EFFECT OF DIFFERENT LEVELS OF SALT STRESS ON GROWTH AND DEVELOPMENT OF INDIAN SPINACH (*Basella alba* L.)

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CERTIFICATE

This is to certify that the thesis entitled ***'EFFECT OF DIFFERENT LEVELS OF SALT STRESS ON GROWTH AND DEVELOPMENT OF INDIAN SPINACH (Basella alba L.)'*** *submitted to the faculty of Agriculture, Sher-e-Bangla Agricultural University (SAU), Dhaka, in partial fulfillment of the requirements for the degree of* ***Master of Science (MS)*** *in* ***Agroforestry and Environmental Science*** *, embodies the result of a piece of bonafide research work carried out by* ***SIRAJUM MOONIRA TUHFA****, Registration No.* ***18-09243,*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: December, 2020
Place: Dhaka, Bangladesh

Dr. Ferzana Islam
Professor
Supervisor

Dedicated To

My

Beloved Parents

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The Author

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ABSTRACT

From November 2020 to January 2021, the experiment was done at Sher-e-Bangla Agricultural University's Agroforestry experimental area to determine the impact of salt on morpho-physiological and yield contributing features of indian spinach (*Basella alba* L.). The experimental treatments were considered six different levels of salinity viz. S_0 = no salt (control), S_1 = 25 mM, S_2 = 50 mM, S_3 = 75 mM, S_4 = 100 mM and S_5 = 150 mM NaCl. Planting material was selected from the varieties BARI Puishak 1 (Chitra) and BARI Puishak 2. With three replications, the experiment was set up using a Completely Randomized Design (CRD). The tallest plant (106.91 cm), the most branches per plant (13.51), the longest leaf (10.62 cm), the widest leaf (8.42 cm), the largest leaf area (85.54 cm^2), the number of leaves per plant (40.83), and the largest plant diameter (1.59 cm). The S0 or controlled condition had the highest SPAD value (74.83), maximum germination (77.76%), plant fresh weight (417.18 gm), highest plant dry weight (60.36 gm), and largest dry matter (14.40 %), while the S_5 (150 mM NaCl) treatment had the lowest value. S_5 or 150 ds/m salt had the highest moisture content (88.87 %). From S_0 to S_5, the highest to lowest value gradually reduced. Finally, it can be stated that from S_0 to S_5, cultivating under saline water (100 mM NaCl) treatment resulted in a drop in yield. As a result, the cultivar may be grown in the southern portion of Bangladesh, where saline levels can reach 100 mM NaCl.

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LIST OF ABBREVIATIONS

FULL WORD	ABBREVIATION
Agro-Ecological Zone	AEZ
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Centimeter	cm
Concentration	Conc.
Completely Randomized Design	CRD
Coefficient of Variance	CV
Degree Celsius	C^0
Days After transplanting	DAT
Duncan`s new Multiple Range Test	DMRT
Dry Weight	DW
And others	*et al.*
Electrical Coductivity of extract	ECe
Food and Agricultural Organization	FAO
Fresh Weight	FW
Gram (s)	g
Per hectare	ha^{-1}
Hydrogen peroxide	H_2O_2
id est (L), that is	i.e.
Kilogram (g)	Kg
Least Significant Difference	Lsd
Muriate of Potash	MOP
Milligram	mg
Millimeter	mm
Maximum	Max
Minimum	Min
Sodium Chloride	NaCl
Non significant	NS
Nitrogen, Phosphorus and Potasium	NPK

LIST OF ABBREVIATIONS (Cont'd)

FULL WORD	ABBREVIATION
Osmotic Potential	OP
Peroxide	POD
Poly phenoloxide	PPO
Parts per thousand	ppt
Reactive Oxygen Species	ROS
Sodium Nitroprusside	SNP
Shoot Distribution Index	SDI
Superoxide Dismetase	SOD
Sher-e-Bangla Agricultural University	SAU
Soil Resources and Development Institute	SRDI
Triple Super Phosphate	TSP
Weight	Wt
Percentage	%

CHAPTER I

INTRODUCTION

Indian Spinach (*Basella alba* L.) is a native Central and Western Asian leafy green flowering plant. It is of the order Caryophyllales, the Amaranthaceae family, and the Chenopodioideae subfamily. Its leaves are a common edible vegetable consumed by canning, freezing, or dehydration, either fresh or after storage using preservation techniques. It can be eaten raw or fried, and the taste varies greatly; through steaming, the elevated oxalate content can be decreased.

Spinach is an essential leafy green vegetable containing large amounts of bioactive compounds and nutrients, such as *p*-coumaric acid derivatives with high antioxidant activity and glucuronic acid flavonoid derivatives, which are not abundant in most other vegetables (Bergman *et al.*, 2001; Edenharder *et al.*, 2001; Pandjaitan *et al.*, 2005). It was described as a vegetable that is moderately salt-sensitive (Shannon and Grieve, 1999). Salt stress decreased germination of spinach, root elongation, growth of seedlings, quality of chlorophyll and photosynthesis, and increased permeability of the membrane (Delfine *et al.* 1998; Downton *et al.* 1985; Kaya *et al.* 2002; Robinson *et al.* 1983).

Salinity means the presence of aqueous samples of the main dissolved inorganic solutes (essentially Na^+, K^+, Mg^+, Ca^{++}, Cl^-, NO_3^-, $SO_4^=$, HCO_3^- and $CO_3^=$). For soil and water, this means the soluble salts in the soil or water plus readily dissolved salts. Some percentages of salts are typically found in all soils, many of which are essential for the healthy growth of the plants. However, if the percentage of salt exceeds a certain amount, the production and/or quality of most of the crops are adversely affected to a degree depending on the type and percentage of salts present, the type of plant and the stage of development. Tolerance of soil salinity for crops depends on the nature of the plant, Development stage, salinity type, soil fertility, climate factors, environmental factors and irrigation frequency.

Salinity causes unfavorable conditions and hydrological conditions that reduce the traditional production of crops throughout the year. As it comes into contact with the sea water, the freshly deposited alluviums from upstream in the coastal areas of Bangladesh become saline and continue to be inundated during high tides and the inflow of sea water through creeks. Tidal flooding during the wet season (June-October), direct flooding by saline or brackish water, and upward or lateral movement of saline ground water during the dry season are factors that contribute significantly to saline soil production (November-May).

One of the most significant problems facing agricultural crops in the world is the high salinity conditions of agricultural soil and irrigation water. Salt-affected soils are estimated to affect almost 10% of the earth's surface and 50 percent of the world's irrigated land (Ruan *et al.*, 2010). Plants response to salinity is complicated and requires changes in morphology, physiology, and metabolism. Cellular water deficiency, ion toxicity, nutrient shortages and oxidative stress are the effects of salinity on plants, leading to growth suppression, molecular damage and even plant death (Orcutt and Nilsen, 2000). All plants do not react to salinity in a similar way; at far higher levels of soil salinity than others, some crops can produce reasonable yields. This is because some crops are better able to make the required osmotic changes that allow them to extract more saline soil water, or they may be more tolerant of some of the salinity's toxic effects. Climate is the single most important factor in the response of plants to soil salinity and plays a vital role. Plants may be able to withstand greater salinity in humid areas than in arid regions. Likewise, it is possible for winter maize or winter sunflower to tolerate higher salinity than summer maize and summer sunflower. The soil that contains excess salt, which is beyond the range of the crop and consequently affects the crop, is thus referred to as the soil affected by salt.

Salinity is one of the main environmental factors contributing to agricultural land degradation and a decline in worldwide crop production (Munns, 2002; Viswanathan *et al.*, 2005). For the distribution of plants and agriculture around the world, the ability of vegetation to thrive under higher salinity conditions is significant. The improvement of plant salt tolerance is an important breeding target in Areas where soil salinity is impaired (Flowers & Flowers, 2005). The ability of a plant to acclimatize to salt stress involves changes at the level of the leaf, related to morphological, physiological and biochemical characteristics that many plants adapt to high salinity and the consequent low availability of soil water (Ashraf, 2004). Halophytic plants prefer to absorb and accumulate Na^+ in their vacuoles under saline conditions and use it as an osmoticum (Glenn & Brown, 1999); nonhalophytic monocotyledons, however, tend to exclude Na^+ to preserve Na^+. A high K^+/Na^+ ratio, which seems to be essential for the tolerance of salt (Greenway & Munns, 1980). A drop in stomatal conductance and transpiration is also caused by salt tension. Stomatal closure helps to retain a higher content of leaf water under saline conditions, but this contributes to a decrease in CO_2 in the leaf level of assimilation.

Large concentrations of salts occupy plant growth through osmotic pressure, ionic imbalance and unique toxicity of ions (Cornillon and Palloix, 1997). The interactions between plant salinity and mineral nutrition are complex and not well known. Nitrogen (N) is typically the most growth-limiting plant nutrient in saline or non-saline soils among the basic elements (Irshad *et al.*, 2002) and an important factor for the economic development of vegetables (Yoldas *et al.*, 2008). The use of N fertilizers in saline soils could minimize the harmful effects of salinity on plant growth (Soliman *et al.*, 1994). Over fertilization with N, can lead to soil salinization and increase the adverse effects of salinity on plant growth (Villa-Castorena *et al.*, 2003). Spinach is extremely responsive to leafy vegetables that are moderately salt sensitive with a tolerance threshold of 2 dS m^{-1} (Shannon and Grive, 1999). This impact depends on the degree of salinity, salt composition, plant species and environmental variables (Grattan and Grieve, 1999). Na^+ and Cl^- more aggregation occurs under salinity stress, resulting in ionic imbalances and symptoms of nutrient deficiency in plants, as Na+ competes with K^+, Ca^{2+}, Mg^{2+}, and Mn^{2+}, while Cl^- limits NO_3, $H_2PO_4^-$ and SO_4^{2-} uptake (Kumar *et al.*, 2008).

Recent observations have shown that standard crop production is becoming more limited thanks to the rising degree in salinity of certain areas and therefore the expansion of salt affected areas as a result of more saline water intrusion. Salinity has gained little or no coverage within the country within the past. Increased pressure demands more food for an increasing population. The likelihood of accelerating the potential of those (saline) lands for increased crop production has thus become increasingly necessary to explore. It needs an assessment of the prevailing state of salinity-impacted land areas.

Considering the importance and constrains to cultivate spinach in saline areas of Bangladesh an investigation was carried out with the following objectives:

- To assess the effect of salinity on some morpho-physiological characters in spinach.
- To evaluate the early seedling growth of Indian spinach under different salinity level.
- To find out the relative performance of two varieties of Indian spinach.

CHAPTER II

REVIEW OF LITERATURE

Spinach is a very important vegetable crop in Bangladesh and is especially valued for its foliage. Many research studies have been carried out on spinach, but there is still insufficient information about salinity tolerance in spinach varieties and their effects on growth, yield and quality parameters (Van Hoorn *et al*., 1993). Some of the relevant and insightful works carried out in this aspect at home and abroad have been checked under the following headings:

Soil Salinity

Salinity is one of the most brutal environmental factors restricting crop plant productivity since most crops, including spinach are susceptible to salinity caused by high salt concentrations in the soil, and the soil affected area by it rises day by day.

It is one of the major constraints of spinach production in Bangladesh's coastal region. The presence of excess quantities of soluble salts in the soil and water induces salinity. The dissolved salt concentration is known as salinity in a given volume of water. Salts are compounds which dissolve into ions, such as sodium chloride, magnesium sulfate, potassium nitrate and sodium bicarbonate. The chemical properties of salinity are temperature and pressure dependent.

The salinity of the soil is measured by calculating the electrical conductivity of the solution extracted from the soil paste, which is water-saturated. Salinity is abbreviated as ECe (Electrical Extract Conductivity) with decisiemens per meter (dSm^{-1}) or millimhos per centimeter (mmhos/cm) units. Both are measurement units which are identical and give the same numerical value. Salinity is expressed either in grams of salt per kilogram of water or in parts per thousand kilograms of water (ppt or percent).

Soil classifications based on EC are provided in dSm^{-1}:

EC 0- 2: Non-saline soil
EC 2-4: Slightly saline, decreased yield of sensitive crops
EC 4- 8: moderately saline, reduction in yields of many crops
EC 8-16: natural yield for salt-tolerant crops only

EC > 16: Acceptable crop yields for very tolerant crops only

Salinity Lab of the US. Employees. (1954) found that a saline soil is classified by the USDA Salinity Laboratory as having an EC of 4 dSm^{-1} or more. U.S. Salinity Laboratory Workers (1954) also found that soil salinity with an electrical conductivity greater than 2 dSm^{-1} at 25° C, an exchangeable sodium percentage (ESP) less than 15 and a pH less than 8.5 was recommended by the Soil Science Society of America (1979).

Manneh (2004) indicated that two salts of calcium salts and sodium salts can be defined as salt stress, although most of the salt stresses in nature are due to Na salts, especially NaCl. It is possible to identify salinity effects as osmotic, toxic, or nutritional. It is possible to identify salinity effects as osmotic, toxic, or nutritional. Main salt injury may be called salt stress inducing toxicity and that causing osmotic stress and nutritional stress (including other nutrient deficiency) is secondary salt-induced stress.

Hu and Schmidhalter (2002) noted that, under salt stress, agricultural crops exhibit a variety of responses. In addition to reducing the agricultural production of most crops, salinity affects the physicochemical properties of the soil and the ecological balance of the region. Low agricultural productivity, low economic returns, and soil erosion are among the impacts of salinity.

Hasan *et al.* (2018) estimated that Bangladesh's coastal zone occupies about 20 percent of the country's total land and over 30 percent of the cultivable land. Water-related hazards due to climate change are likely to become a critical problem for Bangladesh, according to the National Adaptation Program of Action (NAPA). In Bangladesh's coastal region, salinity in surface water, groundwater and soil has become a dominant threat. The results indicate that the western area is a very high saline zone and that, in terms of soil salinity, the eastern region is a medium saline zone. This study seeks to classify the saline affected region from 1973 to 2009 and also aims to provide a risk map of salinity in the southern part of Bangladesh. The amount of the saline affected area is called the parameter and the salinity risk maps are prepared by normalizing the amount of affected areas. Over the last four decades, varying degrees of salinity have affected around 0.223 million ha (26.7 percent) of new land. The highest saline affected area is located in the Patuakhali District of Galachipara Upazila, while the lowest saline affected area is found in the Barisal District of Maladi Upazila. In Khulna, Bagerhat, Satkhira, Patuakhali districts, the saline affected areas are rising. The risk map shows that the lower center and the corner of southern Bangladesh fall within a high and very high risk region.

Aslam *et al.* (2017) revealed that salinity is one of the most destructive abiotic stresses, whether primary or secondary, that disturbs plants from germination to physiological maturity. In arid areas that receive low annual precipitation and are vulnerable to high evapotranspiration, this issue is more severe. Land under salinity stress is increasing on daily basis and it is thought that about half of the fertile land would become saline by the year 2050. The effects of salinity are highly diverse and depends on sizable amount of things like amount, intensity and duration of salinity and crop growth stages. Increased absorption of pairs of toxic ions with minimal uptake of essential minerals results in a substantial decrease in enzymatic activity and cell metabolism disruption.

Payo *et al.* (2017) indicated that understanding the dynamics of salt movement in the soil is a prerequisite for the creation of appropriate management strategies for coastal regions' land productivity, especially low-lying delta regions, which support many millions of farmers worldwide. In this report, we are developing a new holistic approach to soil salinization simulation that includes an emulator-based soil salt and water balance measured at regular time levels. For the agricultural areas of coastal Bangladesh (about 20,000 km^2), this method is seen. This shows that under multiple land applications, including rice crops, combined shrimp and rice farming, as well as non-rice crops, we can replicate the dynamics of soil salinity. For 2009, the model also reproduced the observed spatial soil salinity well. We have estimated soil salinity for three distinct climate classes using this method, including a relative increase in sea level for the year 2050. Projected alterations in soil salinity are substantially smaller than other predictions recorded. The findings indicate that inter-season weather variability is a main driver of coastal Bangladesh's agricultural soil salinization.

Saha (2017) recorded that households in Bangladesh's coastal areas are undertaking various adaptation and coping measures to scale back their vulnerability to cyclone hazards and salinity intrusion, with little attention given to these autonomous measures in the past. The Government of Bangladesh, however, has recently stressed the importance of recognizing these steps so that the required strategies can be implemented to make households more resilient to natural hazards and the adverse effects of climate change. Centered on secondary sources, this paper discusses adaptation and coping measures that households pursue to mitigate their vulnerability to cyclone hazards and salinity intrusion in the coastal areas of Bangladesh. This paper shows that many adaptation and coping measures help to make households less vulnerable and more resilient to cyclone hazards and salinity intrusion, while some coping measures do the reverse, instead of strengthening them, by decreasing the adaptive ability of households. Adaptation and coping steps that lead to reducing the vulnerability of households to natural hazards need to be assisted and directed to make them more successful by the government and NGOs.

Khanom (2016) researched the experience of local people with salinity intrusion in the SW area of the inner coast. Five focus group discussions and eight interviews were conducted in accordance with the semi-structured & open ended questionnaire to outline the relationship between food safety and salinity intrusion in crop production and investigate the effect of salinity on crop production. The study found that salinity is favorable for rice cultivation in both soil and water, while yield losses have increased each year. The Population has moved from indigenous to high yield rice varieties in order to increase productivity and to cope with soil salinity, in turn increasing the use of fertilizers and pesticides. In addition, the production of oil seeds, sugar cane and jute has been stopped for twelve years due to failure to cope with the current level of salinity. A lack of fresh water in the dry season and saline invasion from the sea via downstream rivers are several other explanations suggested for saline intrusion. The research proposes to rigorously quantify impacts and imply required adaptation by defining salinity in the study region, even though the saline level is favorable for rice, to protect the interior coast from misery, such as external coastal districts.

Dasgupta *et al.* (2015) conducted a study estimating location-specific soil salinity for 2050 in coastal Bangladesh. The study was carried out in two stages: first, the changes in soil salinity for the period 2001-2009 were evaluated using information collected by the Soil Science Development Institute at 41 soil monitoring stations. Using these data, a spatial econometric model was calculated to connect soil salinity with nearby river salinity, elevation of land, temperature, and precipitation. Second, from climate-induced changes in river salinity and rainfall and temperature forecasts based on time trends for 20 Bangladesh Meteorological Department weather stations in the coastal region, future soil salinity has been estimated for 69 coastal sub-districts. The results show that in coastal Bangladesh, climate change presents a serious risk of soil salinization. The annual median estimated change in soil salinity is 39 percent by 2050, across 41 monitoring stations. Above the median, 25 percent of all stations have expected 51 percent or greater improvements.

Gupta *et al.* (2014) noted that salinity, due to the growing use of poor water quality for irrigation and soil salinization, is a major abiotic stress that restricts plant growth and productivity in many areas of the world. Complex physiological features, metabolic pathways, and molecular or gene networks are involved in plant adaptation or resistance to salinity pressure. For the production of salt-tolerant varieties of plants in salt-affected areas, a thorough understanding of how plants react to salinity stress at different levels and an integrated approach to integrating molecular resources with physiological and biochemical techniques are crucial. Different adaptive responses to salinity stress at genetic, cellular, metabolic, and physiological levels have been established in recent studies, although the mechanisms underlying salinity tolerance are far from fully understood.

Habiba *et al.* (2014) recorded that salinity in the coastal region of Bangladesh is one of the major problems, contributing to 20 percent of the total land area. Different degrees of salinity affect about 53 percent of the coastal area. In this location, salinity intrusion is mainly derived from climate change and anthropogenic factors that render the region more vulnerable. Salinity intrusion therefore has detrimental effects on the region's water, soils, crops, fisheries, habitats, and livelihoods. This chapter illustrates how individuals and societies have attempted multiple adaptation steps to reduce salinity effects in order to ensure the availability of food and drinking water. In addition, it further exposes the behavior of government and other development organizations against salinity to reduce its impact.

Mahmuduzzaman *et al.* (2014) suggested that in the coastal region, water salinity is highly dependent on the Himalayan ice melting and the discharge of the rivers Ganga, Brahmaputra and Meghna. The average annual flow of these rivers is 1.5 million cases, typically marked by seasonal variation. Salinity is responsible for the peak flow (80%) in the monsoon and lean flow (20%) in the winter/dry season. The reduction in ice melting decreases the discharge of river water and thus increases salinity in the country's coastal region.

Abedin *et al.* (2012) stated that the southwest coastal area is part of the broad Himalayan river's inactive delta and is covered by the Sundarban mangrove forest from tidal surges. This region is the centre of cyclones, tidal waves, flooding, drought, salinity intrusions, repeated waterlogging, and land subsidence for all forms of disasters. The more common disasters are cyclonic tidal waves and flooding, and their impacts are often encountered at the local level. But local livelihoods, people and habitats in this area are threatened by silent and invisible disasters, such as increased salinity, arsenic pollution, and drought. The southwestern region's susceptibility to increased salinity, arsenic pollution and drought is the product of a dynamic interrelationship between the country's biophysical, social, economic and technological features. In addition, the country is likely to be affected by the greatest, longest-lasting, global yet silent catastrophe in the current and near future: increased salinity, natural arsenic pollution, and drought. Because of natural disasters, this region is also considered to be the most disaster-prone region in Bangladesh and highly vulnerable to the effects of climate change.

Islam (2011) examines the approximation of water salinity in the Sundarban rivers, which will be regarded as a decision-making instrument. It will lead to the creation of an interdisciplinary management plan and to ensure that the Ganges supplies fresh water to the Sundarban for the conservation of mangrove habitats. In the Ganges catchment area, regarded as the world's single largest mangrove forest and unique ecosystem, the Sundarban is located. It has an area of 6017 km2 and a natural barrier shielding the coastal area against storm surges and cyclones. In the regional economy and ecosystems, it also plays a potential role. As a result, the water and soil salinity have penetrated since the diversion of Ganges water at Farakka Barrage in India in early 1975. Consequently, water quality in the Sundarban rivers and threats to mangrove habitats have degraded both siltation and increased salinity. At present, because of high salinity intrusion, ground water use in the study region is less. Data from time series for four years (13 rivers) were used for water salinity modeling for salinity investigation. The aims of this paper are to examine the approximation of water salinity in the Sundarban rivers, which will be used as a decision-making method. It will lead to the creation of an interdisciplinary management plan and to ensure that fresh water for the conservation of mangrove habitats is supplied to the Sundarban by the Ganges.

SRDI (2010) has stated that varying degrees of soil salinity affect the cultivable areas in coastal districts. It has been recognized that 8,142 km^2 (5.5 percent of the country) of land in the coastal zone is affected by salt and is increasing at an annual rate of 146 km^2. Over the past decades, salinity intrusion has increased in the coastal areas of Bangladesh. A retrospective analysis of the salt affected region from 1973 to 2009 found that over the last four decades or so, approximately 0.223 million ha (26.7 percent) of new land was affected by varying degrees of salinity. From 2000 to 2009, it was also found that about 35,440 hectares (3.5 percent) of new land had been affected by varying degrees of salinity intrusion over the last 9 decades. Shrimp cultivation plays a major role, along with other variables, in increasing soil salinity, particularly in southwestern coastal areas. Several aspects of reproductive growth, including flowering, pollination, fruit development, yield and food quantity, and seed production, are adversely affected by salinity. In plants, salt injury signs imitate drought. Water stress (wilting) and reduced growth define both conditions. Extreme damage due to prolonged exposure or high salinity results in tissue death and stunted plants. Reduced salinity growth is a progressive condition that rises as salinity increases above the threshold of tolerance of a plant tree species survival in salt affected areas in the homestead forests and they have found that tree growth (2 percent per year) and vegetation coverage have been reduced (1.87 percent per year). In coastal districts, soil salinity is heavily responsible for affecting cultivable land. It has been accepted that 8,142 km^2 (5.5 percent of the country) of land is affected by salt and is growing at an annual rate of 146 sq. km.

Effect of salinity on growth and development

Akbarimoghaddam *et al.* (2011) noted that salinity effects are the result of complex interactions between morphological, physiological, and biochemical processes, including germination of seeds, growth of plants, and absorption of water and nutrients.

Bano and Fatima (2009) noted that almost all aspects of plant growth are influenced by salinity, including germination, vegetative growth and reproductive development. Soil salinity imposes ionic toxicity, osmotic stress, deficiency of nutrients (N, Ca, K, P, Fe, Zn) and oxidative stress on plants, thereby reducing soil water uptake. Since phosphate ions precipitate with Ca ions, soil salinity greatly decreases plant phosphorus (P) uptake.

Munns (2002) assumed that excessive sodium accumulation in cell walls could lead to osmotic stress and cell death quickly.

Blaylock *et al.* (1994) estimated that if the soil contains ample toxic elements, plants susceptible to these elements can be affected at relatively low salt concentrations. High salt levels in the soil can disrupt the nutrient balance in the plant or interfere with the absorption of certain nutrients because many salts are also plant nutrients.

Netondo *et al.* (2004) noted that, salinity also affects photosynthesis primarily through a decrease in leaf area, chlorophyll content and stomatal conductance, and to a lesser degree through a decrease in efficiency of photosystem II.

Ashraf (2004) found that by inhabiting microsporogenesis and filament elongation, improving programmed cell death in some types of tissues, ovule abortion, and fertilized embryo senescence, Salinity adversely affects reproductive development. Owing to the low osmotic ability of soil solution (osmotic stress), specific ionic effects (salt stress), nutritional imbalances or a combination of these factors, the saline growth medium has many adverse effects on plant growth.

Munns and James (2003) noted that, at physiological and biochemical levels and at the molecular level, all these factors cause adverse effects on plant growth and development.

Tester and Davenport (2003) concluded that the growth or survival of the plant is measured in order to determine the resistance of plants to salinity stress since it incorporates the up- or down-regulation of several physiological processes within the plant. For plants growing in saline media, osmotic equilibrium is important. Failure of this equilibrium results in loss of turgidity, dehydration of cells and eventually cell death.

Ashraf (2004) noted that the adverse effects of salinity on plant growth can also result from impairment of the supply to rising tissues of photosynthetic assimilates or hormones. The consequence of ion toxicity is the replacement of K^+ with Na^+ in biochemical reactions, and conformational changes in proteins caused by Na^+ and Cl^-.

Zhu (2002) found that K^+ serves as a cofactor for many enzymes and can not be replaced by Na^+. For the binding of tRNA to ribosomes and thus protein synthesis, high K^+ concentration is also necessary.

Chinnusamy *et al.* (2006) noted that metabolic imbalance is caused by ion toxicity and osmotic stress, which contributes to oxidative stress in turn.

Seckin *et al.* (2009) observed that during the reproductive process, the detrimental effects of salinity on plant growth are more profound. A salt-stress effect on the cell cycle and differentiation can be due to the adverse effects of salinity. Salinity temporarily stops the cell cycle by reducing cycling and cycling dependent kinase expression and activity, resulting in fewer cells in the meristem, thereby restricting development. Posttranslational inhibition during salt stress often diminishes the activity of cycling-dependent kinase. Recent studies also show that salinity has a negative effect on plant growth and production, impeding germination of seeds, growth of seedlings, enzyme activity.

Gupta and Huang (2014) stated that According to adaptive evolution, plants can be divided into two types: first is, halophytes ie. Plats that can survive under salt stress and second, is glycophytes i.e. which cannot survive in salt stress and die.

Shannon and Grieve (1999) found that a moderately salt-sensitive vegetable is spinach. Spinach is an essential green leafy vegetable containing large amounts of bioactive compounds and nutrients that are not common to most other vegetables, such as flavonoid derivatives of bian-coumaric acid exhibiting strong antioxidant activity and flavonoid derivatives of glucuronic acid.

Azooz *et al*. (2009) indicated that salinity tolerance in spinach plants is related to the lipid peroxidation and antioxidant enzyme activity in the leaves. Moreover salt stress induced chlorosis and necrosis of spinach leaves due to decreased chlorophyll and mineral nutrient deficiency by salinity.

Joseph *et al*. (2011) found that Many regions in the world contain soils which are too saline for economic crops which affect the plant growth through oxidative stress and osmotic effects.

Rani *et al*. (2019) elaborated that Salinity is becoming a major problem day by day due to inappropriate management of natural resources. Salinity creates water and ionic imbalance in plants due to existence of poisonous ions. Plants affected by salt stress show stunted growth and the leaf colour gets darker.

Effect of salinity on Growth and Yield

Salinity may be a major problem impacting crop production worldwide: 20% of the world's farm land, and 33% of irrigated land, is affected and depleted by salt. Climate change, the unsustainable use of groundwater (mainly near the sea), the increased use of low-quality water in irrigation and the massive introduction of irrigation associated with intensive irrigation can all accentuate this process farming.

Orcutt and Nilsen (2000) indicated that, the response of plants to salinity is complex and involves changes in morphology, physiology, and metabolism, Cellular water deficiency, ion toxicity, nutrient deficiencies, and oxidative stress are the effects of salinity on plants, leading to growth inhibition, molecular damage, and even plant death.

Ruan *et al*. (2010) reported that one of the most important problems facing agricultural crops in the world is high-salinity conditions in agricultural soil and irrigation water. Salt-affected soils are estimated to affect approximately 10 percent of the surface of the earth and 50 percent of the world's irrigated land.

Läuchli and Grattan (2007) recorded that, due to increased osmotic soil pressure and interference with plant nutrition, salts affect plant growth, reduction of the plant's capacity to acquire water, which is referred to as the osmotic or water-deficit effect of salinity. When the concentration is high enough to begin reducing crop growth, damage occurs. The salinity's osmotic effect causes metabolic changes in the plant similar to those triggered by "wilting" induced by water stress and shows few genotype variations.

Munns *et al*. (1995) indicated that the response of plant growth to salinity should be described by a two-phase model. The first step is very rapid and the creation of a water deficit is attributed to reducing growth. The second stage is due to the accumulation, at toxic levels, of salts in the shoot and is very sluggish.

Flexas *et al*. (2007) said that, salinity influences photosynthesis by minimizing the supply of CO_2 as a result of diffusion limitations and a decrease in the quality of photosynthetic pigments.

Alvino *et al*. (2000) reported that accumulation of salt in spinach inhibits photosynthesis, mainly by decreasing the conductance of stomatal and mesophyll to CO_2 and reducing the content of chlorophyll, which can affect the absorption of light.

Paranychianakis and Chartzoulakis (2005) reported that the accumulation of salt in the root zone causes osmotic stress to develop and disrupts the homeostasis of cell ions by inducing both the inhibition of the absorption of essential elements like K^+, $Ca^{2+,}$ and NO_3^- and the buildup of Na^+ and Cl^-.

Maggio *et al*. (2011) reported that in various vegetable crops under salt stress, a decrease in plant biomass, leaf area, and growth has been observed. There are actually poorly understood effects of salt stress on root architecture/morphology. Root biomass, however, has been reported to be generally less affected than aboveground organs by excess salinity.

Shannon and Grieve (1998) argued that, in plant development, visual symptoms of salt injury occur gradually. Wilting, yellowing leaves, and stunted growth are the first symptoms of salt stress. The damage manifests as chlorosis of green sections, leaf tip burning, and leaf necrosis in a second stage, and scorching occurs on the oldest leaves.

Tamaya *et al.* (2008) said that, salt stress increased the polyphenol content and reduced the concentration of nitrate ions and oxalic acid in spinach. The timing of salt stress application, which could be essential for improved irrigation (e.g., deficit irrigation) and fertilization management strategies, was also affected by the impact of salinity on vegetable yield and quality.

Rashid *et al.* (2004) explained that, due to sea level rise, salinity intrusion will decrease agricultural production through fresh water unavailability and soil degradation. Salinity also decreases some plants' terminative energy and germination rate. There is a downside to performing shrimp cultivation in saline water, and that is a decline in the yield of rice due to degraded soil quality. The decrease rate is very high, and for almost all rice fields in coastal districts the scene is prevalent.

The World Bank (2000) proposed that the rise in salinity alone from an increase in sea level of 0.3 meters would lead to a net reduction in rice production of 0.5 million metric tons. The rise in sea levels affects coastal agriculture in two ways, especially rice production. Salinity intrusion degrades the consistency of the soil, which decreases or prevents the production of rice.

Genuchten and Hoffman (1984) developed that any crop's salinity tolerance is characterized as the ability to withstand the effects of excess salt in the root zone. Models that link the decrease in relative output to the increase in soil salinity are defined as salt tolerance.

Snapp *et al.* (1991) reported that the tolerance of salt crops is rated by the salinity threshold (ECt) and the percentage increase in soil salinity above the threshold of the reduction in relative yield per unit. Most vegetable crops have a salinity threshold of approximately $\leq$2.5 dS m^{-1}.

Jamil *et al.* (2006) found that Saline water irrigation could have negative impacts on crops reduction in growth and yield.

Läuchli and Grattan (2007) suggested that tolerance determination is based on percent survival during germination and emergence, while tolerance is typically measured as relative growth reductions during the later developmental stages.

Ghane *et al*. (2011) stated that several studies have shown that the effects of salinity can be alleviated under salt stress conditions by applying nitrate and ammonium compared to growth only on nitrate or ammonium.

Lakhdar *et al*. (2014) found that by increasing root growth, modifying mineral uptake, and decreasing membrane damage, humic substances can improve the deleterious effects of salt stress, thus inducing salt tolerance.

Bashan *et al*. (2016) indicated that salt tolerance of various crops was improved by the addition of humic acids to the saline medium. Humic acid applications improved the ratios of K^+/Na^+ and Ca^{2+}/Na^+ in pepper.

Hanson and May (2011) said that irrigation methods such as surface drip irrigation (DI) and subsurface drip irrigation (SDI), furrow irrigation, and low energy precision application (LEPA) irrigation must be used where foliar damage by salts in irrigation water is a problem. Compared to other irrigation methods, DI and SDI allow better salinity control by increasing the efficiency of water usage.

Van Hoorn (1991) noted that during germination and emergence, due to the evaporation of soil water, the salinity rises significantly in the top layer of the soil and seeds are exposed to higher salinity than during later growth phases.

West *et al*. (1986) reported that, through its effect on the osmotic capacity of soil water, salinity affects the water stress of the plant. The osmotic capacity decreases with increasing salinity and thus the availability of water for the plant, resulting in increased water stress, which in turn impacts stomatal conductance, leaf growth, photosynthesis and yield.

Turhan *et al*. (2011) examined the effect of different NaCl concentrations (0 to 200 mM) on seeds of four spinach cultivars. The green gold cultivar performed best for most of the defined parameters in exposed salt levels.

Yousif *et al*. (2010) elaborated that Indian spinach performed significantly well for yield (fresh weight) under saline water treatments when compared with Sindhi spinach. This difference in yield may be attributed to genetical variance. Difference in growth and yield parameters for various crops with spinach and among spinach genotypes in saline treatments has also been observed by other researchers.

Bhatti *et al*. (2004) explained that In soil the EC, Na^+ and Cl^- values were increased with rising salt-water levels, but K^+ concentration in soil was decreased with an increase in EC levels of saline waters. The reason for increasing EC and ions (Na^+ and Cl^-) values in soil may be associated to the application of NaCl enriched saline water.

CHAPTER III

Methods and Materials

The experiment was conducted during the period from November 2020 to January 2021 at the Agroforestry field Sector, Sher-e-Bangla Agricultural University, Dhaka-1207. This chapter provides descriptions of the experimental materials and methods adopted in the analysis.

3.1 Site description

3.1.1 Geographical location

At 23°74′ N latitude and 90°35′ E longitude, the experimental area was located. The height was 8 meters above the level of the sea.

3.1.2 Agro-ecological region

The experimental area belongs to 'The Modhupur Tract' Agro-ecological Zone, AEZ-28. This was an area of complex relief and soils formed above the Modhupur clay, where the dissected edges of the Modhupur Tract were buried by flood plain sediments, leaving small hills of red soils as 'islands' surrounded by floodplain.

3.2 Characteristics of soil

The selected land in the experimental field was medium-high in nature and remained used throughout the previous season for crop production. The soil under AEZ No. 28 belongs to the Modhupur Tract. The experimental soil's texture was sandy loam. The nutrient status of the soil was collected within a depth of 0-20 cm from the farm under the experimental plot. The soil characteristics of the experiment were analyzed at the Dhaka Institute for Soil Research and Growth, and the findings were presented in Appendix I.

3.3 Climatic condition of the experimental site

The region has a sub-tropical climate, characterized by high temperatures, high relative humidity and heavy rainfall with intermittent winds during the months from April to September (Kharif season) and plenty of sunshine with little rainfall during October to March (Rabi season). The average maximum and minimum temperatures during the experimental period, respectively, were 28°C and 12°C, which were suitable for growing potatoes in the field.

3.4 Planting materials

The seeds of 'BARI Puishak 1` and 'BARI Puishak 2` of spinach variety was used in the study. The seeds of spinach were collected from Olericulture Division, Bangladesh Agricultural Research Institute (BARI), Joydepur, Gazipur.

The official name of the “Chitra’’ variety was BARI Puishak-1, a modern spinach variety was used as experimental material. BARI Puishak-1 was developed by Bangladesh Agricultural Research Institute (BARI), year of 1983. The entire plant is green at seedling stage but stem and leaf vein gradually turn to light purple, leaves are green, succulent and broad, crop duration 90-120 days. The yield of BARI Puishak-1 range from 58-60 t ha^{-1}. BARI Puishak-2 was developed in 2006 and its identifying character is very soft thick fleshy vines with large green leaves. The yield of BARI Puishak-2 range from 55-60 t ha^{-1}.

3.5 Treatments of the experiment

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

Factor: Different levels of salinity (NaCl)

i. S_0 = without salt (control)
ii. S_1 = 25 mM
iii. S_2 = 50 mM
iv. S_3 = 75 mM
v. S_4 = 100 mM
vi. S_5 = 150 mM

3.6 Design and layout of the experiment

The one-factor experiment was laid out in the the Completely Randomized Design (CRD) with six levels of salinity. The total number of pots was 36 (6×6) with three replications. Each pot was 35 cm (14 inches) in diameter and 30 cm (12 inches) in height. The distances from pot to pot 30 cm.

3.7 Pot preparation and application of the treatment

There were 36 earthen pots, each contained 6 kg of soil (4.5 kg soil and 1.5 kg cow dung). The recommended chemical fertilizer dose was of 1, 0.5, 0.5 kg of Urea, TSP and MOP respectively are used in all pots. All the fertilizers are applied during the pot preparation.

Irrigation water applied before emergence of plant. 0 dS/m, 2dS/m 4 dS/m, 6 dS/m, 8 dS/m,10dS/m, 12 dS/m,14 dS/m, and 16 dS/m treatments were prepared from 0, 1.28, 2.56, 3.84, 5.12, 6.40, 7.68, 8.96 and 10.24 gm of NaCl with 1 liter water. Pots were irrigated with NaCl solution according to treatments after 30 days of planting. Treatments were applied at 4 days interval. Total 6 times treatment were applied.

3.8 Seed sowing:

The 13 seeds of spinach was sown in each pot. Sowing date of spinach was 10 November 2020. The seeds were placed in 2-4 cm depth and then covered with soil properly

3.9 Intercultural operations

3.9.1 Application of irrigation water

Irrigation water was applied to each water cane pot and the first irrigation was carried out 3 days after the seeds were sown. The amount of irrigation water was limited to the amount that did not leach through the rim. The water was collected on the earthen plate and again poured into the pot to preserve the degree of salinity as a cure.

3.9.2 Weeding

Lightly weeding was done when required to keep the plant free from weeds. It was mostly done in vegetative stage.

3.10 Harvesting

On 5 January 2021, the crop was harvested after 56 days. It counted the number of leaves per pot and measured the yield per pot. For the elimination of moisture, the plants were sun-dried.

3.11 Recording of data

Experimental data were recorded from 9th days of germination and continued until harvest. The following data were recorded during the experiment.

3.11.1. Morphological Parameters

1. Plant height (cm)

2. Leaf length (cm)

3. Leaf wide (cm)

4. Plant diameter (mm)

5. Number of leaves pot^{-1}

3.11.2. Yield and yield contributing Parameters

6. Fresh weight of plant

7. Dry weight of plant

3.12 Detailed procedures of recording data

A brief outline of the data recording procedure followed during the study given below:

3.12.1. Plant height:

From the base of the plant to the tip of the stem, it was measured in centimeters and plant height was recorded at 30th, 39th, 47th days after planting (DAP) and at harvest respectively.

3.12.2. Number of leaves per pot:

From each selected plant sample, the number of leaves per pot was counted and registered for 47th days after planting.

3.12.3. Fresh Weight of Plants:

The fresh weight of plants was recorded after harvesting at the central laboratory, Sher-e-bangla Agricultural University, Dhaka-1207.

3.12.4 Dry Weight of Plants:

All plants were sun dried for 4 days for removing the excess moisture, and then dried at 70°C in an oven for 3 days. Just after oven drying the dried plants were weighed.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter contains a presentation of data as well as a discussion of the experiment's findings. The varied saline levels altered the growth and yield components of spinach. The findings are presented in various tables, figures, and appendices. The Appendix additionally includes data analysis of variance for various parameters. In this chapter, the findings of each parameter have been presented, discussed, and interpreted.

4.1. Morphological parameters

4.1.1. Plant height

Different salinity levels had a significant impact on plant height during the growth periods of different varieties. V_1 represent Bari Puishak 1 and V_2 represent Bari Puishak 2. The highest plant was found 88.27 cm at 50 DAT of Bari puishak 2 from table 1. Variety selection is an important against saline condition.

Table 1. Effect of varieties on plant height at different DAT

Variety	Plant height (cm)		
	30 DAT	40 DAT	50 DAT
V_1	42.53b	58.07b	73.93b
V_2	51.12a	69.23a	88.27a
LS	**	**	**
LSD $_{(0.05)}$	1.509	1.733	2.004
CV (%)	4.66	3.94	3.58

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

CV= Coefficient of variation, LS= Level of significance, LSD$_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_2 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

During the growth periods, different salinity levels had a substantial impact on plant height. Plant height reduced as salt levels increased. The Spinach variety's plant height was assessed at 30, 40, and 50 DAT (Days After Transplanting), and it varied dramatically due to salt application. Table 2 demonstrated this. The highest plant height 106.91 cm was found from S_0 (control) followed by 98.92 cm from S_1 (25 mM) at 47 DAT. Then the height of plant gradually reduced with increasing of salinity level as 89.04 cm, 79.62 cm, 62.84 cm with S_2, S_3, S_4 (50 mM, 75 mM and 100 mM NaCl respectively) and the shortest plant height as 49.30 cm was found in S_5 treatment at 50 DAT. Salinity has a considerable impact on plant height, according to Levy (1986). Plant height was lowered by around 17 percent in treatments S_3 and S_4 compared to the control treatment within the first 20 days following application. Throughout the whole growing period, this limitation of plant growth remained more or less consistent. Withholding watering for two weeks, on the other hand, lowered plant height by 25% (S_5). According to Alam *et al.* (2004), the essential salinity level for rice seedling growth is around 6 dS/m. At electrical conductivity values of 6-8 dS/m, the most common saline effect was retardation of plant growth, resulting in less noticeable leaf withering and significant reductions in growth metrics such as dry matter, seedling height, root length, and sprouting of new roots. Because seedling height, root length, and seedling dry weight were all substantially linked with the saline stress tolerance index, these parameters were expected to be useful in determining varietal salt tolerance ratings at an early stage of growth.

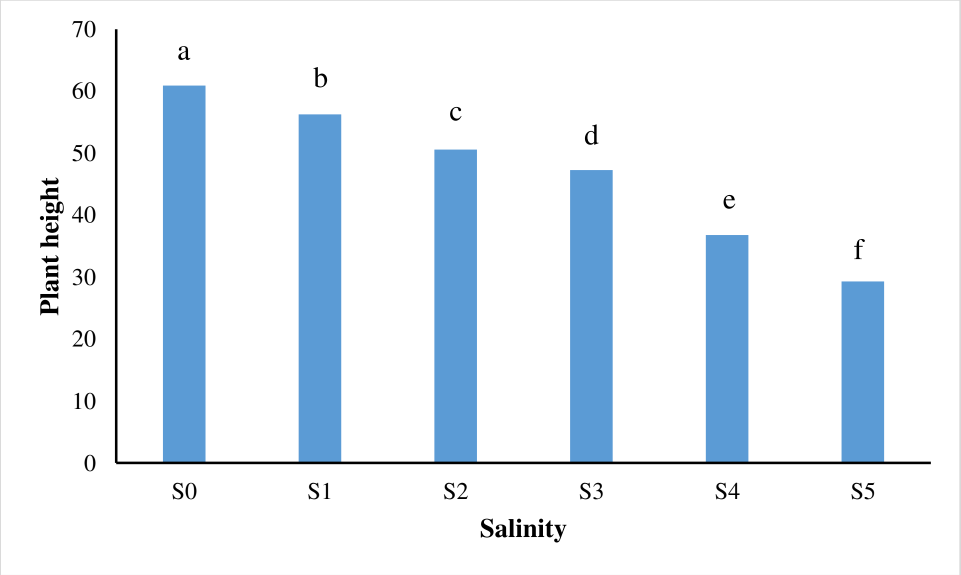

Fig. 01: Effect of salinity on plant height at 30 DAT

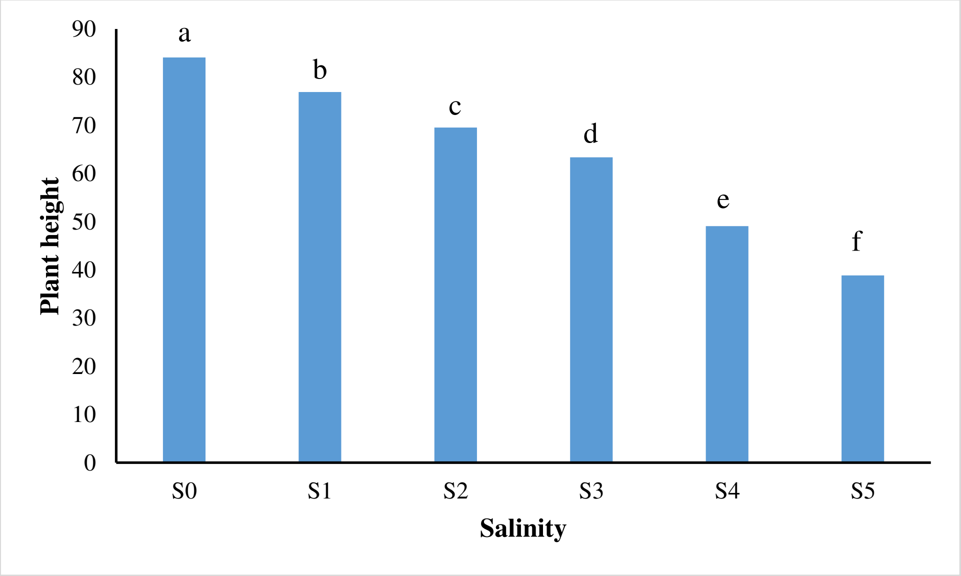

Fig. 02: Effect of salinity on plant height at 40 DAT

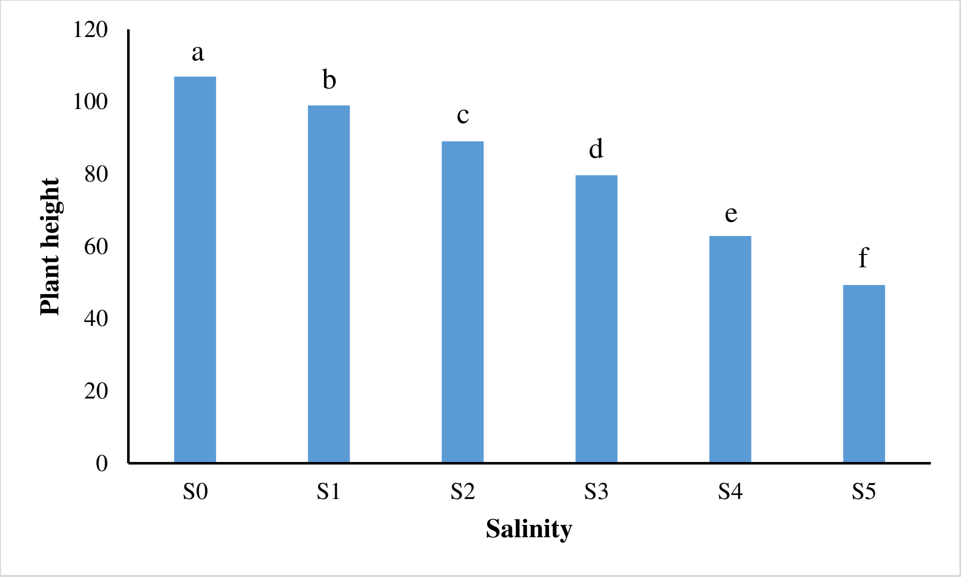

Fig. 03: Effect of salinity on plant height at 50 DAT

Salinity stress lowers the development and yield components of spinach by altering endogenous growth hormones. Physiological reactions such as changes in water status, mineral nutrition, ion balance, stomatal behavior, and photosynthetic effectiveness all contribute to the decline in growth. A drop in fresh or dry weight occurs when salt rises. The effects of salt on plant height at various DATs are the result of the interaction between variety and salinity. The highest value 115.10 cm in V_2S_0 and lowest value 46.38 cm in V_1S_5.

Table 2. Interaction effect of varieties and salinity on plant height at different DAT

Interaction	Plant height (cm)		
	30 DAT	40 DAT	50 DAT
V_1S_0	56.55c	77.79c	98.71c
V_1S_1	51.90d	70.14d	90.57d
V_1S_2	44.58e	62.40e	79.50e
V_1S_3	41.58e	57.07f	72.98f
V_1S_4	32.60g	44.03g	55.46g
V_1S_5	27.94	37.00h	46.38h
V_2S_0	65.20a	90.38a	115.10a
V_2S_1	60.55b	83.67b	107.27b
V_2S_2	56.55c	76.63c	98.58c
V_2S_3	52.89cd	69.71d	86.26d
V_2S_4	40.92e	54.18f	70.21f
V_2S_5	30.61fg	40.79gh	52.23g
LS	*	*	*
$LSD_{(0.05)}$	3.697	4.245	4.910
CV (%)	4.66	3.94	3.58

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

4.1.2. Number of branches/plant:

During the growth periods, different salinity levels had a substantial impact on number of branches of different varieties. The highest value was found 11.10 cm at 50 DAT of V_2 (Table 3).

Table 3. Effect of varieties on Branch number at different DAT

Variety	Branch number		
	30 DAT	40 DAT	50 DAT
V_1	4.32b	7.86b	9.24b
V_2	5.20a	9.35a	11.10a
LS	**	**	**
LSD $_{(0.05)}$	0.148	0.239	0.298
CV (%)	4.57	4.02	4.25

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

The effect of various salinity levels on the number of branches is depicted in the diagram. Due to the application of varying levels of salt, the number of branches/plant measured at 30, 37 and 50 DAP. The number of branches/plant in the salt-treated treatment was found to be lower than in the control treatment for S_3, S_4, and S_5. S_0 (control treatment) was found to produce the highest number of branches. The number of branches were recorded as 13.51, 12.41, 11.14, 9.96, 7.86 and 6.16 cm in S_0, S_1, S_2, S_3, S_4 and S_5 (0 mM, 25 mM, 50 mM, 75 mM, 100 mM and 150 mM respectively) treatment at harvest respectively. S_5 (150 ds/m) treatment produced the lowest number of branches. With increasing the DAT with treatment, the number of branches was decreased gradually.

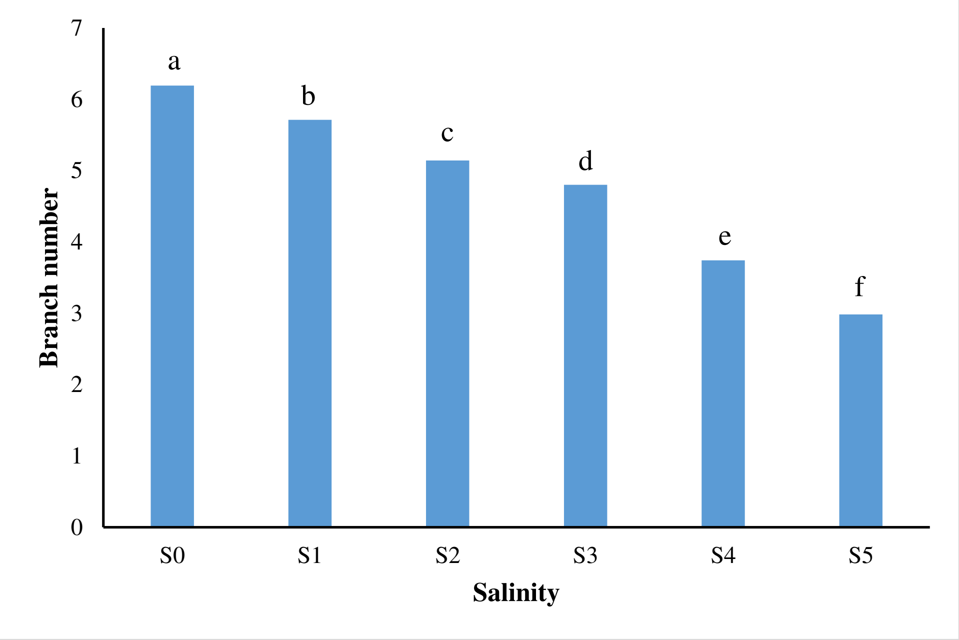

Fig. 04: Effect of salinity on Branch number at 30 DAT

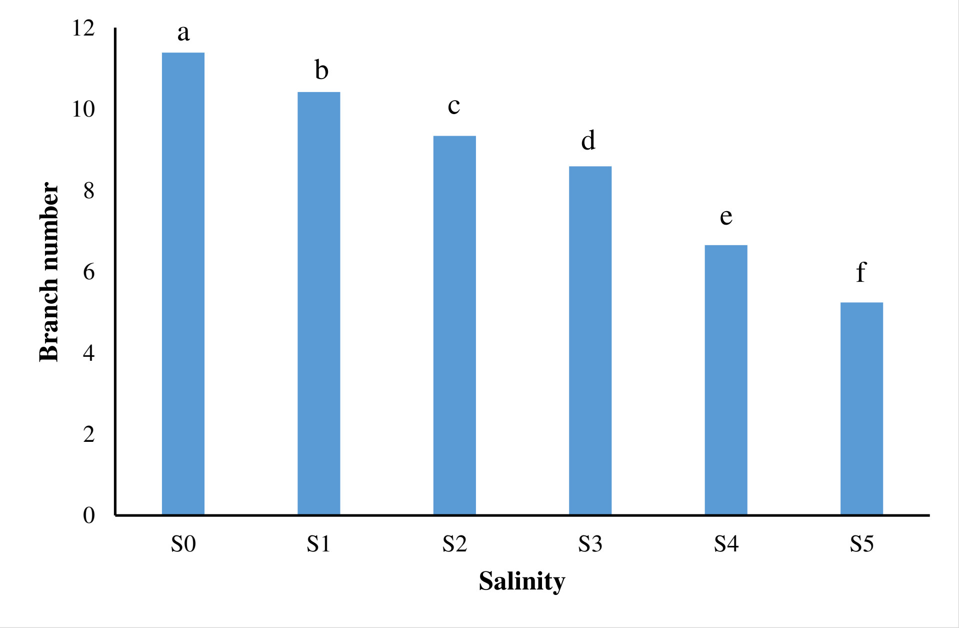

Fig. 05: Effect of salinity on Branch number at 40 DAT

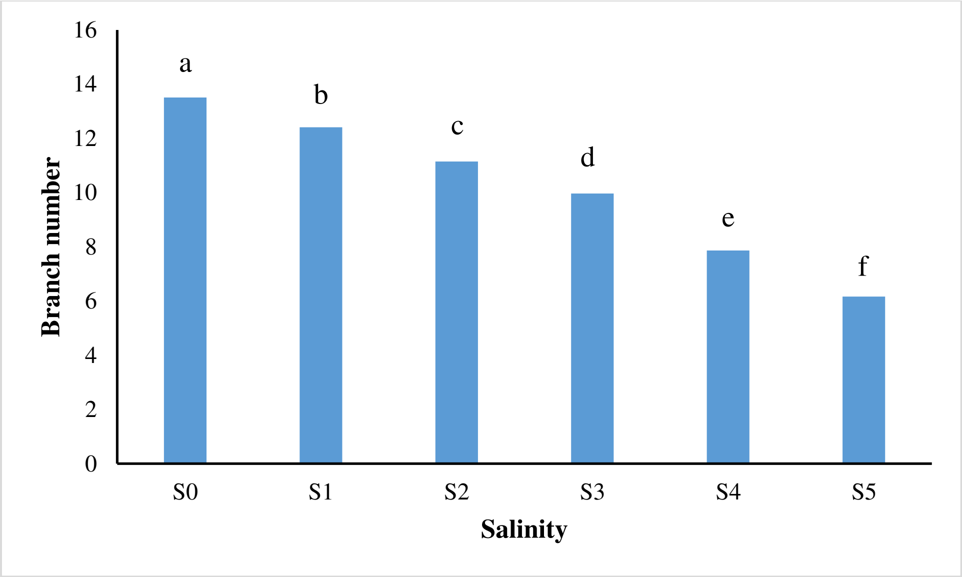

Fig. 06: Effect of salinity on Branch number at 50 DAT

Salinity have interaction effect of varieties and salinity on Branch number at different DAT of different varieties. Salt stress is a serious issue in crop production, and secondary salinization in protected cultivation soil has become one of the most significant variables influencing crops. Salt stress has an impact on plant cell physiological functions. As a result, their production is almost halved, and their product quality suffers. The products of the selected cultivar (Indian Spinach) were much higher than those of the native cultivar, especially at high saline levels (Table 4)

Table 4. Interaction effect of varieties and salinity on Branch number at different DAT

Interaction	Branch number		
	30 DAT	40 DAT	50 DAT
V_1S_0	5.75c	10.54c	12.35c
V_1S_1	5.27d	9.50d	11.33d
V_1S_2	4.53e	8.45e	9.94e
V_1S_3	4.23ef	7.73f	9.13f
V_1S_4	3.31g	5.95g	6.93g
V_1S_5	2.84h	4.98h	5.75h
V_2S_0	6.63a	12.25a	14.68a
V_2S_1	6.15b	11.34b	13.48b

V_2S_2	5.75c	10.22c	12.33c
V_2S_3	5.38d	9.45d	10.79d
V_2S_4	4.16f	7.34f	8.78f
V_2S_5	3.11gh	5.49gh	6.57g
LS	**	**	*
LSD $_{(0.05)}$	0.364	0.585	0.731
CV (%)	4.57	4.02	4.25

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

4.1.3. Leaf length of plant:

Salinity levels had a substantial bearing on leaf length of different varieties plants. The utmost value was found 8.46 cm of Bari Puishak 2 (Table 5).

Table 5. Effect of varieties on Leaf length at different DAT

Variety	Leaf length (cm)		
	30 DAT	39 DAT	47 DAT
V_1	4.76b	6.16b	7.32b
V_2	5.02a	6.51a	8.46a
LS	0.154	0.219	0.223
LSD $_{(0.05)}$	**	**	*
CV (%)	4.57	5.02	4.09

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

The effect of different salinity levels on the leaf length of plant is shown in (Figure 7-9). The leaf length of plant was leisurely at 30, 40 and 50 DAT respectively varied significantly due to the application of different level of salt. For S_3, S_4 and S_5 treatments it was observed the leaf length of plant decreased in salt treated treatment in comparison to the control treatment. S_0 (control treatment) was found to produce the highest number of branches. The number of branches were verified as 10.62, 9.13, 8.39, 7.77, 6.51 and 4.91 in S_0, S_1, S_2, S_3, S_4 and S_5 (0 mM, 25 mM, 50 mM, 75 mM, 100 mM and 150 mM respectively) treatment at harvest respectively. S_5 (150 mM) treatment produced the lowest number of branches. With increasing the DAT with treatment, the leaf length of plant was decreased gradually.

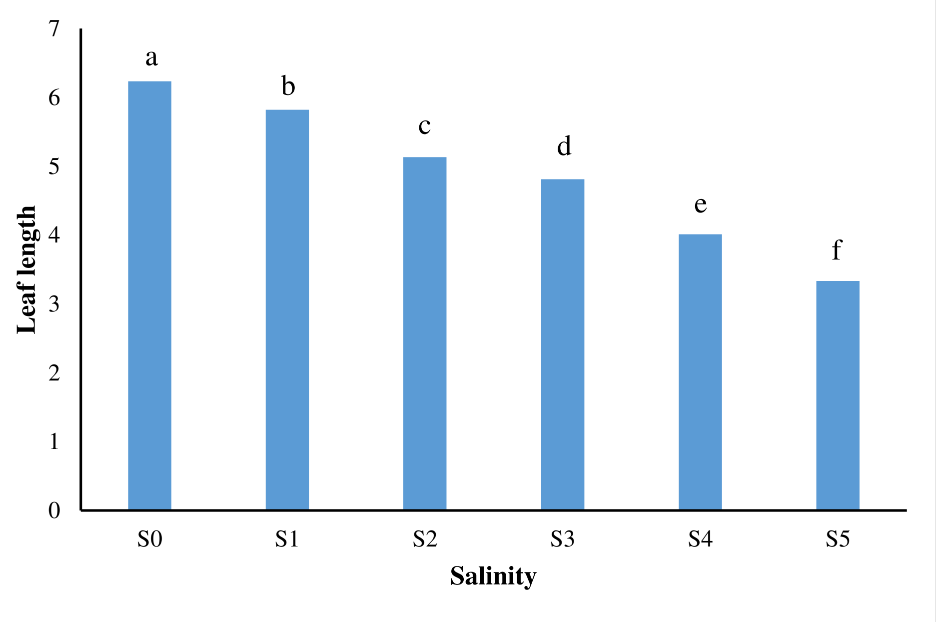

Fig. 07: Effect of salinity on Leaf length at 30 DAT

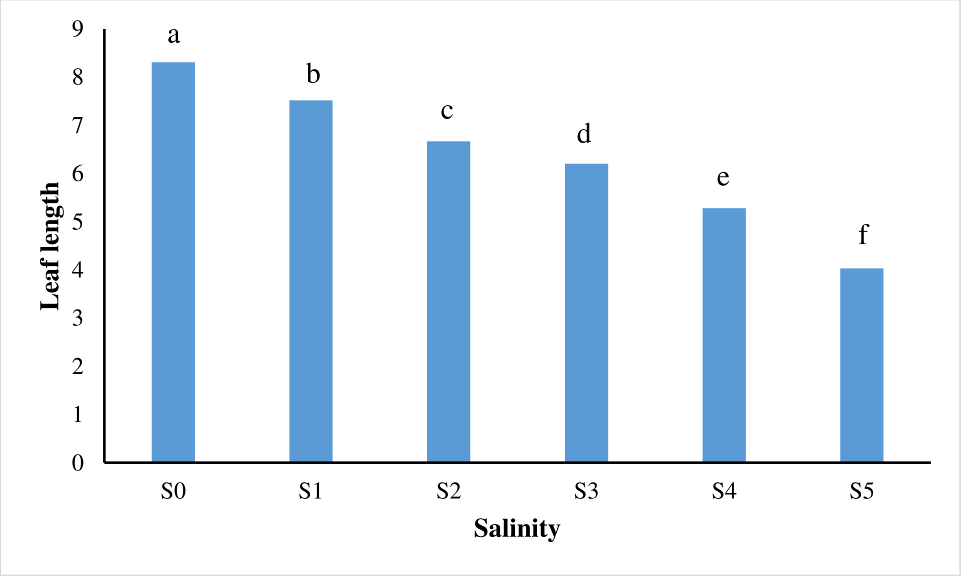

Fig. 08: Effect of salinity on Leaf length at 40 DAT

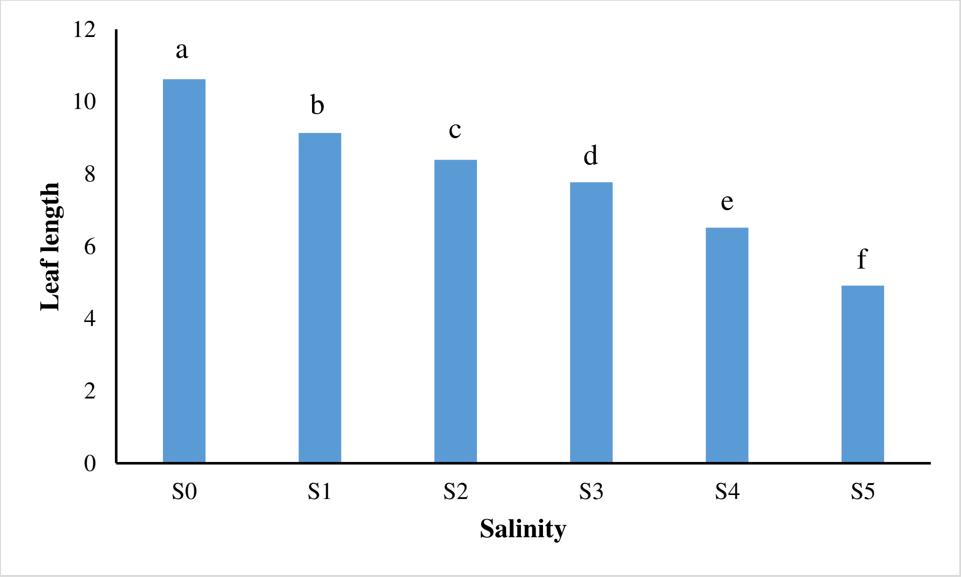

Fig. 09: Effect of salinity on Leaf length at 50 DAT

Different salt concentrations had a substantial impact on the length of spinach leaves at different stages of development. The length of spinach leaves has clearly increased with the passage of time. At 50 DAT, the greatest leaf length (11.25 cm) was observed in V_2S_0, whereas the minimum leaf length (3.94 cm) was observed in the V_1S_5 treatment.

Table 6. Interaction effect of varieties and salinity on Leaf length at different DAT

Interaction	Leaf length (cm)		
	30 DAT	40 DAT	50 DAT
V_1S_0	6.06	8.00b	10.00b
V_1S_1	5.66	7.36c	8.72d
V_1S_2	5.00	6.59de	7.68ef
V_1S_3	4.78	6.27de	7.45f
V_1S_4	3.97	5.24f	6.12h
V_1S_5	3.11	3.47h	3.94i
V_2S_0	6.41	8.62a	11.25a
V_2S_1	5.98	7.67bc	9.55bc
V_2S_2	5.26	6.75d	9.11cd
V_2S_3	4.83	6.13e	8.10e
V_2S_4	4.06	5.31f	6.89g
V_2S_5	3.56	4.58g	5.87h
LS	NS	*	*
LSD $_{(0.05)}$	0.736	0.537	0.546
CV (%)	4.57	5.02	4.09

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

CV= Coefficient of variation, LS= Level of significance, LSD$_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

4.1.4. Leaf wide:

Leaf width is a significant element for spinach yield among the growth and yield influencing characters. With the passage of time, it is clear that the width of the leaf has risen. It varies substantially depending on the variety and salt treatment. Salinity levels had a considerable posture on leaf wide of different varieties plants. The maximum value was found 7.22 cm of Bari Puishak 2 (Table 7).

Table 7. Effect of varieties on Leaf wide at different DAT

Variety	Leaf wide (cm)		
	30 DAT	39 DAT	47 DAT
V_1	4.59b	5.74b	6.71b
V_2	4.83a	6.05a	7.22a
LS	**	**	**
LSD $_{(0.05)}$	0.170	0.219	0.182
CV (%)	5.24	5.38	3.78

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

CV= Coefficient of variation, LS= Level of significance, LSD$_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

The effect of various salinity levels on the number of branches is depicted in the diagram (Figure 10-12). Due to the administration of varying levels of salt, the leaf width was assessed at 30, 39, and 47 DAT and differed significantly. For S_3, S_4 and S_5 treatments it was observed the leaf wide decreased in salt treated treatment in comparison to the control treatment. S_0 (control treatment) was found to produce the highest number of branches. The leaf wide of plants were recorded as 8.42, 7.87, 7.23, 6.72, 6.23 and 5.32 cm in S_0, S_1, S_2, S_3, S_4 and S_5 (0 mM, 25 mM, 50 mM, 75 mM, 100mM and 150 mM respectively) treatment at 47 DAT respectively. S_5 (150 mM) treatment produced the lowest leaf wide of plants. The number of branches significantly decreased when the DAT was increased with therapy.

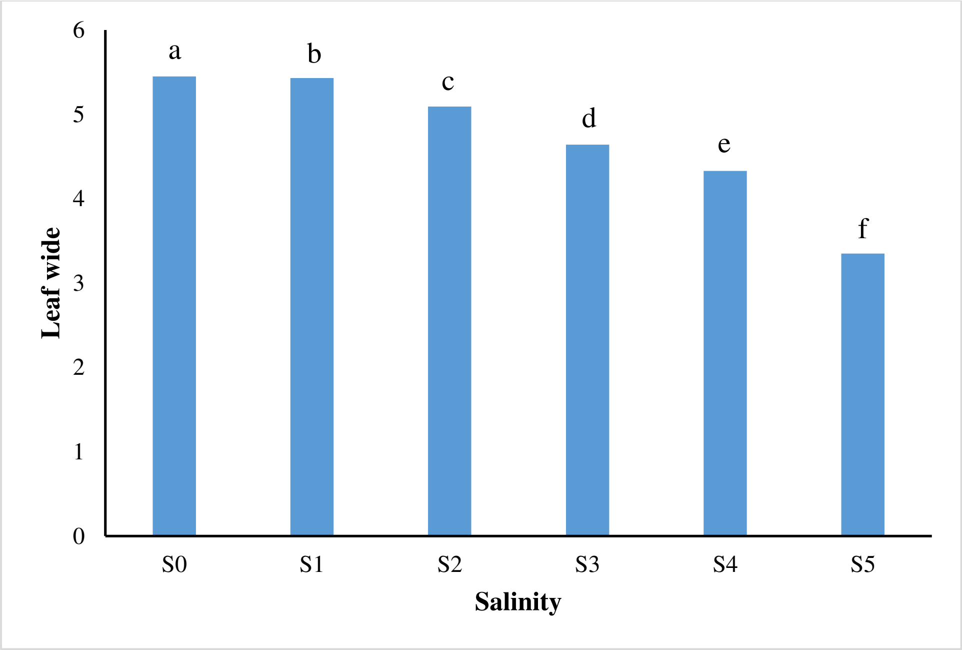

Fig. 10: Effect of salinity on Leaf wide at 30 DAT

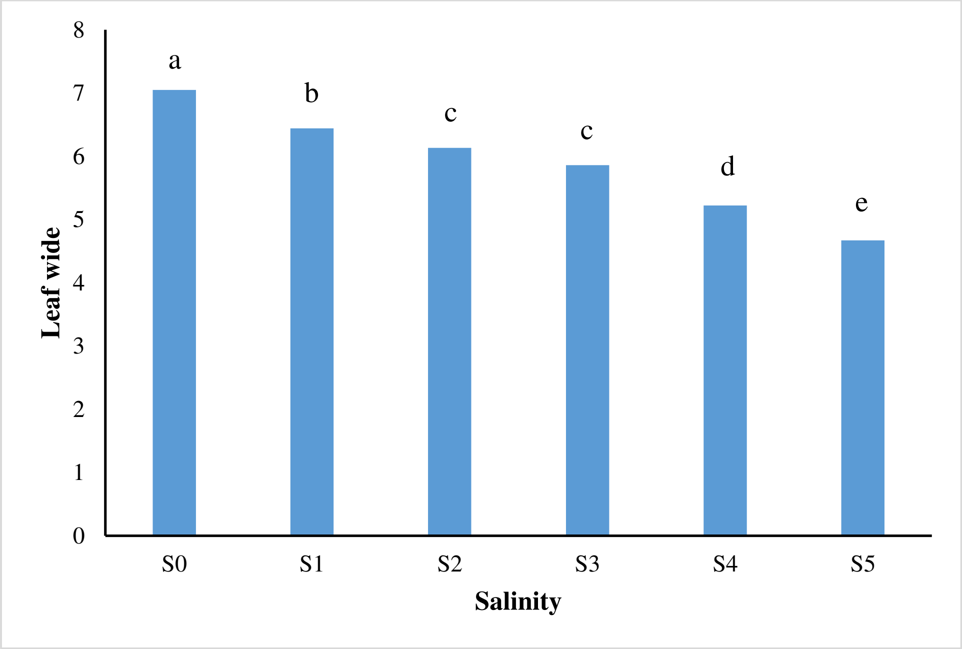

Fig. 11: Effect of salinity on Leaf wide at 40 DAT

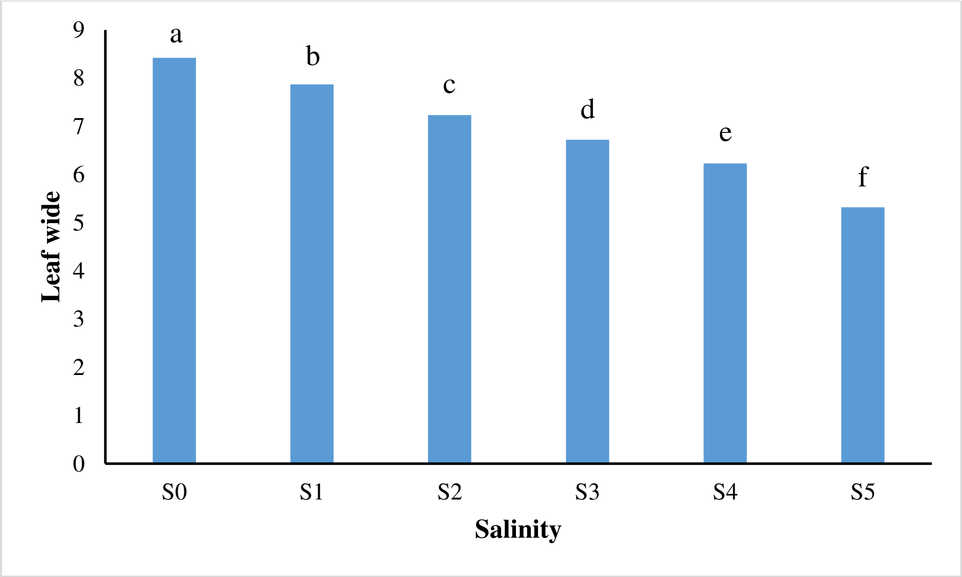

Fig. 12: Effect of salinity on Leaf wide at 50 DAT

The width of the leaf grew wider as time passed, i.e. on different days. The longest leaf wide (8.71 cm) was achieved, while the shortest leaf length (4.50 cm) was discovered. High salt concentrations up to 50 DAT resulted in shorter leaf lengths (4.50 cm), whereas lower salt concentrations resulted in longer leaf lengths (8.71 cm).

Table 8. Interaction effect of varieties and salinity on Leaf wide at different DAT

Interaction	Leaf wide (cm)		
	30 DAT	39 DAT	47 DAT
V_1S_0	5.30a-c	6.65b	8.12b
V_1S_1	5.68a	6.44bc	7.57c
V_1S_2	5.20b-d	6.13b-d	7.18cd
V_1S_3	4.49f	5.97cd	6.65ef
V_1S_4	4.02g	5.08f	6.24fg
V_1S_5	2.87h	4.18g	4.50h
V_2S_0	5.59ab	7.45a	8.71a
V_2S_1	5.18b-d	6.43bc	8.17b
V_2S_2	4.97c-e	6.12b-d	7.27c
V_2S_3	4.79d-f	5.76de	6.80de
V_2S_4	4.63ef	5.35ef	6.22fg

V_2S_5	3.83g	5.17f	6.15g
LS	**	**	**
LSD $_{(0.05)}$	0.417	0.537	0.446
CV (%)	5.24	5.38	3.78

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

CV= Coefficient of variation, LS= Level of significance, LSD$_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

4.1.5. Leaf Area:

The leaf area of spinach was significantly affected by variety and salt content. The value 62.68 cm^2 of Bari Puishak 2 was found to be the highest value (Table 9).

Table 9. Effect of varieties on Leaf Area at different DAT

Variety	Leaf Area (cm^2)		
	30 DAT	40 DAT	50 DAT
V_1	22.79b	36.61b	51.31b
V_2	24.75a	40.42a	62.68a
LS	**	**	**
LSD $_{(0.05)}$	1.252	2.455	1.011
CV (%)	7.62	9.22	6.56

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

CV= Coefficient of variation, LS= Level of significance, LSD$_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

Different salinity levels resulted in a considerable difference in leaf area index (Figure 13-15). As saline levels dose, the area of the leaves shrank. S_0 (control) yielded the highest leaf area index of 89.54 cm^2 at 50 DAP, whereas S_5 (150 mM) yielded the lowest leaf area index of 26.93 cm^2 at same DAT. The results showed that as salinity levels increased at different DAT, the leaf area index fell gradually. Salinity or drought, according to Jefferies (1993), drastically reduced the final size of Spinach leaves. When the crop was irrigated with the more saline water (62 percent), there was a significant reduction in leaf area. The greatest reduction in leaf area was seen in S_5, which was reduced by 86%.

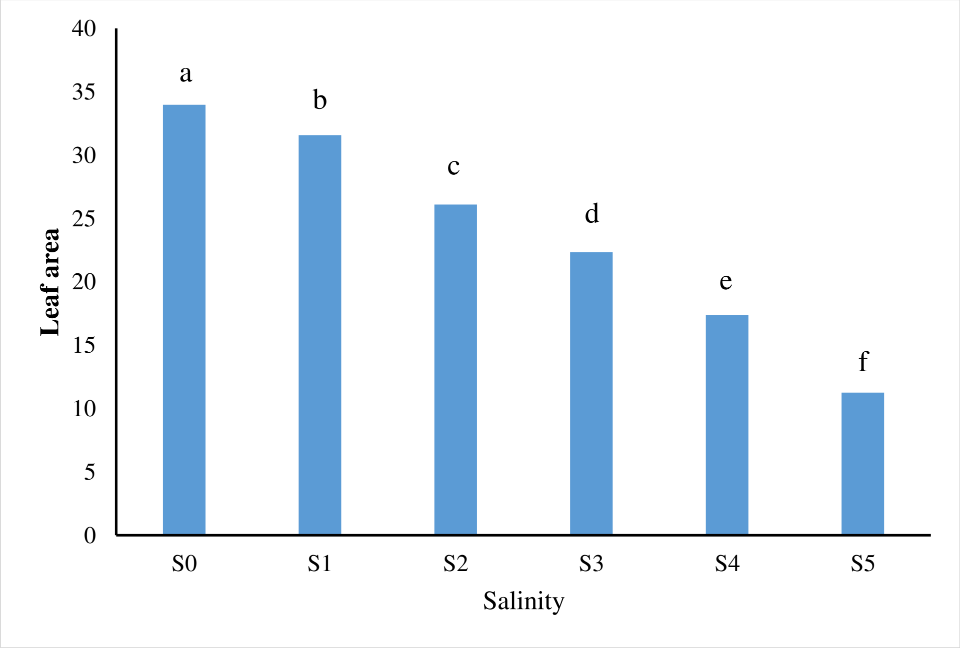

Fig. 13: Effect of salinity on Leaf Area at 30 DAT

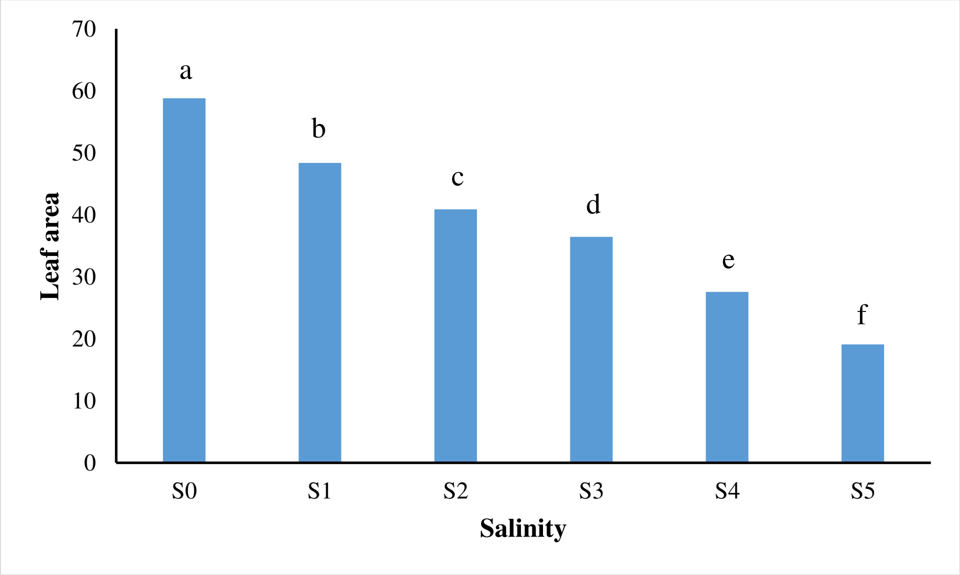

Fig. 14: Effect of salinity on Leaf Area at 40 DAT

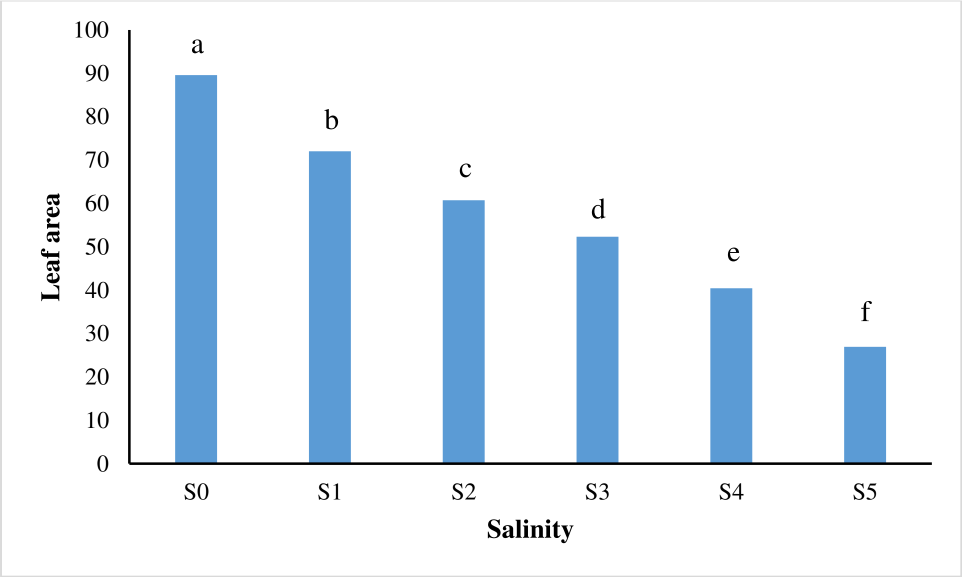

Fig. 15: Effect of salinity on Leaf Area at 50 DAT

Between two spinach cultivars, there was a significant difference in leaf area. The largest leaf area 97.89 cm and the shortest leaf area 17.75 cm were measured (Table 10). The leaf area varied significantly between the different salt treatments. Where no salt treatment was applied, the greatest leaf area (97.89 cm^2) was measured. The treatment with the highest salt content yielded the smallest leaf area 17.75 cm^2 (Table 10). In terms of leaf area development, analysis of variance reveals a substantial combined effect of variety and salt concentration.

Table 10. Interaction effect of varieties and salinity on Leaf Area at different DAT

Interaction	Leaf Area (cm^2)		
	30 DAT	39 DAT	47 DAT
V_1S_0	32.13b	53.24b	81.19b
V_1S_1	32.18b	47.38b	66.01c
V_1S_2	26.08c	40.39cd	55.24d
V_1S_3	21.50de	37.54cd	49.58e
V_1S_4	15.95fg	26.64e	38.12fg
V_1S_5	8.90h	14.48f	17.75h
V_2S_0	35.83a	64.33a	97.89a
V_2S_1	30.97b	49.41b	78.01b
V_2S_2	26.14c	41.33c	66.19c

V_2S_3	23.17cd	35.30d	55.05d
V_2S_4	18.79ef	28.48e	42.84f
V_2S_5	13.61g	23.69e	36.12g
LS	*	*	**
LSD $_{(0.05)}$	3.067	6.013	5.118
CV (%)	7.62	9.22	6.56

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.
CV= Coefficient of variation, LS= Level of significance, LSD$_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

4.1.6. Number of leaves/plant:

At several stages of growth, the combined effect of varied salt concentrations and variety on number of leaves plant^{-1} was substantial. Bari Puishak 2 was 35.61 at 50 DAT found to be the highest value (Table 11).

Table 11. Effect of varieties on Leaf Number at different DAT

Variety	Leaf Number		
	30 DAT	40 DAT	50 DAT
V_1	16.83b	24.78b	28.61b
V_2	20.11a	30.61a	35.61a
LS	**	**	**
LSD $_{(0.05)}$	0.658	1.175	1.387
CV (%)	5.15	6.14	6.25

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.
CV= Coefficient of variation, LS= Level of significance, LSD$_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

At different DATs with varying saline levels, a considerable difference in the number of leaves per plant was observed (Figure 16-18). As the saline level increased, the number of leaves per plant dropped. The highest 40.83 number of leaves were produced by S_0 (control) treatment followed by 36.17, 33.83 in S_1 and S_2 (25 mM and 50 mM respectively) treatment at 47 DAT. The lowest number of leaves were observed 15.00, 20.50 and 23.67 at 30, 39 and 47 DAT respectively in S_5 treatment. The number of leaves was gradually decreased with increasing in salinity levels.

When a plant is subjected to salt stress for an extended period of time, ion toxicity and water deficiency are observed in older leaves, while carbohydrate deficiency and related symptoms are observed in younger leaves. A salt-specific effect manifests itself in the form of salt damage in old leaves, resulting in their death. The loss of a few leaves has no effect on plant growth, but if the rate of leaf death exceeds the rate of new leaf creation, salt can cause a significant decline in the supply of assimilates to the emerging leaves. Plant development is significantly slowed as a result. The drop in leaf area in this experiment was caused by leaf death, which lowered the number of leaves.

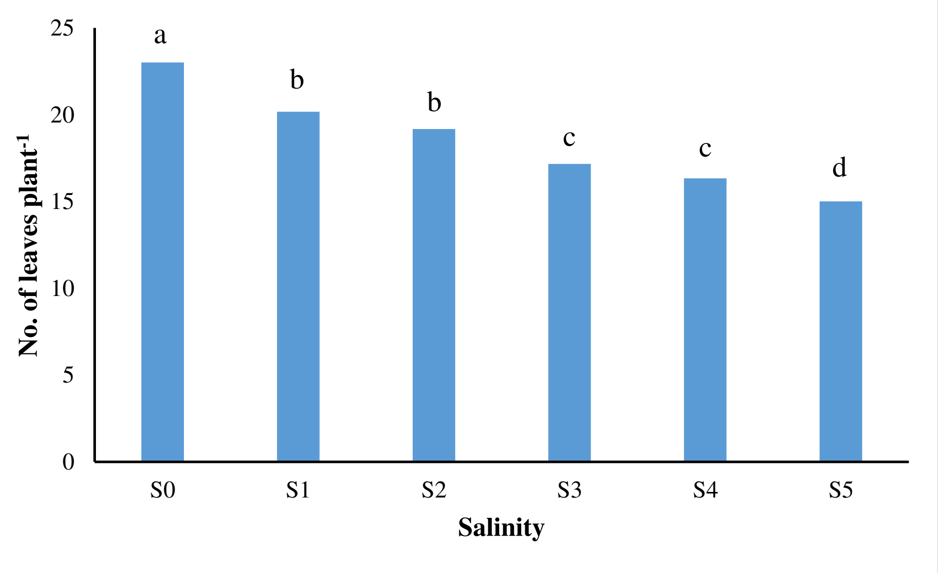

Fig. 16: Effect of salinity on Leaf Number at 30 DAT

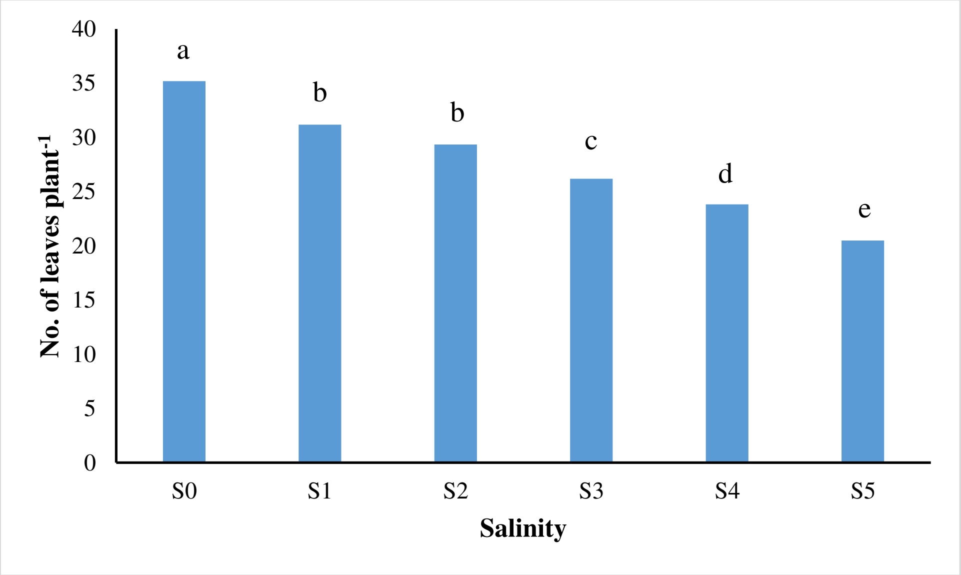

Fig. 17: Effect of salinity on Leaf Number at 40 DAT

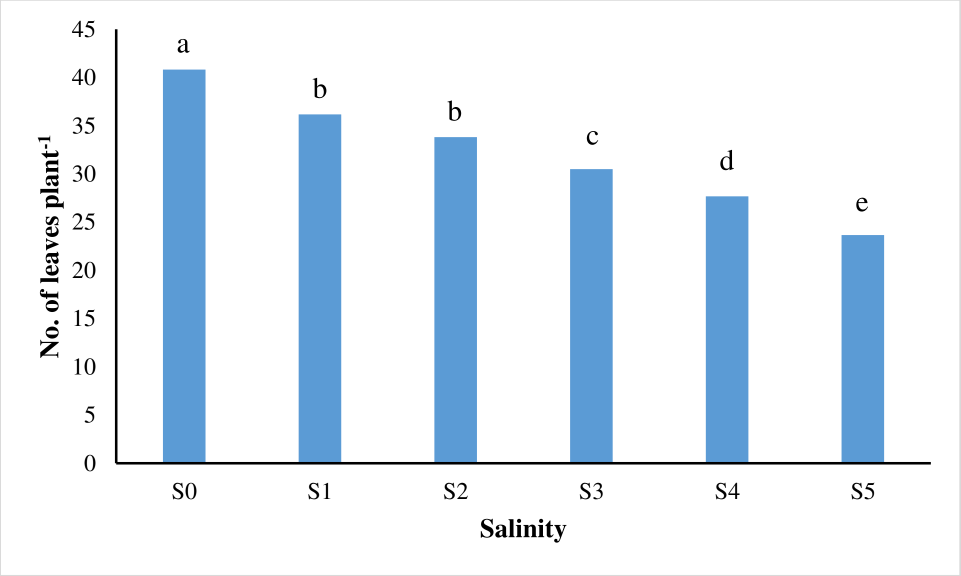

Fig. 18: Effect of salinity on Leaf Number at 50 DAT

The amount of salt in the solution had a substantial impact on the number of leaves produced by the plant. The treatment with no salt concentration resulted in the highest number of leaves (47.00) and the lowest (21.00) number of leaves (Table 12).

Table 12. Interaction effect of varieties and salinity on Leaf Number at different DAT

Interaction	Leaf Number		
	30 DAT	39 DAT	47 DAT
V_1S_0	19.67cd	30.00cd	34.67cd
V_1S_1	18.67d-f	29.00c-e	33.33c-e
V_1S_2	18.00ef	27.33de	31.33de
V_1S_3	15.33hi	23.33f	27.00f
V_1S_4	15.33hi	21.33f	24.33fg
V_1S_5	14.00i	17.67g	21.00g
V_2S_0	26.33a	40.33a	47.00a
V_2S_1	21.67b	33.33b	39.00b
V_2S_2	20.33bc	31.33bc	36.33bc
V_2S_3	19.00c-e	29.00c-e	34.00c-e
V_2S_4	17.33fg	26.33e	31.00de
V_2S_5	16.00gh	23.33f	26.33f
LS	*	*	*
LSD $_{(0.05)}$	1.612	2.879	3.398
CV (%)	5.15	6.14	6.25

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.
CV= Coefficient of variation, LS= Level of significance, LSD$_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

4.1.7. Plant diameter:

Between the two spinach kinds, there was a significant difference in the plant diameter of the roots. Salinity levels have a noteworthy impact on the plant diameter. Bari Puishak 2 was 1.44 cm at 50 DAT found to be the highest value (Table 13).

Table 13. Effect of varieties on Plant diameter at different DAT

Variety	Plant diameter (cm)		
	30 DAT	40 DAT	50 DAT
V_1	0.57b	0.91b	1.26b
V_2	0.65a	1.04a	1.44a
LS	**	**	**
$LSD_{(0.05)}$	0.015	0.023	0.029
CV (%)	3.57	3.53	5.15

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.
CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

The graphic depicts the influence of various salinity levels on the plant diameter (Figure 19-21). The plant diameter was measured at 30, 40 and 50 DAT and varies significantly due to the administration of varying doses of salt. When comparing the S_3, S_4, and S_5 treatments to the control treatment, it was discovered that the plant diameter reduced in the salt-treated treatment. The number of branches produced by S0 (control treatment) was determined to be the highest. The plant diameter of plants were recorded as 1.59, 1.50, 1.39, 1.29, 1.22 and 1.11 cm in S_0, S_1, S_2, S_3, S_4 and S_5 (0 mM, 25 mM, 50 mM, 75mM 100mM and 150 mM respectively) treatment at 50 DAT respectively. S_5 (150 mM) treatment have the lowest plant diameter. The plant diameter significantly decreased when the DAT was increased with remedy.

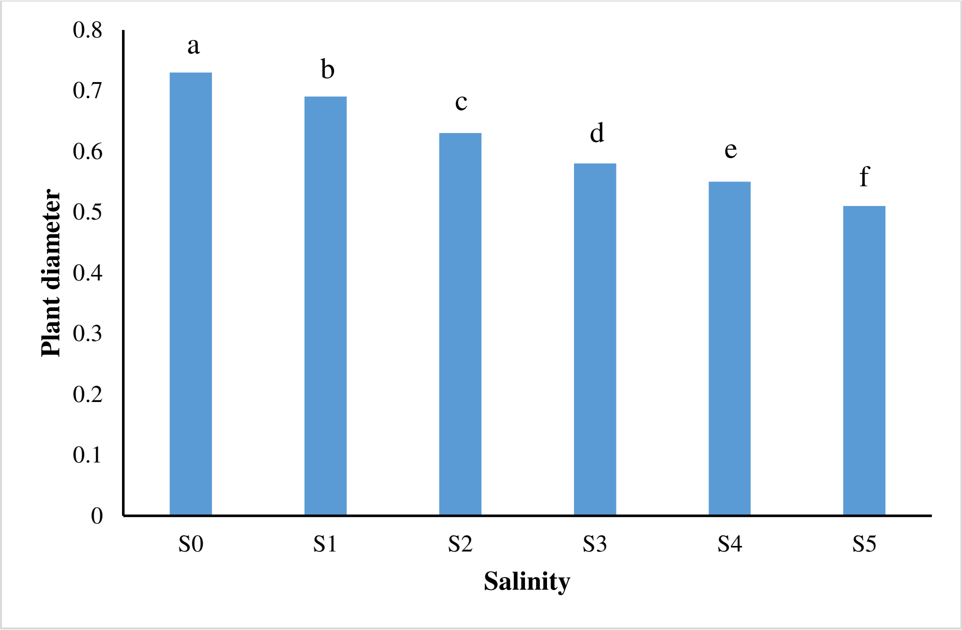

Fig. 19: Effect of salinity on Plant diameter at 30 DAT

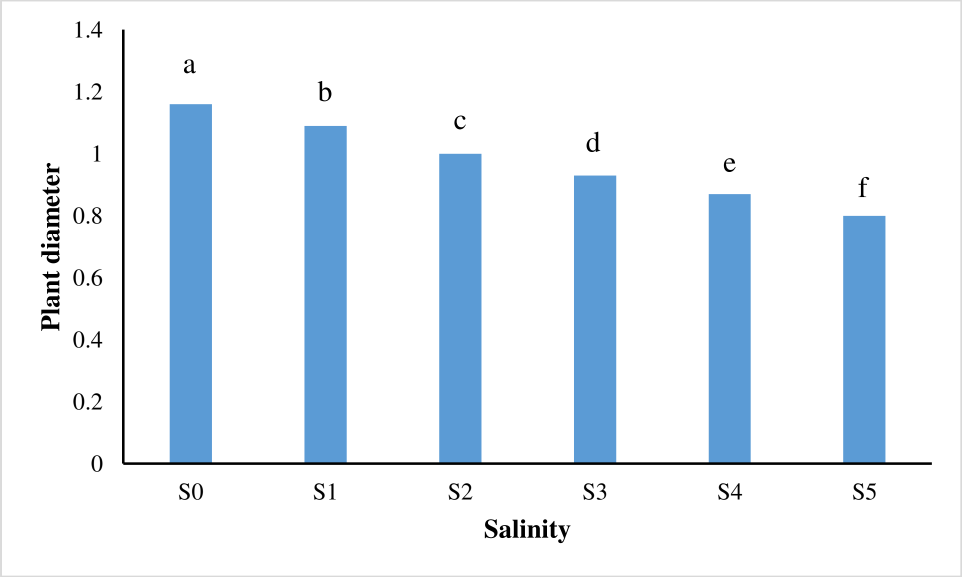

Fig. 20: Effect of salinity on Plant diameter at 40 DAT

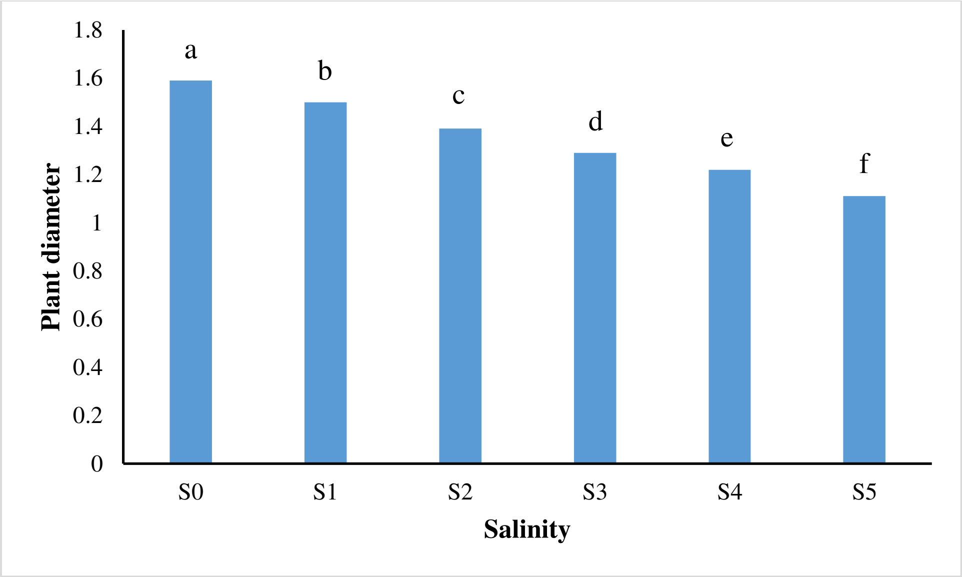

Fig. 21: Effect of salinity on Plant diameter at 50 DAT

Plant diameter is a key element for spinach yield among the growth and yield contributing characters. With the passage of time, it is clear that the plant's diameter increased gradually. It changed greatly depending on the kind and salt treatment used. The maximum plant diameter (1.71 cm) was measured at 47 DAT, while the minimum plant height (1.05 cm) was measured. In addition, the tallest plant was discovered in the control group. On the other hand, the shortest plant was found in V_1S_5.

Table 14. Interaction effect of varieties and salinity on Plant diameter at different DAT

Interaction	Plant diameter (cm)		
	30 DAT	39 DAT	47 DAT
V_1S_0	0.67c	1.06	1.47b
V_1S_1	0.63cd	1.00c	1.36c
V_1S_2	0.60de	0.95de	1.32cd
V_1S_3	0.55fg	0.87fg	1.21e
V_1S_4	0.52g	0.82g	1.15e
V_1S_5	0.48h	0.76h	1.05f
V_2S_0	0.79a	1.26a	1.71a
V_2S_1	0.74b	1.18b	1.65a
V_2S_2	0.66c	1.05c	1.47b

V_2S_3	0.62de	0.98de	1.36c
V_2S_4	0.58g	0.92ef	1.29d
V_2S_5	0.53g	0.85g	1.18e
LS	*	*	*
LSD (0.05)	0.037	0.058	0.072
CV (%)	3.57	3.53	5.15

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

4.1.8. Different characters of Puishak:

Salinity levels have a noteworthy impact on the different characteristics of Puishak (Table 15).

Table 15. Effect of varieties on different characters of Puishak

Variety	SPAD value	Germination %	Plant Fresh weight (g)	Plant dry weight (g)	% Dry Matter	% Moisture Content
V_1	63.67b	49.18b	309.90b	39.08b	12.32b	87.68a
V_2	66.11a	55.98a	329.91a	46.65a	13.96a	86.04b
LS	**	**	**	**	**	**
LSD (0.05)	1.011	1.391	11.091	2.042	0.523	0.523
CV (%)	2.26	3.83	5.02	6.89	5.76	0.87

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

CV= Coefficient of variation, LS= Level of significance, $LSD_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

4.1.9. SPAD Value:

The most significant biochemical event on the planet is photosynthesis. Massive amounts of sunlight are converted into electrical and subsequently chemical energy during photosynthesis (Hall and Rao, 1999). Between the different salinity levels, the SPAD value of spinach plants revealed statistically significant change (Figure 22). With increased salinity, the SPAD value fell. S_0 therapy resulted in the highest SPAD value (74.83), while S_5 resulted in the lowest SPAD value (53.50). Khatun *et al.* (2016) investigated the SPAD value of spinach plants, finding that the maximum value (53.07) was in the S_0 (control) treatment and the lowest value (50.79) was in the S_3 (75 mM) treatment.

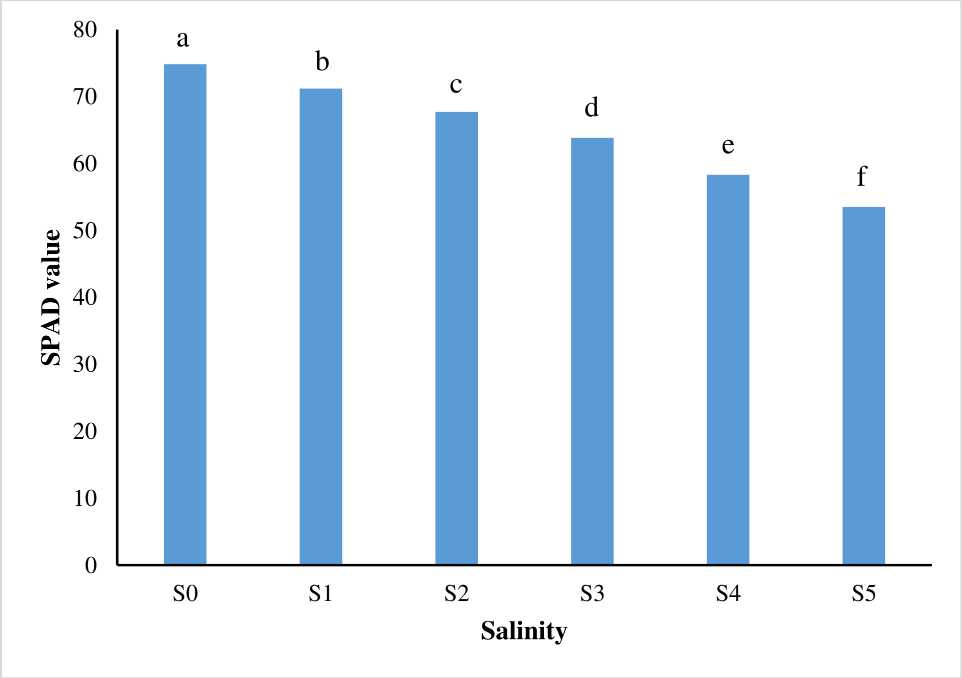

Fig. 22: Effect of salinity on SPAD Value

4.1.10. Germination (%):

Salinity is a prominent environmental stressor that reduces agricultural productivity and sustainability in arid and semiarid areas by delaying germination and subsequent seedling establishment. Salt has a deleterious impact on agricultural yield all over the world. Osmotic stress, ion toxicity, and oxidative stress all have an impact on seed germination and seedling establishment. Salinity can have a negative impact on seed germination by reducing the amount of seed that germinates. The highest value 77.76 % found in S_0 and the lowest value 22.32 % found in S_1 treatment (Figure 23).

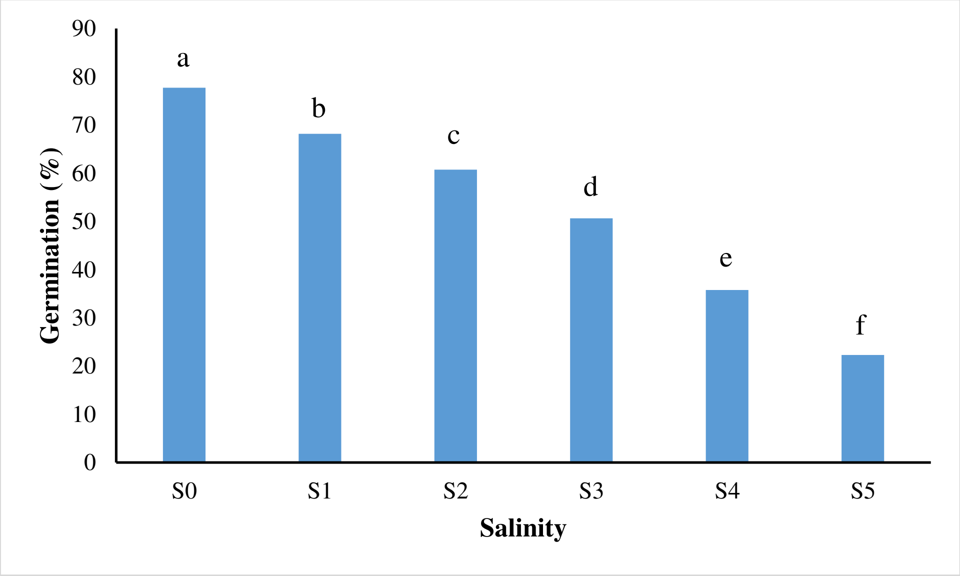

Fig. 23: Effect of salinity on Germination (%)

4.1.11. Plant Fresh weight (gm):

The salinity levels resulted in a considerable difference in the fresh weight of plants (Figure 24). The highest value 417.18 gm was found under S_0 treatment and the lowest value 203.67 gm was found under S_5 treatment.

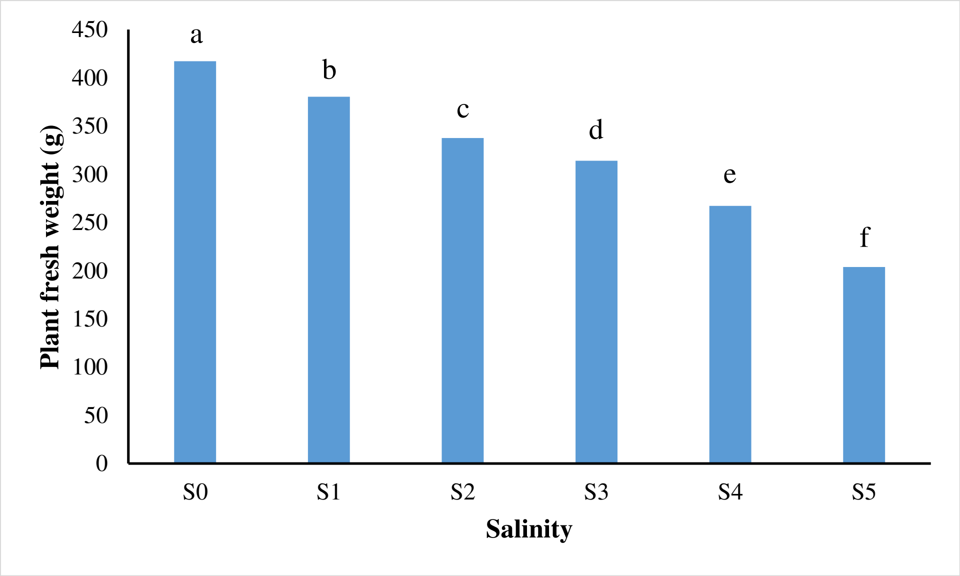

Fig. 24: Effect of salinity on Plant fresh weight (g)

4.1.12. Dry weight of plant (gm):

Different salinity levels resulted in a considerable difference in the dry weight of plants (Figure 25). Plant dry weight decreased as salt levels increased. S_0 (control) yielded the highest dry weight of plant (60.36 gm), followed by S_1, S_2, S_3, S_4 and S_5 (52.28, 46.33, 41.70, 33.52 and 22.99 gm) treatments. S_5 (150 mM) treatment resulted in the lowest dry weight of the plant (22.99 gm). The results showed that when the saline level grew, the plant's dry weight reduced steadily.

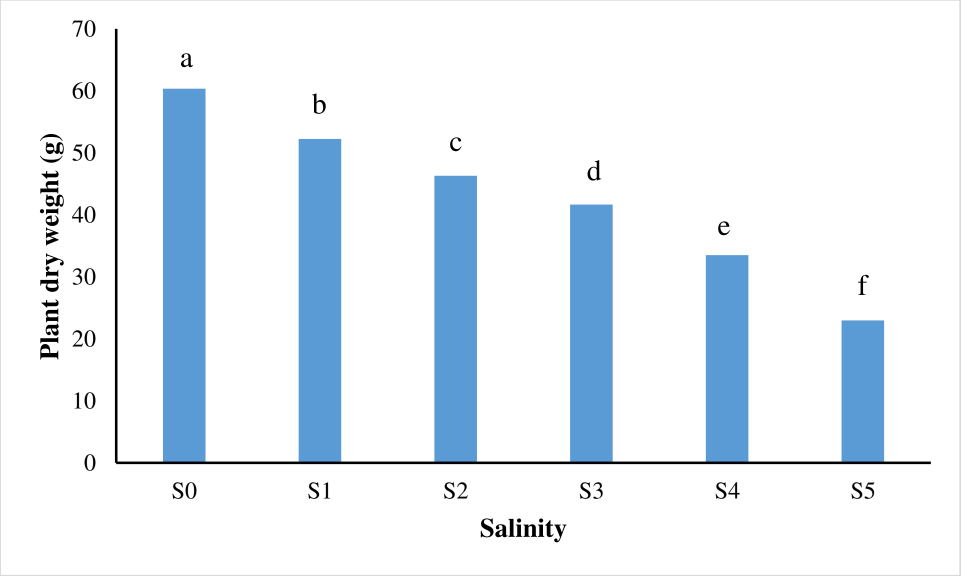

Fig. 25: Effect of salinity on Plant dry weight (g)

4.1.13. Dry Matter (%):

Salinity is arguably the most important ecological constraint causing widespread crop production losses around the world, and its threat is growing by the day. Increasing salinity reduces the average yield of major crops by more than 50%, which is a major source of concern, particularly for countries that rely heavily on agriculture. The highest value of dry matter 14.40 % found in S_0 and the lowest value of dry matter 11.14 % found in S_5 condition.

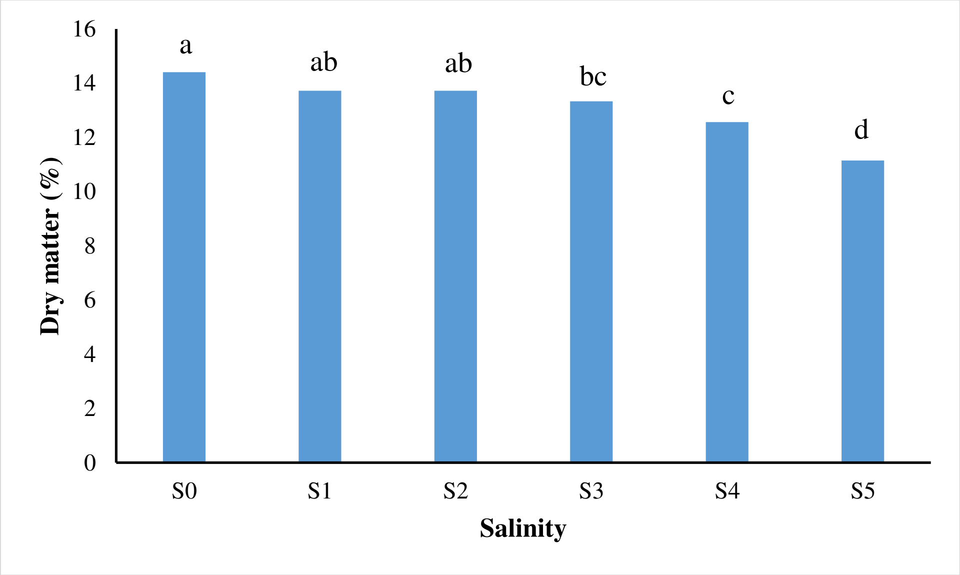

Fig. 26: Effect of salinity on Dry matter (%)

4.1.14. Moisture Content (%):

Salinity is arguably the most important ecological constraint causing widespread crop production losses around the world, and its threat is growing by the day. Increasing salinity reduces the average yield of major crops by more than 50%, which is a major source of concern, particularly for countries that rely heavily on agriculture. The highest value 88.87 % in S_5 condition and the lowest value 85.60 % in S_0 condition (Figure 27).

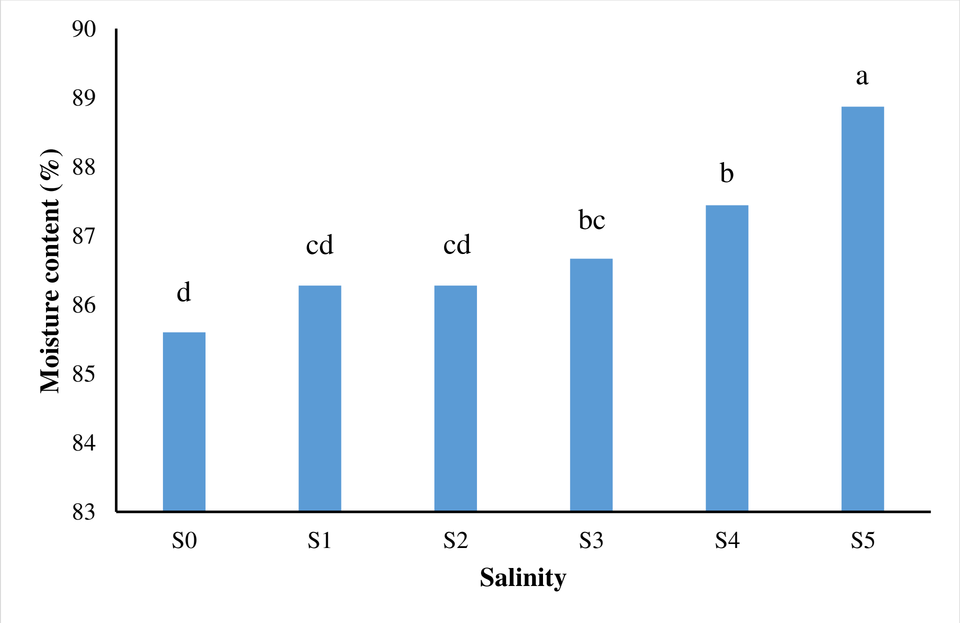

Fig. 27: Effect of salinity on Moisture content (%)

Between two spinach cultivars, there was a significant difference on different characters of Puishak (Table 16).

Table 16. Interaction effect of varieties and salinity on different characters of Puishak

Interaction	SPAD value	Germination %	Plant Fresh weight (g)	Plant dry weight (g)	% Dry Matter	% Moisture Content
V_1S_0	71.67b	72.69b	395.18b	51.66bc	13.08b-d	86.92de
V_1S_1	69.67cd	64.33c	372.59b	49.49cd	13.25b-d	86.75c-e
V_1S_2	67.00e	57.41d	333.45cd	46.11de	13.80bc	86.20c-e
V_1S_3	63.67f	46.15e	317.43cd	40.40fg	12.80cd	87.20cd
V_1S_4	57.33g	32.67g	265.31e	29.44h	11.13ef	88.87ab
V_1S_5	52.67h	21.82h	175.41g	17.34i	9.89f	90.11a
V_2S_0	78.00a	82.82a	439.17a	69.05a	15.73a	84.27f
V_2S_1	72.67b	72.10b	388.10b	55.07b	14.19b	85.81e
V_2S_2	68.33de	64.08c	341.55c	46.54de	13.64b-d	86.36c-e
V_2S_3	64.00f	55.19d	310.01d	43.00ef	13.87bc	86.13de
V_2S_4	59.33g	38.84f	268.68e	37.60gh	13.99bc	86.01de
V_2S_5	54.33h	22.82h	231.92f	28.64	12.38de	87.62bc
LS	*	*	*	*	*	*
LSD $_{(0.05)}$	2.477	3.407	27.167	5.002	1.281	1.281
CV (%)	2.26	3.83	5.02	6.89	5.76	0.87

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

CV= Coefficient of variation, LS= Level of significance, LSD$_{(0.05)}$= Least significant difference, NS= Non Significant *= Significant at 5% level of Probability, **= Significant at 1% level of Probability

V_1 = BARI Puishak 1, V_1 = BARI Puishak 2

S_0 = 0 mM (control), S_1= 25 mM, S_2= 50 mM, S_3= 75 mM, S_4 = 100 mM, S_5= 150 mM

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATION

The experiment was conducted from November 2020 to January 2021 at the Sher-e-Bangla Agricultural University's field of agroforestry, Sher-e-Bangla Nagar, Dhaka-1207. It helps to determine the effect of salinity on the morpho-physiological, yield, and quality characters of indian spinach under sodium chloride (NaCl) salt stress. S_0 =without salt (control), S_1 =25 mM, S_2 =50 mM, S_3 =75 mM, S_4 =100 mM, and S_5 =150 mM NaCl were the six different degrees of salinity used in this experiment. With three replications, the experiment was set up in a Completely Randomized Design (CRD). Data was collected on various growth characteristics, physiological parameters, and yield, as well as yield contributing aspects in spinach. For the purpose of determining the treatment impact, the acquired data were statistically examined.

All of the parameters were significantly affected by salinity. The spinach plant was contaminated with sodium chloride (NaCl) by adding salt to the soil in this experiment. The maximum height was obtained from the plant cultivated on normal soil (control treatment) over the growth period, whereas the lowest height was recorded from the plant treated with 150 mM salinity. The longest plant (60.88, 84.09 and 106.91 cm at 30, 40 and 50 DAT) was recorded in S_0 or controlled condition, whereas the shortest plant (29.27, 38.89 and 49.30 cm at 30, 39 and 47 DAT respectively) in S_5 or 150 ds/m salt. It steadily dropped as the salinity level dose.

The number of branch per plant of spinach was recorded at 30, 40 and 50 DAT. S_0 treatment yielded the highest branch number (6.19, 11.39, and 13.51 at 30, 40, and 50 DAT, respectively), while S_5 or 150 mM of salt yielded the lowest branch number (2.98, 5.24, and 6.16 at 30, 40 and 50 DAT, respectively). Different degrees of salinity have a significant impact. The longest leaf length of spinach was discovered in S_0 (6.23, 8.31, and 10.62 cm at 30, 40 and 50 DAT, respectively), while the shortest leaf length was observed in S_5 (3.33, 4.03, and 4.91 cm at 30, 40 and 50 DAT, respectively). Different degrees of salinity have a significant impact.

The control (S_0) treatment had the largest leaf area (33.98, 58.79, and 85.44 sq. cm at 30, 40 and 50 DAT). S_5 or 150 mM of salt had the smallest leaf area (11.26, 19.08, and 26.93 sq. cm at 30, 40 and 50 DAT, respectively).

S_0 or control treatment had the highest number of leaves/plant (23.00, 35.17, and 40.83 at 30, 40 and 50 DAT, respectively), whereas S_5 or 150 mM of salt had the lowest number of leaves/plant (15.00, 20.50, and 23.67 at 30, 40 and 50 DAT, respectively). Different degrees of salinity have a significant impact. The highest plant diameter (0.73, 1.16 and 1.59 cm at 30, 40 and 50 DAT) was found in S_0 condition. The lowest plant diameter (0.51, 0.80 and 1.11 cm at 30, 40 and 50 DAT respectively) was recorded in S_5 or 150 mM of salt.

Depending on the salt content, the SPAD value of spinach changed statistically substantially. S_0 condition had the highest SPAD value (74.83), whereas S_5 treatment yielded the lowest value (53.50). The effect of varied salinity levels on germination (%) was substantial. The S_0 treatment had the highest germination (77.76 %) and the S_5 treatment had the lowest (22.32 %). The highest plant fresh weight in spinach (417.18 gm) was recorded in S_0 (control) treatment and the lowest value (203.67 gm) was obtained from the S_5 treatment. The production of spinach was significantly affected by different salt levels. The S_0 (control) treatment had the highest plant dry weight (60.36 gm) while the S_5 treatment had the lowest (22.99 gm). Different salinity levels had a substantial impact on dry matter (%). The S_0 produced the dry matter (14.40 %), whereas the S_5 produced the least (11.14 %). The amount of moisture content in the spinach varied statistically significantly depending on the salinity level. The S_5 treatment had the highest moisture level (88.87 %), while the S_0 treatment had the lowest moisture content (85.60 %).

CONCLUSION

From the present study, the following conclusion may be drawn –

Based on the above-mentioned findings, it can be inferred that as saline levels increased, the yield of spinach fell gradually. However, as the salt level grew, the yield and quality characteristics of spinach gradually fell up to 100 mM and then significantly decreased. All morpho-physiological and growth of spinach were affected by increasing the levels of salinity. As a result of the current experimental findings, the variety of BARI Puishak 2 should be considered to be cultivated at least 100 mM salinity level.

Recommendation

From the above study, the following recommendation is given below -

1. Further research in the following areas may be recommended in light of the current experiment's situation:
2. A study like this is needed in Bangladesh's coastline area to compare the experiment's accuracy.
3. Treatment S_0-S_3 may be employed in the southern part of Bangladesh, where fresh water is rare, because only a minor drop in yield was observed under cultivation with salt water (8 ds/m).
4. Experiments must be carried out in order to pinpoint the salt sensitive and salt tolerant stages of spinach.

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APPENDICES

Appendix-I ANOVA on plant height at different DAT

Source of variance	Degree of freedom	Plant height (cm)		
		30 DAT	40 DAT	50 DAT
Replication	2	3.984	25.63	35.98
Factor A (Variety)	1	664.694**	1120.16**	1850.86**
Factor B (Salinity)	5	851.102**	1742.64**	2872.13**
A × B	5	16.229*	22.40*	31.66*
Error	22	4.769	6.28	8.41
Total	35			

Appendix-II ANOVA on branch number at different DAT

Source of variance	Degree of freedom	Branch number		
		30 DAT	40 DAT	50 DAT
Replication	2	0.052	0.367	0.824
Factor A (Variety)	1	6.864**	19.892**	31.333**
Factor B (Salinity)	5	8.790**	32.151**	46.314**
A × B	5	0.167*	0.375*	0.514*
Error	22	0.046	0.119	0.186
Total	35			

Appendix-III ANOVA on Leaf length at different DAT

Source of variance	Degree of freedom	Leaf length (cm)		
		30 DAT	40 DAT	50 DAT
Replication	2	0.097	0.052	0.101
Factor A (Variety)	1	0.581**	1.127**	11.696**
Factor B (Salinity)	5	7.113**	14.260**	24.130**
A × B	5	0.037^{NS}	0.307*	0.355*
Error	22	0.050	0.100	0.104
Total	35			

Appendix-IV ANOVA on Leaf wide at different DAT

Source of variance	Degree of freedom	Leaf wide (cm)		
		30 DAT	40 DAT	50 DAT
Replication	2	0.2109	0.0266	0.7784
Factor A (Variety)	1	0.5041**	0.8250**	2.3368**
Factor B (Salinity)	5	3.8548**	4.3722**	7.5452**
A × B	5	0.4300	0.3537	0.5697
Error	22	0.0608	0.1006	0.0694
Total	35			

Appendix-V ANOVA on leaf area (cm^2) at different DAT

Source of variance	Degree of freedom	Leaf Area (cm^2)		
		30 DAT	40 DAT	50 DAT
Replication	2	11.943	2.97	75.83
Factor A (Variety)	1	34.672**	130.68**	1163.15**
Factor B (Salinity)	5	444.404**	1219.22**	2996.11**
A × B	5	7.518*	40.18*	47.08**
Error	22	3.281	12.61	9.14
Total	35			

Appendix-VI ANOVA on Leaf Number at different DAT

Source of variance	Degree of freedom	Leaf Number		
		30 DAT	40 DAT	50 DAT
Replication	2	2.6944	4.194	4.694
Factor A (Variety)	1	96.6944**	306.250**	441.000**
Factor B (Salinity)	5	50.6278**	167.494**	226.978**
A × B	5	4.7611*	7.983*	11.133*
Error	22	0.9066	2.891	4.028
Total	35			

Appendix-VII ANOVA on plant diameter (cm) at different DAT

Source of variance	Degree of freedom	Plant diameter (cm)		
		30 DAT	40 DAT	50 DAT
Replication	2	0.0004	0.0017	0.0014
Factor A (Variety)	1	0.0592**	0.1534**	0.2970**
Factor B (Salinity)	5	0.0428**	0.1099**	0.1951**
A × B	5	0.0012*	0.0035*	0.0062*
Error	22	0.0004	0.0011	0.0018
Total	35			

Appendix-VIII ANOVA on different characters on puishak

Source of variance	Degree of freedom	SPAD value	Germination %	Plant Fresh weight (g)	Plant dry weight (g)	% Dry Matter	% Moisture Content
Replication	2	40.44	7.66	193.9	10.4	0.42	0.42
Factor A (Variety)	1	53.77**	416.16**	3603.4**	516.6**	24.23**	24.23**
Factor B (Salinity)	5	383.77**	2576.63**	35728.6**	1068.2**	7.99**	7.99**
A × B	5	6.57*	15.32*	929.5*	57.1*	2.18*	2.18*
Error	22	2.14	4.05	257.4	8.7	0.57	0.57
Total	35						