d	81.84 d	90.56 d	95.50 d
12	63.49 e	72.90 e	87.46 e	90.76 e
Significant level	**	**	**	**
$LSD_{0.05}$	0.7414	0.8159	0.3975	0.6016
CV(%)	2.10	1.97	0.41	0.91

** 1% level of significance

In combination effect of cultivars and salinity levels, the highest (161.6 cm) plant height at harvest was found in Lalmota followed by Sadamota (161.1 cm) at 0 dSm^{-1} which were statistically similar and the lowest (58.31 cm) plant height was found in Heera at 12 dSm^{-1}. In all the cultivars, plant height significantly decreased with increase in salinity levels (Table 3).

Table 3: Interaction effect of cultivar and salinity on plant height at different days after transplantation

Cultivar	Salinity level (dSm^{-1})	Plant height at different days after transplanting (DAT)			
		30 DAT	45 DAT	At flowering	At Harvest
Sadamota	0	98.54 a	145.3 a	157.2 a	161.1 a
	3	94.52 b	135.0 d	149.5 b	155.0 b
	6	91.67 c	129.1 f	138.7 c	144.7 c
	9	80.48 d	112.1 h	122.4 d	125.0 d
	12	79.97 d	100.5 j	117.4 e	118.7 e
BRRI dhan40	0	56.02 f	79.53 k	87.59 g	94.02 f
	3	58.33 e	79.07 l	88.60 f	93.72 f
	6	58.29 e	65.07 m	73.62 h	77.51 g
	9	52.84 g	58.98 o	64.01 j	72.47 h
	12	49.40 h	50.43 q	63.13 j	68.03 i
Heera	0	55.19 f	62.40 n	74.17 h	77.02 g
	3	53.02 g	57.90 p	69.86 i	71.87 h
	6	47.72 i	46.38 r	58.65 k	63.74 j
	9	45.60 j	43.47 s	53.97 l	60.25 k
	12	45.24 j	39.44 t	52.47 m	58.31 l
Lalmota	0	97.89 a	142.4 b	156.6 a	161.6 a
	3	93.87 b	135.6 c	148.9 b	154.3 b
	6	91.02 c	129.7 e	138.1 c	144.0 c
	9	79.83 d	112.8 g	121.9 d	124.3 d
	12	79.32 d	101.2 i	116.8 e	118.0 e
Significant level		**	**	**	**
$LSD_{0.05}$		1.646	0.3389	0.8824	1.335
CV (%)		2.10	1.97	0.41	0.91

** 1% level of significance

Cristo *et al*. (2001) conducting a laboratory experiment with new rice lines 8610, 8736, 8734 and cultivars Pokkali (salt tolerant) and Amistad-82 (salt susceptible), at different saline concentrations (0.4, 0.7 and 1.0%). The authors reported that plant height was affected by the increase of salinity levels and the rice lines 8736 and 8734 were better than Pokkali. Thirumeni *et al.* (2001) found that % germination and plant growth decreased with increasing salt concentration in rice cultivars.

Alam *et al*. (2001) stated that the critical level of salinity for plant growth was about 5 dSm^{-1}, the most common salinity effect was stunting of plant growth, whereas leaf withering was less apparent and the growth parameters such as dry matter, plant height, root length and emergence of new roots decreased significantly at electrical conductivity value of 5-6 dSm^{-1}. Plant height, root length, plant dry weight were highly correlated with the saline stress tolerance index, indicating that measuring varietal ratings for salt tolerance at the early stage of growth via these traits was likely to be effective (Gonzalez and Ramirez, 1998).

4.2 Root Length

Relative root length (%) differed significantly in four rice cultivars due to the mean effect of five salinity levels. As for selected cultivars, the highest (87.05%)) relative root length was found in Sadamota and the lowest (76.71%) was in BRRI dhan40. Sadamota was followed by cultivar Lalmota which showed 82.63% value for relative root length (Table 4).

Table 4. Effect of cultivar on relative root length (%) of rice plant (mean of 5 salinity levels)

Cultivar	Relative root length (%)
Sadamota	87.05 a
BRRI dhan40	76.71 d
Heera	78.10 c
Lalmota	82.63 b
Significant level	**
$LSD_{0.05}$	0.3649
CV (%)	0.47

** 1% level of significance

The relative root length (%) decreased significantly with the increase of salinity level due to the mean effect of four cultivars. The highest (100%) relative root length was recorded in 0 dSm^{-1} and the lowest (58.46%) in 12 dSm^{-1} (Figure 1 & Appendix 2).

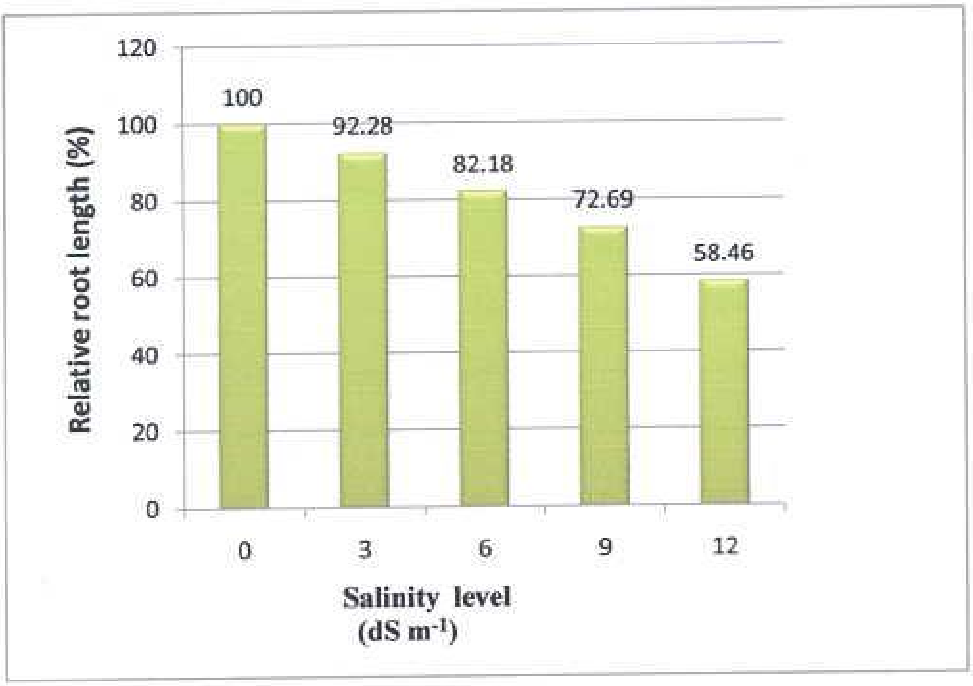

Figure 1. Effect of different salinity levels on relative root length (%) of rice plant (mean of 4 cultivars)

Relative root length (%) showed statistically significant variation in values due to interaction effect of cultivar and salinity. It appeared from the results that with increasing the salinity there was a rapid decrease in the value of relative root length of BRRI dhan40 while in Sadamota, Heera and Lalmota it deceased slowly (Figure 2 & Appendix 3).

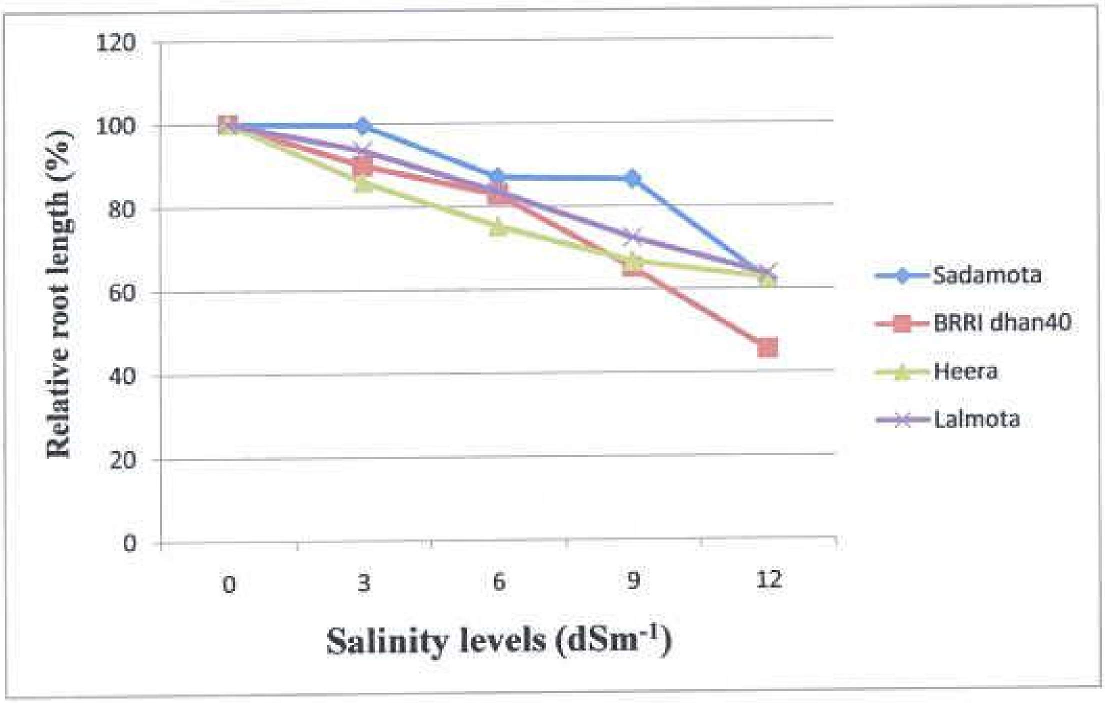

Figure 2. The effect of different salinity levels on relative root length (%) of four rice cultivars

4.3 Root dry weight

Significant variation was observed in values of relative root dry weight (%) of four cultivars due to the mean effect of the five salinity levels. Among the 4 rice cultivars the highest (74.76%) relative root dry weight was recorded in Heera which was statistically similar with Sadamota (74.17%), whereas the lowest (72.14%) was in Lalmota followed by BRRI dhan40 (72.51%) due to the mean effect of different salinity levels under study (Table 5).

Table 5. Effect of cultivar on relative root dry wt. (%) of rice plant (mean of 5 salinity levels)

Cultivar	Relative root dry wt.(%)
Sadamota	74.17 a
BRRI dhan40	72.51 b
Heera	74.76 a
Lalmota	72.14 b
Significant level	**
$LSD_{0.05}$	1.249
CV (%)	6.10

** 1% level of significance

The result presented in Figure 3 and Appendix 2 show that the relative root dry weight (%) significantly decreased with increasing the salinity levels. The relative RDW was highest (100%) at 0 dSm^{-1} and it was lowest (41.10%) at 12 dSm^{-1} level of soil salinity.

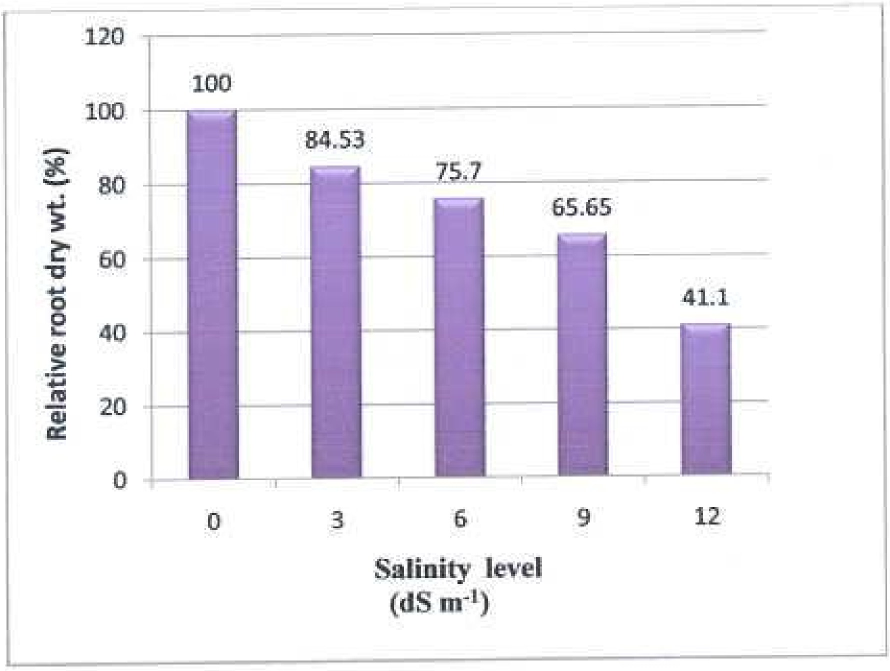

Figure 3. Effect of different salinity levels on relative root dry wt. (%) of rice plant (mean of 4 cultivars)

The effect of different salinity levels on relative root dry weight of selected rice cultivars differed significantly, where relative RDW decreased with increasing salinity levels in all cultivars (Figure 4). This decreasing tendency was very sharp in the BRRI dhan40 from 9 dSm^{-1} salinity than those of Lalmota, Sadamota and Heera (Appendix 3).

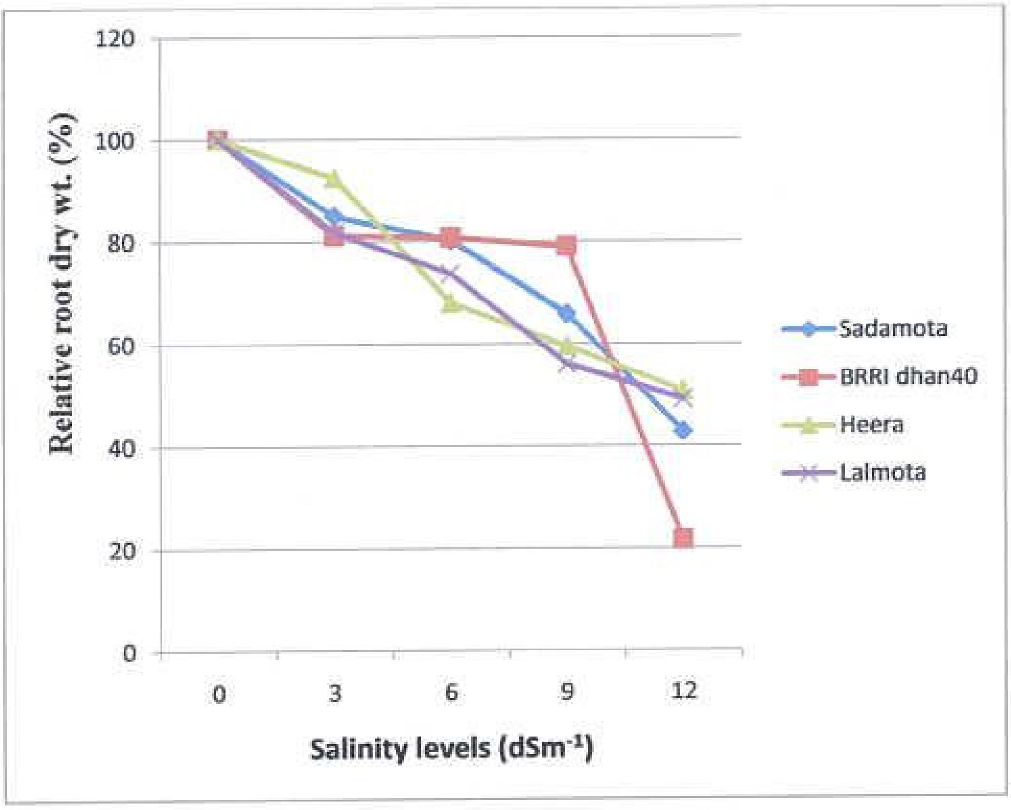

Figure 4. The effect of different salinity levels on relative root dry weight (%) of four rice cultivars

Lin and Kao (2001) studied the relative importance of endogenous abscisic acid (ABA), as well as Na^+ and Cl^- in NaCl induced salinity responses on growth of roots of rice plants and observed that increasing concentrations of NaCl from 50-150 mM progressively decreased root growth. Pushpam and Rangasamy (2002) observed that salinity induced general reduction in shoot and root length in susceptible cultivars (IR-20, IR-50) compared to the tolerant cultivar (Sadamota). Alam *et al*. (2001) stated that the critical level of salinity for plant growth was about 5 dSm^{-1}.

They also found that during vegetative growth, dry weight of roots and root length were affected by salinity. Pareek *et al*. (1998) found that branching of the roots of the plants was arrested in 100 mM NaCl and with further increase in NaCl concentration to 200 mM, the embryonic axis emerged from the seeds but it did not show any further growth with respect to its elongation. With further increase in NaCl concentration, the root morphology was drastically affected as the development of fibrous root system was not seen in NaCl- treated plants. The suppression of root growth seems to be due to osmotic imbalance and excess concentration of Na^+ and Cl^-.

4.4 Shoot dry weight

The relative shoot dry weight (%) of the four rice cultivars varied from 76.84 to 63.47% due to the mean effect of 5 salinity levels. Heera gave the highest relative shoot dry weight (76.84%) followed by Sadamota (70.43%) and the cultivar BRRI dhan40 produced lowest (63.47%) SDW (Table 6).

Table 6. Effect of cultivar on relative shoot dry weight (%) of rice plant (mean of 5 salinity levels)

Cultivar	Relative shoot dry wt.(%)
Sadamota	70.43 b
BRRI dhan40	63.47 d
Heera	76.84 a
Lalmota	67.30 c
Significant level	**
$LSD_{0.05}$	0.8839
CV (%)	3.22

** 1% level of significance

The relative shoot dry weight (%) of different rice cultivars (mean of 4 cultivars) decreased as the level of salinity increased and the reduction of relative shoot dry weight (%) was statistically significant at 1% level of probability (Figure 5 & Appendix 2). The highest shoot dry weight (100%) was observed in 0 dSm^{-1} salinity and it was lowest (41.82%) at the highest level of salinity (12 dSm^{-1}).

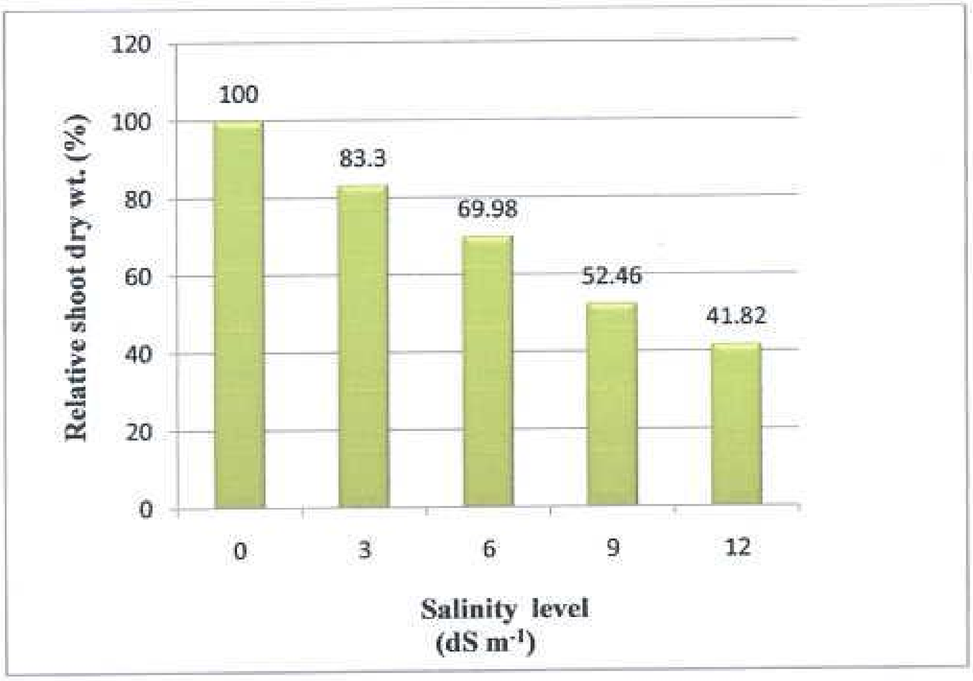

Figure 5. Effect of different salinity levels on relative shoot dry weight (%) of rice plant (mean of 4 cultivars)

Relative shoot dry weight (%) significantly decreased with increasing salinity levels at all cultivars (Appendix 3). But decreasing tendency was found slower in Heera and Sadamota while it was found in very sharp decrease in BRRI dhan40 (Figure 6 and Appendix 3).

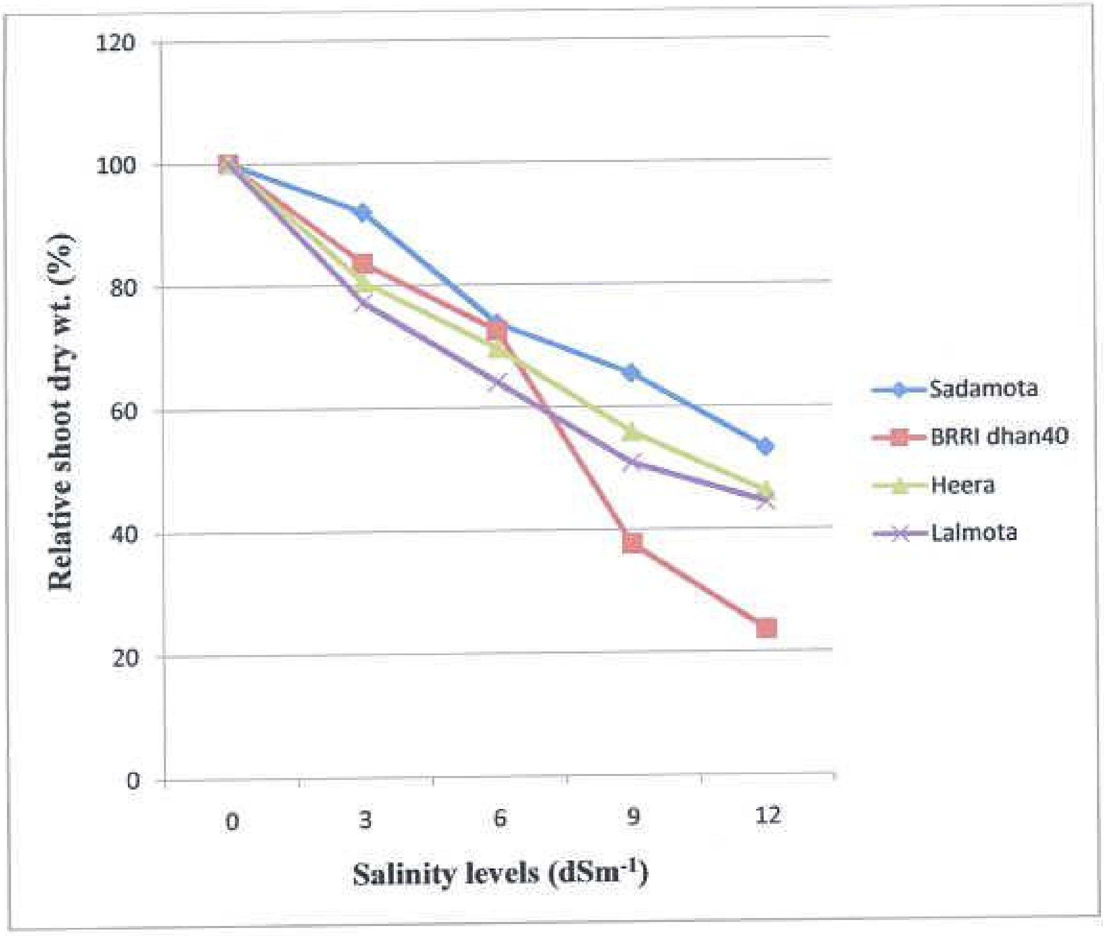

Figure 6. The effect of different salinity levels on relative shoot dry weight (%) of 4 rice cultivars

Cristo *et al*. (2001) stated that at initial stage plant growth was affected by the increase of salinity level. Similar opinion was also given by Rodrigues *et al*. (2002) and Thirumeni *et al*. (2001). Alam *et al*. (2001) stated that the critical level of salinity for plant growth was about 5 dSm^{-1} and growth parameter such as dry matter, plant height, root length and emergence of new roots decreased significantly at an electrical conductivity value of 5-6 dSm^{-1}. They also observed that during vegetative period, the most common salinity effect was stunting of plant growth, and the shoot growth was more suppressed than that of root.

4.5 Total dry matter

Due to the mean effect of five salinity levels, the relative total dry matter (%) of the 4 rice cultivars varied significantly. Heera performed the best (76.10%) followed by the cultivar Sadamota and Lalmota while BRRI dhan40 produced least (64.57%) relative total dry matter due to mean effect of salinity levels used (Table 7). Sadamota (71.18%) and Lalmota (71.03%) showed statistically similar results.

Table 7. Effect of cultivar on relative total dry matter (%) of rice plant (mean of 5 salinity levels)

Cultivar	Relative total dry matter (%)
Sadamota	71.18 b
BRRI dhan40	64.57 c
Heera	76.10 a
Lalmota	71.03 b
Significant level	**
$LSD_{0.05}$	0.7974
CV (%)	2.58

** 1% level of significance

With increasing the salinity levels the relative total dry matter (%) of four rice cultivars (mean of 4 cultivars) decreased at 1% level of significance. It was highest (100%) in 0 dSm^{-1} salinity and it was lowest (41.92%) at the highest level of salinity (12 dSm^{-1}) (Figure 7 and Appendix 2).

The relative total dry matter (%) differed significantly due to the interaction effect of cultivars and salinity levels (Appendix 3). The relative total dry matter (%) significantly decreased with increasing the salinity levels of all the cultivars where the decreasing pattern was very sharp in the cultivar BRRI dhan40 than Heera, Sadamota and Lalmota. Heera showed best result at highest salinity level (Figure 8 & Appendix 3).

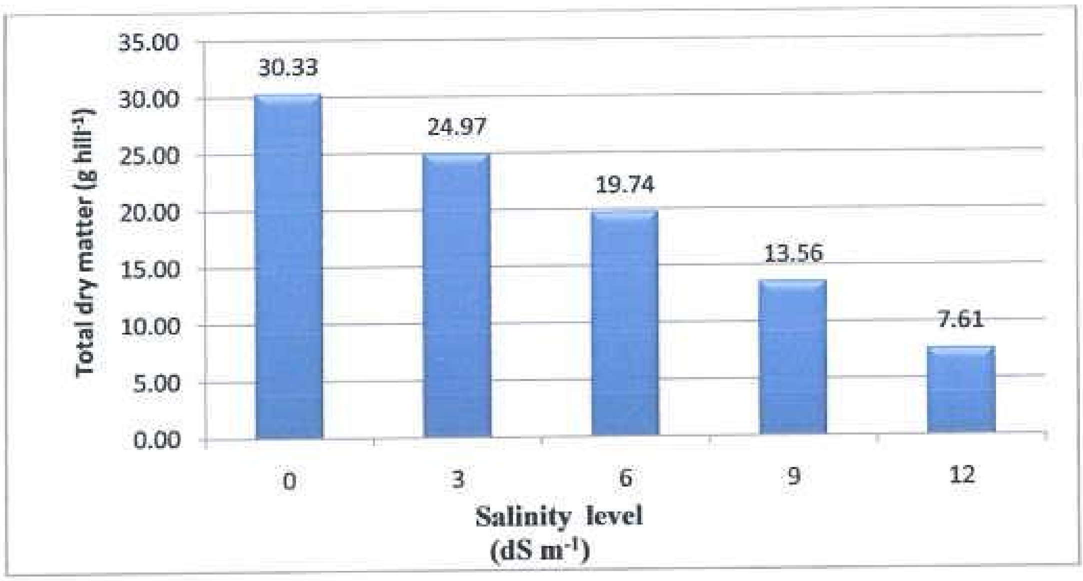

Figure 7 . Effect of different salinity levels on relative total dry matter (%) (mean of 4 cultivars)

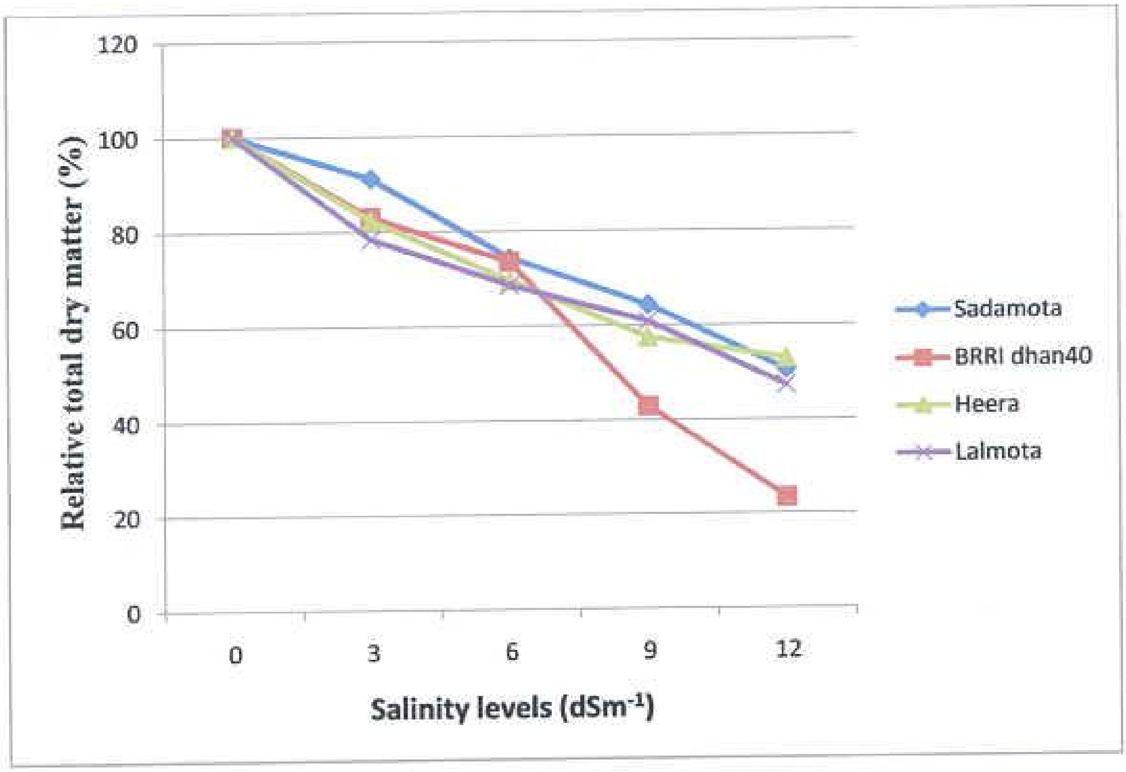

Figure 8. The effect of different salinity levels on relative total dry matter (%) of four rice cultivars

4.6 Number of effective tiller

The results in Table 8 revealed that the effective tillers $hill^{-1}$ of the selected rice cultivars varied significantly due to the mean effect of different salinity levels. The highest effective tillers $hill^{-1}$ (7.23) was found in Heera and the lowest (4.15) was in BRRI dhan40 (Table 8).

Table 8. Effect of cultivar on effective tiller of rice (mean of 5 salinity levels)

Cultivar	Number of effective tillers $hill^{-1}$
Sadamota	5.85 b
BRRI dhan40	4.15 d
Heera	7.23 a
Lalmota	5.52 c
Significant level	**
$LSD_{0.05}$	0.1162
CV (%)	0.70

** 1% level of significance

The number of effective tillers $hill^{-1}$ of selected rice cultivars was significantly influenced by different levels of salinity due to the mean effect of four cultivars (Figure 9). The highest effective tillers $hill^{-1}$ (8.67) was recorded at 0 dSm^{-1} salinity level and the lowest (1.82) was found at 12 dSm^{-1} salinity level (Appendix-4).

The number of effective tillers $hill^{-1}$ significantly decreased with increasing the different salinity levels of four selected rice cultivars (Figure 11). The maximum (11.52) and the minimum (1.08) value of effective tillers $hill^{-1}$ was found in BRRI dhan40 at 0 dSm^{-1} and at 12 dSm^{-1} level of salinity, respectively (Appendix-5). The effective tillers $hill^{-1}$ decreased slowly in cultivar Sadamota and Heera but this decreasing tendency was very sharp in the cultivars Lalmota and BRRI dhan40 with increasing the salinity levels (Figure 10).

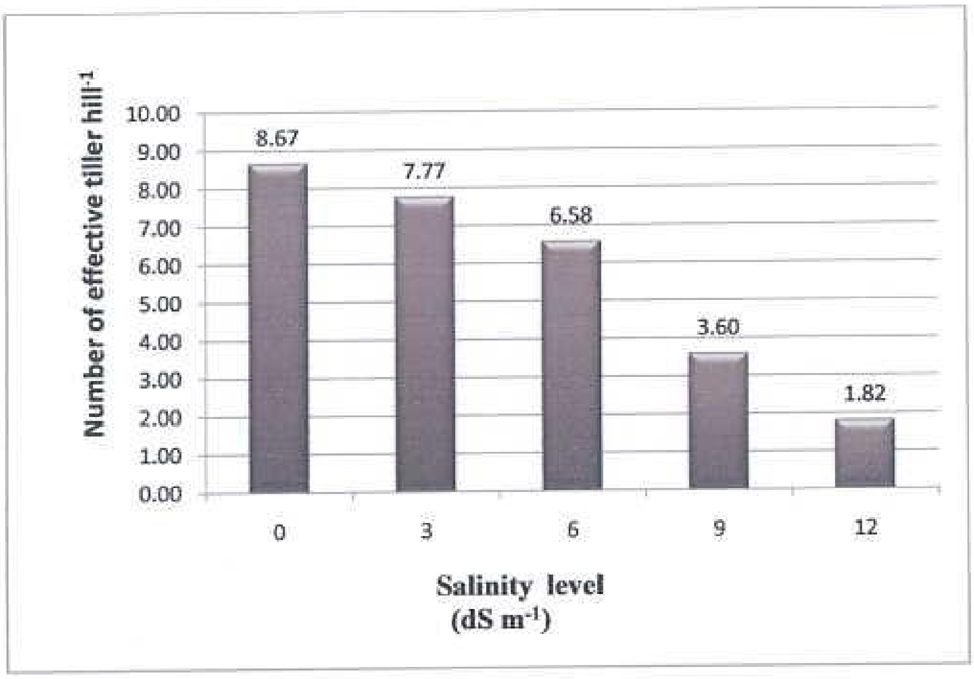

Figure 9. Effects of different salinity levels on effective tillers hill^{-1} (mean of 4 cultivars)

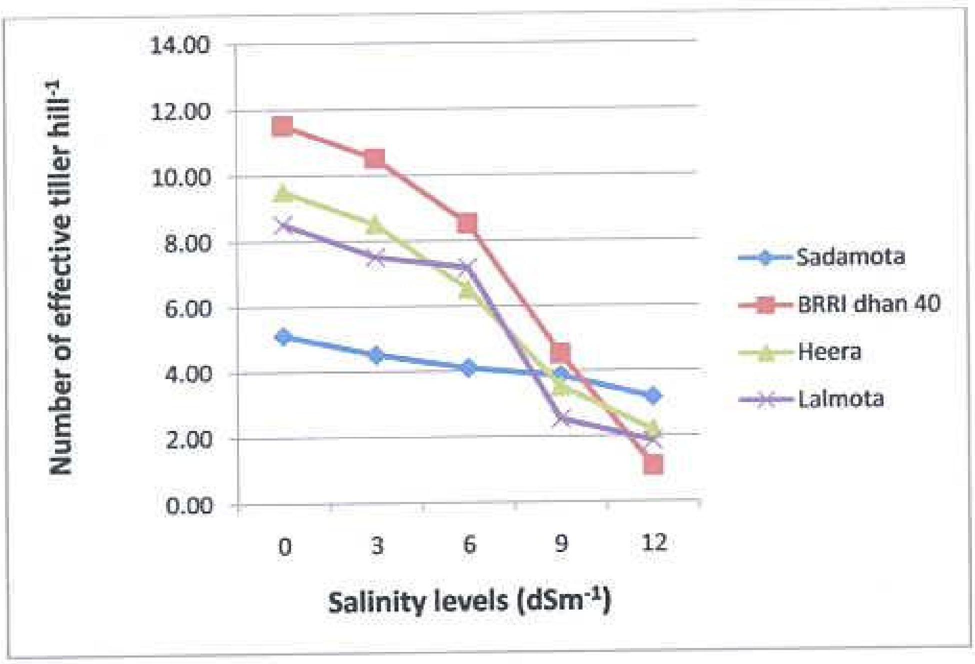

Figure 10. The effect of different salinity levels on effective tillers hill^{-1} of four rice cultivars

Bohra and Doerffling (1993) observed that plant height, number of tillers and Total dry matter reduced under salinity stress in both salt tolerant and salt sensitive rice cultivars. They maintained that salinity stress wasted more energy in salt sensitive rice cultivars than that in salt tolerant ones. Khatun *et al*. (1995) found that salinity delayed flowering, reduced the number of productive tillers, the number of fertile florets per panicle. Salt tolerance indexes in terms of seed yield, seed weight per panicle, spikelet number per panicle, and tiller number per plant were reduced with increasing salinity (Zeng *et al*., 2002). Our results also indicate that the effective tillers $hill^{-1}$ was badly affected at higher salinity levels.

4.7 Number of non-effective tiller

The mean effect of different salinity levels significantly influenced the number of non-effective tillers $hill^{-1}$ of four selected rice cultivars (Table 9). The highest number of non-effective tillers $hill^{-1}$ was observed in Lalmota (1.99) followed by BRRI dhan40 (1.78). Sadamota produced the lowest (0.98) number of non-effective tillers $hill^{-1}$ which was showed statistically similar with Heera (1.09).

Table 9. Effect of cultivar on non-effective tillers $hill^{-1}$ of rice (mean of 5 salinity levels)

Cultivar	Number of non-effective tillers $hill^{-1}$
Sadamota	0.98 c
BRRI dhan40	1.78 b
Heera	1.09 c
Lalmota	1.99 a
Significant level	**
$LSD_{0.05}$	0.1162
CV (%)	0.001

** 1% level of significance

It was evident from the results presented in Appendix 4 that the number of non-effective tillers hill^{-1} of rice cultivars significantly differed to different levels of salinity. The highest non effective tillers hill^{-1} (2.26) was recorded at 12 dSm^{-1} salinity level and it was the lowest (0.83 0.89) at 0 and 3 dSm^{-1} salinity levels with no statistical differences (Figure 11 & Appendix 4).

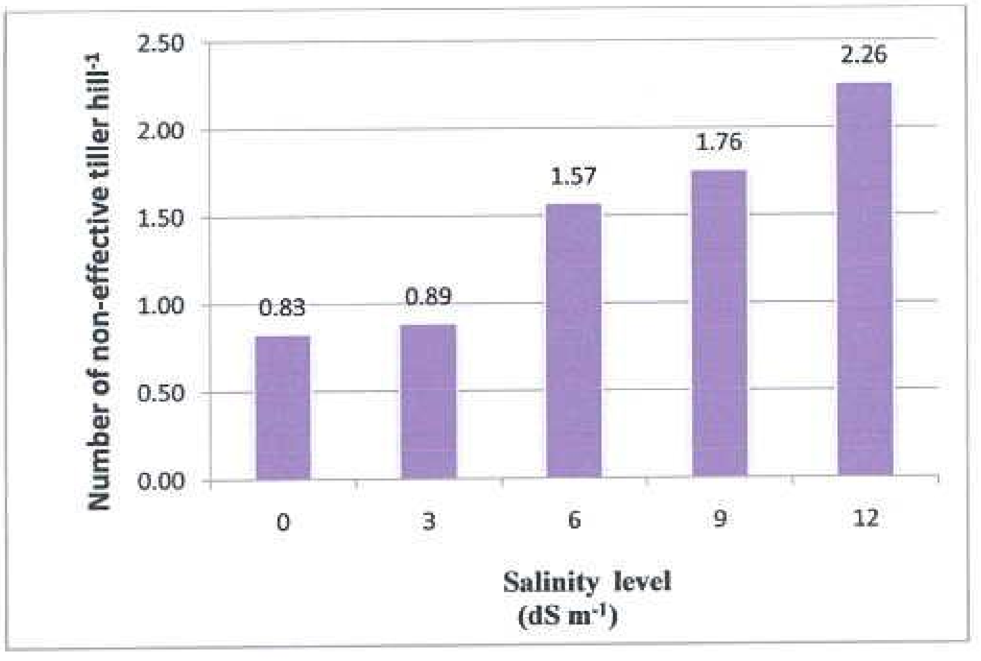

Figure 11. Effects of different salinity levels on non-effective tillers hill^{-1} (mean of 4 cultivars)

It appeared from the results that the different salinity levels had significant effect on sterility of tillers hill^{-1} of four selected rice cultivars (Figure 12 & Appendix 5). The number of non-effective tillers hill^{-1} was highest (3.62) in cultivars BRRI dhan40 and Lalmota at 12 dSm^{-1} and the minimum value (0.65) of non-effective tillers hill^{-1} was found in Sadamota at 0 dSm^{-1} to 9 dSm^{-1} levels of salinity which were statistically identical with BRRI dhan40 at 0 and 3 dSm^{-1} levels of salinity (Appendix 5).

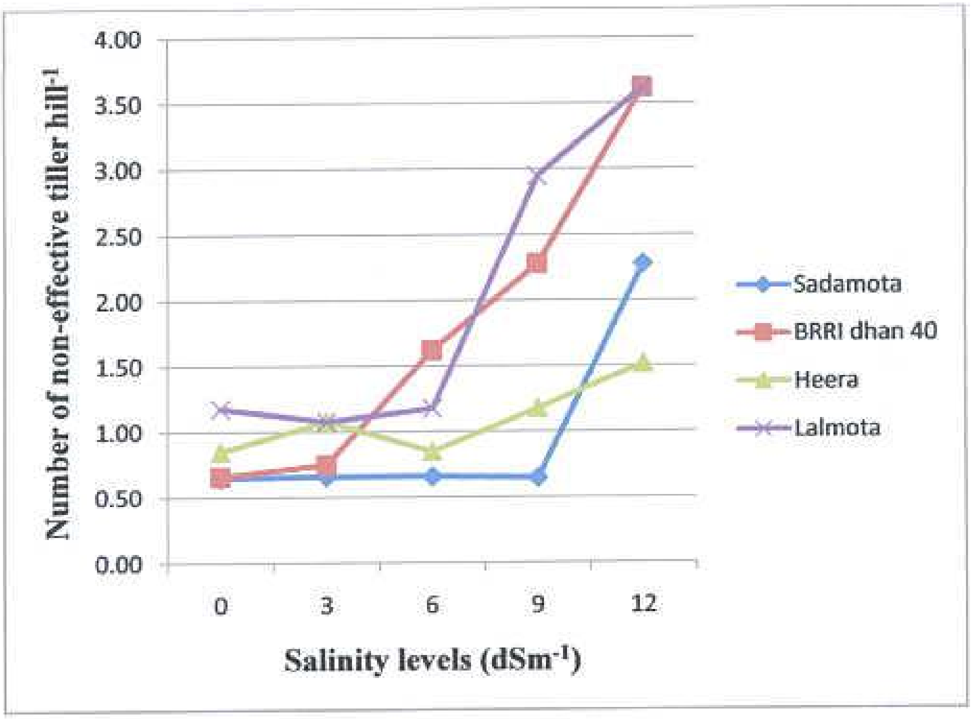

Figure 12. The effect of different salinity levels on non-effective tillers hill^{-1} of four rice cultivars

Alam *et al.*, (2001) stated that the salinity at reproductive stage of rice depressed grain yield much more than that at the vegetative growth stage and at critical salinity levels it might give normal straw yield of rice but produced little or no grain. They also observed that when the plants were continuously exposed to saline media, salinity affected the panicle initiation, spikelet formation, fertilization of florets and germination of pollen grains and hence caused an increase in number of sterile florets. The mutant variety maintained its superiority in various characteristics such as plant height, higher number of fertile panicles per plant (Baloch *et al.*, 2003).

4.8 Panicle length

The panicle length of four selected rice cultivars differed significantly due to mean effect of different salinity levels (Table 10). The highest panicle length (21.93 cm) was obtained in cultivar Sadamota followed by Heera (19.45 cm) and the lowest panicle length (16.76 cm) was recorded in cultivar Lalmota due to the mean effect of salinity treatments.

Table 10. Effect of cultivar on panicle length of rice (mean of 5 salinity levels)

Cultivar	Panicle length (cm)
Sadamota	21.93 a
BRRI dhan40	18.15 c
Heera	19.45 b
Lalmota	16.76 d
Significant level	**
$LSD_{0.05}$	0.3182
CV (%)	1.53

** 1% level of significance

Panicle length of the four selected rice cultivars varied significantly due to the application of different levels of salinity (Appendix 6). The longest panicle (22.28 cm) was found at 0 dSm^{-1} and the lowest panicle length (14.71 cm) was recorded at 12 dSm^{-1} level of salinity (Figure 13 & Appendix 6).

The panicle length of selected four rice cultivars differed significantly due to the application of different salinity levels (Figure 14). The highest panicle length (24.49 cm) was recorded in Heera at 0 dSm^{-1} level of salinity. However, the lowest panicle length (6.35 cm) was recorded in BRRI dhan40 at 12 dSm^{-1} level of salinity (Appendix 7). The Figure 15 showed that the panicle length of BRRI dhan40 cultivar decreased very sharply after the salinity level 9 dSm^{-1}.

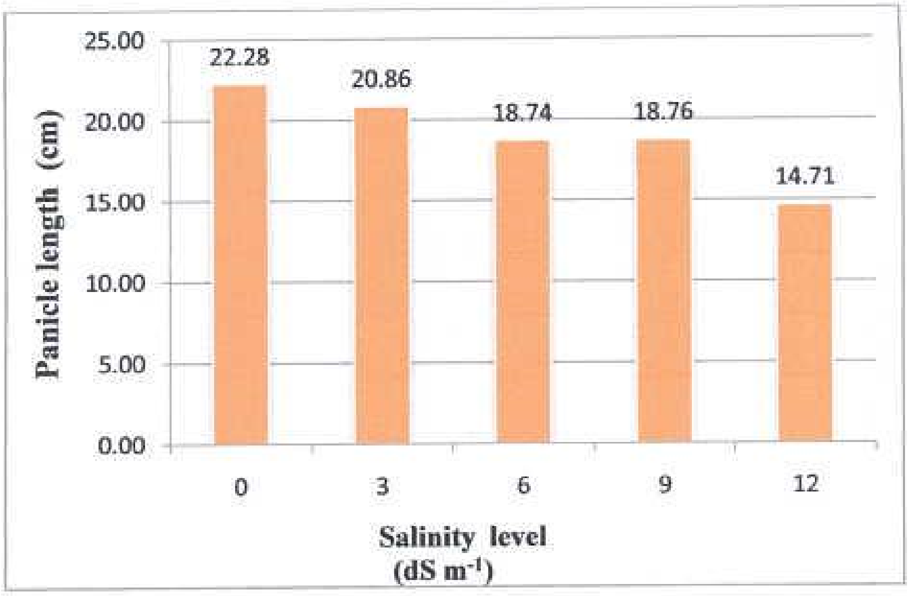

Figure 13. Effect of s different salinity levels on panicle length (cm) of rice plant (mean of 4 cultivars)

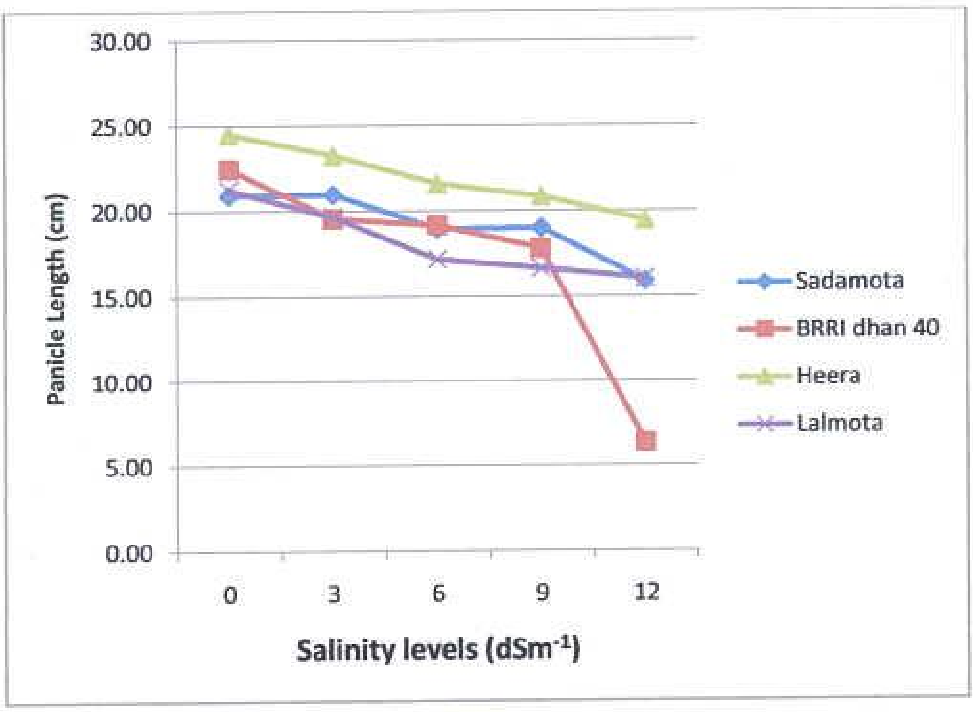

Figure 14. The effect of different salinity levels on panicle length of four rice cultivars

Khatun *et al.* (1995) and Alam *et al.* (2001) reported that salinity severely reduces the panicle length, number of primary branches per panicle, number of spikelet per panicle, seed setting percentage and panicle weight, thereby reducing the grain yield. Marassi *et al.* (1989) and Abdullah *et al.* (2001) observed that panicle length was significantly decreased due to salinity stress. Aslam *et al.* (2001) stated that panicle length of rice adversely affected by both saline and saline sodic soils. Salinity had a negative impact on a number of yield components including stand establishment, panicles, tillers and spikelets per panicle, floret sterility and individual grain size (Grattan *et al.*, 2002).

4.9 Number of filled grain

Different cultivars showed significant variation in number of filled grains panicle^{-1} due to the mean effect of five salinity levels (Table 11). The number of filled grains panicle^{-1} (78.46) was highest in Heera followed by Sadamota (69.82) and that was lowest (58.62) in BRRI dhan40 (Table 11).

Table 11. Effect of cultivar on number of filled grains panicle^{-1} of rice (mean of 5 salinity levels)

Cultivar	Number of filled grains panicle^{-1}
Sadamota	69.82 b
BRRI dhan40	58.62 c
Heera	78.46 a
Lalmota	47.14 d
Significant level	**
$LSD_{0.05}$	0.4510
CV (%)	0.92

** 1% level of significance

The number of filled grains panicle^{-1} was significantly influenced by different salinity levels (Appendix 6). The highest number of filled grains panicle^{-1} (94.32) was recorded at 0 dSm^{-1} and the lowest (31.76) was found at 12 dSm^{-1} salinity level (Figure 15 & Appendix 6).

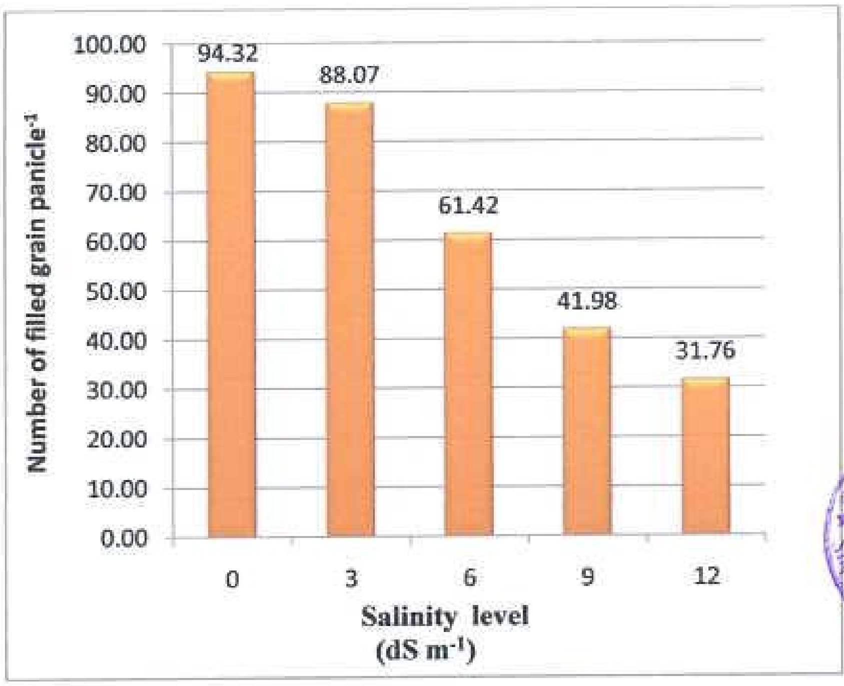

Figure 15. Effect of different salinity levels on number of filled grains panicle^{-1} (mean of 4 cultivars)

The effect of different salinity levels on filled grains panicle^{-1} of four rice cultivars significantly decreased with increase in salinity level, where the decreasing tendency was very sharp in the BRRI dhan40 cultivar than those of other cultivars (Figure 16). The maximum filled grains panicle^{-1} (104.62) was found in cultivar Heera which was statistically similar to BRRI dhan40 at 0 dSm^{-1} and minimum (16.55) filled grains panicle^{-1} was observed in BRRI dhan40 at 12 dSm^{-1} (Appendix 7).

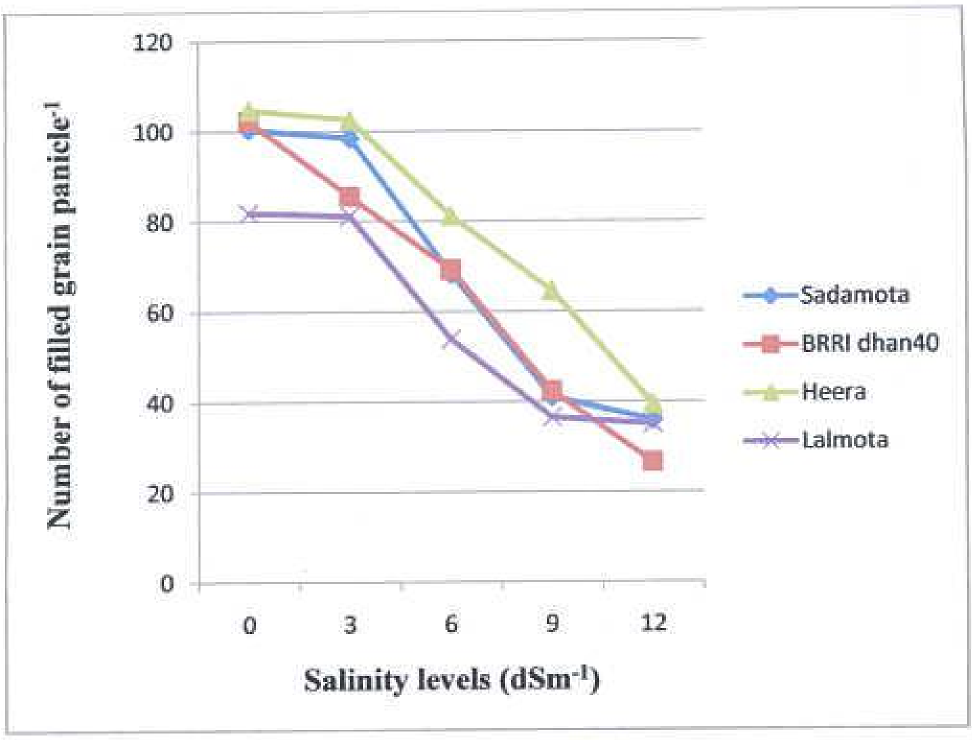

Figure 16. The effect of different salinity levels on the number of filled grains panicle^{-1} of four rice cultivars

These results confirmed those of Islam *et al.* (1998) who found that filled grains panicle^{-1} at maturity were higher in Bina-13 and Bina-19 at lower salinity levels (3.6-6.9 dSm^{-1}). Choi *et al.* (2003) conducted two experiments, with low and medium soil salinity levels with four levels of salt solution mixed with seawater (0.1, 0.3, 0.5 and 0.7%) and control (tap water). They found that panicle number per unit area and percentage of ripened grain *i.e.* filled grain dramatically decreased in 0.5% saline water in the soil with low salinity level and in 0.1% saline water in soil with medium salinity level. The number of filled grains panicle^{-1} was less affected at 6 dSm^{-1} level of salinity in mutant variety Iratom 24 which was in conformity with the findings of Baloch *et al.* (2003). They observed that the mutant variety of rice "Shua-92" maintained its superiority in various characteristics such as plant height, higher number of fertile panicles per plant and more fertile grains per panicle at 7.11- 8.0 dSm^{-1} level of salinity.

4.10 Number of unfilled grain

It was noted that the number of unfilled grains $panicle^{-1}$ of four selected rice cultivars was significantly influenced by the mean effect of different salinity levels. The highest sterility of grain (41.55) was observed in BRRI dhan40 and it was lowest (27.02) in Heera (Table 12).

Table 12. Effect of cultivar on number of unfilled grains $panicle^{-1}$ (mean of 5 salinity levels)

Cultivar	Number of unfilled grains $panicle^{-1}$
Sadamota	28.14 c
BRRI dhan40	41.55 a
Heera	27.02 d
Lalmota	40.65 b
Significant level	**
$LSD_{0.05}$	0.6149
CV (%)	3.14

** 1% level of significance

It is revealed from the results that the number of unfilled grains $panicle^{-1}$ differed significantly due to different salinity levels (Appendix 6). The highest number of unfilled grains $panicle^{-1}$ (44.22) was recorded at 12 dSm^{-1} level of salinity and it was the least (27.12) at 0 dSm^{-1} which was statistically similar with 3 dSm^{-1} (Figure 17 and Appendix 6).

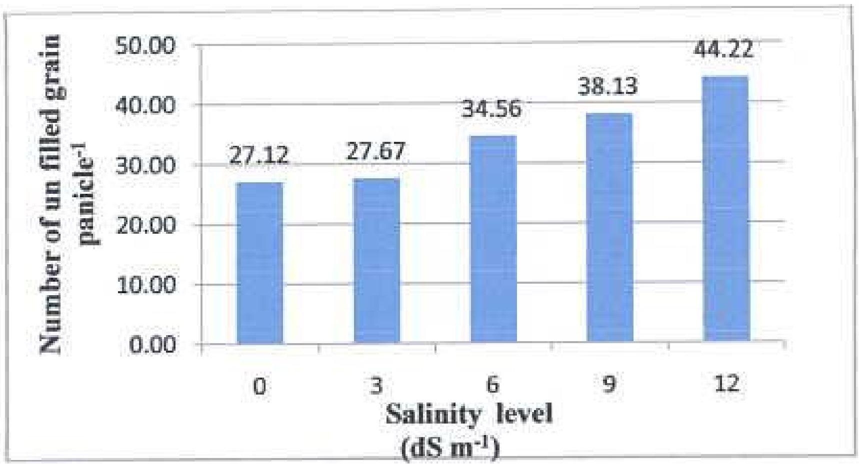

Figure 17. Effect of different salinity levels on number of unfilled grains panicle^{-1} of rice (mean of 4 cultivars)

The results presented in Figure 18 and Appendix 7 show that the different salinity levels significantly influenced the number of unfilled grains panicle^{-1} of four selected rice cultivars. The minimum number of sterile grains panicle^{-1} (19.13) was found in Heera at 0 dSm^{-1} and the maximum number of unfilled grains panicle^{-1} (54.00) was recorded in BRRI dhan40 at 12 dSm^{-1} level of salinity (Appendix 7).

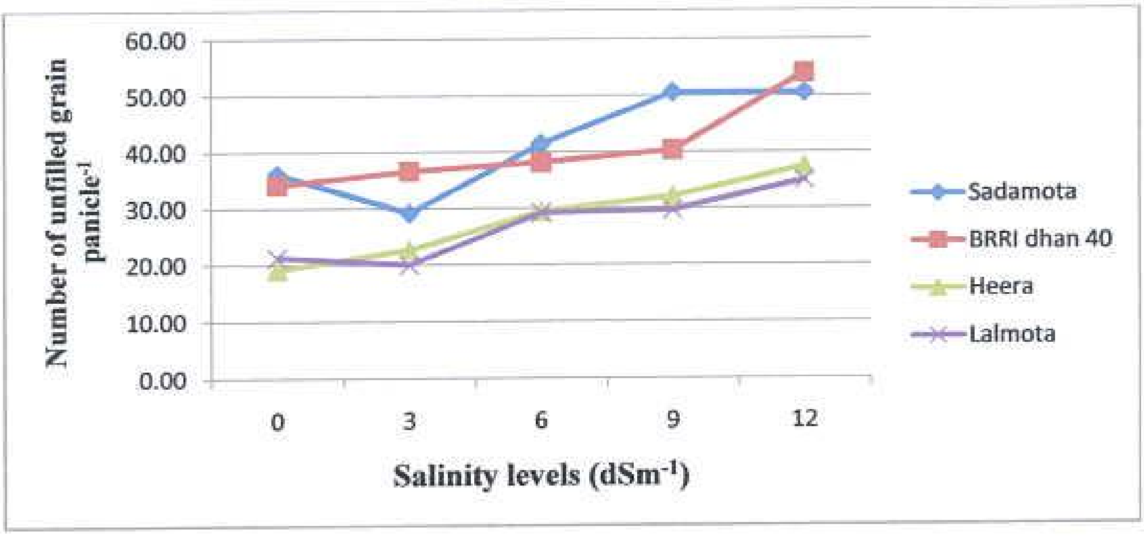

Figure 18. The effect of different salinity levels on number of unfilled grains panicle^{-1} of four rice cultivars

Asch *et al.* (1999) observed that salinity was a major yield-reducing stress in many arid and/or coastal irrigation systems for rice. They further stated that grain weight reduction in the early panicle development stages and spikelet sterility increase were highly correlated with an increase in the concentration of Na^+ in panicle. The significant reduction of grain sterility in seed setting of rice was assumed to be not merely due to reduction or inhibition of different biochemical constituents and physiological functions, but were also due to limitation of soluble carbohydrate translocation in primary and secondary spikelets, accumulation of more Na^+ and less K^+ in all the floral parts, and highly significant inhibition of specific activity of starch synthetase in developing rice grains (Abdullah *et al.*, 2001).

4.11 1000-grain weight

Thousand grain weight of four rice cultivars varied significantly due to the mean effect of five salinity levels (Table 12). Among the four selected rice cultivars, 1000-grain weight of Heera was highest (24.02 g) and it was lowest in BRRI dhan40 (15.78 g) which was statistically identical with Lalmota (15.86 g) due to the mean effect of different salinity levels (Table 13).

Table 13. Effect of cultivar on 1000-grain weight (mean of 5 salinity levels)

Cultivar	1000 grain weight (g)
Sadamota	16.63 b
BRRI dhan40	15.78 c
Heera	24.02 a
Lalmota	15.86 c
Significant level	**
$LSD_{0.05}$	0.4092
CV (%)	2.66

** 1% level of significance

The different salinity levels had significant influence on 1000-grain weight of rice cultivars and it decreased with increasing salinity levels (Figure 19). The highest 1000-grain weight (21.10 g) was recorded at 0 dSm^{-1} and the lowest value (13.12 g) was found at 12 dSm^{-1} level of salinity (Appendix 8).

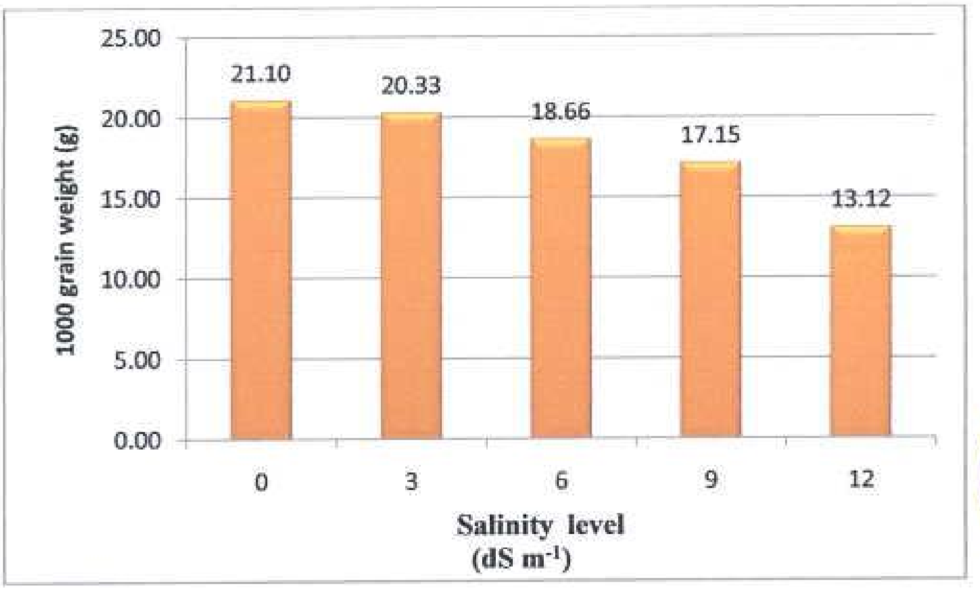

Figure 19. Effect of different salinity levels on 1000-grain weight (g) (mean of 4 cultivars)

The effect of different salinity levels on 1000- grain weight of four rice cultivars significantly decreased with increasing salinity levels where this decreasing pattern was very high after 6 dSm^{-1} level of salinity of BRRI dhan40 (Figure 20). Due to the interaction effect of cultivar and salinity, the highest value of 1000-grain weight (26.42 g) was recorded in Heera at 0 dSm^{-1} level of salinity which was statistically identical with 3 dSm^{-1} salinity of the same cultivar and the lowest value (10.26 g) was obtained in BRRI dhan40 at 12 dSm^{-1} which was statistically same with Sadamota at same salinity (Appendix 9).

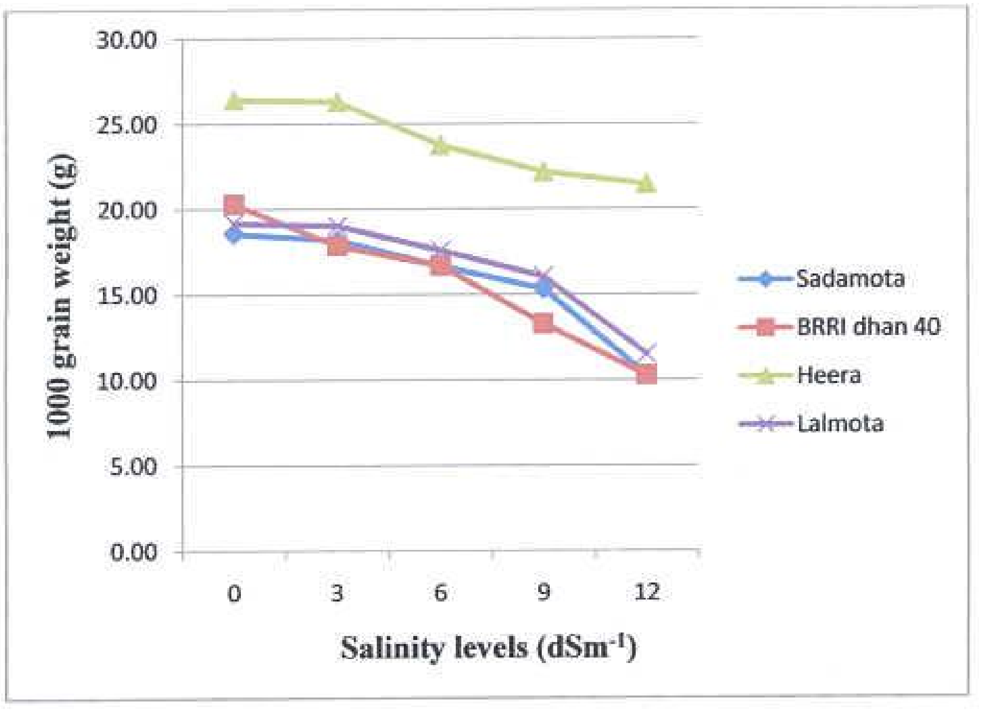

Figure 20: The effect of different salinity levels on 1000 grain weight of four rice cultivars

These results are in agreement with the findings of several researchers (Krishnamurthy *et al.*, 1989; Zaman *et al.*, 1997 and Asch *et al.*, 1999) who found that grain yield and 1000 grain weight reduced as the salinity increased. Khatun *et al.* (1995) found that salinity delayed flowering, reduced the number of fertile florets per panicle, the weight per grain and the grain yield. Saleque *et al.* (2005) observed that salinity strongly reduced spikelet number per panicle, 1000-grain weight and increased sterility, regardless of seasons and development stage of rice. Sultana *et al.* (2002) opined that low concentration of assimilate in the leaves and poor translocation of assimilates from the source resulting decreased rate of dry matter accumulation in developing grains and thereby reduced the 1000-grain weight.

4.12 Grain yield

The grain yield hill^{-1} of four selected rice cultivars differed significantly due to the mean effect of different salinity treatments (Table 14). The highest grain yield (8.49 g hill^{-1}) was found in cultivar Heera and the lowest yield (6.72 g hill^{-1}) was recorded in BRRI dhan40.

Table 13. Effects of cultivar on grain yield hill $^{-1}$ (mean of 5 salinity levels)

Cultivar	Grain yield (g hill^{-1})
Sadamota	7.85 b
BRRI dhan40	6.72 d
Heera	8.49 a
Lalmota	7.45 c
Significant level	**
$LSD_{0.05}$	0.2823
CV (%)	2.98

** 1% level of significance

A highly significant variation in grain yield hill^{-1} of rice cultivars was observed due to the different salinity levels (Figure 21). The highest grain yield (15.58 g hill^{-1}) was recorded at control treatment and it was lowest (1.51 g hill^{-1}) at 12 dSm^{-1} level of salinity (Appendix 8).

It appeared from the results that the grain yield hill^{-1} of selected four rice cultivars were decreased significantly due to different salinity levels (Figure 22). The highest grain yield hill^{-1} (17.52 g) was found in Heera at 0 dSm^{-1} salinity level and the lowest yield (0.89 g) was obtained in BRRI dhan40 at 12 dSm^{-1} (Appendix 9).

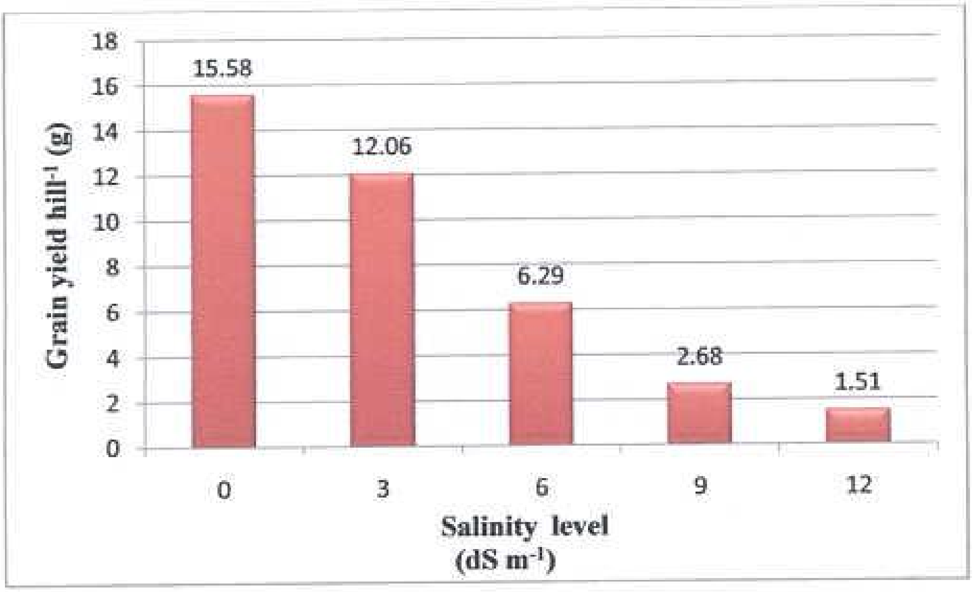

Figure 21. Grain yield hill $^{-1}$ affected by various salinity levels (mean of 4 cultivars)

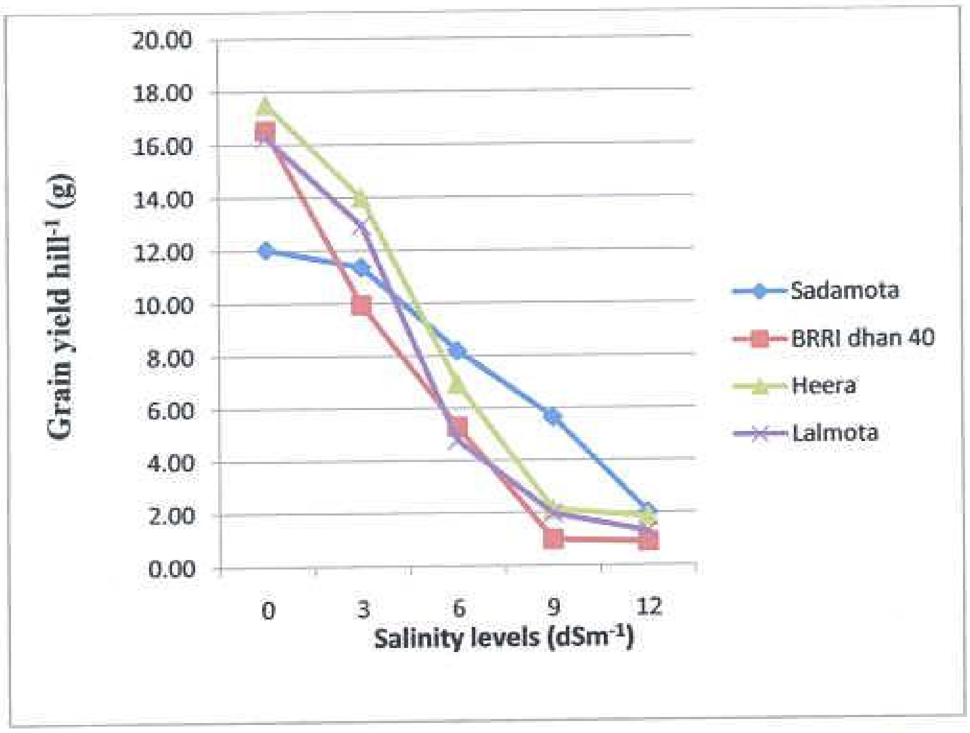

Figure 22: The effect of different salinity levels on grain yield hill $^{-1}$ of four rice cultivars

The above results were confirmed by Mishra *et al.* (1996) and they stated that the reduction in grain yield was 28.9% in tolerant variety CSR10 while susceptible variety IR28 showed 98.2% yield reduction. Salinity reduced yield to nearly zero (Asch *et al.*, 2000). Grain yield is the function of number of panicles hill^{-1}, number of filled grains panicle^{-1} and 1000-grain weight. All the yield contributing characters contributed for the yield reduction hill^{-1} under saline conditions; contribution of the seriously affected number of unfilled grains panicle^{-1} was the highest (Grattan *et al.*, 2002). They also reported that salinity affected rice yield at or above 3.0 dSm^{-1} level of salinity. The negative relationship between grain yield and salinity levels was also reported in rice (Khatun *et al.*, 1995; Arich *et al.*, 1998; Zeng and Shannon, 2000; Zeng *et al.*, 2001 and Zeng *et al.*, 2002). Starch synthetase activity in developing rice grains was inhibited very significantly under salinity stress and it was referred that sterility and significant reductions in seed setting in rice were not merely due to reduction or inhibition of different biochemical constituents and physiological functions, but were mainly due to limitation of soluble carbohydrate translocation in primary and secondary spikelets, accumulation of more Na^+ and less K^+ in all the floral parts, thus resulting in failure of seed set, thereby reducing the grain yield (Abdullah *et al.*, 2001 and Alam *et al.*, 2001). The highest relative grain yield (69.39%) was found in mutant variety Iratom24 in our study. Baloch *et al.* (2003) observed that the mutant variety of rice "Shua-92" maintained its superiority to other varieties in various characteristics such as plant height, higher number of fertile panicles per plant, more fertile grains per panicle, heavy grain size and high plant yield at 7.11- 8.0 dSm^{-1} level of salinity.

Chapter 5
Summary and Conclusions

CHAPTER 5

SUMMARY AND CONCLUSIONS

An experiment was conducted at the net house of the department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207 under pot-culture during the Boro season (December-June) of the year 2010-11 to study the effect of salinity on growth and yield of some rice cultivar. The experiment was completed using four varieties (Sadamota, BRRI dhan40, Heera and Lalmota) and five salinity levels (0, 3, 6, 9 and 12 dS m^{-1}).

Data were taken on plant height, root length, root dry weight, shoot dry weight, total dry matter, number of effective and non-effective tillers $hill^{-1}$, panicle length, number of filled and unfilled grains $panicle^{-1}$, thousand grain weight and grain yield $hill^{-1}$. For comparing the growth of different cultivars; relative root length (%), relative root dry weight (%), relative shoot dry weight (%) and relative total dry matter (%) were calculated and analyzed. Significant varietal differences were found in plant height, relative root length (%), relative root dry weight (%), relative shoot dry weight (%) and relative total dry matter (%). Plant height was highest in Sadamota and Lalmota at all the growth stages while Heera gave lowest results. The highest relative root length was found in Sadamota and lowest was in BRRI dhan40. Highest relative root dry weight was recorded in Heera which was statistically similar with Sadamota, whereas the lowest was in Lalmota followed by BRRI dhan40. Heera gave the highest relative shoot dry weight followed by Sadamota and the cultivar BRRI dhan40 produced lowest SDW. .In case of relative total dry matter (%), Heera performed the best followed by the cultivar Sadamota and Lalmota while BRRI dhan40 produced least. For yield related parameters; number of effective tillers $hill^{-1}$, panicle length, number of filled grains $panicle^{-1}$, thousand grain weight and grain yield hill^{-1} were highest in Heera and lowest in BRRI dhan40 and Lalmota due to the mean effect of five salinity levels. But higher non-effective tillers hill^{-1} was found in Lalmota and BRRI dhan40.

Almost all the growth parameters { plant height, relative root length (%), relative root dry weight (%), relative shoot dry weight (%) and relative total dry matter (%)} decreased with increasing level of salinity. Their values were highest at control that is 0 dSm^{-1} and the lowest values were found at 12 dSm^{-1}. Number of effective tillers hill^{-1}, panicle length, number of filled grains panicle^{-1}, thousand grain weight and grain yield hill^{-1} decreased with increasing the level of salinity. At 12 dSm^{-1} they showed the lowest values where at 0 dSm^{-1} they were maximum. But number of non-effective tillers hill^{-1} and number of unfilled grains panicle^{-1} increased with increasing level of salinity.

Plant height, relative root length (%), relative root dry weight (%), relative shoot dry weight (%) and relative total dry matter (%) showed significant difference due to the interaction effect of cultivar and salinity. At harvest the highest plant height was in Sadamota at 0 dSm^{-1} and the lowest in Heera at 12 dSm^{-1}. The relative root length (%), relative root dry weight (%), relative shoot dry weight (%) and relative total dry matter (%) significantly decreased with increasing the salinity levels in all the cultivars. But the decreasing pattern was very sharp for the cultivar BRRI dhan40 than Heera and Sadamota. The effective tillers hill^{-1} decreased slowly in cultivars Heera and Sadamota but this decreasing tendency was very sharp in the cultivars BRRI dhan40 and Lalmota with increasing the salinity levels. Number of effective tillers hill^{-1} was highest in BRRI dhan40 at 0 dS m^{-1} and lowest at BRRI dhan40 at 12 dS m^{-1}. The number of non-effective tillers hill^{-1} was highest in cultivar BRRI dhan40 at 12 dSm^{-1} and the minimum value of non-effective tillers hill^{-1} was found in Sadamota at 0 dSm^{-1} to 9 dSm^{-1} levels of salinity which were statistically identical with BRRI dhan40 at control and 3 dSm^{-1} levels of salinity. The panicle length of BRRI dhan40 decreased very sharply after the salinity level 9 dSm^{-1}. Panicle length was highest in Heera at 0 dS m^{-1} and lowest at BRRI dhan40 at 12 dS m^{-1}. The number of filled grains $panicle^{-1}$ of 4 rice cultivars significantly decreased with increase in salinity level, where the decreasing tendency was very sharp in the BRRI dhan40 cultivar than those of others. Number of filled grains $panicle^{-1}$ was highest in Heera at 0 dS m^{-1} and lowest at BRRI dhan40 at 12 dS m^{-1}. Number of unfilled grains $panicle^{-1}$ was lowest in Heera at 0 dS m^{-1} and highest in BRRI dhan40 at 12 dS m^{-1}. The effect of different salinity levels on thousand grain weight of four rice cultivars significantly decreased with increasing salinity levels where this decreasing pattern was very high in BRRI dhan40. Thousand grain weight was highest in Heera at 0 dS m^{-1} and lowest at BRRI dhan40 at 12 dS m^{-1}. It appeared from the results that the variation in respect to grain yield $hill^{-1}$ of selected four rice cultivars were decreased significantly due to different salinity levels. Grain yield $hill^{-1}$ was highest in Heera at 0 dS m^{-1} and lowest at BRRI dhan40 at 12 dS m^{-1}.

It seems from the results that Sadamota is the most tolerant rice cultivar to salinity among the four followed by Heera. On the contrary, BRRI dhan40 is the susceptible cultivar. Lalmota is not as susceptible as BRRI dhan40, but its agronomic properties are not good enough.

Based on the results the following recommendations may be made -

- In saline prone cultivable areas, it may be possible to increase the rice production by cultivating Sadamota or Heera.

- Plant breeders may develop cultivars which are able to reduce the effect of salt stress and increase the yield.

Chapter 6

References

CHAPTER 6

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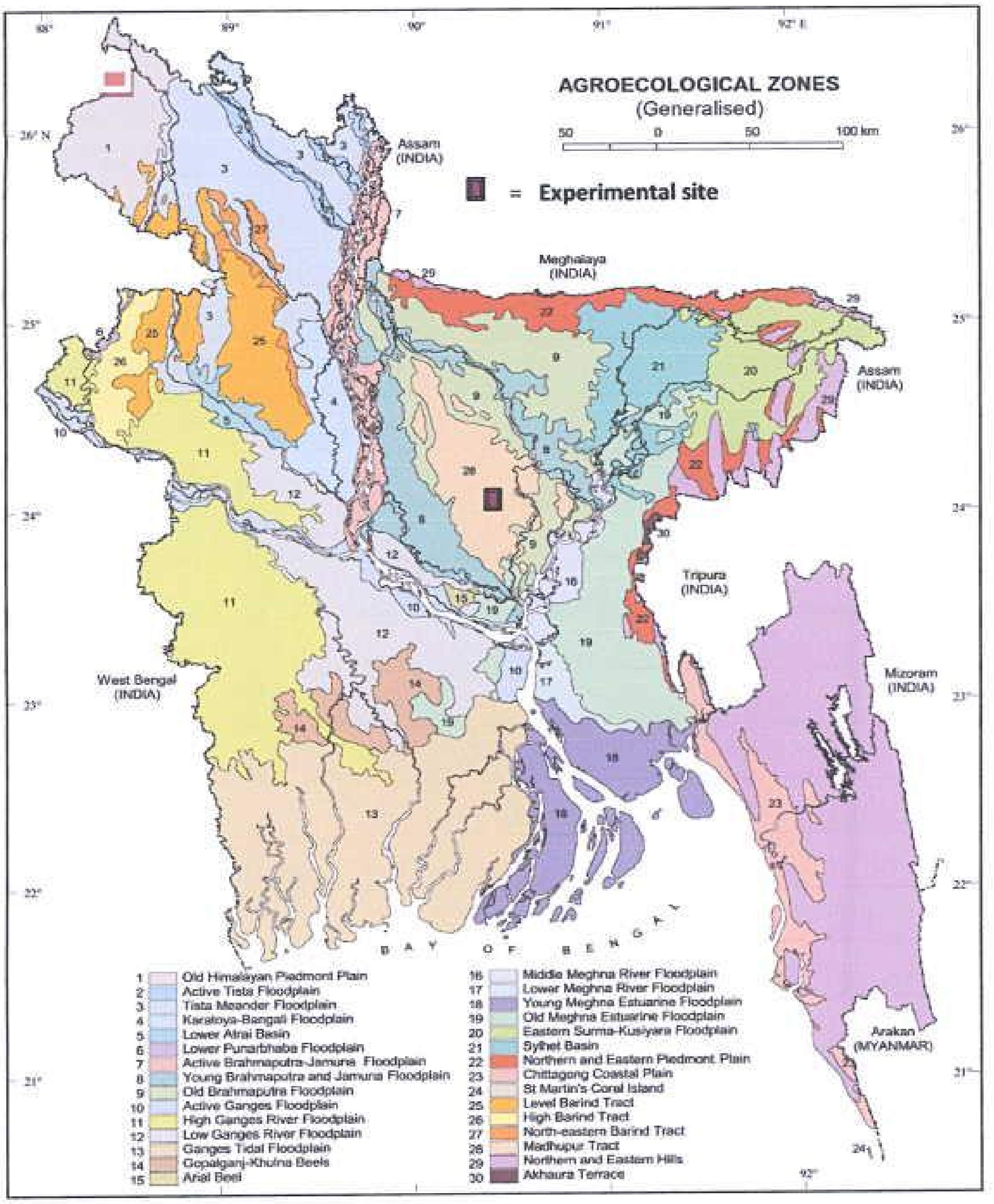
Chapter 7
Appendices

CHAPTER 7

Appendices

Appendix I. Map showing the experimental site under the study



Appendix 2. Effects of different salinity levels on relative root length, relative root dry wt., relative shoot dry wt. and relative total dry matter of rice (mean of 4 cultivars)

Salinity level (dsm^{-1})	Relative root length (%)	Relative root dry wt.(%)	Relative shoot dry wt.(%)	Relative total dry matter (%)
0	100.0 a	100.0 a	100.0 a	100.0 a
3	92.28 b	84.53 b	83.30 b	83.74 b
6	82.18 c	75.70 c	69.98 c	71.50 c
9	72.69 d	65.65 d	52.46 d	56.44 d
12	58.46 e	41.10 e	41.82 e	41.92 e
Significant level	**	**	**	**
$LSD_{0.05}$	0.3763	1.288	0.9117	0.8224
CV(%)	0.47	6.10	3.22	2.58

Appendix 3. Interaction effect of cultivar and salinity on different relative growth parameters

Cultivar	Salinity level (dSm^{-1})	Relative root length (%)	Relative root dry wt.(%)	Relative shoot dry wt.(%)	Relative total dry matter (%)
Sadamota	0	100.0 a	100.0 a	100.0 a	100.0 a
	3	99.54 a	84.93 c	91.91 b	91.21 b
	6	87.05 d	80.24 d	73.67 f	74.33 e
	9	86.48 de	65.85 f	65.42 h	64.34 g
	12	62.17 l	42.77 j	53.18 j	50.62 j
BRRI dhan40	0	100.0 a	100.0 a	100.0 a	100.0 a
	3	90.01 c	81.16 d	83.58 c	83.02 c
	6	82.89 f	80.79 d	72.53 f	73.53 e
	9	65.17 j	78.94 d	37.65 m	42.94 l
	12	45.51 m	21.67 k	23.58 n	23.35 m
Heera	0	100.0 a	100.0 a	100.0 a	100.0 a
	3	85.98 e	92.44 b	80.54 d	82.35 c
	6	75.27 g	68.11 f	69.62 g	69.57 f
	9	66.70 i	59.54 g	55.92 i	57.59 i
	12	62.55 l	50.78 i	46.10 l	53.02 jk
Lalmota	0	100.0 a	100.0 a	100.0 a	100.0 a
	3	93.59 b	81.79 d	77.19 e	78.39 d
	6	83.53 f	73.66 e	64.09 h	68.55 f
	9	72.42 h	56.07 h	50.85 k	60.88 h
	12	63.59 k	49.17 i	44.40 l	47.32 k
Significant level		**	**	**	**
LSD0.05		0.8354	0.3422	2.023	0.8268
CV (%)		0.47	2.79	3.22	1.95

Values having same letter (s) in a column do not differ significantly at 5% level of probability

** —> Significant at 0.01 level of probability;

Appendix 4. Effects of different salinity levels on number of effective and non-effective tiller of rice (mean of 4 cultivars)

Salinity Level(dSm^{-1})	Number of effective tillers $hill^{-1}$	Number of non-effective tillers $hill^{-1}$
0	8.67 a	0.83 d
3	7.77 b	0.89 d
6	6.58 c	1.57 c
9	3.60 d	1.76 b
12	1.82 e	2.26 a
Significant level	**	**
$LSD_{0.05}$	0.1242	0.1133
CV(%)	0.70	0.001

Appendix 5. Interaction effect of cultivar and salinity on number of effective and non-effective tiller

Cultivar	Salinity Level (dSm^{-1})	Number of effective tillers $hill^{-1}$	Number of non-effective tillers $hill^{-1}$
Sadamota	0	8.61 d	0.65 g
	3	7.81 e	0.65 g
	6	6.52 g	0.65 g
	9	4.85hi	0.65d
	12	3.18 l	2.28 c
BRRI dhan40	0	11.52 a	0.66 g
	3	10.52 b	0.75 g
	6	8.52 d	1.62 d
	9	4.52 i	2.28 c
	12	1.08 o	3.62 a
Heera	0	9.52 c	0.85 fg
	3	8.52 d	1.08ef
	6	6.52 g	0.85 fg
	9	3.52 k	1.18 e
	12	2.18 m	1.52 d
Lalmota	0	8.52 d	1.18 e
	3	7.52 e	1.08ef
	6	7.18 f	1.18 e
	9	2.52m	2.95 b
	12	1.85 nl	3.62 a
Significant level		**	**
LSD0.05		0.2698	0.28
CV (%)		0.70	0.001

Values having same letter (s) in a column do not differ significantly at 5% level of probability

** —> Significant at 0.01 level of probability;

Appendix 6. Effects of different salinity levels on panicle length, number of filled and unfilled grain of rice cultivars

Salinity Level(dSm^{-1})	Panicle length (cm)	Number of filled grain $panicle^{-1}$	Number of unfilled grain $panicle^{-1}$
0	22.28 a	94.32 a	27.12 d
3	20.86 b	88.07 b	27.67 d
6	18.74 c	61.42 c	34.56 c
9	18.76 c	41.98 d	38.13 b
12	14.71 d	31.76 e	44.22 a
Significant level	**	**	*
$LSD_{0.05}$	0.3285	0.4651	0.6311
CV(%)	1.53	0.92	3.14

Appendix 7. Interaction effect of cultivar and salinity on panicle length, number of filled and unfilled grainpanicle^{-1}

Cultivar	Salinity Level (dSm^{-1})	Panicle length (cm)	Number of filled grain $panicle^{-1}$	Number of unfilled grain $panicle^{-1}$
Sadamota	0	20.93 d	100.29 c	36.12ef
	3	20.97 d	98.42 c	29.21 i
	6	18.94 e	68.29 f	41.41 c
	9	19.00 e	41.15l	50.53 b
	12	15.90 h	35.95 lm	50.50 b
BRRI dhan40	0	22.47 c	102.24 a	34.17 g
	3	19.55 f	85.54 d	36.63 e
	6	19.16 ef	69.25 e	38.17 d
	9	17.80 e	42.38 i	40.28 c
	12	6.35i	26.55n	54.00 a
Heera	0	24.49 a	104.62 a	19.13 l
	3	23.27 b	102.54 b	22.63 j
	6	21.59 d	81.13 e	29.47 i
	9	20.85 d	64.55 g	32.06 h
	12	19.45 e	39.47 k	37.39 de
Lalmota	0	21.25 d	81.83 e	21.26jk
	3	19.66 e	81.09 e	20.00 kl
	6	17.17 fg	53.87 h	29.21 i
	9	16.64 gh	36.56 l	29.65 i
	12	16.05 h	35.06 m	34.97fg
Significant level		**	**	**
$LSD_{0.05}$		0.7292	5.032	1.401
CV (%)		1.53	6.92	3.14

Values having same letter (s) in a column do not differ significantly at 5% level of probability

** —> Significant at 0.01 level of probability; *—> Significant at 0.05 level of probability

Appendix 8. Effects of different salinity levels on 1000 grain weight and grain yield hill^{-1} (mean of 4 cultivars)

Salinity Level(dSm^{-1})	1000 grain weight (g)	Grain yield hill^{-1}(g)
0	21.10 a	15.58 a
3	20.33 b	12.06 b
6	18.66 c	6.29 c
9	17.15 d	2.68 d
12	13.12 e	1.51 e
Significant level	**	**
$LSD_{0.05}$	0.4226	0.9208
CV(%)	2.66	2.98

Appendix 9. Interaction effect of cultivar and salinity on 1000 grain weight and yield hill^{-1}

Cultivar	Salinity Level (dSm^{-1})	1000 grain weight (g)	Grain yield hill^{-1}(g)
Sadamota	0	18.53ef	12.03 e
	3	18.16ef	11.36 f
	6	16.65gh	8.20 h
	9	15.30 i	5.65 j
	12	10.27 k	2.01 l
BRRI dhan40	0	20.29 d	16.53 b
	3	17.84 f	9.94 g
	6	16.67gh	5.29jk
	9	13.26 i	0.98 n
	12	10.26 k	0.89 n
Heera	0	26.42 a	17.52 a
	3	26.29 a	14.00 c
	6	23.75 b	6.93 i
	9	22.18 c	2.14 l
	12	21.46 c	1.85 lm
Lalmota	0	19.16 e	16.26 b
	3	19.01 e	12.95 d
	6	17.57 fg	4.77 k
	9	16.04 hi	1.97 l
	12	11.50 l	1.29 mn
Significant level		**	**
$LSD_{0.05}$		0.938	0.6439
CV (%)		2.66	2.98

Values having same letter (s) in a column do not differ significantly at 5% level of probability

** —> Significant at 0.01 level of probability