SALINITY INDUCED MORPHO-PHYSIOLOGICAL AND YIELD CHANGES IN FIELD PEA (*Pisum sativum L.*)

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CERTIFICATE

This is to certify that the thesis entitle, **"**SALINITY INDUCED MORPHO-PHYSIOLOGICAL AND YIELD CHANGES IN FIELD PEA (*Pisum sativum* L.*)***"** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE IN AGROFORESTRY AND ENVIRONMENTAL SCIENCE****, embodies the result of a piece of bonafide research work carried out by* ***SUMAIA HOSSAIN****, Registration No.* 15-06371 *under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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Dr. Nazmun Naher
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Dated: June,2022
Dhaka, Bangladesh

Dedicated to

My Beloved

Parents

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ABSTRACT

Salinity is a major abiotic stress inducing morphological and yield changes in plant as well as limiting production. So a pot experiment was conducted during December 2021 to March 2022 at Agroforestry farm, Sher-e-Bangla Agricultural University Sher-e-Bangla Nagar, Dhaka-1207. It was done to evaluate the changes in morpho-physiological and yield characteristics of three field pea varieties (BARI motor 1, BARI motor 2, BARI motor 3) to salinity under different levels. The three salinity levels (4 dS/m, 8dS/m, 12dS/m) along with a control were inclined by irrigation of NaCl salt solution. The experiment was placed out following two factors Complete Randomized Design with three replications. Results indicated that in response to different salinity level, the three genotypes showed clear differences in the changes in plant height, leaf length, number of leaf, chlorophyll content, relative water content, salt tolerant index, number of pod, number of seed, pod length, pod weight and 100 seed weight and yield of field peas which were significantly decreased with the increased of salinity. Vegetative stage is being more sensitive than flowering and pod-filling stages. The tallest plant (57.05cm), number of leaf per plant (9.50), the highest salt tolerant index value (38.47%), relative water content (37.69%), number of pod per plant (7.33), number of seed per pod and yield (2.23g) were observed from BARI motor 2 at 12 dS/m. Therefore, BARI Motor 2 was the most salt tolerant among the varieties in terms of growth and yield production.

ABBREVIATIONS

ABBREVIATION	FULL WORD
AEZ	Agro Ecological Zone
AIS	Agriculture Information Service
ANOVA	Analysis of Variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
Ca	Calcium
Cl	Chlorine
C.V.	Co-efficient of Variation
DAE	Department of Agricultural Extension
DW	Dry weight
EC	Electrical conductivity
e.g.	For example
et. al.	And others
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
FW	Fresh weight
K	Potassium
LSD	Least Significant Difference
Mg	Magnesium
MoA	Ministry of Agriculture
N	North
Na	Sodium
NaCl	Sodium Chloride
RWC	Relative water content
S	South
SAU	Sher-e-Bangla Agricultural University
SE	Standard Error
SI	Serial
STI	Salt tolerant index
Viz.	Namely
cm	centimeter
ºC	Degree Celsius
dS/m	deci Siemens per meter
g	Gram
m	Meter
mg	Miligram
m mhos/cm	Mili mohos per centimeter
%	Percent

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CHAPTER I

INTRODUCTION

Salinity is one of the most important abiotic stress that affects plant productivity worldwide. About 20% of the global land area and over 50% of agricultural irrigated land is salt-affected soils (Cheng *et al.*, 2016). It is also estimated that about 50% of agricultural land will be affected by salt in 2050 (Mahajan *et al.*, 2005; Yan *et al.*, 2005). In Bangladesh, over 30% of the net cultivable areas lie in the coastal area, which approximately 53% are affected by varying degrees of salinity (Haque, 2006).

In Asia alone, 21.5 million ha of land area is thought to be salt- affected, with India having 8.6 million ha of such area (Sahi *et al.*, 2006). Bangladesh is an agricultural oriented country. By the sea level rising, a huge amount of land in the southern coastal region will go under water and salinity will access the new areas of land. It will decrease the exiting crop area severely thereby decreasing agricultural productions. Moreover, the densely populated country might face food shortage to feed the people.

Salinity is a major issue to crop productivity in the southern and south-western part of Bangladesh, where it is increased due to frequent flood sea water of the Bay of Bengal and on the other hand introduction of irrigation with saline water. Coastal saline soils are distributed unevenly in 65 thanas of 19 coastal districts covering 8 agro-ecological zones (AEZ) of the country. The mainly salinity affected land exists in the districts of Khulna, Bagerhat, Barguna, Patuakhali, Pirojpur and Bhola, Satkhira on the western coast and a smaller portion in the district of Chittagong, Cox’s Bazar, Noakhali, Lakshmipur, Chandpur and Feni.

Soil salinity is one of the threatening environmental constraints threatening sustainability in the arid and semi-arid regions (Mustafa *et al.*, 2019). It is the result of salt accumulation at the surface leading to hyperosmotic stress, interfering with the morphological, physiological, and biological activities (Gupta *et al.*, 2020) to roots and the root microbiome. Salt stress imposes substantial adverse effects on the performance and physiology of the crop plants, which eventually leads to plant death as a consequence of growth arrest and metabolic damage (Hasanuzzaman *et al.*, 2012).The adverse effect of salt stress on plant growth is attributed to the specific toxic effect of ions or to the imbalanced of nutritional cations in tissues of the salt affected plant or due to reduction in carbon fixation during photosynthesis and to increasing carbon release in respiration. Salinity stress can affect plant physiology through changes of water and ionic status in the cells. Ionic imbalance occurs in the cells due to excessive accumulation of Na^+ and Cl^- and reduces uptake of other mineral nutrients, such as K^+, Ca^{2+}, and Mn^{2+}. In addition, plant growth is more influenced by salt than other toxic substances (Xiong and Zhu, 2002).

The prevailing salinity intrusion due to climate change is severely affecting the crop productivity in the saline regions of Bangladesh (Haque *et al.*, 2014). The situation calls an urgent need to improve crop productivity. Introduction of new crops and/or crop varieties in the fallow lands of the coastal regions might be the scholastic technique for improvement of system productivity.

Field pea is a cool-season grain legume from the widespread Pisum genus that is produced for fresh or dried seed and fodder in over a hundred nations. With planted areas of 7.2 million hectares as of 2019, field pea was the fourth most extensively produced legume in the world (after common bean, cowpea, and chickpea) (FAO, 2020). It can be economically grown for fresh fruit or dry grain. According to BBS in 2022, 8131.99 metric tons of field pea were produced in Bangladesh in 2021–2022.The pea plant is raised as a food crop for farm animals, a cover crop to prevent soil erosion, and a green compost crop to improve soil (Wolde and Adamu, 2018). Legumes like the pea have the natural ability to get their nitrogen needs from the atmosphere by symbiotically living with *Rhizobium* bacteria in the soil (Schatz and Endres, 1999). Compared to many other broadleaf crops, the pea plant has a relatively short growing season and consumes less water (Johnston *et al.*, 2002). In contrast to other legumes including the broad bean, common bean, and soybean, the plant has been identified as salt-sensitive (Zahran, 1999; Khan *et al.*, 2015).The increased demand for low-cost, high-quality protein as well as the importance of field pea in rotational farming is reviving interest in this plant. To benefit from symbiotic nitrogen fixation and lower crop water usage, field pea is typically cultivated in rotation with cereals. Field pea is becoming more popular as an intercrop plant. Field pea can be introduced in salt intrusion land which remain fallow or can be planted with rice as relay or intercropping.

In the past, the salinity issue received virtually little attention. But in recent years, the signs of this salinization-related land degradation have become too obvious to be disregarded. More food is needed due to rising population strain. It has become essential to look for ways to boost these (saline) lands' potential for increased food crop production. Therefore, it is essential for the country's food security to tackle the problem of land salinization by developing saline tolerance field pea types and implementing a long-term land management strategy. Increased agricultural productivity is essential, and this cannot be emphasized enough. Given the restricted potential for global cultivated land expansion, this represents challenges to developing systems and must mostly come from increasing yield per unit area. It is imperative to increase productivity and introduce new cultivars that can survive in challenging environments, such as those with saline stress (Chartzoulakis and Loupassaki 1997; Abbas *et al*., 2010).

Therefore, the study was conducted to fulfill the following objectives-

- To determine the effects of salinity on morphological and physiological parameters of field pea;
- To assess the salinity effect on yield and yield attributing characteristics of field pea and
- To identify the salt tolerant variety

CHAPTER II

REVIEW OF LITERATURE

The physiological aspects of growth and yield with growth analysis on various crops to know the reason of yield decreasing due to changing of soils has not yet been done at appropriate level. In this chapter a few attempts have been made to review some of available information about soil salinity and its effect on growth and yield components of field pea.

2.1 Soil Salinity

Soil salinity is the term used to describe a condition in which soil has an excessive amount of soluble salts in the soil water (soil solution), high enough to severely impact plant growth, resulting in lower crop yields and in extreme cases, plant mortality.

A saline soil is generally defined as one in which the electrical conductivity of the saturation extract (ECe) in the root zone exceeds 4 dS m^{-1} (approximately 40 mM NaCl) at 25°C and has an exchangeable sodium of 15%. The yield of most crop plants is reduced at this ECe, though many crops exhibit yield reduction at lower ECe (Munns 2005; Jamil *et al.*, 2011).

Munns and Tester, (2008) highlighted that Soils become saline when the soil salt concentration reaches about 40mM NaCl. Most crops are quite vulnerable to saline soil.

According to Flowers (2005), salinity can be referred to as an abiotic stress and includes all issues caused by salts, particularly an excess of sodium chloride (NaCl) via irrigation or natural accumulation. Soil salinity (electrical conductivity: EC > 4 dS m-1) is a major abiotic stress which limits plant growth and development, causing yield loss in crop species (Qadir *et al.*, 2007).The salinity affected areas are increasing day by day at alarming rate due to several reasons such as low precipitation, high surface evaporation, irrigation with saline water including faulty cultured practices. It has been a threat to the agriculture for over 3000 years in some parts of the world (Flowers, 2005).

Rao *et al*. (2016) said that Salinization is a natural process of increasing salts due to lack of water for adequate leaching and poor drainage leading to degradation in the quality of soil. The surface irrigation has aggravated the condition in arid and semi-arid environments. The salinity stress is caused by the accumulation of soluble salts like Cl-, SO_4^{2-}, HCO_3^-, Na^+, Ca^{2+}, and Mg^{2+} and several others. These ions chiefly come from the irrigation and poor soil drainage (Acosta-Motos *et al.,*2 017). Similarly, alkalinity stress is caused by the presence of carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and hydroxyl (OH^-) anions. The excess of borates, phosphates, silicates, and other bases increase concentration of these salts leading to alkalinity which drastically reduces plant growth and development.

Jamil *et al*. (2011) reported that the salinized areas are increasing at a rate of 10% annually, which is expected to cover more than 50% of the arable land by the year 2050. Murtaza *et al.* (2009) explained that salt affected soils can have major effect on soil physical properties, especial on the structure of soils. Soil structure, or the arrangement of soil particles, is critical in affecting permeability and infiltration. If a soil has high quantities of Na+ and the EC is low, soil permeability, hydraulic conductivity, and the infiltration rate are decreased due to swelling and dispersion of clays and slaking of aggregates.

2.2 Salinity built up in soil

The greatest impediment to crop intensification in coastal settings is the seasonally (winter) high salt content of the soil's root zone. The salts enter the inland through rivers and channels, particularly during the dry (winter) season, when the downstream flow of fresh water is quite low. The salinity of the river water rises during this time. The salts enter the soil by floods with saline river water or seepage from rivers, and they concentrate in the surface layers due to evaporation. The saline river water may also increase the salinity of ground water, rendering it unfit for irrigation. The increase in water salinity in these locations has provided an ideal environment for shrimp farming. Shrimp farming, along with other reasons, contributed significantly to increased salinity, notably in the south-western coastal districts. In general, coastal soil salinity levels begin progressively increasing in November at the start of the dry (winter) season and peak in March-May, reaching up to 20 dS/m. Due to soil salinity, a lack of good quality irrigation water, and a late draining condition, most areas remain fallow during the dry season (January-May) (Mandol *et al*., 2003).

Soil salinity is thought to be the primary cause of the area's low land usage and agricultural intensity (Rahman *et al*., 2014). In this circumstance, agricultural land usage, particularly boro rice land use, is extremely low in these locations. However, during the monsoon season, when salinity levels are generally low (June-October) due to salt dispersion in the root-zone of the standing crop, farmers in the moderate to extremely salty south-west coastal areas can only cultivate a single rice (T-aman) crop.

According to Coram *et al*. (2001), as the water table rises, salts contained beneath the soil profile are mobilized and transferred to the soil surface, resulting in salinization. Dry land salinity currently affects at least 2.5 million hectares (5% of cultivated land), and roughly 5.7 million hectares of Australian agriculture has a high salinity risk. In 50 years, this might increase to 12 million hectares (22%).

Yeo (1999) found that Soils affected by secondary salinization account for about 76 Mha of 1.5 Mha cropped land, including 56Mha of 280 Mha irrigated lands in Australia. Abrol and Yadav (1988) found that salt affected soils are more extensive in arid and semi-arid regions compared to humid regions. However, the occurrence of saline soils is not limited to arid environments. Salt affected soils can be found in the tropical regions of Africa and Latin America, and in all continents and under almost all climatic conditions.

According to Russell (1989), salts can also be produced by vegetation growing on salt-affected soils. Ash can account for up to one-quarter of plant dry weight, with a major part of the ash being soluble salts. Vegetation brings over 200 kg ha-1 of salts to the soil surface each year. Plants, albeit minor in comparison to the amounts of salts provided by irrigation, can contribute to the accumulation of salts in the top soil over time. Because of water scarcity and the adoption of agricultural methods such as the use of wastewater in irrigation or over fertilization with the lack or installation of poor drainage systems, the area affected by salts is likely to grow with time. Bertrand *et al*. (2003) stated that secondary salinization, the slow building of salt in previously salt-free topsoil, happens in irrigated areas as salt is injected into the soil with each round of irrigation.

2.3 Salinity around the world and Bangladesh

According to Asib (2011), the ways of using the land use in coastal area are gradually changed and that is diverse, competitive and alarming. Out of 2.85 million hectares of the coastal and off-shore lands about 1.05 million hectares of arable lands are affected by varying degrees of salinity. Fifty percent of coastal lands are subject to inundation of varying degrees and frequency that limit their effective use. The land use of coastal area is used in different purposes such as shrimp culture, ship breaking yards, industry, salt production and settlements etc.

Munns and Tester (2008) reported that more than 45 million hectares of irrigated land have been damaged by salt worldwide and 1.5 million hectares are taken out of production each year due to high soil salinity. Approximately 952 million ha are estimated to be salt affected and this area is increasing year after year all over the world (Wang *et al.*, 2014).

FAO (2015) reported that salt stress negatively influences 60 million hectares, or round about 20% of the total irrigated land area in the world. The problems of salinization are increasing, either due to bad irrigation drainage or agriculture practices. Despite its relatively small area, irrigated land is estimated to produce one - third of the world food (Munns, 2002).

Bangladesh is highly vulnerable to sea level rise (Brammer *et al*., 1993). The whole coast runs parallel to the Bay of Bengal, forming 710 km long coastline (CZP, 2005). The area lies at 0.9 to 2.1 meters above mean sea level (Iftekhar and Islam, 2004). Naher *et al*. (2011) reported that coastal area in Bangladesh constitutes 20% of the country of which about 53% are affected by different degree of salinity.

Soil resource development Institute (2010) showed that soil saline area in the country has increased to 1.02 million ha. Agricultural land used in these areas is very poor, which is roughly 50% of the country's average (Petersen and Shireen, 2001). The coastal zone of Bangladesh covers nearly 20% of the total land and over 30% of the cultivable lands of the country and about 53% of coastal soils are salt-affected (Hasan *et al*., 2020).

Salinity problems might be severe in arid and semi-arid regions since rainfall is not sufficient and water supplies are also scarce as compared to water needs for crop production (Lamsal *et al.*, 1999).

The problems of salinization are increasing, either due to bad irrigation drainage or agriculture practices. Despite its relatively small area, irrigated land is estimated to produce one - third of the world food (Munns, 2002). Hasanuzzaman *et al.* (2013) reported that the arable land is continuously transforming into saline (1- 3% per year) either due to primary/natural salinity or secondary/irrigation-associated salinity, and is expected to increase up to 50% land loss by 2050.

According to SRDI (2010), in Bangladesh out of coastal cultivable saline area, about 328 (31%), 274 (26%) and 190 (18%) thousand hectares of land are affected by very slight (2.0-4.0 dS/ m), slight (4.1- 8.0 dS /m) and moderate salinity (8.1-12.0 dS/ m), respectively are scope to successfully crop production.

Table 1. Soil salinity class and area in coastal saline belt of Bangladesh

Mapping unit	Description	Total cultivated area (1000ha)	Total saline area (1000ha)	%	Salinity class and area (ha)									
					S1 2.0-4.0	%	**S2 4.1-8.0**	%	**S3 8.1-12.0**	%	**S4 12.1-16.0**	%	**S5 >16.0**	%
					dS/m									
1.	Non saline with some very slightly saline	650769	193278	30	133406	69	52375	27	7497	4	0	0	0	0
2.	Very slightly saline with some slightly saline	348090	248337	71	124726	50	82414	33	34532	14	6665	3	0	0
3.	Slightly saline with some moderately saline	271064	218145	80	55402	25	86872	40	43190	20	24635	11	8046	4
4.	Strongly saline with some moderately saline	219448	198014	90	14065	7	40777	21	47257	29	63755	32	22160	11
5.	Very strongly saline with some strongly saline	200460	198486	99	831	0	11782	6	47234	24	66925	34	71714	36
Total		1689831	1056260	63	328430	31	274220	26	189710	18	161980	15	10192 0	10

Source: SRDI, 2012

According to Hasanuzzaman *et al*. (2013), salinity is one of the factors limiting the yield of crops like field pea since the majority of crop plants are sensitive to salinity brought on by excessive concentrations of salts in the soil.

The Government of Bangladesh's Coastal Zone Policy (CZPo, 2005) stated that 19 of the country's 64 districts covering a total of 147 upazilas are in the coastal zone. The central coastal zone, which includes the districts of Noakhali, Barisal, Bhola, and Patuakhali, stretches from the estuary of the Feni River to the easternmost point of the Sundarbans. The Ganges-Brahmputra-Meghna river system discharges a lot of water into the zone, resulting in a lot of silty deposition. Silt makes up more than 70% of the sediment load in the area, and sand makes up the remaining 10% (Allison *et al.*, 2003).

Salinity results in an unfavorable hydrological and environmental scenario, which limits normal crop production all year long. Crops are affected depending on the saline level at key growth phases, which lowers output and, in extreme circumstances, eliminates them entirely. In coastal areas, the pH of the soil ranges from 6.0 to 8.4 (Haque, 2006; Naher *et al.*, 2011). Recent observations showed that normal agricultural production is becoming increasingly constrained due to the increasing salinity of some places and the growth of salt-affected areas as a result of the additional entry of salty water.

2.4 Fertility status of saline soils

The main obstacle to intensification of crop production in the coastal areas is seasonally high content of salts in the root zone of the soil. Due to drainage congestion, the area remains waterlogged, increasing the salinity (Abedin, 2010).

For the growth of crops, soil fertility is crucial. The soil fertility in Bangladesh's coastal regions is often fairly low. Soil nutrients have an impact on plant growth in addition to salinity.

Soil reaction values (pH) range from 6.0-8.4 with the exception of Chittagong and Patuakhali, where the pH values range from 5.0-7.8. The soils are in general poor in organic matter content with the except on of Paikgachha upazila of Khulna district, where the top soils contain high organic matter (7%). The organic matter content of the top soils ranges from less than 1% to 1.5%. The low organic content in soils indicates poor physical condition of the coastal soils. The total N contents of the soils are generally low, mostly around 0.1%. The low N content may be attributed to low organic matter contents of most of the soils. Available P status of the soils ranges from 15-25 ppm. Some deficient P soils are also found in Chittagong, Barguna, Satkhira and Patuakhali districts. Widespread Zn and Cu deficiencies have been observed in the coastal regions (Karim *et al.,* 1990 and Naher *et al*., 2011).

Saline soils contain soluble salts in quantities that affect plant growth adversely, the lower limit for a saline soil being set conventionally at an electrical conductivity of 4 mmho/cm in the soil saturation extract. Nutrient deficiency of n is quite dominant in saline soils. Deficiencies of micronutrients, such as Cu and Zn are widespread. Ions that contribute to soil salinity include Cl^-, $S0_4^{2-}$, HCO_3^-, Na^+, Ca^{2+}, Mg^{2+}, and rarely, NO_3^- or K^+ (Rahman *et al*., 2014).

According to Rahman *et al*. (2014), salinization has a significant negative impact on soil fertility by altering soil organisms' metabolic processes and significantly raising the water resistance of the deeper soil layers.

Soil fertility is an important factor for crop production. In general, the coastal regions of Bangladesh are quite low in soil fertility. Thus, in addition to salinity, plant nutrients in soils affect plant growth. The organic matter content of the soils is pretty low (1.0-1.5%) (Karim *et al.,* 1990). The low organic content in soils indicates poor physical condition of the coastal soils. Nutrient deficiencies of N and P are quite dominant in saline soils. The low N content may be attributed to low organic matter contents of most of the soils. Widespread Zn and Cu deficiencies have been observed in the coastal regions (Karim *et al.,* 1990). During the wet monsoon the severity of salt injury is reduced due to dilution of the salt in the root-zone of the standing crop.

Globally, the issue of soil salinization is a curse on agricultural productivity. Because of severe osmotic stress, nutritional problems and toxins, poor soil physical conditions, and decreased crop output, crops produced on saline soils suffer.

2.5 Present scenario of pulse *i.e.* Field Pea cultivation

Field pea (*Pisum sativum*) is a growingly significant legume crop which is fourth most widely farmed around the world with a total harvested area of 7.2 million ha and an annual production of 16 million tonnes (FAOSTAT,2020). It is originated in Mediterranean region of Southern Europe and Western Asia. In Bangladesh it contributed only 1827.65 acres of land and 8131.99 metric tons production to the total area of cultivation and production of pulses, respectively in Bangladesh (BBS, 2022).

In Bangladesh, many crops viz. lentil, grass pea, chickpea, field pea, mustard etc. are relayed with monsoon rice where monsoon rice harvesting is delayed and/or land remains moist which takes few to more days to become optimum condition for land preparation for next crop cultivation (Islam *et al.*, 2015). In a study of Ali *et al*.(2018) it was found that *among* the pulses, pea is mainly grown after the harvest of monsoon-rice in the winter season (October-March) in Bangladesh. In addition, in cereal-based cropping patterns, pulses contribute significantly to increasing food and feed output without negatively impacting the environment, as well as crop diversification and sustainable agricultural production by supplying nitrogen to the soil and breaking cereal-based monoculture.

A research conducted by Ali *et al*.(2018) revealed that local cultivar of pea named Matore would be extensively cultivated as relay crop with T. Aman rice under residual soil moisture.

Zaki *et al*. (2016) stated that among the agroforestry-based practices, alley cropping system that is based on the use of legumes has received significant attention. “Improved tree fallows” involve the deliberate planting of fast-growing nitrogen-fixing trees or woody shrub species for one to two years, followed by one or two years of cropping and may go through several fallow-cropping-fallow rotational cycles. Field pea is the best choice for this cause. Under the agroforestry system only pea crops give 2 to 3 times more income from the total cost of cultivation and associated agroforestry trees give separate additional income like fruit, fuel and fodder to the farmers (Tariyal, 2022).

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Schatz and Endres (1999) found that Pea is a legume and has the inherent ability to obtain its nitrogen requirement from the atmosphere by forming a symbiotic relationship with Rhizobium bacteria in the soil. The pea plant has quite a short growing season and uses less water than many other broadleaf crops (Johnston *et al*., 2002)

Importantly, field peas provide an abundant, low-cost, and long-term source of nitrogen (N) into the farming system via biological N fixation. Good N fixation is critical for pulse crop productivity and maximization of N benefit for cereal and oilseed crops in subsequent cycles.

Several studies have demonstrated that field pea gets more than 80% of its nitrogen from BNF and can then transmit nitrogen to non-fixing plants in the agricultural system (Murat *et al*., 2008).

Mekonnen *et al. (*2022) stated that Field Pea like other legumes is capable of fixing and utilizing atmospheric nitrogen. Consequently, it is integrated in different crop systems as a sole crop or an intercrop in crop rotation for its capability to fix nitrogen in symbiotic association with root nodule bacteria known as *Rhizobium leguminosarum biovar viciae*. *Rhizobium leguminosarum* are effective in biological nitrogen fixation (BNF) with the capacity of converting nitrogen to the tune of 200-300 kg/ha/yr.

2.6 Socio- economic importance of Field Pea

Field pea is a cool-season legume crop. Field pea, sometimes known as "dry pea," is marketed as a dry, shelled product. Field pea varies from fresh or succulent pea, which is sold as a fresh or canned vegetable. Green and dry foliage are utilized as cattle feed, while green pods, which are highly nutritious, are favored for culinary uses.

According to Han and Baik (2008), peas are an important food component because they are high in carbohydrate, protein, and dietary fiber. They also include considerable amounts of vitamins, minerals, and antioxidant activity, which has been shown to decrease cholesterol (Martins *et al*., 2004).

Pea seeds are of great nutritional value in terms of high-quality protein and energy content. It contains 21-32% of protein rich in lysine (Nikolopoulou *et al*., 2007, Wang *et al*., 1998) which is the limiting amino acid in most of the plant products.

According to Patto (2015), the most prevalent carbohydrate constituent is starch, which has a low glycemic index when it comes to pulses. One of the main reasons why pulses can provide high nutritional value to humans is because part of the starch fraction resistant starch is not digested by the small intestine and functions similarly to dietary fibres, accounting for its numerous health benefits. (Singh *et al*., 2017)

The nutritional statuses of pulses are abundant and they are also valuable foundation of energy. The energy content of most pulses has been found to be between 300 and 540 Kcal/100g (Tiwari *et al*., 2011).

Bangladesh Agricultural Research Institute (2022) reported that the country's daily intake of pulses per head is 17 grams against the World Health Organization (WHO)'s prescribed requirement of 45 gm.

Field pea can be grown as a feed crop for cattle, as a green manure crop for soil development, and as a cover crop to reduce soil erosion. Matured seeds can be used whole or split. Seeds are starchy, ranging from 30 to 50%, but high in fiber, protein, vitamins, minerals, and 1% fat (Chandrasekaran *et al*., 2010).

Field pea has high levels of amino acids, lysine and tryptophan, which are relatively low in cereal grains. According to Miller (2005) peas contain high levels of carbohydrates, are low in fiber and contain 86-87 percent total digestible nutrients, which makes them an excellent livestock feed. Field pea contains 5 to 20 percent less of the trypsin inhibitors than soybean. This allows it to be directly fed to livestock without having to go through the extrusion heating process. Field pea is often cracked or ground and added to cereal grain rations.

2.7 Effect of Salinity on Pulse Crops

Soil salinity, in general, generates an unfavorable soil environment for crop growth and development. Maas and Hoffman (1977) investigated the relationship between agricultural yield response to salinity and measured crop relative growth or yield as a continuous function of steadily increasing levels of soil saline condition, which follows a sigmoid curve. It was discovered that at low salt concentrations, yield is either unaffected or decreases slowly, then at moderate concentrations, yield decreases at a higher but roughly steady rate, and finally at high concentrations, yield begins to decline more slowly towards zero.

Pulse crops are extremely sensitive to saline stress, and as a result, their growth, development, and yield are severely hampered. Excess Ca, Na, K, and Mg ion concentrations degrade the soil, resulting in leaf chlorosis and stunted growth due to excessive Na+ uptake and low nutrient uptake (Millar *et al*., 2007).

Joshi *et al*. (2021) stated that Under salinity stress, phosphorus and potassium contents get reduced while those of calcium, magnesium, sodium, chloride, and sulphate get enhanced. As a result, regulation on the uptake of latter elements under saline conditions is highly affected and, the photosynthetic efficiency of the plant is decreased due to degradation of essential pigments like chlorophyll and carotenoids. Salinity reduces plant
growth chiefly in three mechanism- osmotically induced water stress, specific ion toxicity due to high concentration of sodium and chloride ion and nutrient imbalances which hampers the uptake of water by plants. Salinity stress also limits physiological response and photosynthetic capacity. According to Gama *et al*.(2007) the effect salt stress in common bean (*Phaseolus vulgaris* L.) and found that high concentration of NaCl is associated with a reduction in leaf chlorophyll fluorescence and photosynthesis.

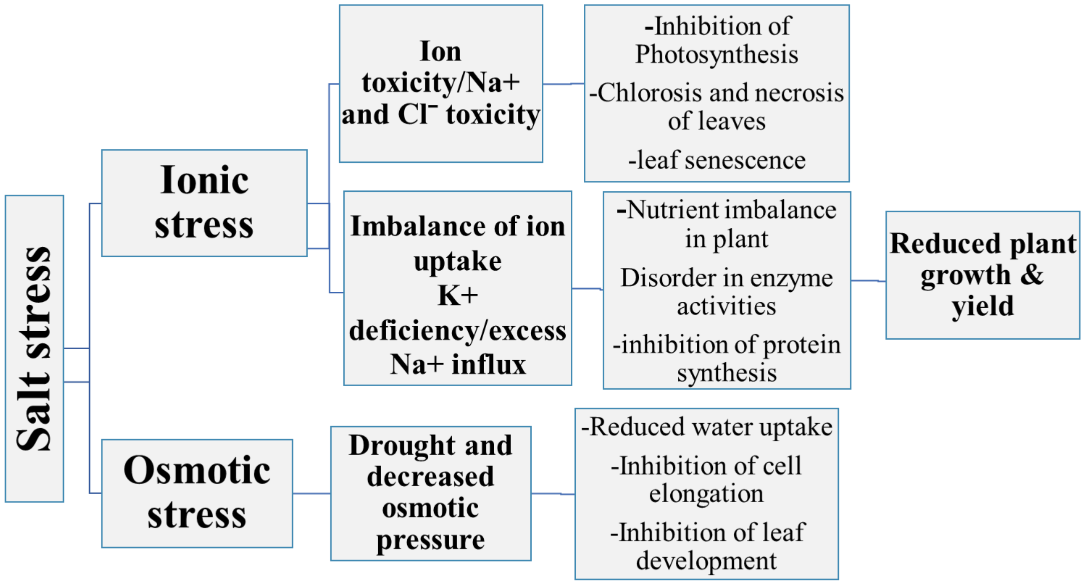


Figure 1. Schematic representation of effect of salinity stress in crop plants
(Source: Joshi *et al*., 2021)

Salinity in irrigation water is a limiting factor for germination, seedling development and productivity of various crops, especially in arid and semi-arid regions (Munns and Tester, 2008). Because it causes ionic imbalance and consequent toxicity, in addition to favoring oxidative stress, physiological drought and nutrient deficiency in the plant, salinity compromises morphological and physiological yields (Zörb *et al.*, 2019). Under conditions of tolerance to salt stress, plants tend to reduce reactive oxygen species, maintaining physiological and biochemical processes, as well as plant growth and production, thus avoiding enzyme inactivation, lack of nutrients, ionic toxicity in tissues and, consequently, cell death (Fernandes *et al.*, 2022).

2.9 Effects of Salinity on Yield Attributes

Under salt stress conditions, plant growth is reduced due to osmotic, nutritional and oxidative imbalance (Sousaa *et al*., 2022).

According to Leonforte (2013), it is highly likely that salinity levels significantly limit grain yield of pulse crops such as field pea in low rainfall environments

Salt stress was reported to reduce the growth of most legumes, as well as mungbean (Kabir *et al.*, 2004). These reductions in growth often resulted in reductions in tissue water potential, eventually reducing water availability to the cells (Garg and Bhandari, 2016), which leads to stomatal closing, less photosynthesis, and ultimately stunted growth was stated by Garg and Manchanda (2009).

Field pea's growth and reproductive responses at later stages of ontogeny need to be better understood, especially because increases in transient salinity (Rengasamy, 2006) are expected as crop production shifts to drier climates, where root systems will be more exposed to salinity (Nuttall *et al*., 2009). Salinity studies in other grain crops, including legumes like mungbean (Ahmed, 2009) and chickpea (Vadeza, 2012), provide appropriate models for examining this variety in field pea.

Approximately 50% yield reduction in pea crop was found at 100 mM NaCl (Subbarao and Johansen 1994, Ouerghi *et al*., 2016) and subsequently, reduction of productivity following high level of salinity (Najafi *et al*., 2007).

According to Wolde and Adamu (2018) salt content of irrigation water greater than 10 mM might reduce yields of field pea.

Joshi *et al*. (2021) reported that since pulses are more vulnerable to salty soil than cereals and oilseeds, the yield loss is substantial. This could be because pulses accumulate excess salts, which accelerates anthocyanin pigmentation in leaves and stems, reducing germination and seedling establishment (Kumar *et al*., 2016). As a result, pulse crop growth and development are more vulnerable to salinity-induced moisture stress. Salt stress, together with other pests (stem and pod-borer) and yellow mosaic disease, caused 80-100 percent yield loss in mungbean, especially during the rainy season confirmed by Sehrawat *et al*. (2015).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from December, 2021 to March, 2022 to study the effect of salt tolerance capability in field pea (*Pisum sativum L.)* under salt stress. The materials and methods describes a short description of the experimental site, climatic condition of the culture room, experimental materials, treatments and design, methods of the study, data collection procedure and data analysis. The detailed materials and methods that were used to conduct the study are presented below under the following headings:

3.1 Experimental Site

A pot experiment was conducted at the Agroforestry Farm, Sher-e-Bangla Agricultural University, Sher-E-Bangla Nagar, Dhaka-1207.The experimental site was at 23^0 $75^{/}$ N latitude and 90^0 $34^{/}$ E longitudes with an elevation of 8.45 meter from sea level (Anon, 1989).in Agro- Ecological Zone of Madhupur Tract (AEZ. 28).

3.2 Experimental Period

The experiment was conducted during the period from December 2021 to March 2022 (rabi season).

3.3 Climatic Condition

The experimental site was situated in subtropical climate zone, characterized by heavy rainfall during the months from April to September (Kharif season) and scanty rainfall during the rest of the year (Rabi season). The soil of the experimental site was collected from SAU Agroforestry Farm which was sandy loam. There was no rainfall during the experimental period. Rabi season is characterized by plenty of sunshine. The monthly total rainfall, temperature, average sunshine per hour during the study period was shown in Appendix I.

3.4 Materials

This experiment comprised of three Field pea varieties including:

- BARI Motor 1
- BARI Motor 2
- BARI Motor 3

The seeds were collected from Pulse Research Center, BARI, Gazipur

3.5 Design and Layout of the experiment

The two factor experiment was conducted in pots following the Complete Random Design (CRD) with three replications.

3.6 Treatments of the experiment

Factor A: Field Pea accessions

SL No

1	$V_1 =$	BARI Motor 1
2	$V_2 =$	BARI Motor 2
3	$V_3 =$	BARI Motor 3

Factor B: Salinity level

Four salinity levels dSm^{-1} (deci-simens per meter),

T_1= Control (Tap water),

T_2= 4 dSm^{-1},

T_3= 8 dSm^{-1} and

T_4= 12 dSm^{-1}

So, there were 12 treatment combinations such as

V_1T_1	V_2T_1	V_3T_1
V_1T_2	V_2T_2	V_3T_2
V_1T_3	V_2T_3	V_3T_3
V_1T_4	V_2T_4	V_3T_4

3.7 Pot preparation

Top soil was collected from experimental field and then pulverized. The inert materials, visible insects, pests and plant propagates were removed. Then the soil was dried thoroughly. Compost (1/4th of the soil volume) and 0.20 g Urea, 0.4 g TSP and 0.12g of MP per pot were incorporated uniformly into the soil. Clean and dry plastic pots of 10 liter size were used for each variety. Each pot was then filled with 8 kg previously prepared growth media (soil and cow dung mixture). Treatments were replicated three times. Salt solution was prepared to give the same concentration levels, and was added as irrigation water to plastic pots, in addition to distill water treatment was applied as a control. Ten seeds had chosen and sowed in each pot at a depth of 1 cm. Intercultural operation, weeding and other measures were taken when necessary.

Plate 1. At the time of pot preparation

3.8 Salinity development

Four doses of salinity namely control, 4, 8 and 12 dS/m were designated as T_1, T_2, T_3 and T_4 respectively. Salt solution was prepared artificially by dissolving calculated amount of commercially available NaCl with tap water to make 40, 80 and 120 Mm

NaCl solution. The electrical conductivity (EC) of the respective salt solutions was equivalent to 4, 8 and 12 dS/m (1 dS/M=10 mM NaCl) respectively and 0.30 dS/M for tap water (control). Pots were maintained at field capacity until seed sowing. Salt solutions were applied once in a week to impart salt stress. The plants provided with equal volume of water without NaCl were used as control.

3.9 Plant sampling

Plant samples were collected from the pot at different stages of the crop. During the course of experiment, three plants were sampled randomly from each pot for data collection. The plant samples then separated into stem, leaf and reproductive organs at harvest. After recording growth characters these samples were oven dried to a constant weight and the dry weight of the different parts was recorded separately.

Plate 2. At the time of harvesting

3.10 Data Collection

Plant height (cm)

Plant height was recorded at two stages. Height was measured by scale. Plant height was measured from base to the tip of the plant. Height of 3 plants from each plot was recorded.

No. of leaves/plant

Numbers of leaves of 3 randomly selected plants were counted at vegetative and fruiting stage. All the leaves of each plant were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from counting. The average number of leaves of 3 plants gave the number of leaves per plant.

No. of branches/plant

Number of branches of 3 randomly selected plants were counted at vegetative and pod filling stage. Only the smallest young branches at the growing point of the plant were excluded from counting. The average number of branches of 3 plants gave number of branches per plant.

Length of leaves (cm)

Three plants from each pot were randomly selected at vegetative and pod filling stage for collecting data on length of leaves. Length of leaves were measured by scale.

Chlorophyll content in leaf (SPAD Unit)

Chlorophyll content of leaf was measured by SPAD meter (SPAD 502 chlorophyll meter). Data was recorded from 3 leaves of each sampling plant and at three stages *i.e* vegetative stage, flowering stage and pod filling stage.

Relative water content (%)

The amount of water in leaf tissue compared to its maximum water content at full turgidity is known as relative water content, or RWC. Water absorbed by roots and water lost through transpiration is influenced by the RWC. The following formula was used to determine the RWC according Pieczynski *et al.*(2013).

RWC (%) = (fresh weight – dry weight)/(turgid weight – dry weight) × 100

Salt Tolerance Index (%)

The following equation is used to determine the salt tolerance index (STI), which is measured as a ratio to the total dry weight under salt stress and represented as a percentage:

STI (%) =DW (salt stress)/DW (control)×100

Number of nodule per plant

Number of nodule per plant was counted from the three replications. The numbers of nodule per plant was taken from the average value.

No. of pod/plant

Number of pod per plant was counted from the three replications. The numbers of total pod per plant were obtained from the average value.

No. of seed per pod

Three pods were selected randomly for counting the no of seed and average value was taken for obtaining no. of seed per pod.

Pod length (cm)

Three pods were selected randomly from each replication and length was measured by a scale.

Fresh wt. of one pod (g)

Three pods were selected randomly from each treatment immediately after harvest. Then these were placed on the digital balance for the calculation of fresh weights.

Dry wt. of one pod (g)

Three pods were selected randomly from each treatment and were put into envelop and placed in oven and dried at 60°C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken.

100 seed wt. (g)

100 seeds were weighted by digital balance and it was converted into 100 seed weight.

Yield/plant (g)

Total weight pod/plant was taken by digital balance.

3.11 Statistical analysis

The data obtained for different parameters were statistically analyzed to observe the significant difference among the treatment. The mean value of all the parameters was calculated and analysis of variance was performed. The recorded data on different parameters were statistically analyzed by using STATISTIX version 10 software to find out the significance of variation resulting from the experimental treatments. The mean values for all the treatments were accomplished by Dancan test. The significance of difference between pair of means was tested at 5% and 1% level of probability.

CHAPTER IV

Results and Discussion

In this experiment, efforts were made to find out the effect of salt stress on morpho-physiological and yield contributing parameters of three field pea varieties. Data on different parameters were analyzed statistically and the results have been reported in this chapter.

4.1. Effect of salinity on morphological characteristics of field pea

4.1.1. Effect of salinity on Plant height

Plant height is an important indicator of plant growth. The height of three field pea plants was measured at different stages. The effect of salinity on plant height was statistically significant ($P<0.05$) at vegetative and fruiting stage (Figure 2). Plant height decreased with increasing of different salinity levels at harvesting stage. At vegetative stage the tallest plant was (61.73cm) was obtained from control. The height 56.09cm and 50.85 cm was recorded from 4 and 8 dS/m salinity level respectively. The shortest plant (36.58 cm) was obtained from the salinity at 12 dS/m.

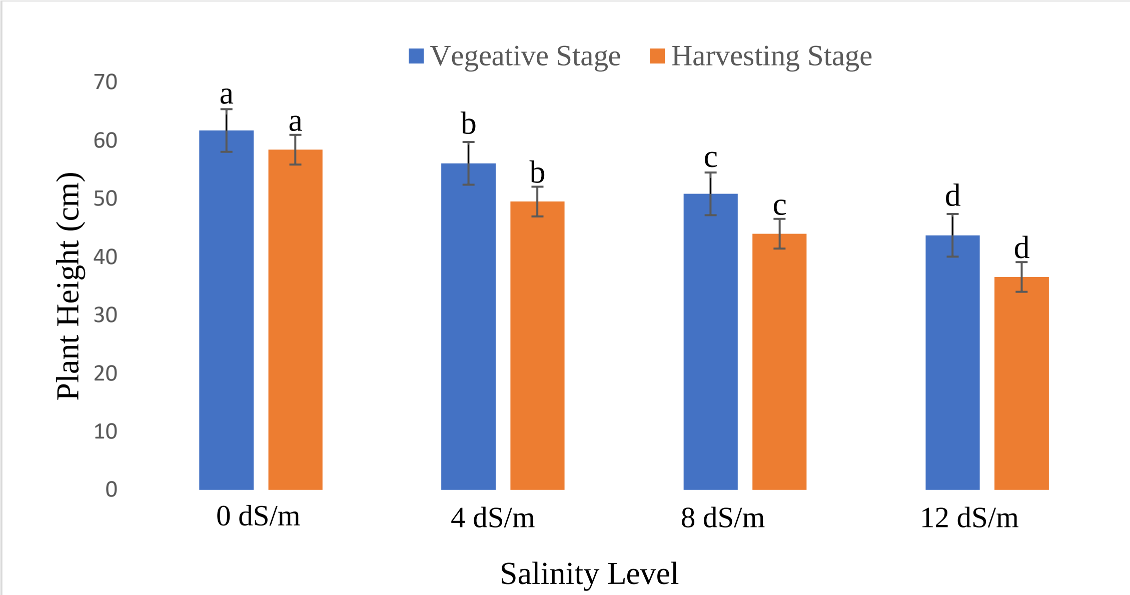
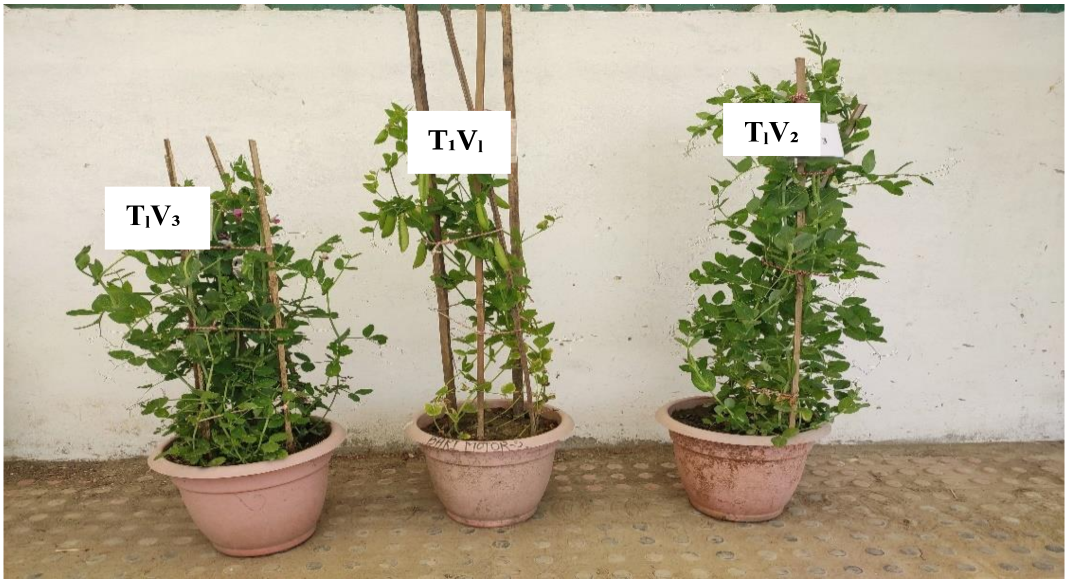


Figure 2. Effect of salinity level on plant height (cm) of field pea varieties at [LSD $_{(0.05)}$ 2.07 (vegetative stage) 3.92 (harvesting stage)].Here vertical bar shows standard deviation

At harvesting stage the tallest plant (58.43cm) was recorded from control. From the salinity at 4 and 8 dS/m level the plant height was obtained 49.53 cm and 44.00 com respectively. The shortest plant (36.58 cm) was recorded from at 12 dS/m salinity level.

This result is in line with the result of Wolde and Adamu (2018) who found that an increase in NaCl levels reduced the height of field pea plants. Salinity reduces plant growth through osmotic and toxic effects and high sodium uptake ratio values cause sodicity, which increases soil resistance, reduces root growth, and reduces water movement through the root with a decrease in hydraulic conductivity was found by Katerji, *et al*.(2001).



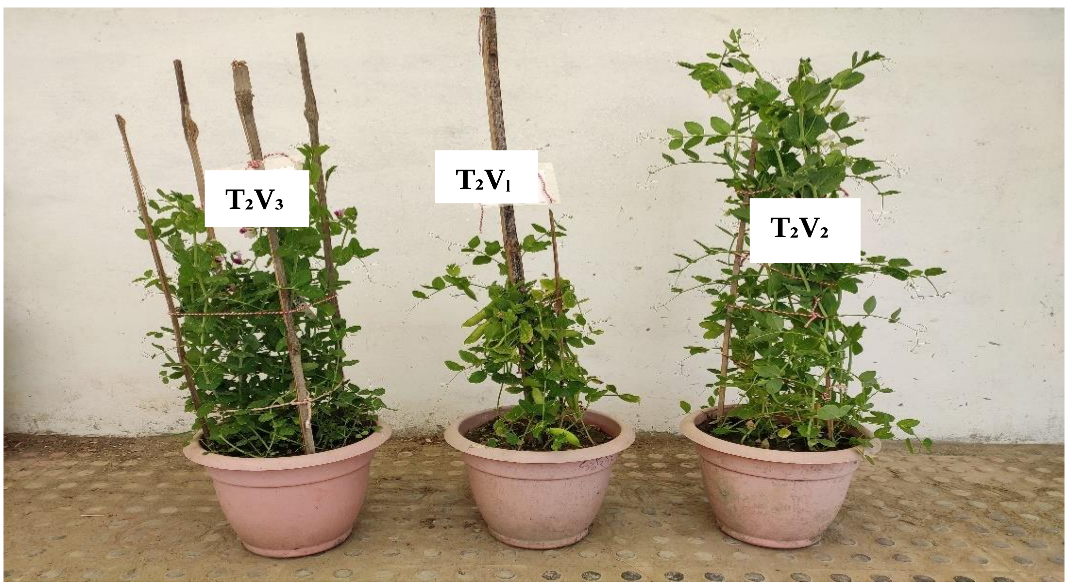
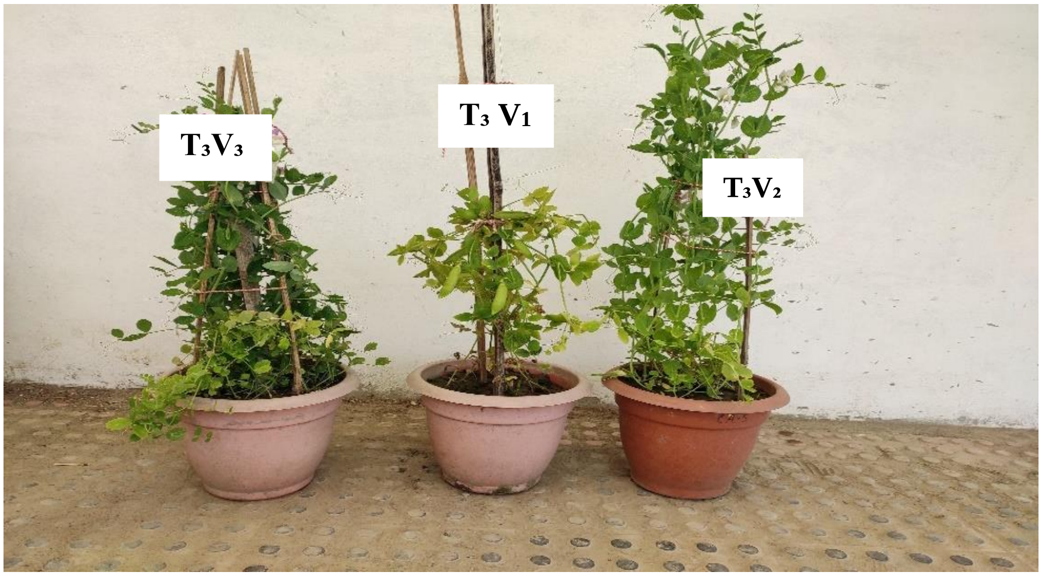


Plate 3. Effect of Salinity on Plant Height (cont'd)



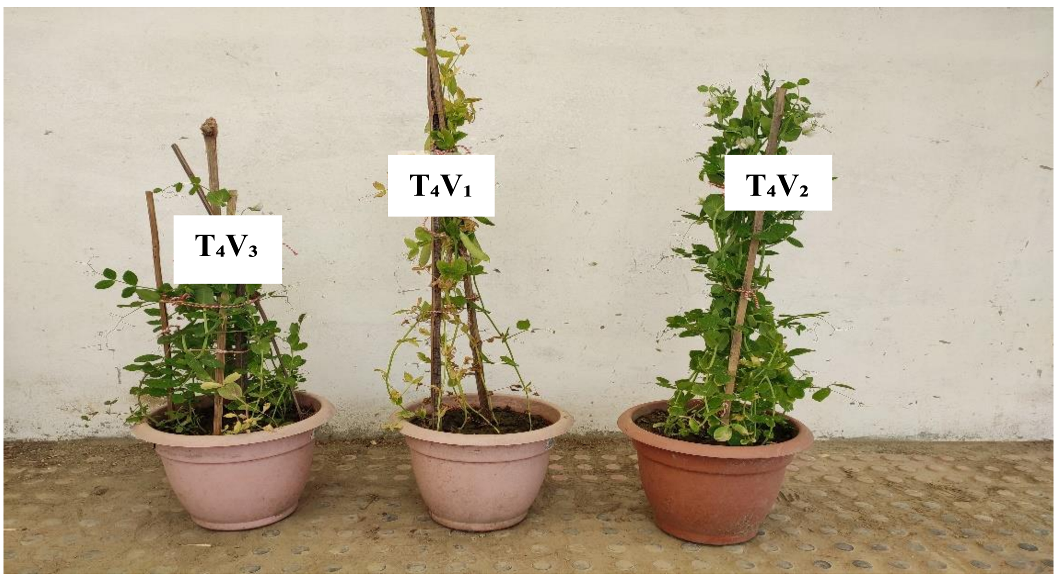


Plate 3. Effect of Salinity on plant height

Interaction effect of salinity level and variety

The interaction effect on plant height between varieties and salinity levels was found significant. From the Table 2, it was observed that the tallest plant was found (68.20 cm) in BARI Motor 2 at 4 dS/m salinity level at vegetative stage and the shortest plant (34.18 cm) was found in BARI Motor 1 at 12 dS/m salinity level at maturity stage.

Significantly reduced plant height was observed with the increase of salinity level i.e., BARI Motor 1 (T_2 = 4dS/m 45.63 cm, T_3 = 8 dS/m 42.55cm and T_4 = 12 dS/m 39.65 cm). This tables shows that in the maturity stage plant height drastically reduced at the salinity level of 12 dS/m. Like the vegetative stage the lowest plant height was recorded at BARI Motor 1 (39.65 cm) followed by BARI Motor 3 (48.66 cm). Here also significant reduced plant height was observed with the increase of salinity level i.e., BARI Motor 2 (T_2 = 4 dS/m 68.20 cm, T_3 = 8 dS/m 64.60cm and T_4 = 12 dS/m 60.87cm). In the reproductive phase, it might be concluded that the increase of salinity level decrease plant height. Salinity stress resulted in a clear stunting of plant growth in BARI Motor 1, so it showed the lowest plant height at all stage.

Table 2. Interaction effect of salinity level and field pea variety on plant height (cm)

Interaction	Plant height at vegetative stage (cm)	Plant height at maturity stage(cm)
Treatment ×Variety		
Control ×BARI Motor 1	48.73 h	49.13 g
Control ×BARI Motor 2	70.42 a	73.52 a
Control ×BARI Motor 3	57.05 e	62.64 b
4 dS/m× BARI Motor 1	45.63 i	42.11 h
4 dS/m× BARI Motor 2	68.20 b	64.07 b
4 dS/m× BARI Motor 3	54.43 f	54.40 e
8 dS/m× BARI Motor 1	42.55 j	37.70 i
8 dS/m× BARI Motor 2	64.60 c	59.70 c
8 dS/m× BARI Motor 3	51.41 g	49.60 f
12 dS/m× BARI Motor 1	39.66 k	34.18 j
12 dS × BARI Motor 2	60.87 d	57.05 d
12 dS × BARI Motor 3	48.66 h	45.50 g
SE(±)	**0.165**	**0.771**
CV	**5.74**	**6.83**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly

There were declining plant height characteristics in all varieties as saline levels increased. Ehtaiwwesh and Emsahel (2020) found that under increased salinity levels, the plant height was significantly reduced in field pea plants. Wests and Francios (2004) reported that vegetative growth reduced 9.0% for each unit increase in electrical conductivity of in cowpea. According to Khan *et al*. (2019) significant reduction was observed in relative plant height (%) of pulse species as affected by salt stress and the lowest (51%) was found in lentil. Similar trends were also reported by Hossain *et al*. (2008), Qados (2011) and Velmani *et al*. (2012) in *Vigna spp* and Bakht *et al.* (2011) in *Zea mays.* The reduction of the plant height due to increasing salinity may be a result of a combination of osmotic ion effects of Na and Cl (Zhu *et al.*, 2001). Singh *et al.* (1993) discovered similar results. They investigated the influence of varied degrees of soil salinity on the plant height parameter and discovered that increasing soil salinity lowered plant height.

4.1.2. Effect of salinity level on leaf length

Effects of different salinity levels

The leaf length was significantly ($P<0.05$) affected by salinity stress during both vegetative and maturity stage given in Figure 2. At vegetative stage the highest leaf length (14.22 cm) was found from control followed by 4 dS/m(11.37cm). The lowest leaf length (6.43cm) was recorded at 12 dS/m salinity level followed by 8dS/m(8.54cm). At maturity stage the lowest (5.03 cm) was recorded from the salinity level 12 dS/m and the highest (10.58 cm) was observed from control followed by 4 dS/m (7.39cm). At 8 dS/m salinity level leaf length was found 6.43 cm.

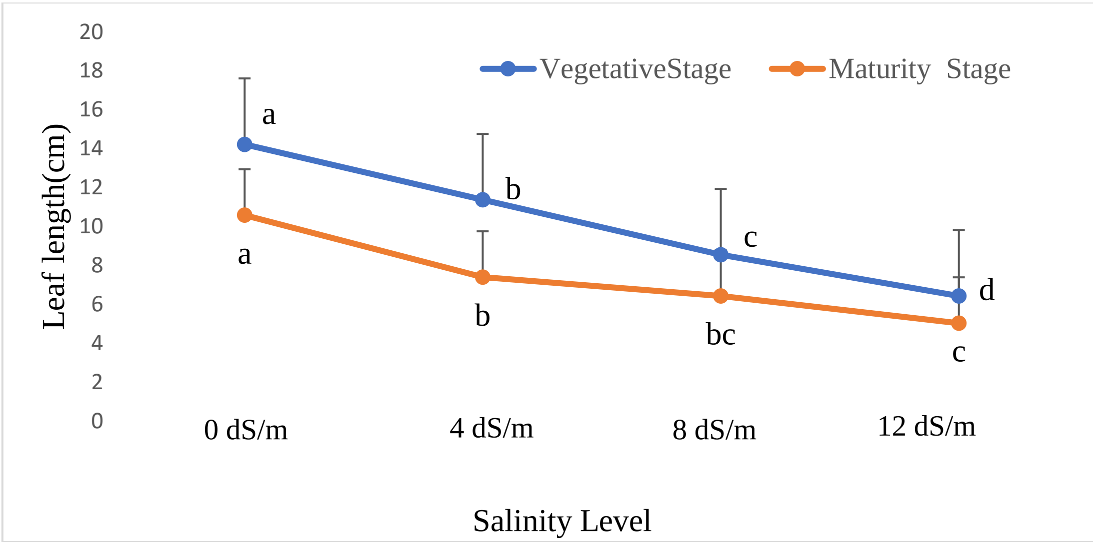


Figure 3. Effect of salinity level on leaf length (cm) of field pea at LSD $_{(0.05)}$ (2.04) (vegetative stage) 1.72(maturity stage). Here vertical bar shows standard deviation

The result of the study is in the line with of Kagan *et al.* (2010) and Saratale *et al*. (2010) who reported that salinity inhibits elongation of shoot in lentil and increasing NaCl treatment results significant reduction of shoot growth. It was reported by Tesfaye *et al.* (2014) that the reduction of shoot length was probably due to the excessive accumulation of salts in the cell wall elasticity thus, secondary cell appears sooner and cell wall becomes rigid as a consequence the turgid pressure efficiency in cell enlargement decreases that result in short shoot growth.

Interaction effect of salinity stress and variety on leaf length (cm)

The interaction effect on leaf length between varieties and salinity levels was found significant. From the Table 3, it was observed that the maximum leaf length was found BARI Motor 2 (17.70 cm) at control and (8.520 cm) at 12 dS/m and minimum leaf length was found in BARI Motor 1(4.33cm) at 12 dSm^{-1} salinity level in vegetative stage. Again, it was found that the maximum leaf length was found BARI Motor 2 (11.007 cm) at control and 6.60 cm at 12dS/m in maturity stage. In this stage minimum leaf length was found in BARI Motor 1(4.103cm) at 12dS/m salinity level.

Table 3. Interaction effect of salinity level and field pea variety on leaf length (cm)

Interaction	Leaf length at vegetative stage (cm)	Leaf length at maturity stage (cm)
Treatment ×Variety		
Control ×BARI Motor 1	11.567	8.270 bc
Control ×BARI Motor 2	17.700 a	11.007a
Control × BARI Motor3	13.400 c	10.01b
4 dS/m× BARI Motor 1	7.667ef	6.733cd
4 dS/m× BARI Motor 2	14.833 b	8.183bc
4 dS/m× BARI Motor3	11.600 d	7.267cd
8 dS/m× BARI Motor 1	5.633 gh	5.733d
8 dS/m× BARI Motor 2	11.100d	7.147cd
8 dS/m× BARI Motor 3	8.900 e	6.410cd
12 dS/m× BARI Motor 1	4.333 h	4.103d
12 dS × BARI Motor 2	8.520 e	6.60cd
12 dS × BARI Motor3	6.433 fg	6.38cd
SE(±)	**0.646**	**0.564**
CV	**7.81**	**16.13**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly

Munns and Tester (2008) found that in early leaves, salinity stress impacts cell expansion, which typically results in a reduction in area of leaf. Lee *et al*.(2010) found a marked decline (27%) in shoot length when soybean plants were exposed to 80 mM NaCl Again, salinity also affects photosynthesis mainly through a reduction in leaf growth , chlorophyll content and stomatal conductance (Netondo *et al.,* 2004).

4.1.3 Effect of Salinity on Number of Leaf

Salinity adversely affected the production of leaf number in field pea plants. The leaf number is the very important character for plant growth as leaf is the main photosynthetic organ. The influence of salt stress on the number of leaf/plant was significant (Table 4) at vegetative and harvesting stage. The highest (14.667) number of leaf/ plant was found in BARI Motor 2 from control followed by BARI Motor 3 and lowest (5.583) in BARI Motor 1 at 12 dS/m salinity level at vegetative stage. There was significant variation in vegetative stage under different salinity stage. i.e, BARI Motor

1(T_2 = 4dS/m 8.533, T_3 = 8 dS/m 6.833 and T_4 = 12 dS/m 5.583), BARI Motor 2 ,(T_2 = 10.333, T_3 = 8 dS/m 8.583 and T_4 = 12 dS/m 6.977), BARI Motor 3 (T_2 = 12.600, T_3 = 8 dS/m 10.00 and T_4 = 12 dS/m 8.617), In the vegetative phase, it might be concluded that the increase of salinity level decreases the number of leaves per plant. At maturity stage the highest number of leaves per plant was recorded at BARI Motor 2 (14.667) followed by BARI Motor 3 (12.600) in the control condition. This value indicates that there are significant positive correlations among different stages. Significantly reduced number of leaves per plant was observed with the increase of salinity level i.e., BARI Motor 2 (T_2 = 4 dS/m 10.33, T_3 = 8 dS/m 8.53 and T_4 = 12 dS/m 6.97). This table shows that in the reproductive stage number of leaves per plant drastically reduced the salinity level of 12 dS/m. The lowest number of leaves per plant was recorded at BARI Motor 1 (5.58). Here also significant reduced number of leaves per plant was observed with the increase of salinity level i.e., BARI Motor 3 (T_2= 4 dS/m 10.00, T_3 = 8 dS/m 8.61 and T_4 = 12 dS/m 6.16). In the reproductive phase, it might be concluded that the increase of salinity level decreases the number of leaves per plant.

Table 4. Effect of Salinity and varieties on Number of Leaf of field pea at different stages

	Vegetative Stage				**Maturity Stage**			
	Salinity Level (dS/m)				**Saliniy Level** (dS/m)			
Varieties	0	4	8	12	0	4	8	12
BARI Motor 1	10.58c	8.53d	6.83ef	5.58g	14.33c	12.17d	10.00f	7.17h
BARI Motor 2	14.67a	10.33c	8.58d	6.97e	18.00a	14.03c	11.00e	9.50f
BARI Motor 3	12.60b	10.00c	8.62d	6.17fg	16.00b	11.70de	10.13f	8.00g
SE(±)	**0.3597**				**0.3421**			
CV	**5.83**				**3.54**			

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Hassine and Lutts (2010) and Bakht *et al.* (2011) tested *Solanum tubersum, Atriplex halimus, and Zea mays* respectively under saline circumstances and discovered a significant reduction in internodal distance in response to salt stress. This decrease in internodal distance and leaf number may be due to a decrease in turgor potential, which is required for cell elongation (Iqbal and Ashraf, 2005) as well as turgor pressure which was lowered during salt stress (Ashraf and Harris, 2004). In the current study, salt stress increased the concentration of abscisic acid (ABA) in leaves, which acts as a senescing agent; consequently, the reduction in the number of leaves in tested pea genotypes may also be connected with the synthesis of ABA under salt stress.

Ehtaiwwesh and Emsahel (2020) reported that reduction in the leaf number of field pea under increase of different salinity level. Similar trend was found by Wolde and Adamu (2018).

4.1.4 Effect of Salinity on Number of Branch/plant

The interaction effect of salinity levels and field pea varieties on Number of branch/ plant was also varied insignificantly (Table 4). The highest number of branch/plant was found in BARI Motor 3 (5.33) at control condition which was followed by BARI Motor 1 (4.67) at vegetative stage. The value of number of branch/plant is similar to the value when it was treated with salt stress. Same trend was found also at maturity stage.

Table 5. Interaction effect of salinity level and field pea variety on number of branch/plant

Interaction	Number of Branch/plant at vegetative stage	Number of Branch/plant at maturity stage
Treatment ×Variety		
Control ×BARI Motor 1	4.67	12.33
Control ×BARI Motor 2	4.00	11.00
Control × BARI Motor3	5.33	11.33
4 dS/m× BARI Motor 1	4.33	8.67
4 dS/m× BARI Motor 2	3.67	9.67
4 dS/m× BARI Motor3	4.35	9.67
8 dS/m× BARI Motor 1	4.39	8.00
8 dS/m× BARI Motor 2	3.33	8.33
8 dS/m× BARI Motor3	4.33	7.67
12 dS/m× BARI Motor 1	4.00	7.33
12 dS × BARI Motor 2	4.35	8.33
12 dS × BARI Motor3	4.33	7.67
SE(±)	**2.879**	**2.843**
CV	**19.40**	**11.38**

Wolde and Adamu (2018) found that number of branches per plant was not significantly influenced by salt concentrations in field pea plants like any other legume crops.

4.2 Effect of Salinity on Physiological Characteristics

4.2.1 Effect of Salinity on Chlorophyll Content

The amount of photosynthesis harvested is critical to yield accumulation. The center of photosynthesis is the SPAD value of the leaf. The higher the SPAD value, the higher the photosynthesis. SPAD value is not highest in the vegetative stage but in the reproductive stage, and it stars declining at maturity stage as the leaves become old. So, the graph (4) is positivity skewed from vegetative stage but in the reproductive stage and negatively skewed from reproductive stage to maturity stage. At reproductive stage the highest amount of leaf SPAD value was recorded at BARI Motor (55.00) followed by BARI motor 3 (49.57) in the control condition. At 8dS/m salinity level the highest amount was observed from BARI Motor 2(47.28) followed by BARI Motor 3(43.00). This value indicates that there are significant positive correlations among different stages. This graph (4b) shows that in the reproductive stage amount of leaf SPAD value drastically reduced the salinity level of 12 dS/m. The lowest SPAD value was recorded at BARI Motor 1(31.7) followed by BARI Motor 3 (39.12). In the reproductive phase, it might be concluded that the increase of salinity level decreases the amount of leaf chlorophyll content.

At maturity stage the amount of leaf SPAD value significantly reduced than the reproductive phase. At maturity stage the highest amount of leaf SPAD value recorded at BARI Motor 2 (57.02) followed by BARI Motor 3(50.03) in the control condition. At 12 dS/m salinity level the lowest amount SPAD value was obtained from BARI Motor 1 (32.08) followed by BARI Motor 3(35.2). Maturity stage were similar with the vegetative and reproductive stage. This value indicates that there are significant positive correlations among different stages.

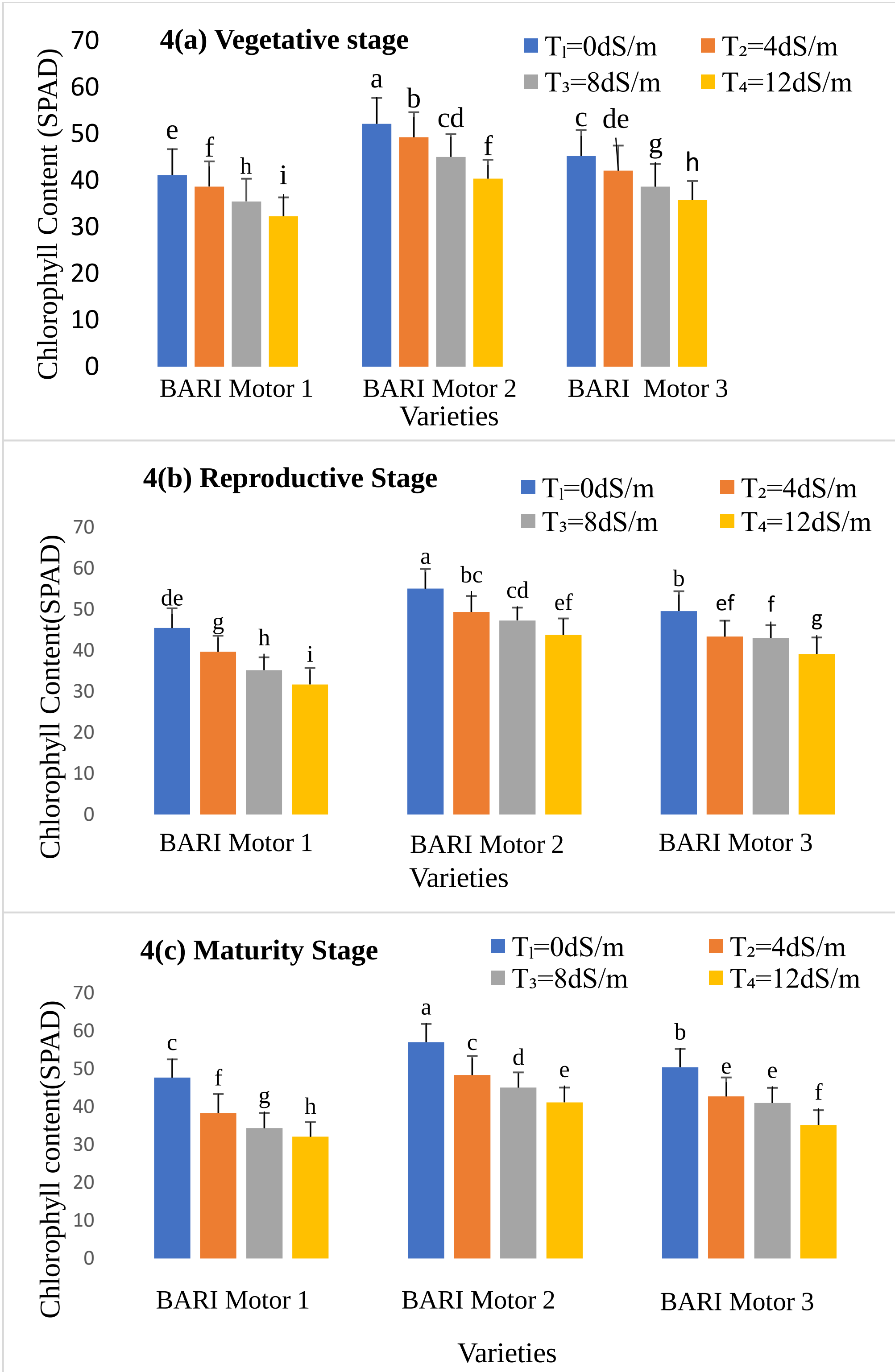


Figure 4(a) (b) (c). Leaf SPAD value at different salinity (T_1, T_2, T_3 and T_4) level LSD $_{(0.05)}$ 1.33 (vegetative), 1.47 (reproductive), 1.72 (maturity)] Here, the vertical bar represents the standard deviation

Salinity stress caused swelling of membranes in chloroplasts of sensitive plants which affected their chlorophyll content, or it occurred due to excess ions (Na+ and Cl-) in leaves which induced loss of chlorophylls (Wahid *et al*, 2004 and Arulbalachandran *et al.*, 2009). Accumulation of toxic ions under salinity stress reduced the water and osmotic potential that further caused disturbances in photosynthetic processes (Khan *et al*., 2010). According to Singh *et al*.(2016) reduction in chlorophyll content might be due to salt-induced increase in the activity of the chlorophyll degrading enzyme, chlorophyllase) or it could be related to photo-inhibition or ROS formation (Kato and Shimizu, 1985). Sanwal *et al*. (2018) found that a significant reduction in SPAD values were seen in almost all the genotypes of pea.

4.2.2 Effect of Salinity on Relative Water Content

Salinity, measured in varied concentration, has positive effect on the relative water content. Water content decreased as salinity increased. Increasing salinity caused a decrease in water content in leaf tissue. Significant changes in relative water content were observed in leaf tissue at various NaCl concentrations. The RWC is related to water uptake by the roots as well as water loss through transpiration. Salinity, imposed in terms of different concentration levels, profoundly affected the relative water content in all varieties used in this experiment. The highest relative water content was found in BARI Motor 2(84.36%), and the second highest was in BARI Motor 3 (80.76%) at control. The stress condition (8 dS/m) for BARI Motor 2 and BARI Motor 3 exhibited the maximum relative water content. Reduced water content was found in stress conditions of 12 dS/m where highest value (37.69%) was found in BARI Motor 2 and lowest value (33.10%) was found in BARI Motor 1.

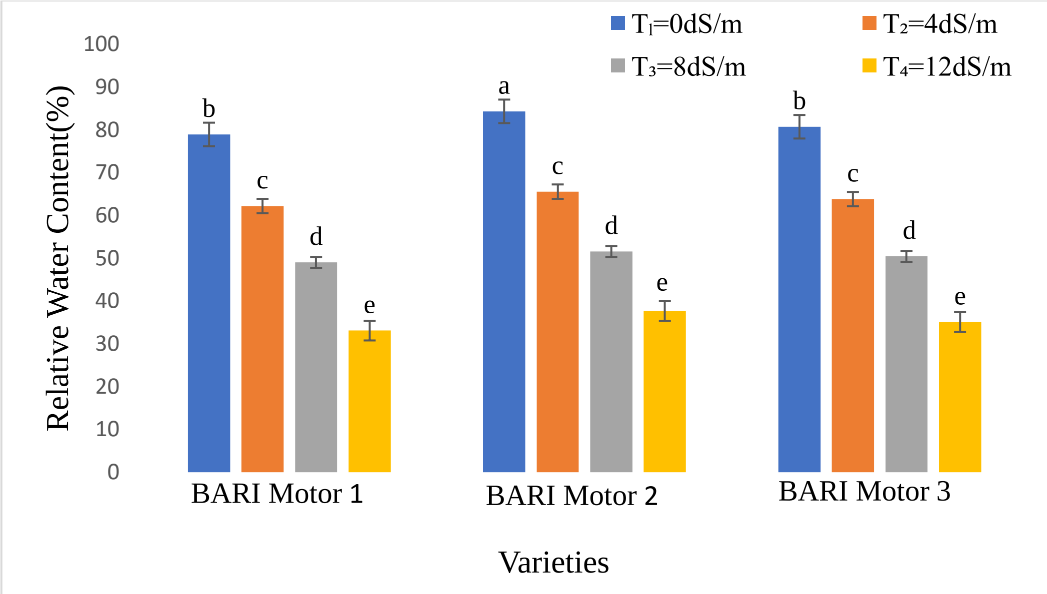


Figure 5. Effect of salt stress on the relative water content of selected field pea varieties under different salinity level during $LSD_{(0.05)}$ 4.14. Here, the vertical bar represents the standard deviation

According to Katerji *et al*. (1997) Salt treatment induced a reduction in leaves' RWC, which indicates a loss of turgor that resulted in limited water availability for cell extension process. Thus, the growth inhibition in less tolerant plants could be related to the decrease of RWC provoked by the salt treatment (Ahmed *et al*., 2005).

Khan *et al*. (2022) reported that increase in salt stress cause the reduction in relative water content of leaves of different genotypes of field pea. Similarly, other researchers (Polash *et al*.,2018 and Ibrar *et al*.,2003) reported decreasing water contents with increased salt stress in different crops, such as rice and Medicago, polymorpha while root moisture contents were enhanced with increasing salinity levels.

4.2.3 Effect on Salt Tolerance Index

Salt tolerant index decreased as salinity stress increased. At 12 dS/m salinity level BARI Motor 2 showed the highest STI value (38.47%) whereas BARI Motor 1 displayed the lowest STI value (32.23%). Similar trend was also observed at 8 ds/m salinity level. There was significant variation (P<0.05) under different salt stress.

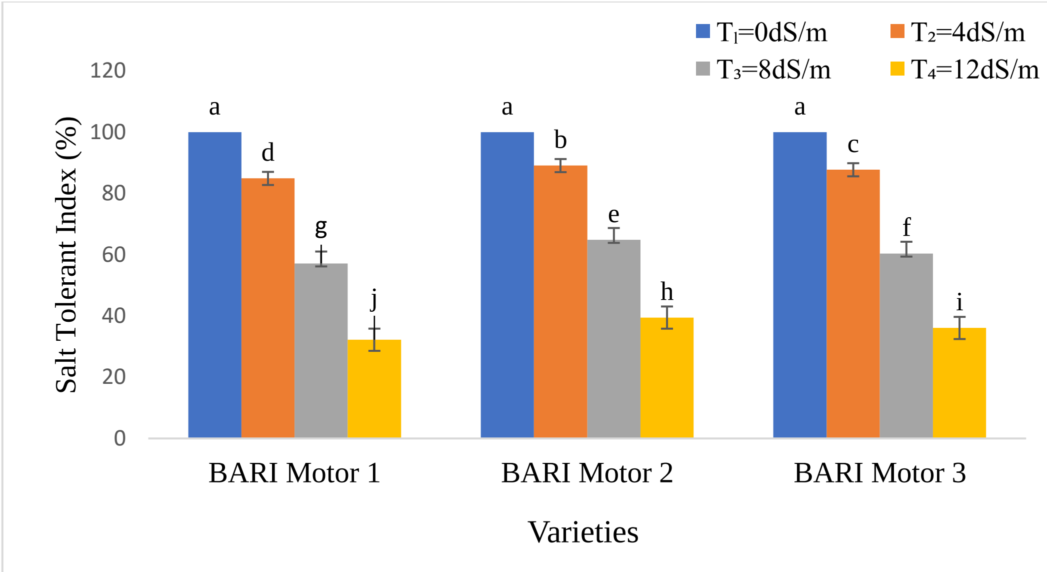


Figure 6. Effect of salt stress on salt tolerant index of selected field pea varieties during LSD $_{(0.05)}$ 1.48. Here, the vertical bar represents the standard deviation

The results were in line with Awasthi *et al*., (2016) in which *Vigna mungo* displayed the maximum STI at 50 mM salt stress level (46.5%), whereas *Vigna radiata* displayed the lowest STI at 100mMsalt stress level (20.8%). Similar outcomes were also observed by Khan *et al*. (2022) and Ehtaiwwesh and Emsahel (2020).

4.2.4 Effect of Number of Nodule/plant

Significant variation($P<0.05$) was found with the increase of salinity stress on nodule number/plant. At 12 dS/m salinity level the greatest reduction in nodule number was observed from BARI Motor 1 (34) followed by BARI Motor3 (37.33). Similar trend was also found from at 8 dS/m where the minimum reduction was in BARI Motor 2 (62.67) followed by BARI Motor 3 (54.33). The highest nodule number/plant (106.00) was obtained from control in BARI Motor2.

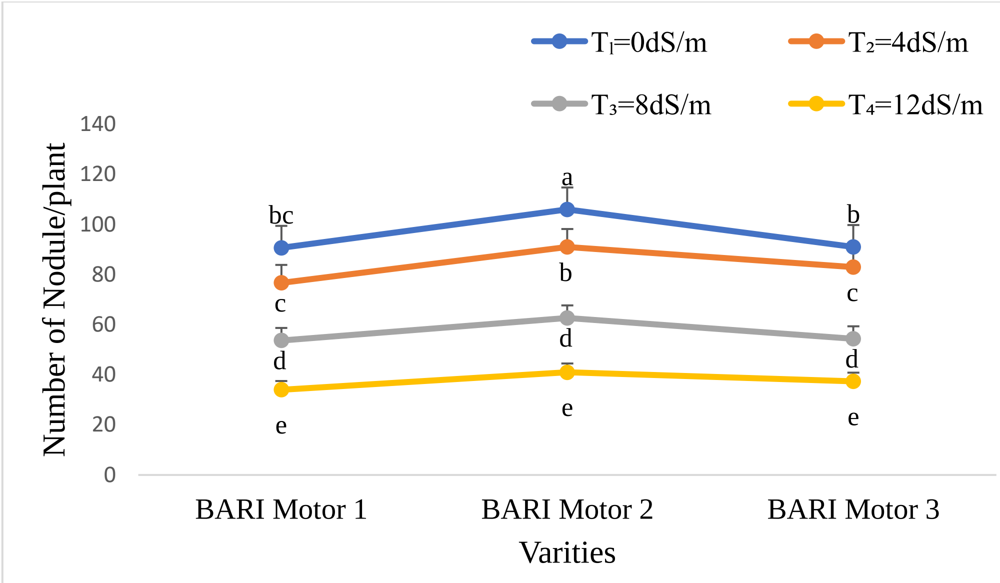


Figure 7. Effect of salt stress on number of nodules of selected field pea varieties. during LSD $_{(0.05)}$ 4.06. Here, the vertical bar represents the standard deviation

Salinity inhibited the formation of new nodules (Yousef and Sprent,1983). According to Zahran and Sprent (1986), Salinity reduced the expansion and curling of root hairs, as well as the quantity of nodules,). Many studies have found a decrease in plant nodulation under salinity: bean (Steinborn and Roughley,1975; Abdel-Wahab and Zahran,1981), soyabean broad bean (Abdel-Wahab and Zahran,1981), and pea (Zahran and Sprent, 1986; El-Hamdaoui *et al*., 2003).

T_1= 0 dS/m **T_2= 4dS/m** **T_3= 8 dS/m** **T_4=12dS/m**

Plate 4. Effect of salinity on number of nodule/plant of BARI Motor 2

4.3 Effect of Salinity on Yield Characteristics

4.3.1 Effect of Salinity on Number of Seed/pod and Number of pod/plant

Salinity has adverse effect on number of seed/pod and number of pod/plant. The reduction in number of pod and seed was significant ($P<0.05$) increasing of salinity. At 12 dS/m salinity level the highest number of seed/pod (4.40) was found in BARI Motor 2 followed by BARI Motor 3(3.91). Similar trend was seen at 8dS/m salinity level. The highest number of seed/pod (8.20) observed in BARI Motor 2 and the lowest (6.00) in BARI Motor 1 from control.

Under various salinity stresses, the number of pods/plant was also reduced. The highest number of pod/plant (7.33) was found in BARI Motor 2 followed by BARI Motor 3 (5.00) and the lowest (4.33) in BARI Motor 1.BARI Motor 2 displayed the highest result also at 8 dS/m(10.33) and 4dS/m(13.67) salinity level followed by BARI Motor 3 7.00 and 8.67 respectively.

Table 6. Effect of Salinity and varieties on Number of Seed/pod and Number of Pod/plant of field pea varieties

	Number of seed/pod				**Number of pod/plant**			
	Salinity Level (dS/m)				**Saliniy Level** (dS/m)			
Varieties	0	4	8	12	0	4	8	12
BARI Motor 1	6.00c	5.00de	4.33ef	3.01g	9.33de	7.33fg	6.00gh	4.33i
BARI Motor 2	8.20a	7.00b	5.33cd	4.05f	17.00a	13.67b	10.33cd	7.33fg
BARI Motor3	7.00b	5.70cd	4.40ef	3.91f	11.00c	8.67ef	7.00g	5.00hi
SE(±)	**0.399**				**0.778**			
CV	**9.07**				**10.69**			

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Both salt and water stress can cause shriveled seeds and a decreased yield. As a result, it is possible to assume that reduced yield under salt stress is attributable to reduced plant efficiency per day in filling developing seeds, which may result in a lower number of seeds per pod/or plant and dry matter yield of individual seed. Delayed maturity owing to salt stress exposes the plant to desiccation stress, resulting in shriveled seeds. Raptan *et al*. (2001) added that the reduction in number of seeds per pod of the plants which irrigated with 100 mm NaCl was 50% as compared to the plants which irrigated with tap water. In the study of Leonforte (2013) it was found that seven genotypes of field pea showed significant variation for number of pod and seeds set per plant.

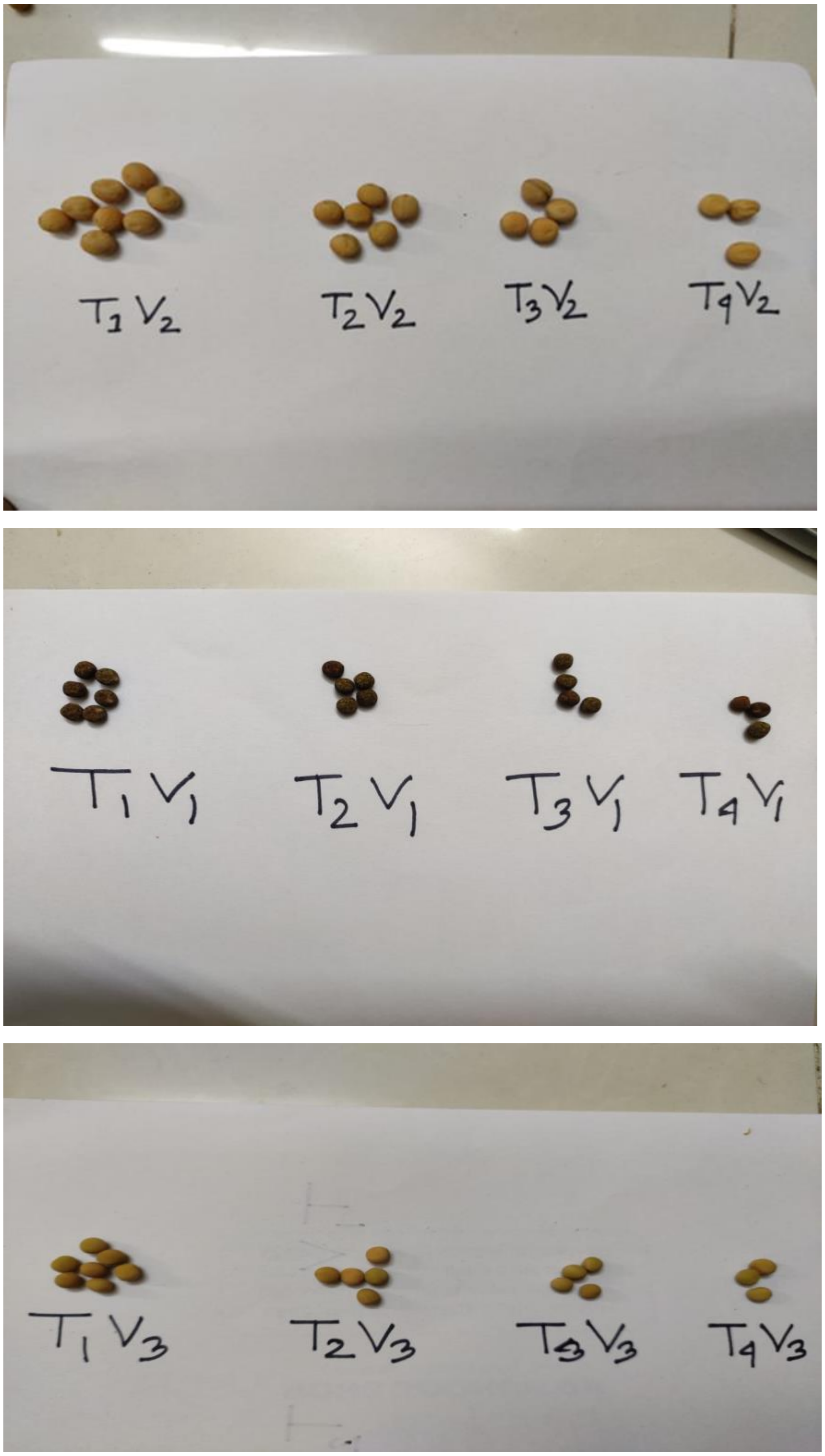


Plate 5. Effect of salinity on number of seed of different varieties of field pea

4.3.2 Effect of Salinity on pod length

There was significant variation of salinity and field pea varieties on pod length. The longest pod(5.03cm) was found in BARI Motor 2 followed by BARI Motor3 (4.93cm) from control. BARI Motor 2 showed the highest result at 4dS/m(4.67cm),8dS/m (4.2cm) and 12dS/m(4.0cm) salinity level. At 12 dS/m the shortest pod was found in BARI Motor 1(3.7cm) followed by BARI Motor 3. Same trend was found at 4 and 8dS/m salinity level.

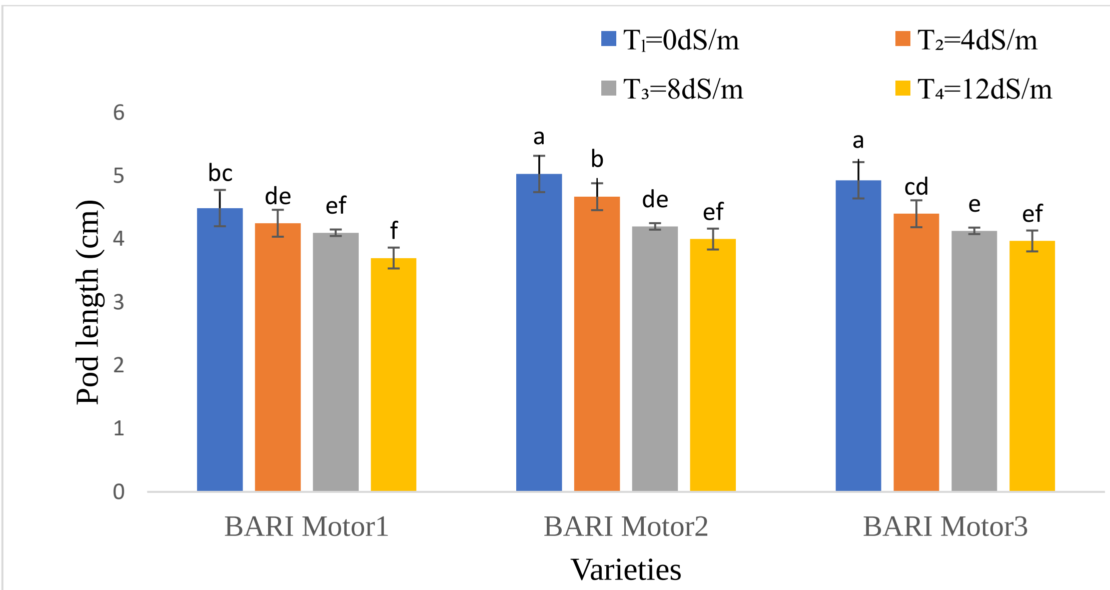


Figure 8. Effect of salinity level on pod length (cm) of field pea varieties. Here, the vertical bar represents the standard deviation, and LSD $_{(0.05)}$ 0.23

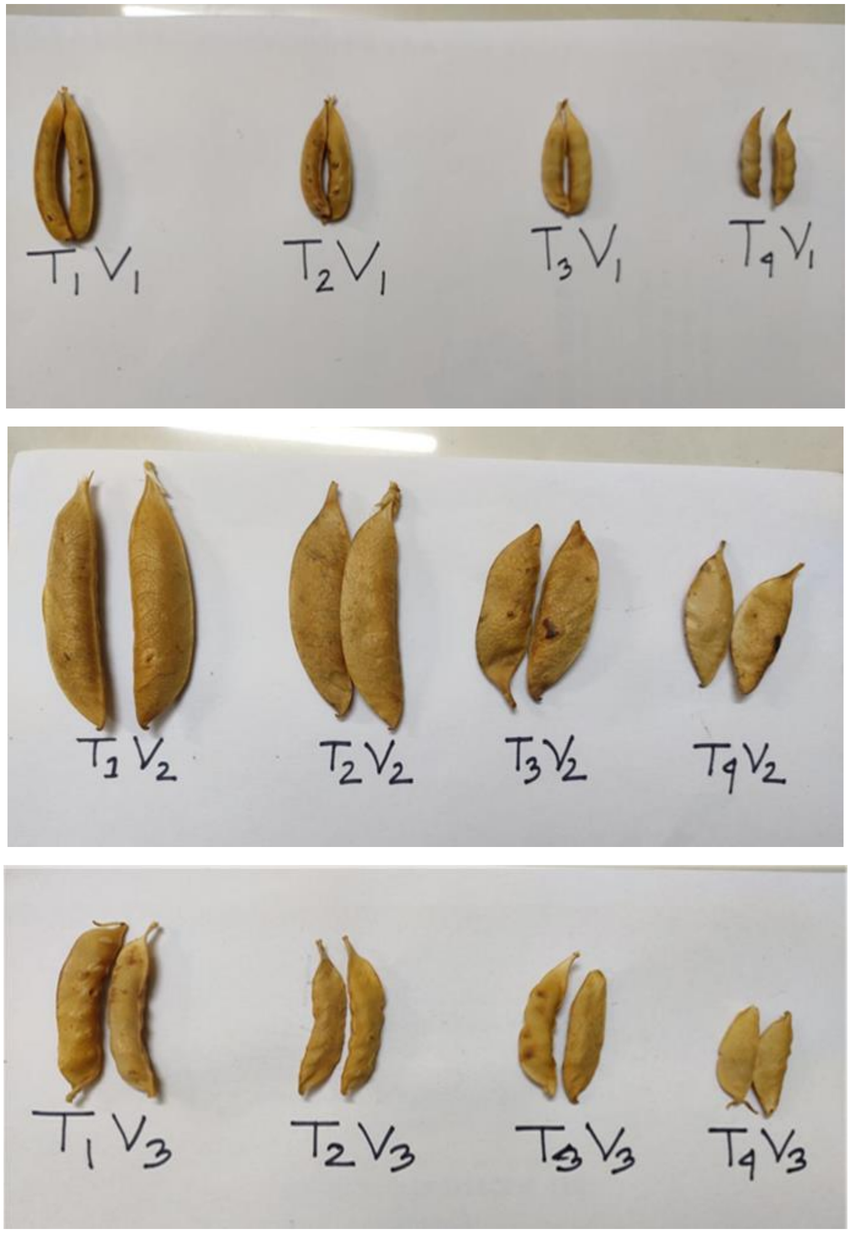


Plate 6. Effect of salt stress on pod length of different field pea varieties

4.3.3 Effect of Salinity on individual weight of pod/plant (g)

The figure shows the relationship between salinity and individual fresh and dry weight of pod/plant. Salinity is strongly (r=0.99) positively (R^2=0.988) related with individual fresh weight of pod/plant and individual dry weight of pod/plant (R^2=0.996).An increase in salinity level significantly (P<0.001) decreased the individual fresh and dry weight of pod/plant.

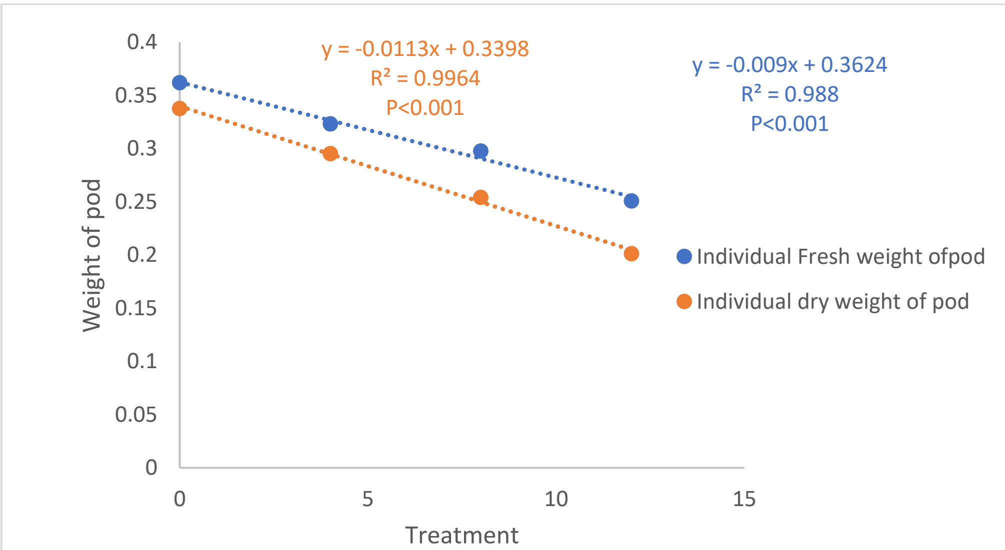


Figure 9. Effect of Salinity on individual fresh and dry weight of pod

Interaction effect of salt stress and varieties

The interaction effect of salinity stress varieties on individual pod weight was also varied significantly. At 12 dS/m salinity level The highest individual fresh pod weight(0.30g) was found in BARI Motor 2 followed by BARI Motor 3(0.26g). At 8dS/m the lowest individual fresh weight of pod was observed in BARI Motor 1(0.22g) followed by BARI Motor 3(0.30g) and BARI Motor 2(0.34g). Similar trend was found in individual dry weight of pod. As the level of salt raised the dry weight of pod decreased. At high salinity level 12 dS/m the lowest individual dry weight of pod (0.16g) was found in BARI Motor 1 followed by BARI Motor 3(0.20g). Similar trend was observed in 8dS/m and 4dS/m. The highest amount was found from control in BARI Motor 2(0.36g) as there was no salt stress there.

Table 7. Interaction effects between salinity level and varieties on individual pod weight (g)

	Individual weight of pod(g)	
Interaction	**fresh wt. of one pod (g)**	**dry wt. of one pod (g)**
Treatment ×Variety		
Control ×BARI Motor 1	0.30d	0.25e
Control ×BARI Motor 2	0.39a	0.36a
Control × BARI Motor3	0.36b	0.30c
4 dS/m× BARI Motor 1	0.26e	0.23f
4 dS/m× BARI Motor 2	0.38a	0.32b
4 dS/m× BARI Motor3	0.33c	0.27d
8 dS/m× BARI Motor 1	0.23f	0.19g
8 dS/m× BARI Motor 2	0.34bc	0.27d
8 dS/m× BARI Motor3	0.30d	0.24f
12 dS/m× BARI Motor 1	0.19f	0.16h
12 dS × BARI Motor 2	0.30d	0.25e
12 dS × BARI Motor3	0.26e	0.20g
SE(±)	**0.050**	**0.090**
CV	**3.29**	**2.64**

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

4.3.4 Effect of Salinity on 100 seed weight

Seed weight gradually reduced as salinity levels rose. This graph shows that the highest value (38.43g) of 100 seed weight was found in BARI Motor 2 followed by BARI Motor 3 (34.87g) from control. When the salinity level is high (12dS/m) BARI Motor 2 (28.02g) showed highest result again followed by BARI Motor 3 (20.88g) and the lowest (17.86g) result was showed by BARI Motor 1. At 8 dS/m the lowest value (20.38g) was found in BARI Motor 1 followed by BARI Motor 3(27.28g).

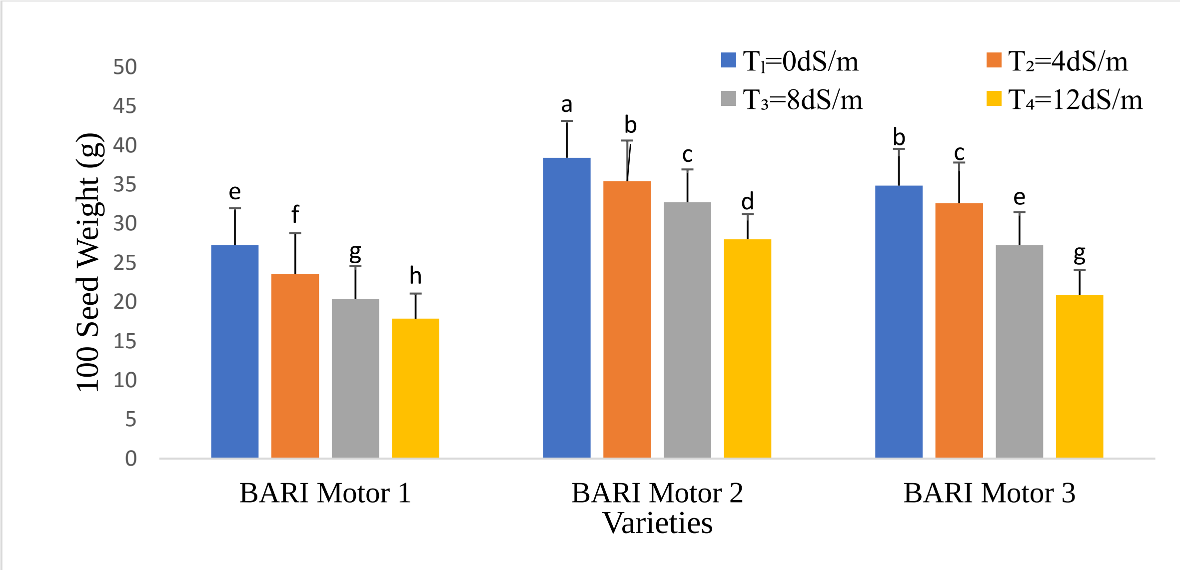


Figure 10. Effect of salinity and varieties on 100 seed weight. Here, the vertical bar represents the standard deviation, and LSD (0.05) 1.19

With the increased salinity level the 100-grain weight gradually decreased. Study revealed the effect of varying salinity levels on weight of seeds of cowpea and found that seed yield/plant gradually decreased with increasing salinity level. Research disclosed that soil salinity affected seed yield of chickpea and soybean.

According Leonforte (2013), the seed yield was highly decreased while the salt stress was 12 dS/m and 18dS/m in field pea genotypes.

4.3.4 Effect of Salinity on yield/plant

Increased salt content caused a yield reduction in different field pea varieties. The highest yield (6.68g) was obtained from control in BARI Motor 2 followed by BARI Motor 3(3.96g). At 8 dS/m the lowest yield was found in Bari motor 1(1.92g) followed by BARI motor 3 (2.96g).Same trend was seen in case of 4dS/m also. The highest reduction was seen at 12 dS/m salinity level where BARI motor 2 showed the best result (2.23g) and the lowest yield was observed in BARI Motor 1 (0.93g).

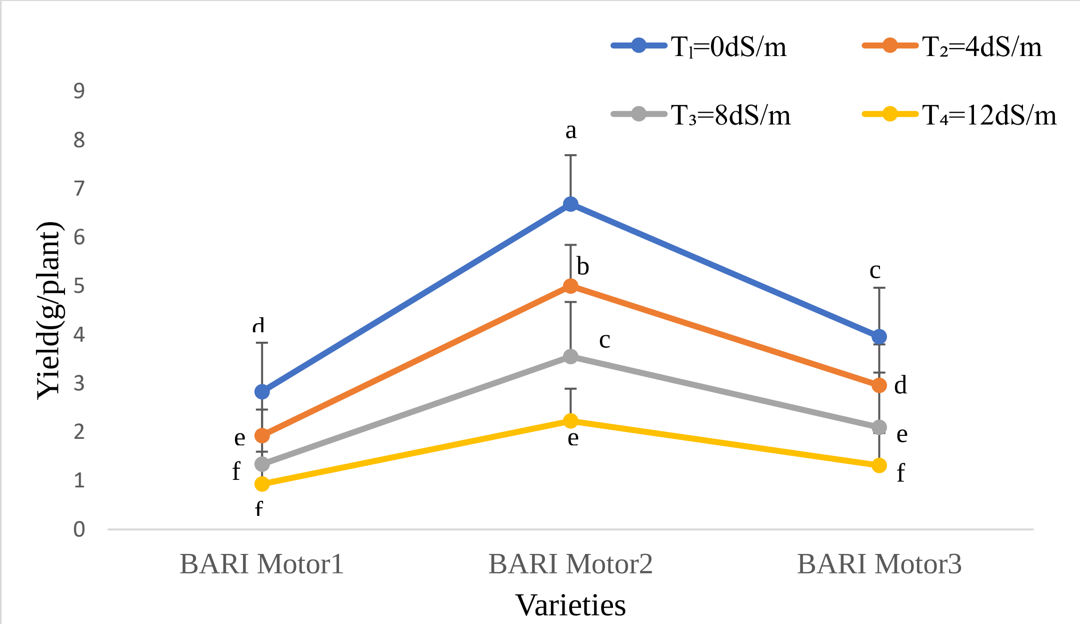


Figure 11. Effect of salinity and varieties on yield(g/plant). Here, the vertical bar represents the standard deviation, and LSD (0.05) 0.53

The yield and yield components of black gram (number of seed per plant, and yield per plant) reduced due the imposition of salt stress reconfirms by Ahmed (2009) and Hossain *et al.*(2008). According to Ouerghi *et al.* (2016), field pea yields were shown to be reduced by almost 50% at 100 mM NaCl, and productivity decreased after being exposed to high salinity levels (Najafi *et al.*, 2007). It was reported by Joshi *et al*. (2021) that during pod filling stage, a fully formed leaf retains high levels of Na+ and Cl- ions in the reproductive organs that leads to limited ion buildup floral blossoms and the ovules that are growing. The high levels of ion accumulation in leaves may lead to a reduction in the efficiency of photosynthesis, which in turn impacts the yield of seeds.

4.4 Correlation among the variable studied

There was correlation among the parameters studied above. Correlation was seen between the morpho-physiological and yield characteristics. Plant height is strongly positively (r=0.998) correlated with chlorophyll content (SPAD value) and yield(r=0.999). Number of leaf has strong positive(r=0.999) correlation with chlorophyll content (SPAD value) and number of pod/plant(r=0.997). Correlation among the chlorophyll content (SPAD value) , relative water content and salt tolerant index was also seen in the table 7. Salt tolerant index had strong positive correlation with yield/plant (r=0.997) and 100 seed weight (r=0.999).From the table 8 the correlation among the yield attributes i.e number of seed/pod, number of pod/plant, yield/plant and 100 seed weight was seen significant.

Table 8. Correlation among the parameters studied

	Plant height	Leaf length	Number of leaf	Chc(SPAD value)	RWC	STI	Number of nodule/plant	Number of pod/plant	Number of seed/pod	Yield/ plant	100 seed weight
Plant height	**1**										
Leaf length	.977	**1**									
Number of leaf	.911	.801	**1**								
Chc (SPAD value)	.998*	.962	.999*	**1**							
RWC	.998*	.813	1.000*	1.000**	**1**						
STI	1.000*	.982	.899	.998*	.908	**1**					
Number of nodule	.992	.996	.852	.983	.997*	.998*	**1**				
Number of pod	.998*	.802	1.000**	.935	1.000*	.900	.852	**1**			
Number of seed	.997*	.880	.997*	.976	.992	.953	.919	.997*	**1**		
Yield/plant	.999*	.855	.995	.997*	.997*	.997*	.898	.999*	.999*	**1**	
100 seed weight	1.000*	.972	.920	.999*	1.000**	.999*	.989	.998*	1.000**	.999*	**1**

***. Correlation is significant at the 0.05 level.**
****. Correlation is significant at the 0.01 level.**
Abbreviation: Chc= Chlorophyll content, STI= Salt tolerant index, RWC= Relative water content

CHAPTER V

SUMMARY AND CONCLUSION

5.1 SUMMARY

Salinity has severe effect on morphology, biomass, and biochemical processes of the plants, and ultimately results in plant damages. A pot experiment was conducted at the agroforestry farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from December 2021to March 2022 to evaluate morpho-physiological and yield changes. Significant variations and adaptability among stressed and non-stressed plants were observed in all varieties. The data recorded from different characters were statistically analyzed to find out the significance of difference of different levels of salinity on morpho-physiological and yield attributes of three field pea varieties. The experiment was conducted using three varieties -BARI Motor 1, BARI Motor 2 , BARI Motor 3 and three salinity levels viz. Control, 4 dS/m, 8 dS/m and 12 dS/m were outlined in Randomized complete block design (RCBD) with three replications. Collected data were statistically analyzed for the evaluation of treatments for the searching of suitable field pea variety in high salinity level. Summary of the result have been described in this chapter.

The tallest plant was (61.73cm) was obtained from control and the shortest plant (39.67 cm) was obtained from the salinity at 12 dS/m at vegetative stage. In interaction of field pea varieties and different salinity level. the tallest plant was found in BARI Motor 2(57.05cm) and shortest one found in BARI Motor 1(34.18cm) at 12 dS/m salinity stress at harvesting stage. In terms of leaf length, the maximum leaf length (11.01cm) was recorded from BARI Motor 2 followed by BARI Motor 3(6.38com) while the minimum (8.27cm) from BARI Motor 1 at mature stage. The highest number of branch/plant was found in BARI Motor 3(5.33) from control condition which was followed by BARI Motor 1(4.67) at vegetative stage. At maturity highest number of branch/plant was found in BARI Motor 1(12.33) from control and lowest was observed in BARI Motor 3 (7.67). The maximum number of leaf was found from control condition in BARI Motor 2 and the minimum one in

BARI Motor1 at 12dS/m. With the increase of salinity level the physiological characteristics decreased. Chlorophyll content, Relative water content, salt tolerant index showed reduced result at high salt (12dS/m) stress. In term of these characteristics BARI Motor 2 displayed the best result in 12 dS/m salinity level followed by BARI Motor 3.

In the terms of yield attributes number of seed, number of pod, pod length, individual pod weight and 100 seed weight were reduced when different salinity level was applied. For number of seed at 12 dS/m BARI Motor 2 gave the highest value (4.05) and the lowest value (3.01) found from BARI Motor 1. Significant variation was found for number of pod. The highest number of pod (7.33) was observed from BARI Motor 2 and lowest number (4.33) found from BARI Motor 1 at high salt stress (12 dS/m). Similar trend was observed for the individual dry weight of pod. The best seed yield obtained from BARI Motor 2 (28.02g) and the lowest from BARI Motor 1(17.63g).

5.2 Conclusion

Salinity stress is one of the most influential environmental variables limiting the productivity of field pea in arid and semiarid areas. Considering the findings of the recent experiment following conclusions might be found-

- The morphological characteristics such as plant height, leaf length, number of leaf were decreased with increase of salinity level.
- Salt tolerant index, relative water content, number of nodules/plant was reduced with increase of different salinity level.
- Yield attributes were also found decreasing with increase of salinity such as number of seed /plant, number of pod/plant, individual pod weight, 100 seed weight and yield.

It would be concluded that morpho-physiological and yield contributing characteristics were changed according to different salinity and variety factors. BARI Motor 2 was better variety for the both the salinity level of 8 dS/m and 12 dS/m for plant growth related characteristics and yield attributes under saline affected soil than BARI Motor 3 followed by BARI Motor 1. Therefore, BARI Motor 2 and BARI Motor 3 can be added in the existing cropping pattern where salinity level exists about 12 dS/m.

CHAPTER VI

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APPENDICES

Appendix I. Characteristics of soil of experimental field

A. Morphological features of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Agroforestry Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

Appendix II. List of necessary tables for result and discussion.

Table 1. Effect of salinity level on plant height (cm) of field pea

Treatment	Plant height at vegetative stage	Plant height at maturity stage
Control	61.73 a	58.43 a
4 dS/m	56.08 b	49.53 b
8 dS/m	50.85 c	44.02 c
12 ds/m	43.73 d	36.57 d
SE(±)	1.19	1.44
$LSD_{(0.05)}$	2.07	3.92

Table 2. Effect of salinity level on leaf length (cm) of field pea

Treatment	Leaf length at vegetative stage	Leaf length at maturity stage
Control	14.222 a	10.582 a
4 dS/m	11.367b	7.394b
8 dS/m	8.544c	6.43c
12 ds/m	6.429d	5.029d
SE(±)	0.97	0.61
$LSD_{(0.05)}$	2.04	1.27

LSD All-Pairwise Comparisons Test of chlorophyll content veg for Variety*Treatment

Variety	Treatment	Mean	Homogeneous Groups
2	1	52.170	A
2	2	49.260	B
3	1	45.250	C
2	3	45.067	CD
3	2	42.100	DE
1	1	41.150	E
2	4	40.397	F
1	2	38.750	F
3	3	38.667	G
3	4	35.817	G
1	3	35.497	H
1	4	32.300	I

Alpha 0.05 Standard Error for Comparison 0.6352
Critical T Value 2.074 Critical Value for Comparison 1.3273
There are 9 groups (A, B, etc.) in which the means
are not significantly different from one another.

LSD All-Pairwise Comparisons Test of chlorophyll content reproductive stage for Variety*Treatment

Variety	Treatment	Mean	Homogeneous Groups
2	1	55.000	A
3	1	49.567	B
2	2	49.333	BC
2	3	47.283	CD
1	1	45.410	DE
2	4	43.750	EF
3	2	43.333	EF
3	3	43.000	F
1	2	39.660	G
3	4	39.127	G
1	3	35.167	H
1	4	31.693	I

Alpha 0.05 Standard Error for Comparison 1.1183
Critical T Value 2.074 Critical Value for Comparison 1.4692
There are 9 groups (A, B, etc.) in which the means
are not significantly different from one another

LSD All-Pairwise Comparisons Test of chlorophyll content maturity for Variety*Treatment

Variety	Treatment	Mean	Homogeneous Groups
2	1	57.020	A
3	1	50.433	B
2	2	48.333	C
1	1	47.667	C
2	3	45.027	D
3	2	42.600	E
2	4	41.167	E
3	3	40.967	E
1	2	38.330	F
3	4	35.200	F
1	3	34.333	G
1	4	32.083	H

Alpha 0.05 Standard Error for Comparison 0.8304
Critical T Value 2.074 Critical Value for Comparison 1.7222
There are 8 groups (A, B, etc.) in which the means
are not significantly different from one another.

LSD All-Pairwise Comparisons Test of relative water content for Variety*Treatment

Variety	Treatment	Mean	Homogeneous Groups
2	1	84.360	A
3	1	80.760	B
1	1	78.957	B
2	1	65.590	C
3	2	63.840	C
1	2	62.227	C
2	3	51.590	D
2	3	50.447	D
1	3	49.033	D
2	4	37.697	E
3	4	35.103	E
1	4	33.153	E

Alpha 0.05 Standard Error for Comparison 2.4820
Critical T Value 2.074 Critical Value for Comparison 4.1474
There are 5 groups (A, B, etc.) in which the means
are not significantly different from one another.

LSD All-Pairwise Comparisons Test of STI for Variety*Treatment

Variety	Treatment	Mean	Homogeneous Groups
1	1	100.00	A
2	1	100.00	A
3	1	100.00	A
2	2	89.08	B
3	2	87.72	C
1	2	84.89	D
2	3	64.85	E
3	3	60.37	F
1	3	57.17	G
2	4	39.47	H
3	4	36.08	I
1	4	32.23	J

Alpha	0.05	Standard Error for Comparison	0.6986
Critical T Value	2.074	Critical Value for Comparison	1.4789

There are 10 groups (A, B, etc.) in which the means
are not significantly different from one another.

LSD All-Pairwise Comparisons Test of nodule number per plant for Variety*Treatment

Variety	Treatment	Mean	Homogeneous Groups
2	1	106.00	A
2	2	91.00	B
3	1	91.07	B
1	1	90.67	BC
3	2	83.00	C
1	2	76.67	C
2	3	62.67	D
3	2	54.33	D
1	3	53.67	D
2	4	41.33	E
3	4	37.33	E
1	4	34.00	E

Alpha	0.05	Standard Error for Comparison	2.0939
Critical T Value	2.074	Critical Value for Comparison	4.065

There are 5 groups (A, B, etc.) in which the means in which the means
are not significantly different from one another.

LSD All-Pairwise Comparisons Test of podlength for Variety*Treatment

Variety	Treatment	Mean	Homogeneous Groups
2	1	5.0333	A
3	1	4.9333	A
2	2	4.6733	B
1	1	4.4967	BC
3	2	4.4000	CD
1	2	4.2500	DE
2	3	4.2000	DE
3	3	4.1333	E
1	3	4.1000	EF
2	4	4.0000	EF
3	4	3.9733	EF
1	4	3.7000	F

Alpha	0.05	Standard Error for Comparison	0.1123
Critical T Value	2.074	Critical Value for Comparison	0.2329

There are 6 groups (A, B, etc.) in which the means
are not significantly different from one another.

LSD All-Pairwise Comparisons Test of yield per plant for Variety*Treatment

Variety	Treatment	Mean	Homogeneous Groups
2	1	6.6833	A
2	2	5.0007	B
3	1	3.9600	C
2	3	3.5500	C
3	2	2.8367	D
1	1	2.8300	D
2	4	2.2267	E
3	3	2.1000	E
1	2	1.9267	E
1	3	1.3400	F
3	4	1.3167	F
1	4	0.9330	F

Alpha	0.05	Standard Error for Comparison	0.2584
Critical T Value	2.074	Critical Value for Comparison	0.5359

There are 6 groups (A, B, etc.) in which the means
are not significantly different from one another.

LSD All-Pairwise Comparisons Test of 100 seed weight for Variety*Treatment

Variety	Treatment	Mean	Homogeneous Groups
2	1	38.433	A
2	2	35.433	B
3	1	34.867	B
2	3	32.737	C
3	2	32.620	C
2	4	28.020	D
3	3	27.280	E
1	1	27.280	E
1	2	23.587	F
3	4	20.883	G
1	3	20.380	G
3	4	17.863	H

Alpha 0.05 Standard Error for Comparison 0.5742
Critical T Value 2.074 Critical Value for Comparison 1.1909
There are 9 groups (A, B, etc.) in which the means
are not significantly different from one another.

Appendix III: Analysis of variance tables

Table 1: Analysis of variance on plant height at vegetative stage

Source	DF	SS	MS	F	P
Replication	2	0.14	0.07		
Variety	2	2911.39	1455.69	8928.52	0.0000
Treatment	3	412.52	137.51	843.40	0.0000
Variety*Treatment	6	2.55	0.43	2.61	0.0459
Error	22	3.59	0.16		
Total	35	3330.1			
Grand Mean	54.351				
CV	5.74				

Table 2: Analysis of variance on plant height at maturity stage

Source	DF	SS	MS	F	P
Replicati	2	6.17		3.08	
Variety	2	2888.52	1444.26	1617.83	0.0000
Treatment	3	840.88	280.29	313.98	0.0000
Variety*Treatment	6	54.29	9.05	10.14	0.0000
Error	22	19.64	0.89		
Total	35	3809.49			
Grand Mean	51.635				
CV	6.83				

Table 3: Analysis of variance on leaf length at vegetative stage

Source	DF	SS	MS	F	P
Replicati	2	4.400	2.200		
Variety	2	197.630	98.815	157.74	0.0000
Treatment	3	310.387	103.462	165.16	0.0000
Variety*Treatment	6	10.814	1.802	2.88	0.0318
Error	22	13.781	0.626		
Total	35	537.011			
Grand Mean	10.141				
CV	7.81				

Table 4: Analysis of variance on Number of leaf at vegetative stage

Source	DF	SS	MS	F	P
Replicati	2	1.377	0.6886		
Variety	2	31.388	15.6938	80.87	0.0000
Treatment	3	198.084	66.0280	340.24	0.0000
Variety*Treatment	6	8.264	1.3773	7.10	0.0003
Error	22	4.269	0.1941		
Total	35	243.382			
Grand Mean 9.1222					
CV 5.83					

Table 5: Analysis of variance on Number of leaf at maturity stage

Source	DF	SS	MS	F	P
Replicati	2	0.305	0.153		
Variety	2	31.644	15.822	90.10	0.0000
Treatment	3	306.883	102.294	582.54	0.0000
Variety*Treatment	6	7.883	1.314	7.48	0.0002
Error	22	3.863	0.176		
Total	35	350.578			
Grand Mean 11.836					
CV 3.54					

Table 6: Analysis of variance on Number of branch at vegetative stage

Source	DF	SS	MS	F	P
Replicati	2	7.1667	3.58333		
Variety	2	3.5000	1.75000	1.51	0.2430
Treatment	3	2.3056	0.76852	0.66	0.5836
Variety*Treatment	6	2.2778	0.37963	0.33	0.9153
Error	22	25.5000	1.15909		
Total	35	40.7500			
Grand Mean 4.2500					
CV 19.40					

Table 7: Analysis of variance on Number of branch at Maturity stage

Source	DF	SS	MS	F	P
Replicati	2	3.167	1.5833		
Variety	2	1.500	0.7500	0.70	0.5063
Treatment	3	90.306	30.1019	28.18	0.0000
Variety*Treatment	6	8.278	1.3796	1.29	0.3018
Error	22	23.500	1.0682		
Total	35	126.750			
Grand Mean 9.0833					
CV 11.38					

Table 8 : Analysis of variance on leaf length at maturity stage

Source	DF	SS	MS	F	P
Replicati	2	22.150	11.0748		
Variety	2	24.711	12.3555	7.27	0.0038
Treatment	3	114.956	38.3186	22.56	0.0000
Variety*Treatment	6	27.490	4.5817	2.70	0.0407
Error	22	37.373	1.6988		
Total	35	226.680			
Grand Mean 7.6089					
CV 16.13					

Table 9: Analysis of variance on chlorophyll content(SPAD value) at vegetative stage

Source	DF	SS	MS	F	P
Replicati	2	0.02	0.009		
Variety	2	737.89	368.945	609.65	0.0000
Treatment	3	314.55	104.851	173.26	0.0000
Variety*Treatment	6	13.51	2.252	3.72	0.0105
Error	22	13.31	0.605		
Total	35	1079.28			
Grand Mean	42.539				
CV	1.83				

Table 10: Analysis of variance on chlorophyll content (SPAD value) at Reproductive stage

Source	DF	SS	MS	F	P
Replicati	2	0.89	0.447		
Variety	2	740.92	370.461	197.50	0.0000
Treatment	3	633.75	211.249	112.62	0.0000
Variety*Treatment	6	23.35	3.891	2.07	0.0480
Error	22	41.27	1.876		
Total	35	1440.18			
Grand Mean	43.459				
CV	3.15				

Table 11: Analysis of variance on chlorophyll content (SPAD value) at Maturity stage

Source	DF	SS	MS	F	P
Replicati	2	6.05	3.027		
Variety	2	605.38	302.691	292.61	0.0000
Treatment	3	1065.55	355.183	343.35	0.0000
Variety*Treatment	6	30.47	5.078	4.91	0.0025
Error	22	22.76	1.034		
Total	35	1730.21			
Grand Mean	43.014				
CV	2.36				

Table 12: Analysis of variance on relative water content

Source	DF	SS	MS	F	P
Replicati	2	21.93	10.96		
Variety	2	94.54	47.27	5.12	0.0150
Treatment	3	8640.64	2880.21	311.69	0.0000
Variety*Treatment	6	257.90	42.98	4.65	0.0034
Error	22	203.30	9.24		
Total	35	9218.30			
Grand Mean	58.338				
CV	5.21				

Table 13: Analysis of variance on Salt Tolerant Index

Source	DF	SS	MS	F	P
Replicati	2	1.0	0.52		
Variety	2	44.2	22.11	30.21	0.0000
Treatment	3	22759.7	7586.56	10362.38	0.0000
Variety*Treatment	6	449.6	74.94	102.36	0.0000
Error	22	16.1	0.73		
Total	35	23270.7			
Grand Mean 70.322					
CV 1.22					

Table 14 Analysis of variance on Number of nodule/plant

Source	DF	SS	MS	F	P
Replicati	2	75.1	37.53		
Variety	2	711.1	355.53	9.13	0.0013
Treatment	3	16421.7	5473.89	140.64	0.0000
Variety*Treatment	6	828.5	138.08	3.55	0.0131
Error	22	856.3	38.92		
Total	35	18892.6			
Grand Mean 67.611					
CV 5.23					

Table 14: Analysis of variance on Number of seed/pod

Source	DF	SS	MS	F	P
Replicati	2	3.5776	1.7888		
Variety	2	10.4339	5.2169	21.76	0.0000
Treatment	3	50.7235	16.9078	70.51	0.0000
Variety*Treatment	6	5.0617	0.8436	3.52	0.0136
Error	22	5.2757	0.2398		
Total	35	75.0724			
Grand Mean 5.3986					
CV 5.07					

Table 15: Analysis of variance on Number of pod/plant

Source	DF	SS	MS	F	P
Replicati	2	0.667	0.3333		
Variety	2	188.667	94.3333	103.77	0.0000
Treatment	3	233.861	77.9537	85.75	0.0000
Variety*Treatment	6	21.556	3.5926	3.95	0.0079
Error	22	20.000	0.9091		
Total	35	464.750			
Grand Mean 8.9167					
CV 10.69					

Table 16: Analysis of variance on pod length

Source	DF	SS	MS	F	P
Replicati	2	0.12167	0.06084		
Variety	2	0.36537	0.18269	9.65	0.0010
Treatment	3	3.78628	1.26209	66.69	0.0000
Variety*Treatment	6	0.43718	0.07286	3.85	0.0089
Error	22	0.41633	0.01892		
Total	35	5.12683			
Grand Mean 4.3336					
CV 3.17					

Table 17: Analysis of variance on individual fresh weight of pod(g)

Source	DF	SS	MS	F	P
Replicati	2	0.00101	0.00050		
Variety	2	0.07504	0.03752	376.14	0.0000
Treatment	3	0.05152	0.01717	172.18	0.0000
Variety*Treatment	6	0.00109	0.00018	1.83	0.0397
Error	22	0.00219	0.00010		
Total	35	0.13086			
Grand Mean 0.3039					
CV 3.29					

Table 18: Analysis of variance on individual dry weight of pod(g)

Source	DF	SS	MS	F	P
Replicati	2	0.01372	0.00686		
Variety	2	0.00127	0.00063	2.64	0.0440
Treatment	3	0.03584	0.01195	49.75	0.0000
Variety*Treatment	6	0.00069	0.00011	0.48	0.0173
Error	22	0.00528	0.00024		
Total	35	0.05680			
Grand Mean 0.2900					
CV 2.64					

Table 19: Analysis of variance on 100 seed weight(g)

Source	DF	SS	MS	F	P
Replicati	2	2.04	1.019		
Variety	2	929.75	464.876	939.92	0.0000
Treatment	3	510.84	170.280	344.28	0.0000
Variety*Treatment	6	52.00	8.667	17.52	0.0001
Error	22	10.88	0.495		
Total 35 1505.51					
Grand Mean 28.275					
CV 2.49					

Table 20: Analysis of variance on Yield/plant(g)

Source	DF	SS	MS	F	P
Replicati	2	0.1800	0.0900		
Variety	2	45.4515	22.7258	226.88	0.0000
Treatment	3	46.1609	15.3870	153.62	0.0000
Variety*Treatment	6	5.8239	0.9706	9.69	0.0000
Error	22	2.2036	0.1002		
Total	35	99.8199			
Grand Mean 2.8983					
CV 9.92					