EFFECT OF SALINITY ON GERMINATION, GROWTH AND YIELD OF RADISH (*Raphanus sativus* L.) VARIETIES

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By

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Examination Roll: MS 100801

In Partial Fulfillment of the Requirements
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The undersigned certify that they have read and recommended to the Agrotechnology Discipline for acceptance, an M. S. Thesis entitled:

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AUGUST, 2013

DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

The laboratory and pot experiments were conducted at Molecular Horticulture Lab and Germplasm Centre, Khulna University, Khulna during December 2012 to March 2013 to assess the effect of salinity on germination parameters, growth and yield contributing characters of three radish varieties viz. V_1 = Tasakisan Mula-1 (BARI Mula-1), V_2 = Druti (BARI Mula-3) and V_3 = Red Bombay. Four salinity levels control (0.66 dS m^{-1}), 4, 8 and 12 dS m^{-1} were used as treatment in the experiments. The experiments were laid out in a factorial Completely Randomized Design (CRD) with three replications. Germination test was done in the laboratory following pertidish method. Data were collected on germination (%), germination energy, germination capacity, germination speed, average root and shoot length and dry weight of root and shoot per seedling. There was wide variation in germination parameters and growth parameters among the varieties due to different level of salt applications. In all the germination and growth parameters Tasakisan Mula-1 (BARI Mula-1) was found superior. Red Bombay was inferior regarding germination and growth parameters. Number of leaf per plant, leaf fresh weight (g), leaf length (cm), leaf width (cm), leaf dry weight (g), root fresh weight (g), root dry weight (g), root length (cm), root diameter (cm) and yield (g/plant) progressively decreased with the increasing salinity level as compared to control. Tasakisan Mula-1 (BARI Mula-1) showed better performance in the above mentioned morphological parameters and yield attributes. Druti (BARI Mula-3) was found intermediate. Red Bombay showed the lower value of those parameters. Among the varieties Tasakisan Mula-1 (BARI Mula-1) was the best tolerant to salinity at 12 dS m^{-1} followed by Druti (BARI Mula-3) at final harvest. Considering all the parameters observed in the experiment Tasakisan Mula-1 (BARI Mula-1) was found the best.

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CHAPTER I

INTRODUCTION

Radish (*Raphanus sativus* L.) is a popular and important cruciferous vegetable crop in Bangladesh (Rashid *et al.,* 1983). Radish is popular for its pungent aroma and taste. This crop can withstand so diversified climate that the crop is grown in tropical, subtropical and even in temperate countries. China and India are supposed to be its native (Katyal and Chandha, 1985). Radish is grown for its young tender tuberous roots which is eaten raw as salad and cooked as vegetables. The young leaves are also eaten as vegetables. It is a good source of protein, carbohydrate, Ca, K, P and ascorbic acid (Larry, 1977). Tender leaf is a good source of protein and vitamin C (Eguchi, 1979). The pungent flavor characteristics of radish are due to the presence of volatile isothiocyanates (trans-4-methyl-thiobutenyl isothiocyanate) (Srinivas and Naik, 1990). Pink skinned radish is generally richer in vitamin C than the white skin one. Vitamin C content of radish roots is greatly influenced by light condition (Jamil *et al.,* 2005).

Radish contain 17 mg (Pink cultivar) vitamin C and 5.0 I.U. of vitamin A (Gopalan and Balasubramanium, 1966). The radish root contains protein 0.7 g, fat 0.3 g, minerals 0.9 g, carbohydrate 6.8 g, calcium 50 mg, phosphorus 22 mg, thiamine 0.06 mg, riboflavin 0.02 mg, nicotinic acid 0.5 mg and fiber 0.8 g per 100 g of edible portion. Further, it has some medicinal values (Bose and Som, 1986). Radish preparations are useful in liver and gall bladder troubles. In homoeopathy, they are used for neuralgic headaches; sleeplessness and chronic diarrhea. Roots, leaves, flowers and pods are active against gram-positive bacteria. The roots are said to be useful in urinary complaints and piles. A salt extracted from roots, dried and burnt white ash is used in stomach troubles. The seeds are said to be peptic, expectorant, diuretic and carminative (Kirtikar and Basu, 1935). The radish has the cooling effect on human body and is thought suitable for patient suffering from liver troubles and jaundice and juice of fresh leaves is used as diuretic and laxative (Katyal and Chandha, 1985). Radish has also been tried successfully as a fodder crop in some countries like the U.K. and South Africa. In South Africa, the giant radish of Japan has shown much promise as a fodder crop yielding more than 60 t/ha of roots and 12-25 t/ha of leaves (Kolbe and Voss, 1952).

Now a days radish enjoys the popularity among all classes of people, rich or poor, urban and rural. Some consumers always prefer medium sized or even small roots for their small families but it is available in the market only for a limited period. Though radish is a cold weather and quick growing vegetables yet its best flavor, texture and size are developed at 10^0-15^0 C. If grown in hot weather small rooted varieties produces and extremely pungent roots, so they should be harvested at till young and small rather than allowed to reach the edible size (Sonneveld *et al.,* 1995). Radish classified as a crop which yield is moderately sensitive to salinity (Maas and Hoffman, 1977), but sometimes it is a crop of low sensitivity (Sonneveld, 1988). Although salinity may reduce growth, raising the salinity in the root zone is also used as a method to enhance the quality of some vegetables including radish (Mizrahi and Pasternak, 1985).

Considering the area and production radish stands as one of the major vegetables crop of Bangladesh (Anonymous, 1989) but the production is quite low as compared to the national requirement. Although it is mainly a winter vegetable crop, it becomes available in Bangladesh market as early as September and last as May. However, now a days it can be grown any time of the year in Bangladesh (Rashid *et al.,* 1983). Total vegetable production in Bangladesh is about 3.47 million tons per year of which 83.09% produced in winter and 16.91% in summer season (Anonymous, 2010). The present per hectare yield of radish is far below the levels attainable in the developed countries of the world (Shahidullah *et al.*, 1991).

In Bangladesh, radish is cultivated in an area of 25.5 thousand hectares of land producing 85.42 thousands MTs of fleshy edible roots with per hectare yield of 8.60 MTs (BBS, 2010). Radish is a short duration root crop and it is well known as a cool season vegetable. Although it is generally considered hardy in cold temperatures, its optimum growth temperature is 15-20° C (Malcolm and Smith, 1971). Its yield can be increased in different ways such as use of improve high yielding varieties, proper cultural management, judicial application of fertilizer etc. (Sadu, 1986).

Salinity remains as one of the world oldest and most serious environmental problems in crop production (William, 1986). Excess soluble salt content is the principal growth limiting factor for the cultivated plants on the coastal saline soil. The nature and content of soluble salts, salt dynamic and water regimes during the growth season strongly influence crop growth (Karim *et al.*, 1990). Salinity causes not only the yield reductions but also it affects the germination in many glycophyte crop plants throughout the world. Growth suppression may be a non-specific effect of salts, depending more on the total concentration of soluble salts than on specific ions (Adams, 1991). In general, salinity affects almost every aspect of the physiology and biochemistry of plants (Cuartero *et al.*, 2005). Salinity can induce water stress as it increases the osmotic pressure of the soil solution. High salinity may also result in too high an internal ion concentration (ion excess) and thus cause growth reduction. It is often difficult to assess the relative importance of ion excess and water stress as growth limiting factors (Greenway and Munns, 1980). Germination and water stress induced by salinity may influence plant growth by adverse effects on dry matter partitioning, cell extension, cell division, leaf photosynthesis and or transpiration (Maas and Hoffman, 1977). Effects on photosynthesis may be attributed both to stomatal and nonstomatal responses due to excess salinity (Cheeseman, 1988). The reduction of leaf photosynthesis at high salinity was the result of reduced stomatal conductance (Xu *et al.*, 1994).

In Bangladesh, more than 30% of the total cultivable area is in the coastal belt. Out of 2.85 million hectares of the coastal and off-shore areas, about 0.83 million hectares are affected by different degrees of salinity (Karim *et al.*, 1990). Moreover, the salt affected area is increasing day by day. About 2.8 million hectares of land under saline area remain fallow for about 4-7 months (middle of November-June) in each year ((Karim *et al.*, 1982). So the presence of excess soluble salt in soil is one of the major factors that reduces the growth and development of cultivated crop plant in coastal areas of Bangladesh and the reasons for salinity in Bangladesh are: 1) intrusion of sea water due to river drying in the winter, 2) cyclone and other natural disasters in the coastal area and 3) influx of salts from the ground to the surface through capillary movement during dry season. The salinity problem is severe in the winter though during summer the salt concentration decreases (Karim *et al.*, 1990). The need to develop crops with higher salt tolerance has increased greatly within the last decade due to increased salinity problems throughout the world (Sivritepe *et al.*, 2003).

The yield of radish is much lower in saline soil compared to salt free soil. The production technology of any vegetable as well as radish is a complex process and in saline condition it becomes more complex. So it is important to know the effect of varying degree of salinity on radish seed germination with a view to ensure optimum plant population and high yield. Therefore, the present research work was undertaken keeping in mind the following objectives:

- To observe the effect of salinity on germination of radish seed
- To assess the effect of salinity on the growth and yield contributing characters of radish

CHAPTER II

REVIEW OF LITERATURE

Radish is an important and popular winter vegetable in Bangladesh. A few information have been obtained for the response of salinity on radish. The effect of salinity levels on morphological characters, physiological attributes, yield and yield components of radish and some other relevant crops are collected from the available literatures and some of the findings are reviewed in this section.

2.1 Characteristics of saline soil

Akbar and Ponnamperuma (1982) reported that saline soils are those which contain sufficient water soluble salts in the root zone to impair plant growth. They also reported that since salt injury of plants usually depends on species, variety, growth stage and environmental factors. They reported that saline soils vary widely in there chemical and physical characteristics, salt dynamics and hydrology, the variables include salt source, nature and content of salts, soil pH, nature and content of clay, organic matter content, nutrient status, water regime and temperature. Saline soils vary greatly in the composition of salts present in them.

The U.S. Salinity Laboratory, Riverside California, defined and classified saline soils on the basis of agricultural value (Richards, 1954). According to them saline soil is a non alkali soil in which the soluble salt content is high enough to inhibit growth of most agricultural crops. ECs of such soil above 15 mmhoscm^{-1}. pH is below 8.5 and exchangeable sodium percentage (ESP) is below 15%. However, according to Stocker (1933) the critical level of salinity for plants is 0.05% of the dry soil weight.

Samuel *et al.* (1995) reported that growth inhibition in salt-sensitive crops, even at low salinity levels, is caused primarily by toxicity from Na^+ and Cl^-. The high osmotic pressure in the soil solution causes correspondingly low soil water potential and when in contact with a plant cell, the solute moves toward the soil solution and the cell collapses (called plasmolysis). They also said that Na is particularly detrimental, both because of its toxic effects on plants and its effect on soil structure. When a high percentage of the EC is occupied by Na, the soil aggregates disperse. These soils become impermeable to water, develop hard surface crusts and may keep a water layer or 'slic spot' on the surface longer than adjacent soils.

Biswas and Mukherjee (1995) reported that inland saline soils form due to faulty irrigation water containing a high concentration of soluble salts, primarily of sodium (Na) leads to soil salinity if proper drainage is not provided to leach the salt beyond the root zone.

Carter *et al.* (2005) defined saline soil as those with (EC) which is more than 4 mmhoscm^{-1} at 25^0 C and with less than 15% exchangeable sodium. The pH ordinarily is less than 8.5. The principal characteristics of saline soil are the presence of sufficient salt that affect or impair the growth of plants.

Curtain *et al.* (1993) suggested that Chlorides (sodium chloride) are dominant in coastal saline soils, where as chloride sulfates are prominent in inland area The texture of saline soils vary from sandy to clayey while its clay composition from kaolinite to montmorilonite. In mangrove area, the predominant texture is clayey, originating from rivers or the offshore sea (Moorrmann and Pons, 1974).

Ponnamperuma and Bandyopadhya (1980) said that in coastal areas salinity is either due to direct inundation by salt water, or upward or lateral movement of saline water. In general sodium chloride is the dominant salt, although sulfate may constitute a high proportion of the electrolysis present in saline acid sulfate soils. The pH ranges from 2.5 for saline acid sulfate soils to about 8.5 in slightly alkaline soils. Organic matter content of coastal saline soils may vary from 1 to 5 percent depending on the presence or absence of peat. The soil may be eutric (fertile), dystric (infertile), calcareous, thionic (sulfide or sulfatic), or histic (organic).

2.2 Salinity and germination

Khan *et al.* (2000) reported that seed germination takes the most important part in life cycle of plants. In many plant type, germination and seedling growing phase is very sensitive to salt stress. In general, the highest germination percentage occurs in non-salty conditions and it decreases depending on the ascending salt concentrations.

Shannon and Grieve (1999) said that salinity slows the germination rate and higher levels of salinity reduce the germination percentage. Low concentrations of salinity affect the germination rate but not the total percentage of seeds germinated.

Coopland and McDonald (1995) reported that germination is a system in which the rootlet's coming out of the testa and it is greatly hampered in the saline condition.

Grieve and Suarez (1997) reported that high levels of soil salinity can inhibit seed germination and seedling growth, due to the combined effects of high osmotic potential and specific ion toxicity. Ascending salt concentrations not only prevent the germination of the seeds but also extend the germination time by delaying the starting of germination (Rahman *et al.,* 2008).

Murillo-Amodor *et al.* (2002) and Shokohhifard *et al.* (1989) observed that the decrease in water intake of the seed in salty conditions, osmotically and by the ion toxicity with accumulation of Na and Cl ions highly around the seed and prevents the seed germination.

Begum *et al.* (1992) reported that salinity stress consistently decreased the rate of germination of wheat. NaCl salinity increased accumulation of Na^+ and Cl^- while it decreased K^+ accumulation in germination of seeds.

Othman (2005) reported that seed germination begins with water intake but it is decreased by the salt and the reported data are dependent upon the time of observation as well as on the germination conditions. Generally, low salt concentration decreases the germination rate and high salt concentration decreases germination percentage.

Akbar and Ponnamperuma (1982) found that the osmotic effect due to salinity is the main cause of reduce the germination.

Khan *et al.* (1997) subjected Chinese cabbage (*Brassica chinensis*) seeds to salinities of 0, 4, 8, 12 and 16 mmhos cm^{-1} and temperature of 20, 25, 30 and 35^0 C. They found that germination percentage declined as salinity or temperature increased. Seed germination and seedlings growth were best at 4 mmhos cm^{-1} and 25^0 C.

2.3 Salinity and plant growth

Most plants suffer salt injury at EC values exceeding 4 $mmhoscm^{-1}$ at 25^{0} C. Ponnamperuma (1984) have indicated that tolerance of crops varies with salt composition, if the solution consists at physiographically balanced salt as in sea water.

Roundy (1985) reported that successful seedling establishment depends on the frequency and the amount of precipitation as well as on the ability of the seed species to germinate and grow while soil moisture and osmotic potentials decrease. Salts taken up by plants may not directly control their growth by affecting turgor pressure, photosynthesis or enzyme activities rather than buildup of salt in old leaves may hasten leaf death (Munns, 1993).

Marcelis and Hooijdonk (1999) suggested that salinity reduced growth in radish (*Raphanus sativus* L.) and high salinity level could be attributed to a reduction in leaf area expansion and hence to a lower light interception.

Yoshida (1981) reported that salinity was most harmful to young plants and as they become older, their tolerance to salinity increased, at 90 days the plants were hardly affected by salt concentrations in the as high as 1.05%.

2.4 Growth

Panaullah and Ponnamperuma (1980) said that usually salinity affects the growth of different types of vegetables as well as radish plant at all stage of life cycle. The effect may vary depending on the stage of plant development. The growth stage of which radish plant in most exposed to salt injure is still controversial.

Borroton *et al.* (1997) conducted an experiment on the effect of salinity to potato, cassava and onion. They reported that the degree of tolerance is higher in cassava cv. Holgoin, sour oranges.

Levy *et al.* (1986) investigated the response of radish cultivars to 20.5, 34.2 and 51.3 mM NaCl. They found that salinity increased tuber dry matter (DM) content and reduced tuber yields.

Bilski *et al.* (1987) conducted a greenhouse study with the radish varieties and they were watered with solution containing various rates of NaCl and Na_2SO_4. On a mole basis Na_2SO_4 was more toxic than NaCl to plant growth addition of $CaSO_4$ reduced the deleterious effect of NaCI and Na_2SO_4.

Munns and Termaat (1986) reported that the growth of plants is ultimately reduced by salinity stress although plant species differ in their tolerance to salinity. Sankov (1976) shown that concentrated salt solution formed in soil disrupts the absorbing activities of roots, which inhibits growth and decreased yield. It was also noted that the salinity tolerance levels of radish types differed (Waisel and Breckle, 1987). It has been reported that radish is a salt sensitive crop (Shannon and Grieve, 1999).

Liu *et al.* (1998) conducted a research with radish to study chlorophyll content under salt stress. They reported that total chlorophyll content of the leaves decreased with increase of salinity. They also found that salt stress leading to leaves yellowing and eventually to decrease yield.

Scialabba and Melati (1990) reported that salinity caused a lack of coordination between cellular expansion and differentiation in radish seedlings; as salinity increased structural and cellular modifications in the form of wall thickening and metabolic aggregates inside parenchyma cells were evident.

Yuqin *et al.* (2001) examined the salinity effect on radish varieties and exposed to NaCl at 0, 85, 170, 255 and 340 mmol L^{-1} for 6 days, and their functional leaves were used for the analysis of various physiological indices. With increase of NaCl concentration in the field condition, photosynthetic rate declined markedly.

Morpurgo and Silva (1986) conducted an experiment to test the responses to 0-9000 ppm NaCl on hybrid radish seeds. Average germination percentage ranged from 22.59 to 98.3, germination velocity index from 6.86 to 67.14 and root length after 7 days from 0.16 cm to 9.24 cm, at 9000 and 0 ppm NaCl, respectively.

Wang *et al.* (1999) conducted an experiment with six radish varieties of high starch content where the effects of 3 types of saline soils were investigated. Varieties showed significant difference in growth and yield. Salt sensitive varieties had poor emergence, retarded growth and low yields.

Silva *et al.* (2001) observed that effect of NaCl stress on radish varieties. Three varieties of radish were subjected to 0, 25, 50, 75 and 100 mmolL^{-1} NaCl. Growth and root development were evaluated. Growth and root development were significantly affected by salinity. The highest saline level (100 mmolL^{-1} NaCl) completely inhibited root development in all varieties.

Ghosh *et al.* (2001) conducted a research with radish production to study salt stress by NaCl. They applied NaCl at the rate of 0, 10, 20 and 30 g $plot^{-1}$ and the corresponding EC values of 0.20, 0.71, 1.37 and 1.95 dS m^{-1}, respectively. Growth and dry mater production especially tubers were inhibited with increased salt level. The salt stress lower downs the total and marketable tuber yield by decreasing tuber size and average tuber weight. They also found that NaCl content of leaves and tuber markedly increased with the increase of the salt level.

Bilski *et al.* (1988) grown radish for 28 days in a greenhouse and were watered with 0-120 mol NaCl/m^3 or 20-40 mol Na_2SO_4/m^3 alone or in combination with 0-20 mol $CaSO_4/m^3$, NaCl and Na_2SO_4. Watering with NaCl or Na_2SO_4 also reduced the size of the root of the plants.

2.5 Yield

Levy (1992) conducted three field trials in sandy loam soil in Israel to assess the response of various radish cultivars to drip irrigation with water commonly used for irrigation (1.0-1.4 dS m^{-1}), Saline water from a local well (6.1-6.9 dS m^{-1}) or a mixture of the two (3.8-4.3 dS m^{-1}). Salinity retarded seed germination, plant emergence and reduced the growth of roots. Increasing the salinity progressively reduced the growth of root. Increasing the salinity progressively reduced root yields. Application of the saline water 66 days after planting was decreased tuber yields by 6-15% and 22-31% in the intermediate and the high salinities, respectively. When irrigation with saline water was started soon after planting, root yields were decreased by 0-17 and 21-79% in the intermediate and the high salinities, respectively.

Efron *et al.* (1988) conducted an experiment on radish in Israel in 1987. They observed that increasing salinity reduced root size, while root weight was less affected. Percentage of dry matter (DM) of root increased slightly with increasing salinity.

Wongsamun *et al.* (1989) observed that radishes were suitable for sand or sandy loam soils with negligible salinity. Farmer's procedures and cultural practices for growing plant seeds for the following year's crop were studied. Radish needed little attention after planting. Roots matured approximately within 3 months.

Caliandro *et al.* (2000) reported that salinity affects on soil fertility, plant physiology, morphology, and yield and plant adaptability of radish in Italy. Result of experiment carried out on the use of Brakish water on radish. Negative effects were observed due to rising water salinity almost in each situation, both on morphological parameters (water potential, photosynthesis, transpiration) and on yield.

Zhang *et al.* (2001) investigated possible carry over effects of moderate salt stress on the production cycle. The yields of roots derived plants of two radish varieties, grown in both non-saline and saline (NaCl) conditions. They were evaluated under non-saline and saline irrigation (0 or 60 mM NaCl) in a green house trial. There was no effect on yield, no apparent residual carry over effect of salt stress on plants. Irrigation with a 60 mM NaCl solution depressed total root fresh weight in both varieties.

Yadav *et al.* (2001) grown radish in pots was treated with various levels of phosphorus (0, 30, 60 and 90 mg kg^{-1} Soil) and five salinity levels 1.0 (control), 4, 6, 8 and 10 dSm^{-1}. Result revealed that seeds germination was delayed by about 10 days at salinity level of 10 dS m^{-1} EC compared to the control. The growth was delayed and yield was reduced with increasing in salinity levels.

CHAPTER III

MATERIALS AND METHOD

The study was undertaken during rabi season from December 2012 to March 2013 to evaluate the effect of salinity on germination, growth, yield and yield attributing characters of radish. Details of the materials and methods of the experiment are presented in this chapter.

3.1 Experiment 1: Effect of different salinity levels on radish seed germination

3.1.1 Experimental site

The research work was conducted at the Molecular Horticulture Lab. Agrotechnology Discipline, Khulna University, Khulna during December 2012 to March 2013.

3.1.2 Treatments

There are two factors-

Factor A: salinity levels- 4

S_0 = Control (0.66 dS m^{-1})

S_1 = 4 dS m^{-1}

S_2 = 8 dS m^{-1}

S_3 = 12 dS m^{-1}

Factor B: radish varieties- 3

V_1 = Tasakisan Mula-1 (BARI Mula-1)

V_2 = Druti (BARI Mula-3)

V_3 = Red Bombay (Local variety)

3.1.3 Experimental design

The experiment was laid out in a factorial Completely Randomized Design (CRD) with three replications.

Total number of petridishes = 3 (varieties) × 4 (salinity) × 3 (replication) = 36

3.1.4 Preparation of the solutions

Different concentrations of salt (0.66 dS m^{-1}, 4 dS m^{-1}, 8 dS m^{-1} and 12 dS m^{-1}) were used in the study. Required amount of common salt (NaCl) was estimated using the following formula and added to distilled water to make the required solution of NaCl.

Percent of salt = 0.064 × EC (dS m^{-1})

To make 4 dS m^{-1} salt solution 1.9 g sodium chloride (NaCl) was taken in a 1000 ml volumetric flask and filled up to the mark with distilled water. Then 8 dS m^{-1} and 12 dS m^{-1} salt solutions were prepared in the same way by taking 3.8 g L^{-1} and 5.7 g L^{-1} NaCl, respectively.

3.1.5 Germination test

The germination test was conducted using petridish method. Two pieces of blotting papers (soaked with distilled water and saline solutions) were used in each petridish as substrate. Twenty five seeds for each variety were placed in each petridish at an equal distance from one another. Each treatment was replicated three times. The solutions were used for germination of seeds and distilled water was used in control. The petridishes were observed every day and respective solutions were supplied whenever required.

3.1.6 Data collection

3.1.6.1 Germination parameters

The petridishes were observed every day and the numbers of germinated seeds were recorded. After one day of seed settings in petridishes, few of the seeds were germinated. Within 7 days after seed setting in petridishes maximum number of seeds were germinated. A seed was considered to be germinated as seed coat ruptured, plumule and radical came out. Germination count was expressed in percentage. The germination percentage was calculated using the following formula-

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds placed in petridish}} \times 100$$

The rate/speed of germination was calculated using the following formula (Krishnaswamy and Seshu, 1990).

Germination energy = Percentage of seeds germinated at 72 h (Bam *et al.,* 2006).

Germination capacity = Percentage of seeds germinated at 168 h (Bam *et al.,* 2006).

$$\text{Speed of germination (\%)} = \frac{\text{Number of seeds germinated at 72 h}}{\text{Number of seeds germinated at 168 h}} \times 100$$

3.1.6.2 Root and shoot length measurement

Randomly selected five seedlings were taken from each petridish to measure root and shoot length. It was measured with a measuring scale and expressed in centimeters. Root and shoot length of the seedlings were measured after 14 days of seed settings.

3.1.6.3 Dry weight of root and shoot measurement

After 14 days of seed settings the roots and shoots of the seedlings of each petridish were wrapped with brown paper and dried in oven at 70^0 C for 48 hours. These were measured by four digit balance and expressed in gram.

3.1.6.4 Statistical analysis

All the data collected were analyzed using analysis of variance (ANOVA) techniques using F test. The differences between the treatment means were determined by using Duncan's New Multiple Range Test (DMRT). Functional relationships between salinity level and germination percentage, salinity level and root and shoot length were developed using simple linear regression analysis.

3.2 Experiment 2: Effect of different salinity levels on growth and yield contributing characters of radish

3.2.1 Location

A pot experiment was conducted at the Germplasm Centre of Agrotechnology Discipline, Khulna University, Khulna during the rabi season from December 2012 to March 2013. Geographically the University as well as the experimental area is located in Ganges Tidal Flood Plain Agro Ecological Zone (AEZ) 13 with $22^0\ 47'$ North latitude $89^0\ 34'$ East longitude.

3.2.2 Climate

The experimental site was under the subtropical humid climate and is characterized by moderate high temperature and heavy rainfall during the kharif season (April-September) and scanty rainfall with moderately low temperature during the Rabi season (October-March). Records of weather conditions during the experimental period (December 2012 to March 2013) have been presented in (Appendix I).

3.2.3 Soil

The soil used in pots was collected from the garden of Germplasm Centre of Agrotechnology Discipline, Khulna University, Khulna. The collected soil belongs to the soil series Bazoa and Barisal. The average character of the soil was clay loam to clay. The soil of this area contains low N and Zn, very low P, K and S were very high in soil. B, Ca, Mg, Cu, Fe and Mn were present high in the soil (SRDI, 2008). After collecting the soil it was sun dried and ground well. Then the soil debris was removed by sieving and the soil was put into earthen pot after mixing with manure and fertilizer.

3.2.4 Preparation of pots

Earthen pots having 24.5 cm diameter at the top and 14 cm at the bottom were used. The depths of the pot were 20.8 cm. Each earthen pot was filled-up with sun dried soil and kept under natural light. Cowdung, Urea, TSP and MoP were uniformly incorporated to the soil before pot filling. Cowdung (81.8 g), N (500 mg), P (425 mg) and K (920 mg) were applied in each pot. At the beginning of the pot preparation full dose of cowdung, phosphorus, potassium and half dose of nitrogen were mixed with the soil. The rest half dose of N was top dressed in two equal installments at 20 and 50 days after sowing (DAS). The pots were pre-labeled for each variety and treatment.

3.2.5 Planting materials

Three varieties of radish (*Raphanus sativus.* L) seeds were used as the planting material in the experiment. They were Tasakisan Mula-1 (BARI Mula-1), Druti (BARI Mula-3) and Red Bombay (Local variety) and denoted as V_1, V_2, V_3, respectively. Tasakisan Mula-1 (BARI Mula-1) and Druti (BARI Mula-2) are developed and released by Bangladesh Agricultural Research Institute (BARI) and Red Bombay is a local variety. The characteristics of three varieties of radish are given below:

Table 1: Morphological characteristics of three radish varieties

Variety	Leaf margin	Leaf hairiness	Leaf vain color	Leaf end
Tasakisan Mula-1	Not serrated	Absent	Light green	Round
Druti	serrated	Present	White	Round
Red Bombay	serrated	Present	Pink	Intermediate round

3.2.6 Collection of Seed

The experiment was conducted with seeds of radish cv. Tasakisan Mula-1 and Druti which are BARI registered variety and the Red Bombay variety is originated from India. Seeds of all the varieties were obtained from the Capital Seed House, Nirala, Khulna.

3.2.7. Soaking

Seeds were soaked in water for 24 hours and then wrapped with a piece of thin cloth prior to planting. Then they were spreaded over polythene sheet for 2 hours to dry out surface water. This treatment was given to help quick germination of seeds.

3.2.8 Seed sowing

Radish seeds of the tested varieties were sown in pots on 2 December 2012. Required amounts of seeds were sown in each pot. After seed sowing, the pots were watered and the soil of the pots was kept well moisture to ensure proper germination of the seeds. Other cultural practices were done wheneven required i.e. timely weeding and water supply.

3.2.9 Intercultural operations

Seedling emergence was completed within ten days after sowing seeds. Seedlings were thinned out timely. Only three plants were kept in each pot and extra plants were uprooted when the plants were established. Weeding was done when needed. Besides this, irrigation was continued upto harvest at three days interval.

3.2.10 Preparation of salt solution

Different concentrations of salt (0.66 dS m^{-1}, 4 dS m^{-1}, 8 dS m^{-1} and 12 dS m^{-1}) were used in the study. Required amount of common salt (NaCl) was estimated using the following formula and added to distilled water to make the required solution of NaCl.

Percent of salt = 0.064 × EC (dS m^{-1})

To make 4 dS m^{-1} salt solution 1.9 g sodium chloride (NaCl) was taken in a 1000 ml volumetric flask and filled up to the mark with distilled water. Then 8 dS m^{-1} and 12 dS m^{-1} salt solutions were prepared in the same way by taking 3.8 g L^{-1} and 5.7 g L^{-1} NaCl, respectively.

3.2.11 Treatments

The experiment was designed to study the effect of growth, yield and yield attributes of radish. Thus the experiment consisted of two factors.

Factor A: salt solutions-4

S_0 = Control (0.66 dS m^{-1})

S_1 = 4 dS m^{-1}

S_2 = 8 dS m^{-1}

S_3 = 12 dS m^{-1}

The required amount of salts was dissolved in each one liter of water and the solutions were then poured uniformly into the pots to get homogenous distribution. Salinity treatments were given in each pot regularly at 15 days interval.

Factor B: radish varieties-3

V_1 = Tasakisan Mula-1 (BARI Mula-1)

V_2 = Druti (BARI Mula-3)

V_3 = Red Bombay (Local variety)

3.2.12 Experimental design

The two factor experiment was laid out in a factorial Completely Randomized Design (CRD) with three replications. Factor A consisted of four salt levels (0 dS m^{-1}, 4 dS m^{-1}, 8 dS m^{-1} and 12 dSm^{-1} of EC) while factor B consisted of three radish varieties Tasakisan Mula-1 (BARI Mula-1), Druti (BARI Mula-3) and Red Bombay (Local variety).

Number of pots = 3 (varieties) × 4 (salinity) × 3 (replication) = 36

Extra pots were kept for installment harvesting for each treatment.

3.2.13 Data collection

The data were collected from 36 randomly selected pot of plants tagged at the different stage of growth. Data on the following parameters were collected from the sample plants during the experimentations. For data collection at different growth stages, three (3) plants were selected from each treatment. To ensure growth, one harvest was done at 90 DAS. At final harvest, the sampled plants were kept into paper bag and carried out to the laboratory. The plant parts were separated into shoots, roots and leaves and their fresh and dry weight were taken. The separated different parts were dried at 70^0 C for 48 hours prior to recording the dry weight. The following data were collected by three plants from each treatment.

3.2.13.1 Number of leaves

The number of leaves per plant was counted after final harvesting. The leaves of each plant were counted separately. Only the fully opened leaves were included in the count.

3.2.13.2 Weight of fresh leaves

Fresh leaves of the above mentioned selected plants were collected and the total leaf per plant was recorded in gram (g).

3.2.13.3 Length of leaves

The length of leaf blade was recorded from the base to the tip with the help of a centimeter scale.

3.2.13.4 Width of the leaves

The width of the biggest leaf was measured in centimeter (cm) at the widest position.

3.2.13.5 Weight of dry leaves

After harvesting leaves were weighed and dried in an oven at 70^0 C for 48 hours. The dry weight was then measured in gram (g).

3.2.13.6 Weight of fresh roots

Roots of the selected plants were detached by a knife and after cleaning soil and fibrous roots fresh weight was taken by a balance in gram (g) and then the average value was calculated.

3.2.13.7 Length of root

The average length of the roots was measured in centimeter (cm) with the help of a scale from the proximal end of the root to the last point of the tapered end of the root (distal end) in each treatment.

3.2.13.8 Diameter of root

To measure the diameter of the root a slide calipers was used. Average diameter of the root was measured in centimeter (cm) at the time of harvest at the thickened portion of the root.

3.2.13.9 Weight of dry roots

Roots were weighed and dried in sun and then dried in an oven at 70^0 C for 48 hours. The dry weight was then measured by using electric balance.

3.2.13.10 Yield

The weight of all roots from each treatment was recorded and the yield (g/plant) was recorded.

3.2.14 Statistical analysis

All the data collected were analyzed using analysis of variance (ANOVA) techniques using F test. The differences between the treatment means were determined by using Duncan's Multiple Range Test (DMRT) at 1% and 5% level of significance. Functional relationships between salt concentration and yield, number of leaf per plant and yield, root length and yield, leaf fresh weight and yield were developed using simple linear regression analysis.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Experiment 1: Effect of different salinity levels on radish seed germination

4.1.1 Germination parameters

All the studied germination parameters viz. germination percentage, germination energy (%), germination capacity (%) and germination speed (%) are presented in tables and figures in this section.

4.1.1.1 Germination percentage

The germination percentage was differed significantly among the varieties (Appendix II). The range of germination percentage was 82.33 to 86.33 % (Table 2). The highest germination percentage (86.33%) was observed in Tasakisan Mula-1 which was statistically similar to Druti (85.00%). The improved variety Red Bombay was inferior to Tasakisan Mula-1 and Druti whose germination percentage was 82.33% (Table 2).

There was significant variation in germination percentage from different salinity levels. The highest germination percentage (95.55%) was found at control (0.66 dS m^{-1}) while 12 dS m^{-1} treatment gave the lowest (72.88%) results (Table 3).

Seed germination percentage differed significantly due to interaction of different radish varieties and different levels of salinity (Appendix II). Germination percentage ranged between 70.66 to 97.33%. The highest germination percentage (97.33%) was found in Tasakisan Mula-1 with distilled water and lowest germination percentage (70.66%) was recorded in Red Bombay at 12 dS m^{-1} level of salinity (Table 4).

Jeannette *et al.* (2002) reported seed germination is not significantly affected up to 16.3 dS m^{-1}, but is severely inhibited when salinity increased to 22 dS m^{-1}. Demir and Arif (2003) also demonstrated that the suppression of germination at high levels might be mainly due to osmotic stress and salinity also decreased germination percentage.

4.1.1.2 Germination energy (%)

There was significant variation in germination energy among the three radish varieties (Appendix II). The maximum germination energy (79.00%) was observed in Tasakisan Mula-1 which was statistically similar to Druti (75.33%) and minimum (74.00%) was in Red Bombay (Table 2).

Different salinity levels affected the germination energy of seeds significantly (Appendix II). The highest germination energy (89.33%) was found at control treatment and the lowest germination energy (62.22%) at 12 dS m^{-1} salinity level (Table 3).

The interaction effect of seeds of radish varieties and different salinity level on germination energy was found significant (Appendix II). The highest germination energy (92.00%) was observed in Tasakisan Mula-1 at control condition and the lowest (58.66%) was recorded in Red Bombay at 12 dS m^{-1} salinity level (Table 4). Marcelis (1999) also reported variation in germinability across varieties in radish.

4.1.1.3 Germination capacity (%)

The germination capacity was differed significantly among the varieties (Appendix II). The range of germination capacity was 82.33 to 86.33 % (Table 2). The highest germination capacity (86.33%) was observed in Tasakisan Mula-1 which was statistically similar to Druti (85.00%). The improved variety Red Bombay was inferior to Tasakisan Mula-1 and Druti whose germination capacity was 82.33% (Table 2).

Table 2: Varietal differences on germination parameters among three radish varieties

Varieties	Germination percentage	Germination energy (%)	Germination capacity (%)	Germination speed (%)
Tasakisan Mula-1	86.33 a	79.00 a	86.33 a	91.37 a
Druti	85.00 a	75.33 a	85.00 a	88.29 b
Red Bombay	82.33 b	74.00 b	82.33 b	89.59 b
Level of significance	0.01	0.01	0.01	0.05
CV (%)	3.35	3.50	3.35	4.39

The figures having different letter(s) in a column are significantly different at 1% or 5% level and figures having same letter(s) in a column are not significantly different by DMRT.

Table 3: Effect of different levels of salinity on germination parameters of three radish varieties

Salinity levels (EC dS m^{-1})	Germination percentage	Germination energy (%)	Germination capacity (%)	Germination speed (%)
0 (0.66)	95.55 a	89.33 a	95.55 a	93.51 a
4	87.11 b	79.55 b	87.11 b	91.41 a
8	82.66 b	73.33 c	82.66 b	88.82 b
12	72.88 c	62.22 d	72.88 c	85.26 b
Level of significance	0.01	0.01	0.01	0.01
CV (%)	3.35	3.50	3.35	4.39

The figures having different letter(s) in a column are significantly different at 1% or 5% level and figures having same letter(s) in a column are not significantly different by DMRT.

Table 4. Interaction effect of varieties and different salinity levels on germination parameters of three radish varieties

Salinity levels (EC dS m^{-1})	Variety	Germination percentage	Germination energy (%)	Germination capacity (%)	Germination speed (%)
0 (0.66)	Tasakisan Mula-1	97.33 a	92.00 a	97.33 a	94.55
	Druti	96.00 ab	89.33 bc	96.00 ab	93.05
	Red Bombay	93.33 ab	86.66 bc	93.33 ab	92.93
4	Tasakisan Mula-1	89.33 cd	81.33 bc	89.33 cd	91.10
	Druti	88.00 cd	80.00 c	88.00 cd	90.95
	Red Bombay	84.00 cd	77.33 de	84.00 cd	92.19
8	Tasakisan Mula-1	82.66 de	74.66 de	82.66 de	90.39
	Druti	84.00 d	72.00 de	84.00 d	85.84
	Red Bombay	81.33 e	73.33 de	81.33 e	90.23
12	Tasakisan Mula-1	76.00 ef	68.66 fg	76.00 ef	89.45
	Druti	72.00 ef	60.00 g	72.00 ef	83.32
	Red Bombay	70.66 f	58.66 i	70.66 f	83.00
Level of significance		0.01	0.05	0.01	NS
CV (%)		3.35	3.50	3.35	4.39

The figures having different letter(s) in a column are significantly different at 1% or 5% level and figures having same letter(s) in a column are not significantly different by DMRT.

NS = Non significant

There was significant variation in germination capacity from different salinity levels (Appendix II). The highest germination capacity (95.55%) was found at control (0.66 dS m^{-1}) while 12 dS m^{-1} treatment gave the inferior (72.88%) results (Table 3).

Germination capacity differed significantly due to interaction of different radish varieties and different levels of salinity (Appendix II). Germination capacity ranged between 70.66 to 97.33%. The highest germination capacity (97.33%) was found in Tasakisan Mula-1 with distilled water and lowest germination capacity (70.66%) was recorded in Red Bombay at 12 dS m^{-1} level of salinity (Table 4).

4.1.1.4 Germination speed (%)

There was significant variation in germination speed among the three radish varieties (Appendix II). The maximum germination speed (91.37%) was observed in Tasakisan Mula-1 and minimum (88.29%) was in Druti (Table 2).

Different salinity levels affected the germination speed of seeds significantly (Appendix II). The highest germination speed (93.51%) was found at control treatment and the lowest germination speed (85.26%) at 12 dS m^{-1} salinity level (Table 3).

The interaction effect of seeds of radish varieties and different salinity level on germination speed was not significant (Appendix II). However, numerically the highest germination speed (94.55%) was observed in Tasakisan Mula-1 at control condition and lowest (83.00%) was recorded in Red Bombay at 12 dS m^{-1} salinity level (Table 4).

4.1.2. Growth parameters

All the studied growth parameters viz. shoot length (cm) $seedling^{-1}$, root length (cm) $seedling^{-1}$, dry weight of shoot (g) $seedling^{-1}$, dry weight of root (g) $seedling^{-1}$ are presented in tables and figures in this section.

4.1.2.1. Shoot length (cm) seedling^{-1}

Radish varieties differ significantly (Appendix II) in shoot length and the range was from 6.61 cm to 6.27 cm (Table 5). The highest shoot length (6.61 cm) was found in Tasakisan Mula-1. The lowest shoot length (6.27 cm) was recorded from Red Bombay.

Varietal differences in shoot length were reported by Zaman *et al.* (1995) and they also observed that plant height was decreased with increasing salinity.

Shoot length varied greatly across salinity levels. As the salt concentration increased, shoot length reduced. Shoot length varied from 7.27 cm to 5.50 cm (Table 6). The highest shoot length (7.27 cm) was recorded from control treatment. The lowest shoot length (5.50 cm) was recorded at 12 dS m^{-1} EC.

The interaction effect of shoots length of different radish varieties and different salinity level was significant (Appendix II). Shoot length varied from 7.54 cm to 5.26 cm (Table 7). The highest shoot length (7.54 cm) was found in Tasakisan Mula-1 at control level. The lowest shoot length (5.26 cm) was noticed from Red Bombay at 12 dS m^{-1} level of salinity.

The results of the present study was in agreement with Gupta *et al.*, (1993) who reported that shoot length generally decreased with increasing salinity levels.

4.1.2.2. Root length (cm) seedling^{-1}

There was significant variation in root length among the three radish varieties (Appendix II). The maximum (6.29 cm) was observed in Tasakisan Mula-1 which was statistically similar to Druti (6.08 cm) and minimum (5.96 cm) was in Red Bombay (Table 5).

Table 5. Varietal differences on length and dry weight of shoot and root among the three radish varieties

Varieties	Shoot length (cm) seedling^{-1}	Root length (cm) seedling^{-1}	Dry weight of shoot (g) seedling^{-1}	Dry weight of root (g) seedling^{-1}
Tasakisan Mula-1	6.61 a	6.29 a	0.028 a	0.024 a
Druti	6.42 a	6.08 a	0.022 a	0.021 a
Red Bombay	6.27 b	5.96 b	0.018 b	0.018 b
Level of significance	0.01	0.01	0.01	0.01
CV (%)	2.13	4.82	23.20	11.72

The figures having different letter(s) in a column are significantly different at 1% or 5% level and figures having same letter(s) in a column are not significantly different by DMRT.

Table 6. Effect of salinity levels on length and dry weight of shoots and roots among three radish varieties

Salinity levels (EC dS m^{-1})	Shoot length (cm) seedling^{-1}	Root length (cm) seedling^{-1}	Dry weight of shoot (g) seedling^{-1}	Dry weight of root (g) seedling^{-1}
0 (0.66)	7.27 a	6.99 a	0.036 a	0.032 a
4	6.84 b	6.55 a	0.025 a	0.025 ab
8	6.12 c	5.86 b	0.019 b	0.017 b
12	5.50 d	5.04 c	0.011 b	0.009 c
Level of significance	0.01	0.01	0.01	0.01
CV (%)	2.13	4.82	23.20	11.72

The figures having different letter(s) in a column are significantly different at 1% or 5% level and figures having same letter(s) in a column are not significantly different by DMRT.

Table 7. Interaction effect of varieties and salinity levels on length and dry weight of shoots and roots among the three radish varieties

Salinity levels (EC dS m^{-1})	variety	Shoot length (cm) $seedling^{-1}$	Root length (cm) $seedling^{-1}$	Dry weight of shoot (g) $seedling^{-1}$	Dry weight of root (g) $seedling^{-1}$
0 (0.66)	Tasakisan Mula-1	7.54 a	7.24 a	0.048 a	0.037
	Druti	7.22 ab	6.96 ab	0.033 ab	0.032
	Red Bombay	7.06 ab	6.76 ab	0.027 b	0.027
4	Tasakisan Mula-1	6.95 bc	6.87 ab	0.030 ab	0.028
	Druti	6.85 cd	6.55 bc	0.025 bc	0.025
	Red Bombay	6.72 cd	6.24 cd	0.021 c	0.023
8	Tasakisan Mula-1	6.21 de	5.84 e	0.022 bc	0.019
	Druti	6.12de	5.87cd	0.018 cd	0.017
	Red Bombay	6.03 e	5.86 cd	0.016 cd	0.014
12	Tasakisan Mula-1	5.73 f	5.20 ef	0.013 cd	0.011
	Druti	5.50 f	4.93 g	0.011 ef	0.009
	Red Bombay	5.26 f	5.00 e	0.010 ef	0.006
Level of significance		0.05	0.01	0.05	NS
CV (%)		2.13	4.82	23.20	11.72

The figures having different letter(s) in a column are significantly different at 1% or 5% level and figures having same letter(s) in a column are not significantly different by DMRT.

NS = Non significant

Salinity also influences the root length (Table 6). The maximum length of roots (6.99 cm) was obtained from the control level and the minimum (5.04 cm) was recorded when seeds were subjected to 12 dS m^{-1} EC. Gupta *et al.* (1993) observed increased root length at moderate salinity levels (7.5 dS m^{-1}) that do not support the result of the present study. However, Zaman *et al.*, (1995) showed a significant reduction in root length due to salinity that is similar to the result of the present experiment.

Root length due to interaction effect of different radish varieties and different levels of salinity was found significant (Appendix II). Root length of radish varieties of different salinity level varied from 7.24 cm to 4.93 cm. The maximum root length was recorded in Tasakisan Mula-1(7.24 cm) with control and the minimum was in Druti (4.93 cm) at 12 dS m^{-1} level of EC (Table 7).

4.1.2.3. Dry weight of shoot (g) seedling^{-1}

Radish varieties show significant differences (Appendix II) in dry weight of shoots. Shoot weight varied from 0.028 g to 0.018 g (Table 5). The highest shoot dry weight (0.028 g) was found in Tasakisan Mula-1 which was statistically similar to Druti (0.022 g). The lowest shoot dry weight (0.018 g) was found in Red Bombay (Table 5).

Different level of salinity had significant effect on dry weight of shoot (Table 6). The dry weight of shoot was reduced with the increase in salt concentration. The highest dry weight of shoots (0.036 g) was found in control and the lowest dry weight of shoots (0.011 g) was recorded when seeds were subjected to 12 dS m^{-1}.

Interaction between salt levels and varieties had significant effect on dry weight of shoots (Appendix II). The maximum weight of dried shoots (0.048 g) was found in Tasakisan

Mula-1 at control. The lowest weight of dried shoots was found in Red Bombay (0.010 g) at 12 dS m^{-1} level of salinity (Table 7).

4.1.2.4. Dry weight of roots (g) seedling^{-1}

Radish varieties show significant differences (Appendix II) in dry weight of roots. Roots dry weight varied from 0.024 g to 0.018 g (Table 5). The highest roots dry weight was found in Tasakisan Mula-1 (0.024 g) which was statistically similar to Druti (0.021 g). The lowest roots dry weight was found in Red Bombay (0.018 g) (Table 5).

Different level of salinity had significant effect on dry weight of roots (Table 6). The highest dry weight of roots (0.032 g) was found in control treatment and the lowest dry weight of roots (0.009 g) was recorded from 12 dS m^{-1} level of salinity (Table 7).

Interaction between salinity levels and varieties on dry weight of roots was not statistically significant (Appendix II). The weight of dried roots of radish varieties at different salinity levels varied from 0.037g to 0.006 g (Table 7). The maximum roots weight was recorded in Tasakisan Mula-1 (0.037 g) at control treatment while the minimum was found in Red Bombay (0.006 g) at 12 dS m^{-1}.

In response of length and dry weight of shoots and roost all the varieties showed reduction with the increase in salinity. The varieties showed well performances in control level at all growth parameters but showed inferior performance with the increase of salinity levels. The reasons for decreasing the length of plants may be due to the fact that high concentration of soluble salts created high osmotic pressure, which disturbed the uptake of water and other nutrients (Heenan *et al.* 1988).

4.1.3 Functional relationship

The response of germination percentage in different salt solutions was compared using simple linear regression analysis. Germination percentage decreasing with the increasing of salinity level (Fig. 1). A linear but negative relationship existed between salinity level and germination percentage of different radish seeds and expressed by the equation of Y=-1.811x+95.41 (R^2=0.982), respectively, where R is highly significant. That means 98.2% germination variation was found due to salinity.

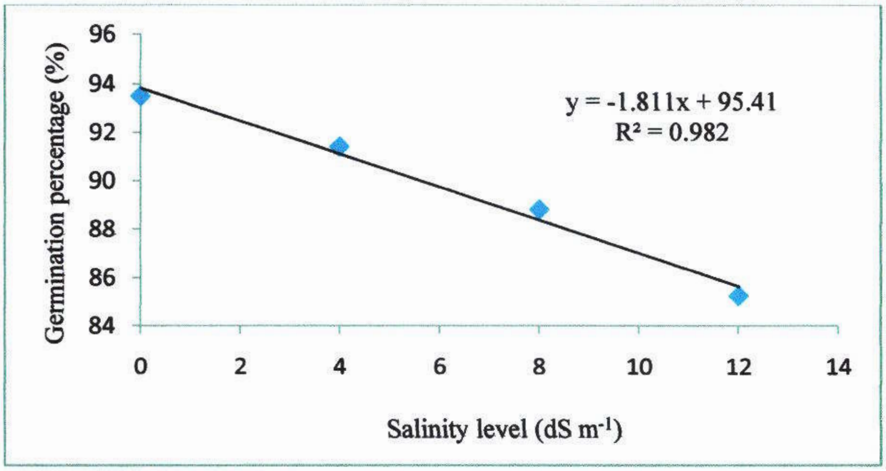


Figure 1. Functional relationship between salinity level and germination percentage

It is obvious from Fig. 1 that is a steep linear reduction in germination (%) was evident as the salt concentration increased.

Germination energy decreasing with the increasing of salinity level (Fig. 2). A linear but negative relationship existed between salinity level and germination energy of radish seeds and expressed by the equation Y=-2.188x+89.24 (R^2=0.989), respectively, where R is significant. That means 98.9% variation of germination energy was found due to salinity.

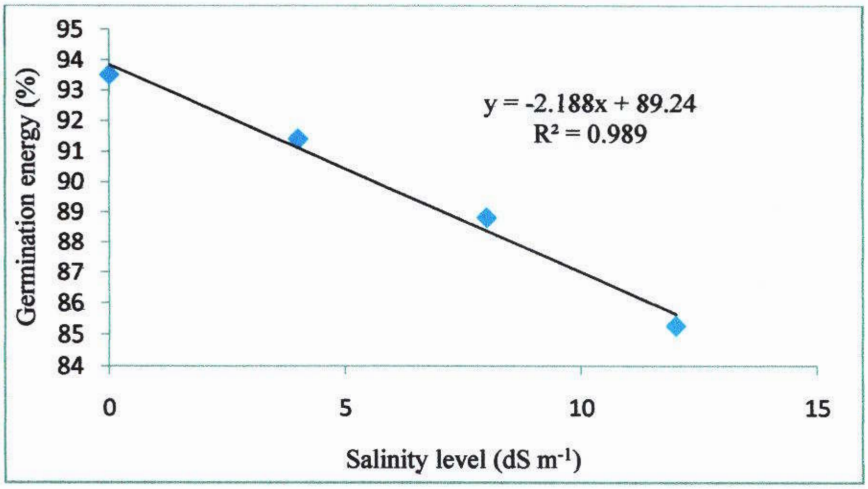


Figure 2. Functional relationship between salinity level and germination energy

It was found that the germination capacity decreasing with the increasing of salinity level (Fig. 3). A linear but negative relationship existed between salinity level and germination capacity of radish seeds and expressed by the equation Y=-1.811x+95.41 (R^2=0.982), respectively, where R is significant. That means 98.2% variation of germination capacity was found due to salinity.

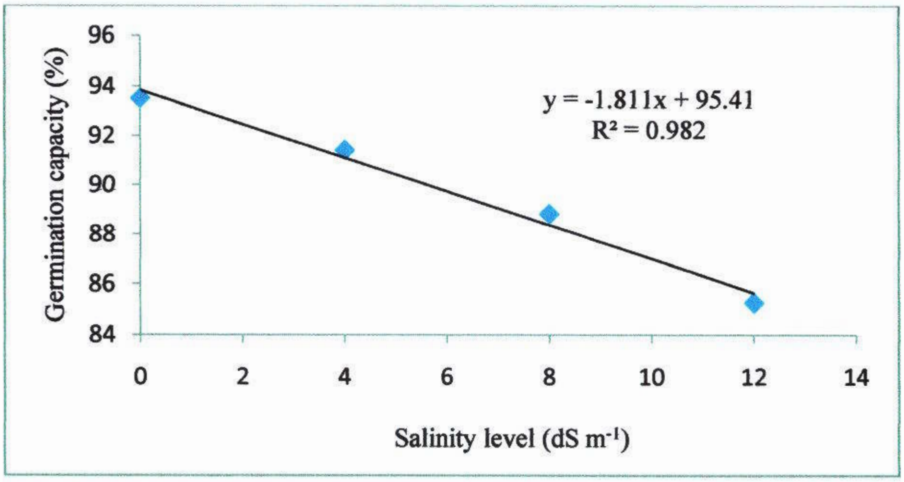


Figure 3. Functional relationship between salinity level and germination capacity

In (Fig. 4) it was found that a linear but negative relationship existed between salinity level and germination speed and expressed by the equation Y=-0.683x+93.85 (R^2=0.985), respectively. The value (R^2=0.985) suggest that over 98.5% of the variation in germination speed could be explained by the variation in the salinity level.

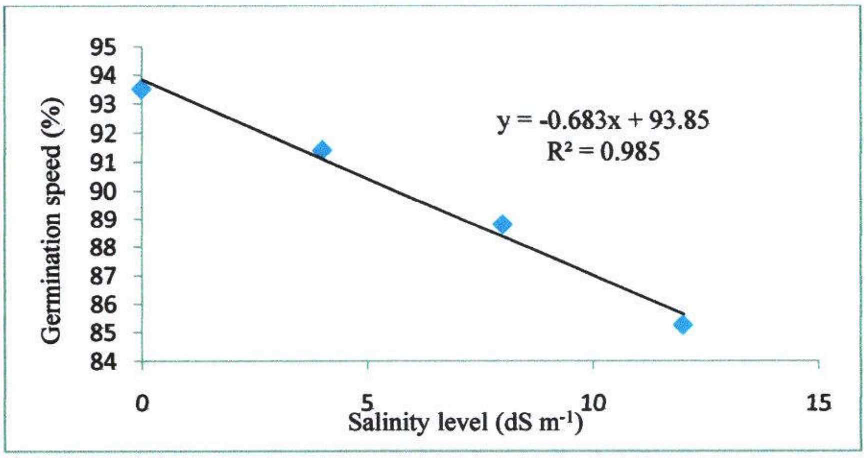


Figure 4. Functional relationship between salinity level and germination speed

In (Fig. 5) it was found that a linear but negative relationship existed between salinity level and shoot length and expressed by the equation Y=-0.150x+7.337 (R^2=0.990), respectively. That means 99% variation of shoot length was found due to salinity.

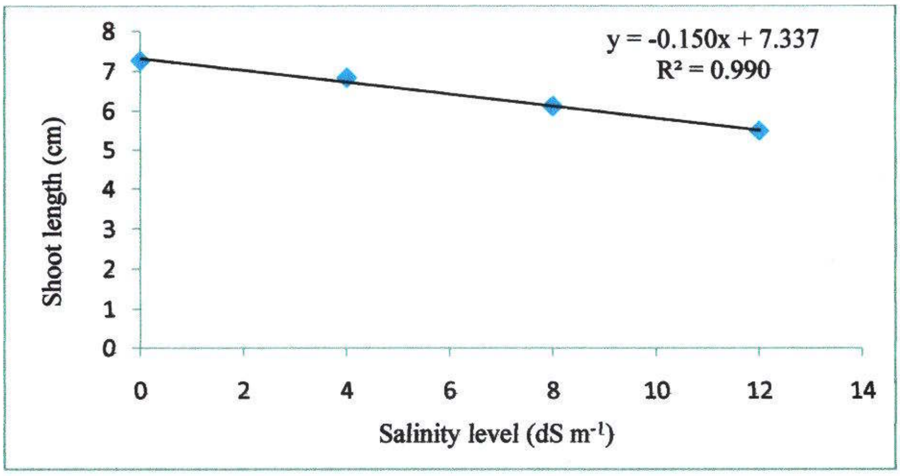


Figure 5. Functional relationship between salinity level and shoot length in radish varieties

It was found that the root length decreasing with the increasing of salinity level (Fig. 6). A linear but negative relationship existed between salinity level and root length of radish seeds and expressed by the equation $Y=-0.163x+7.091$ ($R^2=0.983$), respectively, where R is significant. That means 98.3% variation in root length could be explained by the variation in the salinity level.

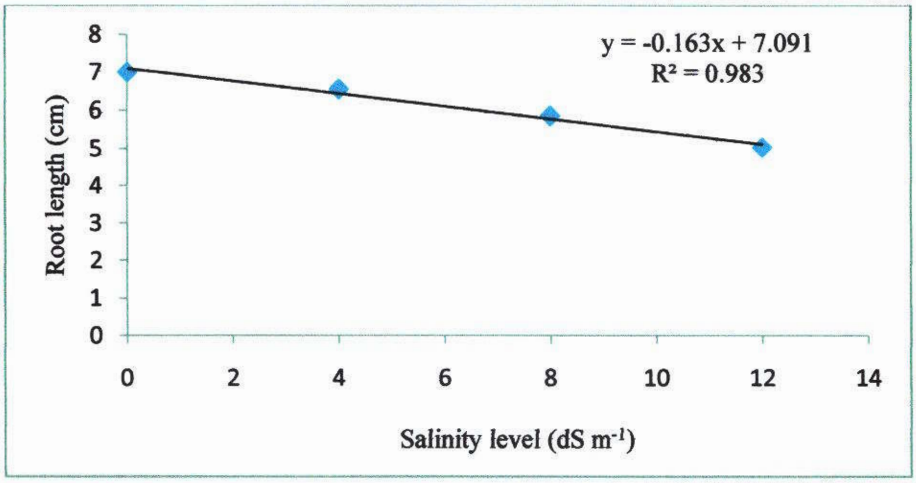


Figure 6. Functional relationship between salinity level and root length in radish varieties

The results are in agreement with those of Ahmad *et al,* (2000) who reported that salinity significantly affected plant height, fresh weight as well as dry weight of root and shoot. Although due to salinity both root and shoot length decreased but the rate of reduction in root length was more than that of shoot length.

Control × Tasakisan Mula-1

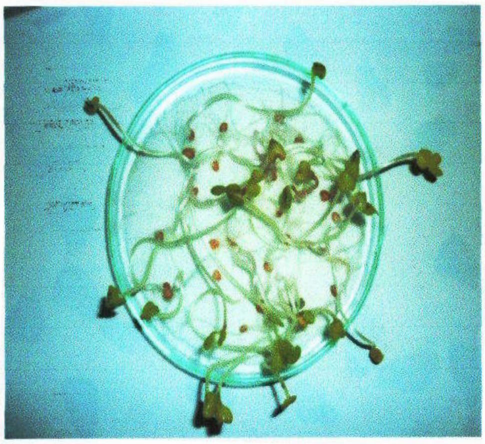
4 dS m^{-1} × Tasakisan Mula-1

8 dS m^{-1} × Tasakisan Mula-1

12 dS m^{-1} × Tasakisan Mula-1

Plate 1. Seedlings of Tasakisan Mula-1 at 14 days after germination (DAG) at different salinity level

Control × Druti



4 dS m^{-1} × Druti

8 dS m^{-1} × Druti

12 dS m^{-1} × Druti

Plate 2. Seedlings of Druti at 14 days after germination (DAG) at different salinity level

4.2 Experiment 2: Effect of different salinity levels on growth and yield contributing characters of radish

The results of the experiment as influenced by the effect of different salinity levels, varieties and their interaction on growth and yield contributing characters are presented in tables and figures in this section.

4.2.1 Number of leaves per plant

Leaves per plant are one of the most important characters of radish. A significant variation (Appendix III) was recorded among the radish varieties for producing the number of leaves per plant (Table 8). The highest (13.05) number of leaves was produced by Tasakisan Mula-1 and the lowest (12.58) was found in Red Bombay. It was observed from the experiment that Tasakisan Mula-1 was the highest resistant variety for producing number of leaves and which was in agreement with Druti (Table 8).

The highest number of leaves (14.33) was found in control treatment and the lowest number of leaves was (11.44) in the highest salinity level at 12 dS m^{-1}. The number of leaves significantly higher in control plant, which was gradually decreased with the increase in salinity levels (Table 9).

Interaction between varieties and different salinity levels on number of leaves per plant was found significant (Appendix III). The highest number of leaves (14.44) was recorded from Tasakisan Mula-1, under control condition and the lowest (11.22) were found in Druti at 12 dS m^{-1} level of salinity. In all cases, the number of leaves per plant was decreased with increased in the level of salinity (Table 10). Mangal *et al.,* (1993) reported that most plants had fewer leaves those were exposed to saline condition.

4.2.2 Weight of fresh leaves

Fresh weight of leaves gives an identification of leaf age of the plant. The leafage indicates the size of the photosynthetic system. The leaf fresh weight, among the varieties was significantly (Appendix III) varied at final harvest. The highest amount of leaf fresh weight (257.94 g) was observed in Tasakisan Mula-1 where Druti produced statistically similar to Tasakisan Mula-1. The minimum leaf fresh weight (246.30 g) was recorded from Red Bombay at final harvest (Table 8). Result of the present study showed that Tasakisan Mula-1 was the highest resistant variety for producing leaf fresh weight and which was followed by Druti.

A significant variation in leaf fresh weight was observed in different salinity levels (Table 9). The maximum leaf fresh weight (277.96 g) was obtained from control and the minimum leaf fresh weight (216.29 g) was found in 12 dS m^{-1} salinity level (Table 9). It was found from the experiment that leaf fresh weight decreased gradually with the increase of salinity levels.

The interaction effect among the varieties with different salinity levels on leaf fresh weight was showed significant variation (Appendix III). The variety Tasakisan Mula-1 produced the highest amount of leaf fresh weight (281.99 g) at control and the lowest (212.11 g) was obtained from 12 dS m^{-1} salinity level for the variety Red Bombay (Table 10). Rashid *et al.,* (1983) found the differences in weight of fresh leaves among four radish cultivars which was significant at 1% level.

4.2.3 Length of leaves

There was a significant variation in length of leaves among the three radish verities (Appendix III). The highest length of leaves (28.99 cm) was found in Tasakisan Mula-1 and the lowest one (27.27 cm) was observed in Red Bombay (Table 8). It was found from the experiment that Tasakisan Mula-1 was the resistant variety for producing highest leaf length.

Different salinity levels affected length of leaves significantly. The highest leaf length (31.77 cm) was found at control treatment and the lowest leaf length was (24.40 cm) at 12 dS m^{-1} salinity level. Plants in control treatment had the highest length of leaves, which was gradually decreased with the increase in salinity levels (Table 9). However, the decrease was perceptible even at the level of salinity and it was significantly different at the highest level of salinity.

The interaction effect of genotypes and different salinity levels on length of leaves was not significant (Appendix III). However, numerically the highest leaf length (32.33 cm) was observed in Tasakisan Mula-1 at control condition and the shortest (23.88 cm) was recorded in Red Bombay at 12 dS m^{-1} level of salinity (Table 10).

4.2.4 Width of leaves

Tasakisan Mula-1 was recorded superior in respect of leaf width (7.93 cm) which was statistically similar to Druti. Lowest leaf width was obtained from Red Bombay (7.70 cm) (Table 8).

Different salinity levels affected leaf width significantly (Appendix III). The highest leaf width (9.20 cm) was recorded from the control treatment and the lowest leaf width (6.44 cm) was at 12 dS m^{-1} salinity level. Plants in control treatment had the highest leaf width, which gradually decreased with the increase in salinity (Table 9).

The interaction effect of varieties and different salinity levels on leaf width was not significant (Appendix III). However, numerically the highest leaf width (9.27 cm) was

Table 8. Effect of variety on yield and yield contributing characters of radish

Varieties	No of leaf per plant	Leaf fresh weight (g)	Leaf length (cm)	Leaf width (cm)	Leaf dry weight (g)	Root fresh weight (g)	Root dry weight (g)	Root length (cm)	Root diameter (cm)	Yield g/plant
Tasakisan Mula 1	13.05 a	257.94 a	28.99 a	7.93 ab	17.50 a	281.23 a	29.80 a	16.45 a	4.92 a	281.23 a
Druti	12.66 bc	251.77 a	28.13 b	7.83 ab	17.44 ab	264.87 b	28.11 ab	15.51 b	4.85 ab	264.87 b
Red Bombay	12.58 bc	246.30 b	27.27 c	7.70 b	16.90 b	258.80 b	27.39 b	15.35 b	4.74 ab	258.80 b
CV (%)	2.59	4.16	5.25	3.27	5.44	2.26	3.11	2.54	1.93	2.26
Level of significance	0.01	0.05	0.05	0.05	0.05	0.01	0.01	0.01	0.01	0.01

The figures having different letter(s) in a column are significantly different at 1% or 5% level and figures having same letter(s) in a column are not significantly different by DMRT.

Table 9. Effect of different salinity levels on the growth and yield of radish

EC (dS m^{-1})	No of leaf per plant	Leaf fresh weight (g)	Leaf length (cm)	Leaf width (cm)	Leaf dry weight (g)	Root fresh weight (g)	Root dry weight (g)	Root length (cm)	Root diameter (cm)	Yield g/plant
0 (0.66)	14.33 a	277.96 a	31.77 a	9.20 a	20.22 a	313.66 a	31.68 a	18.25 a	5.19 a	313.66 a
4	13.14 b	264.10 ab	29.03 ab	8.31 b	18.47 ab	295.57 b	30.14 ab	16.52 b	5.00 a	295.57 b
8	12.14 c	249.66 b	27.33 bc	7.34 c	16.42 b	273.40 c	28.36 b	15.36 c	4.76 b	273.40 c
12	11.44 c	216.29 c	24.40 c	6.44 d	14.00 c	190.57 d	23.55 c	12.95 d	4.40 c	190.57 d
CV (%)	2.59	4.16	5.25	3.27	5.44	2.26	3.11	2.54	1.93	2.26
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

The figures having different letter(s) in a column are significantly different at 1% or 5% level and figures having same letter(s) in a column are not significantly different by DMRT.

Table 10. Interaction effect of radish varieties and different salinity level on growth and yield of radish

EC ($dS\ m^{-1}$)	Varieties	No of leaf per plant	Leaf fresh weight (g)	Leaf length (cm)	Leaf width (cm)	Leaf dry weight (g)	Root fresh weight (g)	Root dry weight (g)	Root length (cm)	Root diameter (cm)	Yield g/plant
0 (0.66)	Tasakisan Mula 1	14.44 a	281.99 a	32.33	9.27	20.13	321.11a	32.62 a	18.55 a	5.24 a	321.11a
	Druti	14.35 ab	277.99 ab	31.55	9.22	20.50	312.77 ab	31.19 b	18.05 b	5.19 b	312.77 ab
	Red Bombay	14.22 ab	273.88 ab	31.44	9.11	20.03	307.11ab	31.23 ab	18.16 ab	5.13 ab	307.11ab
4	Tasakisan Mula 1	13.44 bc	272.99 ab	30.88	8.32	18.52	311.66 ab	31.52 ab	17.33 ab	5.04 bc	311.66 ab
	Druti	12.99 cd	261.77 cd	29.44	8.33	18.87	292.29 cd	30.20 b	16.16 bc	5.02 bc	292.29 cd
	Red Bombay	12.99 cd	257.55 d	26.77	8.27	18.04	282.77 d	28.72 c	16.08 cd	4.94 cd	282.77 d
8	Tasakisan Mula 1	12.55 d	356.66 bc	27.77	7.44	16.79	298.88 bc	30.63 bc	16.16 bc	4.83 cd	298.88 bc
	Druti	12.10 de	250.66 e	27.22	7.33	16.35	262.33 e	27.44 cd	15.03 cd	4.82 cd	262.33 e
	Red Bombay	11.77 ef	241.66 e	26.99	7.27	16.12	259.00 e	27.03 cd	14.88 de	4.65 de	259.00 e
12	Tasakisan Mula 1	11.77 ef	220.11 f	24.99	6.71	14.56	193.27 f	24.44 de	13.77 ef	4.58 ef	193.27 f
	Druti	11.22 g	216.66 fg	24.33	6.44	14.04	192.10 f	23.61 de	12.80 ef	4.39 g	192.10 f
	Red Bombay	11.33 g	212.11 g	23.88	6.16	13.41	186.32 f	22.59 e	12.27 fg	4.24 h	186.32 f
CV (%)		2.59	4.16	5.25	3.27	5.44	2.26	3.11	2.54	1.93	2.26
Level of significance		0.01	0.01	NS	NS	NS	0.01	0.05	0.05	0.05	0.01

The figures having different letter(s) in a column are significantly different at 1% or 5% level and figures having same letter(s) in a column are not significantly different by DMRT.

NS= Non significant

observed in Tasakisan Mula-1 with control condition and the shortest (6.16 cm) was recorded in Red Bombay at 12 dS m^{-1} level of salinity (Table 10). Other combinations showed the medium leaf width.

4.2.5 Leaf dry weight

Significant variation was found among the varieties in respect of dry weight of leaves (Table 8). The maximum leaf dry weight (17.50 g) was observed in Tasakisan Mula-1 which was statistically identical to Druti and the minimum (16.90 g) leaf dry was produced in Red Bombay (Table 8). It was found from the experiment that Tasakisan Mula-1 and Druti were the higher resistant varieties for producing leaf dry weight and Red Bombay was susceptible.

The maximum leaf dry weight (20.22 g) was found in the control treatment and the minimum (14.00 g) was found in 12 dS m^{-1} level of salinity (Table 9). It was found from the experiment that leaf dry weight decreased gradually with the increase of salinity levels.

The interaction effect of varieties with different salinity levels for leaf dry weight was not significant (Table 10). However, numerically the maximum leaf dry weight (20.50 g) was found in control level with Druti and the minimum (13.41 g) was obtained in 12 dS m^{-1} level of salinity with Red Bombay. Gardner *et al.* (1984) mentioned that leaf dry weight decreased gradually with the increase of salinity levels.

4.2.6 Root fresh weight

Significant variation was found among the varieties in respect of fresh weight of root (Appendix III). Fresh weight of roots varied from 258.80 g to 281.23 g. The highest fresh weight of roots was observed in Tasakisan Mula-1 (281.23 g) and the lowest (258.80 g) was observed in Red Bombay. But intermediate yield production was found in the variety Druti (264.87 g). It was found from the experiment that Tasakisan Mula-1 was the highest resistant variety for producing maximum root fresh weight.

Different salinity levels affected root fresh weight significantly. The highest root fresh weight (313.66 g) was at control treatment and the lowest root fresh weight (190.57 g) was at 12 dS m^{-1} salinity level. Plants in control treatment had the highest root fresh weight, which gradually decreased with the increase in salinity level (Table 9).

Significant variation was found among the varieties with different salinity levels on root fresh weight (Appendix III). The variety Tasakisan Mula-1 produced the highest root fresh weight (321.11 g) at control level and the lowest (186.32 g) was obtained from 12 dS m^{-1} salinity level for the variety Red Bombay (Table 10). It was found from the experiment that roots fresh weights were gradually decreased with increased salinity levels.

This is in agreement with the results reported by Mack (1979); Fritz and Weighmann (1979); and Salter *et al.* (1979).

4.2.7 Root dry weight (g)

Significant variation was found among the varieties in respect of the root dry weight (Table 8). The maximum root dry weight (29.80 g) was observed in Tasakisan Mula-1 and the minimum (27.39 g) in Red Bombay (Table 8). It was found from the experiment that Tasakisan Mula-1 was the higher resistant variety for producing leaf dry weight and Red Bombay was susceptible.

The maximum root dry weight (31.68 g) was found in the control treatment and the minimum (23.55 g) was found in 12 dS m^{-1} level of salinity (Table 9). It was found from the experiment that root dry weight decreased gradually with the increase of salinity levels.

Significant variation was found in the interaction effect of varieties with different salinity levels for root dry weight (Table 10). The maximum root dry weight (32.62 g) was found in control with Tasakisan Mula-1 and the minimum (22.59 g) in 12 dS m^{-1} level of salinity with Red Bombay.

4.2.8 Root length (cm)

The mean length of root of three radish varieties ranged from 16.45 cm to 15.35 cm (Table 8). The maximum length (16.45 cm) of root was found in Tasakisan Mula-1 and the minimum root length (15.35 cm) was found in Red Bombay.

The length of root was significantly affected by the salinity levels (Table 9). The maximum (18.25) root length was found in control treatment and that was the lowest 12.95 cm in 12 dS m^{-1} level of salinity (Table 9).

Significant variation was found in the interaction effect of varieties with different salinity levels for root length (Table 10). The maximum root length (18.55 cm) was recorded in control with Tasakisan Mula-1 and the minimum (12.27 cm) in 12 dS m^{-1} level of salinity with Red Bombay (Table 10).

4.2.9. Root diameter (cm)

The mean values of root diameter varied markedly among the varieties under the study (Table 8). The highest diameter (4.92 cm) was found in the variety of Tasakisan Mula-1 and that was minimum in Red Bombay (4.74 cm) (Table 8).

The highest root diameter (5.19 cm) was found in control treatment and the lowest (4.40 cm) in the highest salinity level at 12 dS m^{-1}. The root diameter was significantly higher in control plant, which was gradually decreased with the gradual increase in salinity levels (Table 9).

Interaction between varieties with different salinity levels on root diameter was found significant (Appendix III). The highest root diameter (5.24 cm) was recorded in Tasakisan Mula-1 under control condition and the lowest (4.24 cm) were found in Red Bombay at12 dS m^{-1} level of salinity (Table 10).

4.2.10 Yield (g/ plant)

Significant variation was found among the varieties in respect of the yield which indicates the weight of fresh roots (Appendix III). Fresh weight of roots in three varieties varied from 258.80 g to 281.23 g. The highest fresh weight of roots was observed in Tasakisan Mula-1 (281.23 g). The lowest (258.80 g) root fresh weight was observed in Red Bombay. But intermediate yield production was found in the variety Druti (264.87 g). There was statistically significant variation was observed in different salinity levels (Table 9). The highest root fresh weight (313.66 g) was at control treatment and the lowest root fresh weight was (190.57 g) at 12 dS m^{-1} salinity level. Plants in control treatment had the highest root fresh weight, which gradually decreased with the increase in salinity levels (Table 9).

Significant variation was found in the interaction effect of varieties with different salinity levels on root fresh weight (Table 10). The varieties Tasakisan Mula-1 produced the highest root fresh weight (321.11 g) at control level and the lowest (186.32 g) was obtained from 12 dS m^{-1} salinity level for the variety Red Bombay (Table 10). Varieties showed gradually decreased root fresh weight with increased salinity levels.

4.2.11 Functional relationship

The yield decreasing with the increasing salinity level (Fig. 7). A linear but negative relationship existed between salinity level and yield (g/plant) of radish varieties and expressed by the equation y=-9.786x+327.0 (R^2=0.8630), respectively, where R is highly significant (Fig. 7). That means 86.30% yield variation was found due to salinity.

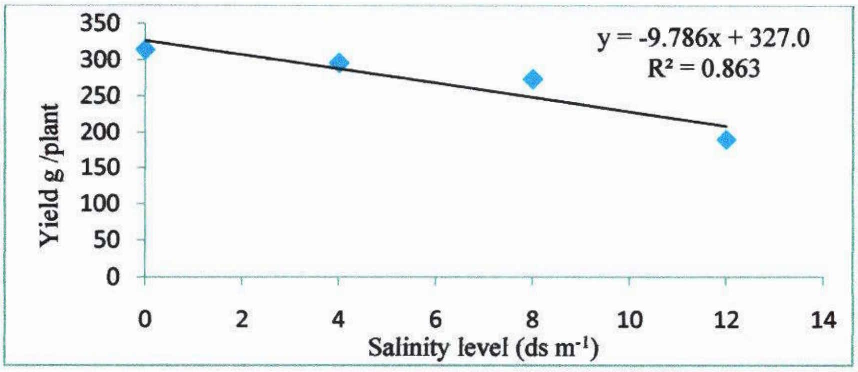


Figure 7. Functional relationship between salinity level and yield

The yield increases with the increasing number of leaf per plant (fig. 8). A linear but positive relationship existed between number of leaf per plant and yield (g/plant) of radish varieties and expressed by the equation y=38.22x-219.5 (R^2=0.780), respectively, where R was significant (fig. 8). That means 78.00% yield increased due to increasing of number of leaf per plant.

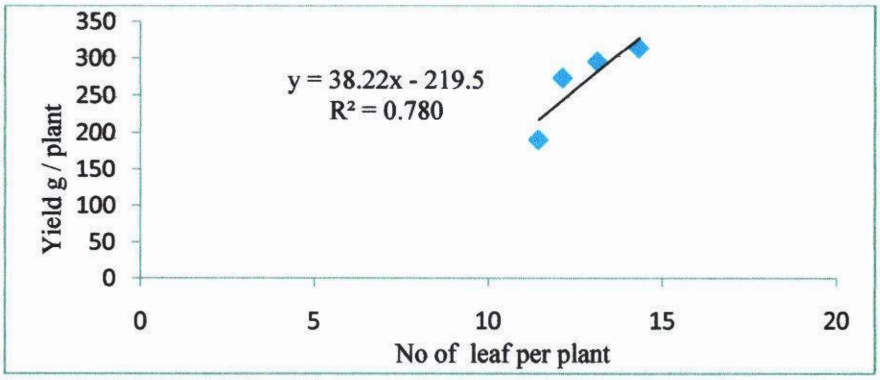


Figure 8. Functional relationship between number of leaf per plant and yield

It was found that yield increased with the increasing of root length (Fig. 9). A linear but positive relationship existed between root length and yield (g/plant) and expressed by the equation Y= 23.59x-103.8 (R^2= 0.931), where the value of R referred that 93.10% yield increased with increasing root length.

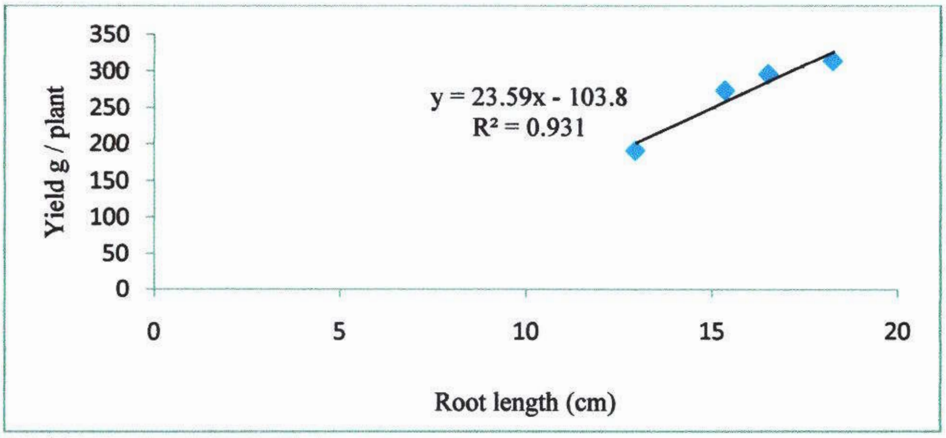


Figure 9. Functional relationship between root length and yield

In (Fig. 10) it was found a positive linear relationship between leaf fresh weight and yield (g/plant). The equation was Y=2.033x-244.0 (R^2=0.979). The value of R referred that 97.90% yield variation were found due to variation of leaf fresh weight.

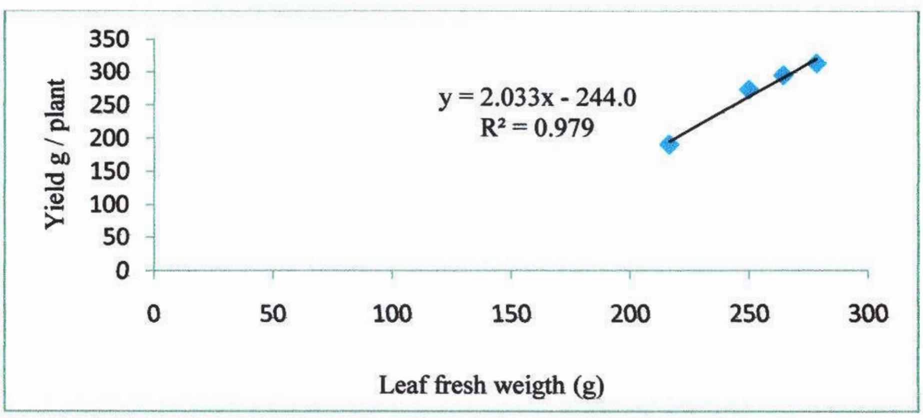


Figure 10. Functional relationship between leaf fresh weight and yield

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at the Molecular Horticulture Lab. Agrotechnology Discipline, Khulna University, Khulna to observe the effect of different level of salinity on germination parameters and growth parameters of three different radish varieties and a pot experiment was conducted at the Germplasm Centre of Agrotechnology Discipline, Khulna University, Khulna during the rabi season from December 2012 to March 2013 with three radish varieties to study the effect of salinity levels on growth, yield and yield contributing characters. The seeds of three radish varieties Tasakisan Mula-1 (BARI Mula-1), Druti (BARI Mula-3), Red Bombay (Local variety) were used in the study. Four different concentrations of NaCl along with distilled water were used as treatment variables in the experiment.

To observe the effect of different level of salinity on above three radish varieties seeds of the each variety were treated with salinity levels of 0 (0.66) dS m^{-1}, 4 dS m^{-1}, 8 dS m^{-1} and 12 dS m^{-1}. The experiments were laid out in a factorial Completely Randomized Design (CRD) with three replications. Germination test was performed following the petridish method. Germination was counted at an interval of 24 hour and continued for seven days and was expressed in percentage.

There was wide variation in germination parameters, length and dry weight of shoot and root among radish varieties due to different level of salinity. The highest germination percentage (86.33%), germination energy (79.00%), germination capacity (86.33%) and germination speed (91.37%) were observed in Tasakisan Mula-1. The lowest germination percentage (82.33%), germination energy (74.00%) and germination capacity (82.33%) were in Red Bombay. The lowest germination speed (88.29%) was showed by variety Druti. In all the germination parameters Tasakisan Mula-1 was found superior.

Germination parameters differed significantly at different level of salinity. In all germination parameters controlled treatment (0.66 dS m^{-1}) gave the best results and 12 dS m^{-1} was the inferior.

Interaction of varieties and salinity levels was found significant variation in germination percentage, germination energy and germination capacity but germination speed was not significant. The highest germination percentage (97.33%), germination energy (92.00%), germination capacity (97.33%) and germination speed (94.55%) were observed in Tasakisan Mula-1 at control (0.66 dS m^{-1}) treatment which was followed by Druti and Red Bombay. The lowest germination percentage (70.00%), germination energy (58.66%), germination capacity (70.66%) and germination speed (83.00%) were observed in Red Bombay at 12 dS m^{-1} salinity level.

Radish varieties showed significant effect on shoot and root length. The highest shoot length (6.61 cm) was found in Tasakisan Mula-1 and the lowest (6.27 cm) was in Red Bombay. The highest root length (6.29 cm) was in Tasakisan Mula-1 while the lowest (5.96 cm) was noticed from Red Bombay.

Length of shoot and root varied significantly across salinity levels. The highest shoot length (7.27 cm) and root length (6.99 cm) was recorded from the control. The lowest shoot length (5.50 cm) and root length (5.04 cm) was found at 12 dS m^{-1}.

Radish varieties differed significantly in dry weight of shoot and root. The maximum dry weight of shoot (0.028 g) and dry weight of root (0.024 g) were found in Tasakisan Mula-1. The lowest shoot dry weight (0.018 g) and lowest root dry weight (0.018 g) was found in Red Bombay.

The different levels of salts affected dry weight of root and shoot. The maximum dry weight of shoot (0.036 g) and dry weight of root (0.032 g) were due to the treatment of distilled water. The lowest shoot dry weight (0.011 g) and root dry weight (0.009 g) were found at 12 dS m^{-1} level of salinity.

Interaction of varieties and salinity levels was found significant in shoot length (cm) $seedling^{-1}$, root length (cm) $seedling^{-1}$ and dry weight of shoot (g) $seedling^{-1}$ but dry weight of root (g) $seedling^{-1}$ was not significant. The highest shoot length (7.54 cm), root length (7.24cm), dry weight of shoot (0.048 g) and dry weight of root (0.037g) were observed in Tasakisan Mula-1 at control (0 dS m^{-1}) treatment. But the lowest shoot length (5.26cm), dry weight of shoot (0.010 g) and dry weight of root (0.006 g) were observed in Red Bombay and lowest root length was observed in Druti, respectively at 12 dS m^{-1} salinity level.

In the pot experiment four salinity levels 0.66 dS m^{-1}, 4 dS m^{-1}, 8 dS m^{-1} and 12 dS m^{-1} were imposed by adding NaCl solution to pot soils. There was noticeable variation among the radish varieties in growth, yield and yield contributing characters.

In the present study the morphological parameters like number of leaf per plant, leaf fresh weight (g), leaf length (cm), leaf width (cm), leaf dry weight (g), root fresh weight (g), root dry weight (g), root length (cm), root diameter (cm) and yield (g/plant) showed significant variation. Among the varieties, the maximum number of leaf (13.05) was produced by Tasakisan Mula-1 and minimum (12.58) was in Red Bombay at final harvest. The maximum leaf fresh weight (257.94 g) was found in Tasakisan Mula-1 which was statistically similar to Druti and the minimum leaf fresh weight (246.30 g) was found in Red Bombay. The highest leaf length (28.99 cm) and leaf width (7.93 cm) was in Tasakisan Mula-1 where as the lowest leaf length (27.27 cm) and leaf width (7.70 cm) was observed in Red Bombay.

The variety Tasakisan Mula-1 produced maximum leaf dry weight (17.50 g) and lowest leaf dry weight (16.90 g) was produced by Red Bombay. The highest root fresh weight (281.23 g) was found in Tasakisan Mula-1 and the lowest root fresh weight (258.80 g) was in red Bombay. At final harvest the maximum root length (16.45 cm) and root diameter (4.92 cm) was observed in Tasakisan Mula-1 where as the minimum root length (15.35 cm) and root diameter (4.74 cm) was observed in Red Bombay. The highest yield (281.23 g/plant) was found in Tasakisan Mula-1 and the lowest yield (258.80 g/plant) was in Red Bombay.

Number of leaf per plant, leaf fresh weight , leaf length, leaf width and leaf dry weight were maximum at control level and lowest at 12 dS m^{-1} level of salinity. These parameters were found intermediate at 4 dS m^{-1} level. The values of the above parameters were gradually decreased with the increased of the level of salinity. Number of leaf per plant, leaf fresh weight, leaf length, leaf width and leaf dry weight were maximum in Tasakisan Mula-1 at almost all the harvests. But Druti produced medium values on the above parameters. Red Bombay produced the least values of the parameters.

Other parameters viz. root fresh weight, root dry weight, root length, root diameter and yield were drastically reduced by the highest salinity level 12 dS m^{-1}. These parameters were maximum at control condition. The salinity level 4 dS m^{-1} was found lesser detrimental than 8 dS m^{-1}. Among the varieties Tasakisan Mula-1 showed maximum values on the above parameters. From the above results it may be stated that the salinity level 12 dS m^{-1} decreased growth, yield and yield contributing characters of radish varieties. The highest salinity level (12 dS m^{-1}) was found much detrimental for the varieties. However, among the varieties Tasakisan Mula-1 and Druti showed some tolerance to salinity stress. But Red Bombay was found more susceptible to salinity.

Interaction of varieties and salinity levels was found significant variation in number of leaf per plant, leaf fresh weight, root fresh weight, root dry weight, root length, root diameter and yield. But the interaction of varieties and salinity levels was not significant in leaf length, leaf width and leaf dry weight. The maximum number of leaf per plant (14.44) was found in Tasakisan Mula-1 at control (0.66 dS m^{-1}) but the minimum number of leaf per plant (11.22) was found in Druti at 12 dS m^{-1} salinity. Leaf fresh weight (281.99 g), leaf length (32.33 cm) and leaf width (9.27 cm) were significantly higher in Tasakisan Mula-1 at control (0 dS m^{-1}) than other variety which was followed by Druti and Red Bombay. But the lowest Leaf fresh weight (212.11 g), leaf length (23.88 cm) and leaf width (6.16 cm) were found at 12 dS m^{-1} salinity level in Red Bombay. Druti produced the maximum leaf dry weight (20.50 g) in control followed by Tasakisan Mula-1 and Red Bombay.

The maximum root fresh weight (321.11 g), root dry weight (32.62 g), root length (18.55 cm) and root diameter (5.25 cm) were found higher in Tasakisan Mula-1 at control (0.66 dS m^{-1}) than other variety which was followed by Druti and Red Bombay. Tasakisan

Mula-1 produced the highest yield (321.11 g/plant) in control which was followed by Druti. Minimum yield (186.32 g/plant) was observed in Red Bombay under 12 dS m^{-1} salinity level.

From the findings of the present study it might be reasonably concluded that

- Germination parameters are negatively affected with the increasing salinity
- Tasakisan Mula-1 (BARI Mula-1), was superior to others considering germination percentage, germination energy, germination capacity and germination speed
- The length and dry weight of shoot and root of seedlings of different radish varieties decreased with increasing salinity levels except the Tasakisan Mula-1
- Increasing salinity levels decreased yield and yield contributing characters of radish
- Among the varieties on an average Tasakisan Mula-1 gave highest yield followed by Druti at 8 dS m^{-1} salinity levels. The minimum performance was shown by Red Bombay

The variety Tasakisan Mula-1 may be tested in the saline areas for final recommendation.

CHAPTER VI

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Appendix I. Record of monthly average temperature (^{0}C), total rainfall (mm) and relative humidity during the study period.

Month	Monthly average temperature (^{0} C)		Average humidity (%)
	Maximum	Minimum	
December, 2012	26.2	14.2	79
January, 2013	24.2	11.9	80
February, 2013	29.4	15.5	73
March, 2013	34.7	23.4	71

Source: Regional Inspection Centre, Bangladesh Meteorological Department, Gallamary, Khulna.

Appendix II. Analysis of variance for different parameters of radish seed varieties due to salinity

Sources of variation	Degree of freedom	Mean Sum of Square (MSS)							
		Germination Percentage	Germination Energy	Germination Capacity	Germination Speed	Shoot length (cm) $seedling^{-1}$	Root length (cm) $seedling^{-1}$	Dry weight of shoot (g) $seedling^{-1}$	Dry weight of root (g) $seedling^{-1}$
Salinity (A)	3	801.630 **	1161.926 **	801.630 **	113.864 **	5.546 **	6.520 **	0.001 **	0.001 **
Variety (B)	2	49.778 **	80.444 **	49.778 **	28.707 *	0.349 **	0.322 *	0.000 **	0.000 **
(A × B)	6	4.741 **	11.704 *	4.741 **	11.582 NS	0.021 *	0.070 **	0.000 *	0.000 NS
Error	24	8.000 **	7.111	8.000 **	15.516	0.019	0.087	0.000	0.000
CV (%)		3.35	3.50	3.35	4.39	2.13	4.82	23.20	11.72

**= Significant at 1% level, *=Significant at 5% level and NS= Non Significant