



**EFFECTS OF SALINE WATER AND IRRIGATION INTERVAL ON SOYBEAN
(*GLYCINE MAX*) YIELD AND ALTERING SOIL PHYSICO-CHEMICAL
PROPERTIES**

MSc THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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(*GLYCINE MAX*) YIELD AND ALTERING SOIL PHYSICO-CHEMICAL
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**A THESIS SUBMITTED TO THE
DEPARTMENT OF WATER RESOURCES AND IRRIGATION ENGINEERING,
FACULTY OF BIOSYSTEMS AND WATER RESOURCES ENGINEERING
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**IN PARTIAL FULFILLMENT OF THE
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ADVISORS' APPROVAL SHEET
SCHOOL OF GRADUATE STUDIES
HAWASSA UNIVERSITY

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DEDICATION

I dedicate this thesis manuscript to my beloved father Awoke Sheferia, my beloved mother Tiblet Ademe ,my sister Tirewerk Awoke and my brother Yeshewend Awoke for nursing me with affection and for their dedicated partnership in the success of my life.

STATEMENT OF THE AUTHOR

I declare that this thesis, which is titled “**Effects of Saline water and Irrigation Interval on Yield of Soybean (*Glycine Max*) and Soil physico-chemical properties**” is a result of my genuine work and that I have duly acknowledged all sources of materials used for writing it. I submit this to the school of graduate studies of Hawassa University in partial fulfillment of the requirements governing the award of the Degree of Master of Science in Irrigation and Drainage Engineering. The thesis is deposited at the library of the University to be made available to borrowers for reference. I solemnly declare that I have not so far submitted this thesis to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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LIST OF ABBREVIATIONS

ASW	Available Soil Water
AWC	Available Water Holding Capacity
CO ₂	Carbon dioxide
RCD	Randomized complete design
dS/m	DeciSiemens per meter
EC	Electrical Conductivity
ECW	Electrical Conductivity of water
FAO	Food and Agriculture Organization
FC	Field Capacity
GIR	Gross Irrigation Requirement
IF	Infiltration
LSD	List significance Difference
m.a.s.l	Meter above sea level
mg/L	Milligrams per liter
MoARD	Ministry of Agriculture and Rural Development
NIR	Net Irrigation Requirement
PWP	Permanent Wilting Point
Kpa	Kilo Pascal
SAS	Statistical Analysis System

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ABSTRACT

The declining availability of fresh water has become a worldwide problem, which maintains the development of alternative, secondary quality water resources for agricultural use. Several studies recommend that the need of attention for selected crops that can tolerate water and salinity stresses when saline water is used for irrigation. In this study, the effects of different irrigation intervals and salinity levels of irrigation water on Soybean yield and their impacts on soil physico-chemical properties were investigated using three irrigation intervals ($I_1=3$ days, $I_2=4$ days and $I_3=5$ days) with four salinity levels ($S_1=4$ dS m^{-1} , 5 dS m^{-1} and 6 dS m^{-1}) in a factorial combination using CRD with three replications. The result showed that salinity, irrigation interval and their interaction had shown highly significance effects ($p<0.001$) on number of pod per plant, number of seed per plant and grain yield of Soybean. The highest number of pod number (88.33), grain yield (2.31ton/ha) and number of seed per plant (172.33) was recorded from Soybean which was irrigated with the first salinity level, i.e. fresh water (S_1) with irrigation interval of (3 days), S_1I_1 , while the lowest pod number per plant (6.67), number of seed per plant (12.67) and minimum grain yield (0.034 ton/ha) were obtained from Soybean irrigated by salinity level four (S_4) with 5 days irrigation interval (S_4I_3). Statistical analysis showed that salinity, irrigation interval and their interaction showed highly significance effects ($p<0.001$) on electrical conductivity of soil. Irrigation with highest salinity level (S_4) with five days of irrigation interval resulted in the salt accumulation in the root zone from $0.41 \mu S m^{-1}$ (before sowing) up to $13.73 \mu S/cm$ at the end of growing period and exchangeable Sodium of 0.2 cmol/Kg was found before sowing while 0.82 cmol/kg was found after harvesting. Therefore, based on soil salinity and crop yield, irrigation interval of 3 days at lower levels of irrigation water salinities (up to 3 dS m^{-1}) is suitable for soybean production in the study area. The study also showed that salinity and irrigation interval significantly affected the soil nutrients ($p<0.001$) despite their interaction were not significantly affected on soil nutrients. Increasing the concentration of salt in irrigation water reduce availability of nutrients in the soil. Soil which was irrigated by salinity level four ($S_4=6$ dS/m) had lowest Organic Matter, Organic Carbon, Nitrogen (N), Phosphorus (P) and Potassium (K) content. Highest Organic Matter, Organic Carbon, N and P content were observed at soils which were irrigated by fresh water. This indicates that there is a need for giving attention for management of soil besides achieving Soybean yield production when saline water is used for irrigation.

Key Words: - Salinity, Soybean, Irrigation interval, Soil Physico-Chemical properties

1 INTRODUCTION

Water Salinity is the most serious water quality problem in agriculture and an environmental stress factor that hinder growth and yield of different crops in many regions of the world (Soha *et al.*, 2016). Water quality is deteriorating and water salinity is increasing due to uncontrolled discharges of untreated or poorly treated wastewater over-abstraction of the aquifers, and the excessive use of fertilizers in agriculture (Mahaound, 2013). According to FAO about 30% of the irrigated area is suffer by salinity problems, which corresponds to an area of more than 100 million ha worldwide .Most of the developing countries, irrigated agriculture plays an important role in food supply of a growing population (Hamdy, 1999).

In Ethiopia, approximately 11 million ha of land is salt affected .These areas are mainly concentrated in the Rift Valley (Fantaw, 2007). In some parts of Ethiopian Rift Valley, high saline water is present due to the influence of saline geothermal water. The Rift extends across Ethiopia via Lakes Rudolf and Chamo in the southwest; Awasa, Nazret, Mile and Lake Afrera in the North (British Geology Survey, 2001). High concentrations of dissolved salts in the ground water from the sedimentary formations are also familiar as a result of reaction of the often-abundant evaporation of minerals. Increased salinity in many ground water from sediments in the south, southeast and northeastern parts of the country arises from the dissolution of evaporate minerals (the products of evaporation) in certain horizons of the sediments (Meron, 2007).

Salinity is also one of the most serious factors limiting the productivity of agricultural crops, with adverse effects on germination and crop yield (Munns and Tester 2008). Several crops are sensitive to salinity and the negative effect on growth leads to the decrease in potential profits. For this reason, salinity has been considered as one of the most factors in irrigation water (Beltran, 1999).

Most of the salt stresses in nature are due to Na^+ salts, particularly NaCl (Demirel, 2005). In most of the cases, the negative effects of salinity have been attributed by increase in Na^+ and Cl^- ions in different plants hence these ions produce the critical conditions for plant survival by intercepting different plant mechanisms. Although both Na^+ and Cl^- are the major ions

which produce many physiological disorders in plants, Cl^- is the most risky (Tavakkoli, *et al.*, 2010).

Irrigating using saline water can also result in salt accumulation in soil, leading to the decrease in yield and deterioration in soil resource. High salinity lowers water potential and encourages ionic stress, and results in secondary oxidative stress. It severely limits growth and development of plants by affecting different metabolic processes such as CO_2 assimilation, oil and protein synthesis (Khan *et al.*, 2007).

Soybean has been displayed a broad spectrum of salt tolerance ability and the degree of their salt tolerance varied with the developmental stages and environmental factors (Chang *et al.*, 1994). Soybean is classified as a moderately salt-tolerant crop (Ashraf, 1994).

Soybean is one of the most important crops in the world, with production of 210.9 million tons (Anonymous, 2010). Soybean is grown in almost all parts of the world for human consumption, industry and animal feed (Boydak *et al.*, 2002). Soybean was introduced to the west world at the beginning of the twentieth century and started to enlarge to tropical and sub-tropical regions (Tukamuhawba *et al.*, 2002). Soybeans were first grown in Ethiopia in 1950. Trials began again in the late 1960s, and with the introduction of new high-yielding cultivars in the 1970s. In 1970s, Ethiopia produced 6,000 tons of Soybeans a year, making it one of the top four African Soybean producing countries (Amare, 1987).

Soybean seed is a major source of high quality protein and oil for human consumption (Katerji *et al.*, 2003) which contains 37% - 48% Protein, 16% - 22% fats and oil, and 30% carbohydrates. Soybean oil is the second most important vegetable oil after palm oil. It accounts for 25 % of global vegetable/animal oils and fats consumption (Thoenes, 2014).

1.1 Statement of the Problem

Due to increasing of world population and demand for food, use of fresh water resources has increased. On the other hand, the world's fresh water resources are insufficient that forced farmers to use low quality waters (Wallace, 2000).

The declining availability of fresh water has become a worldwide problem, which increases the development of alternative, secondary quality water resources for agricultural use. The UNEP (United Nations Environment Program) estimates that 20% of the agricultural land and 50% of the cropland in the world is salt affected (Yan, 2008).

In Ethiopia there are 12 river basins, 11 fresh lakes, 9 saline lakes, 4 deep lakes and over 12 major swamps. However, today In addition to shortage the quality of water is also a problem to all developing countries (Milda, 2009). There is a high saline ground water in Ethiopia in some parts of rift valley including southern Ethiopia due to saline geothermal water.

Several studies recommended offering attention for selected crops that can tolerate a degree of water and salinity stress when saline water is used for irrigation (Hammer and Broad, 2003). But, the salt tolerability of Soybean at different salinity levels is not studied in study area. Therefore, determination of salinity tolerance of Soybean at different irrigation interval through saline water is vital for increasing Soybean production .On the other hand using saline irrigation water for crop production affect soil physical and chemical properties. Consequently, determining the effect of saline water on soil properties is important for salinity management and sustainable use of land in the study area.

1.2 Objectives

1.2.1 General Objective

The general objective of this study was to determine the effects of different salinity levels of water and irrigation interval on yield of soybean and the physico-chemical properties of soil.

1.2.2 Specific Objectives

The specific objectives of the study were to:

- Identify favorable irrigation interval in saline water condition for Soybean crop production
- Determine the irrigation schedule of Soybean in the study area and
- Determine the effects of saline water and irrigation interval on soil properties.

1.3. Significance of the Study

Soybean is a multi-use crop, which can be used for various purposes including preparation of different foods, animal feed, soy milk, raw material for the processing industry, and it counter effects on depletion of plant nutrients in the soil resulting from continuous mono-cropping of cereals, especially maize and sorghum, thereby contributing to increasing soil fertility (Hailegiorgis, 2010). It is also a possible to intercrop soybean with long stem crops such as maize and sugarcane (Jagwe and Owuor, 2004). This implies that the crop is a very important food, oil and industrial material (MoARD, 2007).

Having better irrigation interval on different salinity level is important for Soybean production Therefore, this experiment was done to determine better irrigation interval within different level of saline water for good Soybean production. The experiment was also providing information on effects of saline water on soil for researchers and farmer to take salinity management.

2 LITERATURE REVIEW

2.1 Soybeans Production and its Importance

According to Agricultural survey 283459. 26 tons of Soybeans was produced from the 14198.20 hectares of land (CSA, 2011). Ethiopia produced an estimated volume of 150,000 tons of soybean in 2014/15, from combined production of smallholders and commercial farmers. The growth in production is attributed mainly to the increase in area cultivated and productivity. The total area of land under soybean production during the last 10 years has increased tenfold, while the total volume of production during the same period increased 21 times (Sopov, 2015).

There are favorable climatic and soil conditions for Soybean production in South and Western Ethiopia which is essential both for commercial as well as subsistence farming (Centre for Development Innovation, 2012). In Ethiopia Soybean is cultivated mainly in the southern and western parts around Hawassa, Jimma, Bako, Pawe and Assosa (Aregu, 2012).

The soybean (*Glycine max*) is one of the most important food plants of the world, and seems to be growing in importance. It produces more protein and oil per unit of land than almost any other crop. It is a versatile food plant that, used in its various forms, is capable of supplying most nutrients. It can substitute for meat and to some extent for milk. It is a crop capable of reducing protein malnutrition In addition to a source of high value animal feed (Martin, 1998).

Soybean is a high value and profitable crop. The economic viability of soybean production is determined by the commercial utilization of both its sub-products, meal and oil, which, respectively, account for about two thirds and one third of the crop's economic value. Soybean oil and meal are consumed worldwide as a food. Soybean oil is intensively consumed vegetable oil worldwide. Although it is also used as cooking oil in private households its main use is that of key fat ingredient in industrial food manufacturing, where, together with palm oil, it represents the most commonly used fat (Thoenes, 2014).

In addition to oil, soybeans are used to make a variety of local foods, such as bread, chappati, porridge, soy milk, yoghurt as well as the traditional Ethiopian stew, *Shero wot*. Soybeans are

also used to make corn-soybean blend (CSB) for emergency food assistance programs run by international organizations and the Ethiopian government (FAS/Addis Staff, 2016).

Since the oil content is high (16% and above) Soybean is used for edible oil production in Ethiopia. In Ethiopia, particularly in Addis Ababa, Faffa Food Share Company, East African flour factory, and Health care food manufacturing private limited companies are using local and imported soybeans in the preparation of enriched food products for children and adults (WHO, 2003).

2.2 Climate, Soil and Fertilizer Requirements of Soybean

The suitable Soybean production areas of Ethiopia have been indicated in areas with an altitude ranging between 1100 and 1850 m.a.s.l., with mean maximum temperature of less than 30°C - 37°C, mean minimum temperature greater than 10°C - 12°C. Soybean is considered as a main cash crop in many lowlands and mid-altitude zones of Ethiopia (Imru, 1985).

Fertilizer requirements of Soybean are 200 kg super Phosphate and 150 kg Potassium Chloride per ha. Soybean is capable of fixing atmospheric Nitrogen which meets its requirements for high yields (Pannar, 2006). Soybean (*Glycine max*) plays an important role in the global agricultural Nitrogen cycles by facilitating biological fixation of atmospheric N into plant-available N in symbiotic association with Bradyrhizobium. The N₂ fixation potential of Soybean varies ranging from 0 to 185 kg N ha⁻¹ with an average value of about 84 kg N ha⁻¹ (Russelle and Birr, 2004). However, a starter dose of 10 to 20 kg/ha of Nitrogen (N) is beneficial for good early growth.

Deep, well-drained soil with a fine, fertile and has good water-holding capacity is needed for good soybean production. Soya beans are generally better adapted to heavier soils and better able to utilize water at lower soil depths than most other crops, including maize. Soybeans are better adapted to soil types with a lower pH than other legume crops, but a pH value lower than 5.2 affect Nitrogen fixation. Compacted soils should be avoided because the hypocotyls of the soybean breaks easily during emergence. It is preferable to plant in moist soil, good seed-to-soil contact and formation of a soil crust at this time should be prevented (Department

of Agriculture, Forestry and Fisheries, 2010).

2.3 Irrigation Scheduling

Irrigation scheduling involves determining both the timing of irrigation and the quantity of water to apply. Establishing irrigation scheduling requires knowledge about availability of water supply, crop water use or evapotranspiration (ET), irrigation and effective rainfall, soil water-holding capacity and current available soil moisture content. This information is the main factor to decide when to apply water and how much water to apply. This often results in lower energy and water use and optimum crop yield, and increases irrigation efficiency (FAO, 1996).

2.3.1 Crop water requirement

The amount of water required to balance the evapotranspiration loss from the cropped field is defined as crop water requirement. Although the values for crop evapotranspiration and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied. Crop evapotranspiration refers to the amount of water that is lost through evapotranspiration (Allenet *et al.*, 1998).

Calculation of crop water requirements require basic information from the crops selected and should include, average planting date and average harvesting data. Standard information on crop coefficient, rooting depth, depletion level and yield response factors, and the degree of maturity and length of individual growth stages are needed. In addition to this atmospheric condition, such as radiation, temperature, wind, humidity and soil type are needed (FAO, 1996).

Crop water requirements vary during the growing period and during growth stage, in early stages of growth the water needs are generally low, but they increase rapidly during the maximum growing period to the fruiting stage. During the later stages of maturity, water use decreases as the crops ripen mainly due to variation in crop canopy and climatic conditions, and are governed by crop evapotranspiration (ET_c) (Benli *et al.*, 2006).

Evapotranspiration (ET) taking place within a particular crop is considered as crop water requirement or consumptive use of crop. Crop evapotranspiration has been determined by using the relationship between reference evapotranspiration and crop coefficient (Doorenbos and Pruitt, 1977). An accurate estimation of ET includes integration of a number of factors such as crop characteristics and crop growth stage, weather parameters and environmental conditions and management practices (Kjaersgaard *et al.*, 2008).

2.3.1.1 Reference Evapotranspiration

The E_{To} is the evapotranspiration from a reference crop such as grass or alfalfa with specific characteristics and standard conditions. In other words the reference crop is considered to be a clipped, well watered and healthy grass (Allen *et al.*, 1994).

Many methods are available for estimating reference crop evapotranspiration (E_{To}). The methods proposed by Doorenbos and Pruitt (1977), are the Modified Penman, Blaney-Criddle, Radiation, and Pan Evaporation, have been extensively applied in different climatic conditions. But, determination of E_{To} is best calculated by using the Penman-Monteith (PM) equation. The method has been selected because it closely approximates grass E_{To} at the location evaluated, is physically based, and explicitly incorporates both physiological and aerodynamic parameters. The most accurate, and complex, method is the Penman-Monteith method as presented by (Allen, 1996). The Penman-Monteith method requires climatic data for air temperature and humidity, wind speed, and solar radiation.

2.3.1.2 Crop Coefficient

Crop coefficient (K_c) is defined as the ratio of the crop evapotranspiration to the reference evapotranspiration. Crop coefficient is a function of climate, soil type, crop type, irrigation methods, soil water, nutrient content and plant phenology and so on (Jensen *et al.*, 1990).

The crop coefficient value is different from one crop to another depending on their characteristics and their properties and resulting different amount of water use. There are some important factors affecting crop coefficient which was founded by (Allen *et al.*, 1998).

2.4 Irrigation Water Quality

Irrigation water refers to its suitability for use in irrigated agricultural production. Good quality water has the potential to allow maximum yield. The key qualities of irrigation water that has been considered to affect its suitability consist of the salinity, relative Sodium, the alkalinity and acidity, and the toxic element. The most influential water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity (EC_w) (Bauder *et.al.*, 2011).

In most irrigation situations, the primary water quality concern is salinity levels, since salts can affect both the soil structure and crop yield. Irrigation water quality is related to its effects on soils and crops and its management. High quality crops can be produced only by using good quality irrigation water keeping other inputs. Characteristics of irrigation water that define its quality vary with the source of the water (APHA, 2005).

Great differences in the quality of water available on a local level depending on whether the source is from surface water bodies such as rivers and ponds or from groundwater aquifers with varying geology, and whether the water has been chemically treated (Nahid *et. al.*, 2008).

2.5 Saline Irrigation Water

Salinity refers to the total concentration of dissolved salt in the soil and water. In much arid and semi arid regions, most of the salts present in irrigation water are Chlorides, sulfates, carbonates, and bicarbonates of Calcium, Magnesium, Sodium and Potassium. Highly Saline and Sodic water qualities can cause problems for irrigation, depending on the type and amount of salts present, the soil type being irrigated, the specific plant species and growth stage, and the amount of water that is able to pass through the root zone (Emdadet *al.*, 2006).

Ayers and Westcot further indicates that given water is said to have salinity problem if its EC_w is above 3dS/m. Based on concentration of salt, water is classified into freshwater, slightly brackish, brackish, moderately saline, saline and highly saline. The classification is described in Table 1.

Salinity of water is measured by electrical conductivity (EC_w), or total dissolved solids (TDS). These terms are all comparable and all quantify the amount of dissolved “salts” (or ions, charged particles in a water sample (Bauder, 2014).

Many studies related to salinity have considered Na⁺ and Ca²⁺ cations and Cl⁻ anions (Munns, 1993). To correctly evaluate the effects of salinity on plants, one must first differentiate between low concentrations of salts that may well be beneficial to plant growth, even though they reduce osmotic potential and excessive concentration that may have harmful effects. A simple demonstration of some of the interacting osmotic and toxic effects is found with NaCl. Low levels of Na⁺ are beneficial and Cl⁻ is essential to plant health (Marschner, 1995).

Table1: Classification of water quality based on total salt (Pitman and Lauchli, 2002)

Water designation	Total dissolved salts (mg /L)	EC (dS /m)
Fresh water	<500	<0.6
Slightly brackish	500–1,000	0.6–1.5
Brackish	1,000–2,000	1.5–3.0
Moderately saline	2,000–5,000	3.0–8.0
Saline	5,000–10,000	8.0–15.0
Highly saline	10,000–35,000	15.0–45.0

The maximum irrigation water salinity tolerability of Soybean is 6.7mmhos/cm or dS/m and the irrigation water salinity that Soybean is produce without yield reduction is up to 3.3mmhos/cm or dS/m (Fipps, 2003).

2.6 Electrical Conductivity

Salinity refers to total salt concentration and is most commonly measured and reported as electrical conductivity (EC). The salinity of soil water or irrigation water is measured in terms of its electrical conductivity or in terms of osmotic potential. Electrical conductivity gives an indication of the amount of total dissolved substitution in water (Yilmaz and Koc, 2014).

The electrical conductivity denoted as E_c for extracts from soil and EC_w for irrigation water is a measure of total salinity based on how easily an electric current passes through the extract, but it does not give any indication of the salt composition. Electrical conductivity is an indirect measurement of salinity, and it is temperature dependent and good indicator of the total salinity, Hence E_c does not provide any information about the ionic composition within the water sample .The internationally accepted standard unit for reporting EC of water is deciSiemens per meter (dS/m). The electrical conductivity of a water sample is proportional to the concentration of the dissolved ions in the sample; hence EC is a simple indicator of total salt concentration. Pure water is a very poor conductor of electric current. The conductivity of a water sample is due to the ions dissolved in it. Generally, the higher the salt concentration in water, the greater it's electrical conductivity and the lower its osmotic potential/pressure (Taiz and Zeiger, 2006).

2.7 Total Dissolved Solids

Total dissolved solids (TDS) describes all solids, commonly mineral salts that are dissolved in water .Total dissolved solids TDS is the total amount of solids remaining when a water sample evaporates to dryness. TDS sometimes referred to as the total salinity and is measured or expressed in parts per million (ppm) or in the equivalent units of milligrams per liter (mg/L) .It is also a direct measurement of dissolved ions by an electrode (Stephen and Grattan, 2002).

2.8 Effects of Saline Water on Crop Productions

The most influential water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity. Irrigation water with high EC_w reduces yield potential (Bauder, *et al.*, 2014). The primary effect of high EC_w water on crop productivity is the inability of the plant to compete with ions in the soil solution for water which causes physiological drought. The higher the EC, the less water is available to plants, even though the soil may appear wet (Maggio *et al.*, 2004).

Salinity causes reduced crop growth and yield loss because the plant must redirect energy from growing to extracting pure water from the saline water in the root zone (Glenn, 2010).High salinity causes both hyperionic and hyperosmotic stresses and can lead to plant

death (Hasegawa *et al.*, 2000).

Dissolved Salts in the soil water inhibits crop growth and yield in two ways which are by osmotic influences and specific-ion toxicities. First, the presence of dissolved salt in the soil reduces the ability of the plant to take up water, and this leads to decrease plant growth. This is the osmotic or water-deficit effect of salinity. Second, excessive amounts of salt entering the transpiration stream will eventually injure cells in the transpiring leaves and this may further reduce growth. This is the salt-specific or ion excess effect of salinity (Munns *et. al.*, 2006) and (Farhoudi *et. al.*, 2007).

Osmotic effects: - It is the processes by which salts most commonly reduce crop growth and yield. If the concentration of solutes in the root cell is higher than solutes in the soil water this difference permit water to move freely in to the plant root. But as the salinity of the soil water increases, the difference in concentration between constituent in the soil water and those in the root reduces, initially making the soil water less available to the plant. To prevent salts in the soil water from reducing water availability to the plant, the plant cells must adjust osmotically either accumulate salts or synthesize organic compounds such as sugars and organic acids.

These processes use energy that could otherwise be used for crop growth. Some plants adjust more efficiently, or more capable at excluding salt, this giving them greater tolerance to salinity.

Specific-ion toxicities: -Salinity can also affect crop growth through the effect of specific-ion toxicities such as Chloride, boron, and Sodium ions on plants, which happens when these constituents in the soil water are absorbed by the plant roots and accumulate in the plant's stems or leaves. Frequently high concentrations of Sodium and Chloride are the same with high salinity levels. High Sodium and Chloride concentrations can be toxic to woody plants such as vines, avocado, citrus, and stone fruits. Boron is toxic to many crops at relatively low concentrations in the soil. The result of specific-ion toxicity is leaf burn, which occurs predominately on the tips and margins of the oldest leaves (Brown and Shelp, 1997).

2.8 Soil Physical Properties

Soil texture: -The relative percentage of soil separates (Sand, Silt and Clay) of a given soil is referred to as soil texture. The common textural classes, as recognize by USDA (U.S. Department of Agriculture) are given in triangles model (Shukla and Chandel, 2000).

Soil texture, which is a description of the size distribution of the mineral soil particles composing the solid fraction of the soil (from clay $<2\ \mu\text{m}$ to coarse particles $>2000\ \mu\text{m}$) is perhaps the most important, since it determines many other physical properties (such as infiltration rate) and some chemical properties (such as cation exchange capacity). Texture is the result of 'weathering,' the physical and chemical breakdown of rocks and minerals. Because of differences in composition and structure, materials will weather at different rates, affecting a soil's texture. Soil texture can have a profound effect on many other properties and is considered among the most important physical properties. Texture is the proportion of three mineral particles, sand, silt and clay, in a soil. It affects the soil's ability to hold onto nutrients (cation exchange capacity) and water (Antonio and Jose, 2006).

Bulk density and moisture holding capacity: -Bulk density, the ratio between soil dry mass and volume, is a very important soil property influencing soil water retention, aeration, transfer ability, and infiltration rate, and is extremely sensible to soil management (University of Plymouth, 2006).

Bulk density of a soil is a dynamic property that varies with the soil structural conditions. In general, it increases with profile depth, due to changes in Organic Matter content, porosity and compaction. Bulk density is influenced by the amount of Organic Matter in soils, their texture, constituent minerals and porosity. Knowledge of soil bulk density is essential for soil management, and information about it is important in soil compaction (Pravin, 2013).

Bulk density values are required for converting gravimetric soil water content to volumetric and to calculate soil porosity which is the amount pore space in the soil (Blake and Hartge, 1986).

The available water capacity (AWC) of a soil is the amount of water held to a given depth that is accessible to or can be withdrawn by a crop between the field capacity (FC) and the permanent wilting point (PWP). Field capacity (FC) is the amount of water remaining in a soil under conditions of free drainage, after excess water has drained away following a rain or irrigation that has wet the soil. Permanent wilting point (PWP) is the water content of soil, expressed on an oven-dry basis, at which plants wilt and do not recover their turgidity when placed in a dark humid atmosphere (Armand Bauer, 1974).

2.9 Soil Chemical Properties

Soil pH:-Soil pH is an indication of the acidity or alkalinity of soil and is measured in pH units. Soil pH is defined as the negative logarithm of the hydrogen ion concentration. The pH scale goes from 0 to 14 with pH 7 as the neutral point. As the amount of hydrogen ions in the soil increases the soil pH decreases thus the soil becoming more acidic. From pH 7 to 0 the soil is increasingly more acidic and from pH 7 to 14 the soil is increasingly more alkaline or basic (Ross, McKenzie, 2003).

Soil pH is influenced by both acid and base-forming cations (positively charged dissolved ions) in the soil. Common acid-forming cations are hydrogen (H^+), aluminum (Al^{3+}), and iron (Fe^{2+} or Fe^{3+}), whereas common base-forming cations include Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Potassium (K^+) and Sodium (Na^+) (Ann McCauley *et.al.*, 2017).

Soil pH is the most important factor in the nutrient available of soils. In most cases, a pH range of 6.0-7.5 is optimum for the adequate availability of nutrients in the soil (Bangladesh Agricultural Research Council [BARC], 2005).

Exchangeable Cation of the soil: -The soil's capacity to absorb nutrients in the form of cations is called its cation exchange capacity. Cation Exchange Capacity (CEC) is a parameter of soil which represents the capability of soil to attract, retain and hold exchangeable cations (K^+ , Na^+ , Ca^{2+} , Mg^{2+} , Etc.) and the classification is described in Table2.

Table2: Classification of soil exchangeable cation (cmol/Kg) FAO (2006)

Class	Exch. Na	Exch. Ca	Exch. Mg	Exch. P
Very low	<0.10	<2	<0.3	<0.2
Low	0.1-0.3	2-5	0.3-1	0.2-0.3
Medium	0.3-0.7	5-10	1-3	0.3-0.6
High	0.7-2	10-20	3-8	0.6-1.2
Very High	>2	>20	>8	>1.2

Organic Matter: -Organic Matter plays a vital role in maintaining structural stability including improvement of soil aggregate stability and porosity which in turn promotes water infiltration, enhances salt leaching, soil microbiological activities and also, decreases the exchangeable Sodium percentage and electrical conductivity in most of the agricultural soils. Soil organic matter plays an important role on physical and chemical properties of a soil. Organic matter is known as ‘storehouse of plant nutrients’ and ‘life force of a soil’. A good soil should have at least 2.5% organic matter (BARC) (2005).

Organic Carbon: Soil Organic Carbon (OC) is the carbon that remains in the soil after partial decomposition of any material produced by living organisms. It is the main component of soil organic matter (SOM). Soil organic matter is the organic fraction of the soil that is made up of decomposed plant and animal materials as well as microbial organisms, but it does not include fresh and un-decomposed plant materials, such as straw and litter, lying on the soil surface. SOM supports key soil functions as it is critical for the stabilization of soil structure, retention and release of plant nutrients, and allowing water infiltration and storage in soil. Therefore SOM is essential to ensuring soil health, fertility and food production (FAO, 2017).

Total Nitrogen Phosphorus and Potassium: - N, P and K are essential nutrient elements among these nutrient elements N ranks first in plant requirement and Phosphorus (P) ranks second followed by Potassium (K). N, P, and K are referred to essential nutrients because nearly all plants use them for growth and development. Their deficiencies cannot be corrected by another element and are needed by the plants before they can complete their vegetative and reproductive cycles (Ayeni Leye Samuel and Adeleye Omotayo, 2014).

The availability of N, P and K nutrients may be reduced with the increasing salt concentration due to the highest immobilization of ions in the soil. It would be succeeded with the suitable amendments application to overcome those immobilization complexes in soils (Prapagar, 2015).

2.10 Effects of Saline Water on Soil

The salts accumulation in soil was closely related to the salts concentration of irrigation water. There was a progressive and significant increase in soil salinity values as the increases of salinity in irrigation water (Ragab, 2000).

The effect of the quality of irrigation water on soil properties has been discussed by many researchers. Soil electrical conductivity (EC) values increased with increasing salinity of irrigation water and decreased soil moisture depletion (Romic, 2005, Burkhalter and Gates, 2006 and Galvani, 2007). Applications of saline water for crop production also affect both physical and chemical properties of soil. The change of physical properties of soil occurs after long period of time.

Soil physical and chemical properties affect many processes in the soil that make it suitable for agricultural practices and other purposes. Texture, structure, and porosity influence the movement and retention of water, air and solutes in the soil, which subsequently affect plant growth and organism activity. Most soil chemical properties are associated with the colloid fraction and affect nutrient availability, biota growing conditions, and, in some cases, soil physical properties. Irrigation with saline water may introduce Sodium into the exchange complex of soils (Shainberg *et al.*, 2002).

Exchangeable Sodium deteriorates soil structure and permeability. Further the agriculture-induced salinity and sodicity also influences the chemical and physical characteristics of soils (Rietz and Haynes, 2003).

2.10.1 Effects of Saline Water on Soil Physical Properties

Irrigation water qualities affect soil physical properties. These changes occur in the presence of high solute concentrations normally associated with maintaining soil aggregate stability and

continued throughout the irrigation season. Soil dispersion causes clay particles to plug the soil pores, and increase bulk density. High Sodium levels combined with low soil-water electrical conductivity can lower a soil's permeability. Saline Water can affect soil physical properties by causing fine particles to bind together into aggregates. This process is known as flocculation and is beneficial in terms of soil aeration, root penetration, and root growth. Although increasing soil solution salinity has a positive effect on soil aggregation and stabilization, at high levels salinity can have negative and potentially lethal effects on plants. As a result, salinity cannot be increased to maintain soil structure without considering potential impacts on plant health. But, More than fifty years of research have been conducted to determine the relationship between salinity (EC) of irrigation water and its effects on soil physical properties (Krista and James, 2003).

2.10.2 Effects of Saline Water on Soil Chemical Properties

Irrigation with saline water increases the total soluble salts in the soil. The increases in soil EC is proportional to the salts concentration in the irrigation water (AbdEl-Nour ,1989).

Nutrient uptakes are reduced by salinity of soil and irrigation water. Soluble Sodium content in the soil is increased by increasing Sodium content in irrigation water. And also the content of Chloride ions in the soil increase by increasing the salinity levels of irrigation water (Ragab and Abd El-Hady, 2008).

Increase in the salt concentration of irrigation water resulted in an increase in the exchangeable Na percentage and a decrease in the exchangeable K, Ca and Mg (Cucci *et al.*, 2013).

2.11 Effects of Irrigation Interval on Crop Production

Irrigation interval is one of the most important factors in irrigation scheduling, and a proper irrigation interval can establish moderate moist and oxygen conditions in the root zone throughout the crop period. Irrigating too frequently, results in a very humid region in the root zone, and root growth and function are affected by inadequate oxygen diffusion into the root zone. On the other hand, too long irrigation intervals, results in dramatic fluctuations of soil

moisture in the root zone, and bring about cyclic water stress on crop growth. When the soil moisture is lacking, the development of the root is restrained. Subsequently, when the soil is wet, the root expands rapidly, but the cells in periderm cannot expand correspondingly, and then cause the root to crack. Therefore, both too high and too low irrigation frequencies are not good for crop production (Shuqin Wan and Yaohu Kang, 2005).

Proper irrigation interval is important to reduce salinity and avoid water stress between irrigations. Water stress between irrigations can often be eliminated by increasing the frequency of irrigations, thereby preventing excessive root zone depletion caused by too long interval between irrigations. By decreasing the interval between irrigations, higher soil-water availability could be maintained. Increasing the frequency of irrigations may not always produce the desired results. On the other hand, the poor irrigation interval can lead to the development of crop water deficit and result in a reduced yield due to water and nutrient deficiency (Boamahet *al.*, 2010).

Increasing the irrigation interval causes decreases in both shoot and root dry weights. The proper irrigation interval saves more water at the early growing stage of the plants. The proper irrigation interval which encourages root development in lower soil layers at the early growth stages is a practical tool to increase water use efficiency and to save more water (Saleh and Kiyoshi, 2000).

3. MATERIALS AND METHODS

3.1 Site Description

This experiment was conducted at Hawassa University research farm. Hawassa, is a city in Ethiopia, on the shores of Lake Awasa in the Great Rift Valley. It is located 273 Km south of Addis Ababa. The town serves as the capital of the Southern Nations, Nationalities, and Peoples' Region. It has latitude of 6°49' N-7°15'N and longitude of 38°17' E-38°44' E and elevation of 1708 meters above sea level.

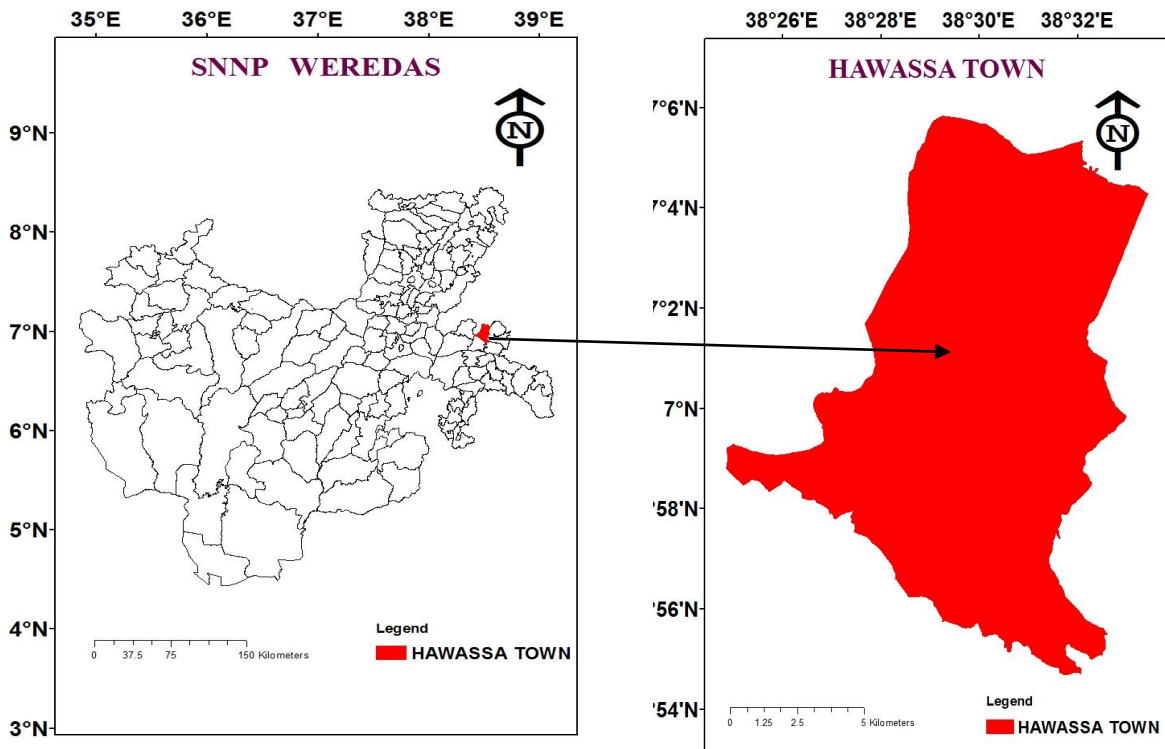


Figure 1:- Location map of the study area

3.2 Physical and Chemical Characteristics of the Soil

Soil samples were taken before sowing up to 30cm to determine particle size distribution, bulk density, available P, soil pH, Organic Matter, Organic Carbon, Exchangeable Cations, EC, total Nitrogen, Phosphorus and water contents at FC and PWP. After harvesting the crop, soil samples were collected again and the parameters were analyzed to observe the change of soil physical and chemical properties.

A disturbed soil sample was collected for the determination soil parameter mentioned above except bulk density, whereas undisturbed sample was collected by using core sampler for the determination of bulk density. The soil sample was being air dried, grounded and passed through a 2 mm mesh sieve to determine soil physico -chemical properties.

Soil texture was determined by using sieving and Hydrometer method , bulk density was estimated by dividing the weight of the oven dried soil sample (dried at 105°C for 24 hr) taken with core sampler. Maximum infiltration rate was conducted using the double ring infiltrometer. Available P, by using Olsen method, soil pH by using pH meter, Organic Carbon by using titration with ferrous ammonium sulfate, using diphenylamine indicator to detect the first appearance of an oxidized ferrous iron, exchangeable cations by using exchangeable Na and K by using Flame Photometer exchangeable Ca and Mg by using atomic absorption spectro Photo meter and the EC was determined by measuring the conductivity of saturated soil extract using Electrical Conductivity meter.

The above soil data were analyzed at Hawassa University, Addis Ababa water work design and supervision and Southern Agricultural Research center of soil laboratory.

3.3 Crop Water Requirement and Irrigation Schedules

Irrigation schedule (amount of water and time to irrigation) and crop water requirement was determined by using CROPWAT Model.

3.3.1 Inputs of CROPWAT Model

Calculations of the crop water requirements and irrigation requirements were carried out with inputs of climatic, crop and soil data. The model required the following data for estimating crop water requirements (CWR).

Climatic Data

In order to calculate the reference evapotranspiration using the CROPWAT model, 11 years (2006 -2017) of average monthly maximum and minimum temperature, relative humidity, sunshine hour and wind speed data that was collected from Hawassa meteorology station which was prepared in Table 3 from monthly maximum and minimum temperature, relative humidity, sunshine hour and wind speed of each year (Appendix Table 1, 2, 3, and 4).

Reference evapotranspiration (ET_o) was determined by using FAO Penman-Monteith equation (Allen, 1998) from climatic dates that was collected from metrological stations.

$$ET_o = \frac{0.408\Delta(Rn - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma (1 + 0.34 U_2)} \dots\dots\dots 1$$

Where, ET_o- reference evapotranspiration [mm day⁻¹],

R_n - net radiation at the crop surface [MJ m⁻² day⁻¹],

G - Soil heat flux density [MJ m⁻² day⁻¹],

T - air temperature at 2 m height [°C],

U₂ - wind speed at 2 m height [m s⁻¹],

E_s - saturation vapour pressure [kPa],

E_a - actual vapour pressure [kPa],

e_s- Saturation vapour pressure deficit [kPa],

Δ- Slope vapour pressure curve [kPa °C⁻¹],

e_s - e_a Saturation vapor pressure deficit [kPa],

Δ - Slope vapor pressure curve [kPa °C-1],

γ - Psychometrics constant [kPa °C-1].

Table3: Average meteorological data from 2006-2017

Month	RF (mm)	Minimum temperature (°C)	Maximum temperature (°C)	Relative humidity (%)	Wind speed (Km/day)	Sunshine hour (hr)	ETo mm/day
Jan	18.0	12	29.1	50	62.65	9.4	4.04
Feb	22.7	13	30.2	49	78.81	9	4.65
Mar	69.2	13.8	30.6	50	61.96	8.4	4.87
Apr	101.3	14.7	29.1	62	55.89	7.2	4.1
May	147.7	15	27.6	69	61.55	7.1	3.96
Jun	103.8	14.9	26.6	68	72.16	6.7	3.77
Jul	133.4	15	25.1	72	64.60	4.9	3.28
Aug	128.4	15	25.2	74	63.62	5.5	3.46
Sep	134.2	14.7	25.8	73	53.56	5.6	3.49
Oct	59.8	14.6	27.3	64	47.65	7.3	3.82
Nov	40.5	12	28.2	55	53.59	8.8	3.92
Dec	21.6	11	28.0	52	59.46	9.5	3.85

Crop Data`

A Crop data includes planting date, crop coefficient data files (including Kc values, stage days, root depth, depletion fraction) and length of individual growth stages. The Crop module requires crop data over the different stages: initial, development, mid and late stages (FAO, 1986).

Soybean crop was sown 02/02/2018 G.C. at the experimental plot. It had 30 cm effective root length, 90 days growth period required, and 50 % critical depletion and was harvested on

02/05/2018 G.C. The Kc values of Soybean at initial, mid and late stages are $K_{c_{initial}}$ (0.15), $K_{c_{mid}}$ (1.1) and $K_{c_{late}}$ (0.3), respectively (Allen.*et al.*, 1998).

Soil Data

Required soil data such as soil texture, maximum infiltration rate, bulk density and water retention at FC and PWP to determine total available soil moisture were measured and results were used as input for the software. The volume of soil in depth of 30cm equals to (0.3m*area) it equal to 0.0212 m³.

The Total available soil moisture (TAW) was calculated as the difference in moisture content between water held at field capacity (FC) and permanent wilting point (PWP). The matrices potentials corresponding to FC (-1/3 bar) and PWP (-15 bars) were applied using the pressure plate apparatus. The soil texture, maximum infiltration rate , FC and PWP of soil that was used for experiment was sandy loam, 12mm/hr , 26.5 % and 16.5 % respectively .The depth of TAW was calculated using (FAO,56) relationship.

$$TAW = 1000(\theta_{FC} - \theta_{PWP}) * Dz \dots\dots\dots 2$$

Where *TAW*= total available water in mm

θ_{FC} = the water content at field capacity (m³m³)

θ_{PWP} = the water content at wilting point (m³m³)

Dz = is the maximum effective root zone depth in m.

After acquiring all the required data crop water requirements were calculated by using CROPWAT (8.0) software.

The software calculates the crop water requirement (ETc) as:

$$ETc = Kc * ETo \dots\dots\dots 3$$

Where, ETC - Crop Water Requirement

Kc - Crop Coefficient

ETo - Reference Evapotranspiration

After calculated Etc to gate the volume of water that applied to each pot multiplied by area of pot which was 0.07065m².

3.4 Irrigation Requirement and Irrigation Schedule

Irrigation requirement (IR) was determined by using ETC and effective rainfall, which is part of the rainfall that entered into the soil and made available for crop production. Generally, IR estimated from the equation.

$$IR = CWR - P_{eff} \dots\dots\dots 4$$

Where, IR = Irrigation requirement (mm),

CWR= Crop water requirement (mm) and

P_{eff}= Effective rainfall (mm) but, in this study effective rainfall was taken as zero

$$\text{Therefore } IR = CW \dots\dots\dots 5$$

Net and Gross Irrigation requirement

The amount of irrigation water that needs to be supplied to the crop to compensate all evapotranspiration losses” (FAO, 2002) was determined by the equation

$$NIR = TAW \times Z \times P \dots\dots\dots 6$$

Where, NIR- Net irrigation required (mm)

P -Allowable soil moisture depletion of crop (50%)

TAW -Total available soil moisture (mm/m).

ETc value was taken from equation3 and TAW from equation 2

$$\text{GIR} = \frac{\text{NIR}}{\text{Ea}} \dots\dots\dots 7$$

Where, GIR – Gross irrigation requirement(mm)

Ea –Application efficiency (take as 95%)

The irrigation intervals (I) in number of days were 3, 4 and 5 days. To determine irrigation interval use CROPWAT software based on yield reduction between 0% and 5%.Irrigation interval that 0% yield reduction is 3days and 5 % yield reduction is 5 days interval. Therefore, irrigation interval, which was used in the experiment, was 3, 4 and 5 days were considered here.

3.5 Salinity and pH value of Fresh Water

Irrigation water samples were collected using plastic cans, which were cleaned in phosphate free detergent and rinsed with tap and distilled waters. The samples were immediately brought to Hawassa University college of Agriculture soil laboratory for testing salinity level and pH values of water by using EC and pH meter respectively.

3.6 Experimental Design and Treatments

The experiment was conducted at Hawassa University research farm by using 32 cm depth and diameter of 30 cm pot to grow the Soybean crops because Soybean roots distribute mainly in the upper layer of 30 cm (Yang Gao, 2010).Soil from the nearby area was composited up to 30 cm depth and filled in to the pots until the 2 cm left. A Soybean, Awassa-95 variety was use for the study which was obtained from Southern Agricultural Research Institute (SARI).

The experimental design were three irrigation intervals which where (I₁), (I₂) (I₃)) and four water salinity levels (fresh water as a control, S₁; 4 (S₂), 5(S₃) and 6 dS m⁻¹ (S₄)) and the experiment was in a factorial combination of salinity level and irrigation interval at Table 4arranged by conducted completely randomized design (CRD) with three replications as described in Figure2.

Different NaCl solutions with salinity levels of fresh water 4, 5, and 6 dS/m were prepared by dissolving 0, 2.56, 3.20 and 3.84 gm of NaCl in one liter of water respectively (Asgharet *al.*, 2009, and Mohammad, 2012). Two seeds were sown 3 cm deep in each pot, after emergence, seedlings were thinned to keep one plant in each pot. Each pot was fertilized with recommended doses of NPK (14.13gm of super phosphate, 1.0598gm of Potassium Chloride and 0.0706gm of Nitrogen).

Table 4: Factorial combination of salinity level and irrigation interval

Salinity level (S)	Irrigation interval (I)		
	I ₁	I ₂	I ₃
S ₁ (fresh water)control	S ₁ I ₁	S ₁ I ₂	S ₁ I ₃
S ₂	S ₂ I ₁	S ₂ I ₂	S ₂ I ₃
S ₃	S ₃ I ₁	S ₃ I ₁	S ₃ I ₁
S ₄	S ₄ I ₁	S ₄ I ₂	S ₄ I ₃

Where, S₁I₁-fresh water 3dS/m with three days of irrigation interval

S₁I₂- fresh water with four days of irrigation interval

S₁I₃- fresh water with five days of irrigation interval

S₂I₁-4dS/m of water with three days of irrigation interval

S₂I₂-4dS/m of water with four days of irrigation interval

S₂I₃ -4dS/m of water with five days of irrigation interval

S₃I₁-5dS/m of water with three days of irrigation interval

S₃I₂-5dS/m of water with four days of irrigation interval

S₃I₃-5dS/m of water with five days of irrigation interval

S₄I₁-6dS/m of water with three days of irrigation interval

S₄I₂ -6dS/m of water with four days of irrigation interval

S₄I₃-6dS/m of water with five days of irrigation interval

Since there were 12 treatments and replicated 3 times, therefore 12*3=36 pots were used for the experiment.



Figure 2: Layout of the Experiment

3.7 Yield Data

At harvest, all plants were taken to determine total number of pods per plant, number of seed per plant and grain yield.

3.8 Statistical Analysis

The various data collected were subjected to analysis of variance appropriate to factorial experiment in randomized complete design (CRD) using SAS software version 9.2 (SAS, 2008). Whenever the treatment effects were found significant, LSD test at 5% was performed to assess significant difference among treatments mean.

4 RESULTS AND DISCUSSION

4.1 Irrigation Schedule

Irrigation schedules and amount of salts in gm that were applied to made salinity level of 3 ,4, 5 and 6 dS/m within three, four and five days of irrigation interval from initial to harvesting time were determined (Appendix Table 9,10 and 11).

Crop water requirement of Soybean was highest at mid stage from the other growth stage for all at three, four and five days of irrigation interval. While the crop water requirement was obtained at initial growth stage for all three, four and five days of irrigation interval compared to the other growth stage of Soybean (Table 5, 6 and 7).

Table 5: CWR of Soybean at different growth stage at 3 days of irrigation interval

Growth Stage	ET _o mm/day	ET _c mm/day	ET _c mm/period	NIR mm/period	Pe _{ff} mm	GIR mm/period	IR mm/period
Init	23.50	3.90	11.70	11.70	0.00	12.32	11.70
Dev	23.70	14.45	43.35	43.35	0.00	45.63	43.35
Mid	65.60	71.14	213.43	213.43	0.00	224.66	213.43
Late	25.46	18.42	55.27	55.27	0.00	58.18	55.27
Total			323.75	323.75	0.00	340.79	323.75

Table 6: CWR of Soybean at different growth stage at 4 days of irrigation interval

Growth Stage	ET _o mm/day	E _t mm/day	ET _c mm/period	NIR mm/period	Pe _{ff} mm	GIR mm/period	IR mm/period
Init	18.60	3.16	12.65	12.65	0.00	13.32	12.65
Dev	19.04	15.71	62.84	50.84	0.00	53.52	62.84
Mid	46.86	51.03	204.13	204.13	0.00	214.87	204.13
Late	17.64	12.97	51.86	51.86	0.00	54.58	51.86
Total	102.14	82.87	331.48	331.48	0.00	336.30	331.48

Table 7: CWR of Soybean at different growth stage at 5 days of irrigation interval

Growth Stage	ET _o mm/day	ET _c mm/day	E _t mm/period	NIR mm/period	Pe _{ff} mm	GIR mm/period	IR mm/period
Init	13.95	2.46	12.32	12.32	0.00	12.97	12.32
Dev	28.12	13.11	65.55	65.55	0.00	69.00	65.55
Mid	37.58	40.83	204.13	204.13	0.00	214.87	204.13
Late	17.22	11.46	57.32	57.32	0.00	60.34	57.32
Total	96.87	67.86	339.32	339.2	0.00	357.12	339.32

The laboratory analysis of fresh water showed that the salinity level and pH value of water that was used for irrigation in the experiment was found to be 3 dS/m and 7.56 respectively.

4.2 Effects of Salinity on Yield and Yield Component of Soybean

4.2.1 Number of Pods per Plant

The result of this study showed that the number of pods per plant was significantly affected by the salinity stress, irrigation interval and by the interaction of salinity and irrigation interval ($p < 0.001$) (Appendix Table 9). The lowest pod number per plant (6.7) was observed from Soybean which was irrigated using salinity level four (S_4) or 6 dS/m with irrigation interval of five days or a treatment S_4I_3 and the highest pod number (88.3) was recorded from Soybean which was irrigated with the first salinity level or fresh water (S_1) with irrigation interval one 3 day or S_1I_1 (Figure 3).

The study also showed that irrigation with fresh water (S_1) in interaction with (I_1) increased number of pod per plant by 6.64% over four days of irrigation interval (I_2) and 8.08% over five day of irrigation interval (I_3), irrigation with 4 dS/m salinity level (S_2) in interaction with three day irrigation interval (I_1) increased number of pod per plant by 2.96% over four day irrigation interval (I_2) and 5.18 % over five day of irrigation interval (I_3). The number of pod per plant was decreased by 15.03% and 20.23% for I_2 and I_3 treatments in compare to the I_1 treatment in interaction with high salinity level treatment (S_3). Also, the grain yield was decreased by 22.48 % for I_2 and 37.98 % for I_3 in compare to the I_1 treatment in interaction with high salinity level of S_4 (Figure 3).

The reason for Salinity stress and irrigation interval encourage significant decrease in the number of pods due to the reduction of plant potential to uptake the water, Soybean plants were most sensitive to water stress or required more water during pod formation and seed filling period than from the other stage .The higher the EC and too long irrigation intervals in this stage, the less water is available to plants, dramatic fluctuations of soil moisture in the root zone, and bring about repeated water stress on crop growth, even though the soil may appear wet. Because plants can only transpire usable water in the soil solution decreases dramatically as EC increases.

The results agree with Khan.*et.al* (2016) who reported that decrease Number pods per plant due to salinity stress. The studies also agreed with Taffouo *et.al* (2009) who reported that, the significant decrease of yield components under salt stress. The results also agreed with Shuqin Wan and Yaohu Kang (2005) who reported that reduce number of pod with increase of irrigation interval.

Nahar and Hasanuzzaman (2009) also reported different yield components were significantly affected by salinity and water stress. The reproductive growth was also affected by salinity as the number of pods per plant significantly decreased with increasing salinity levels.

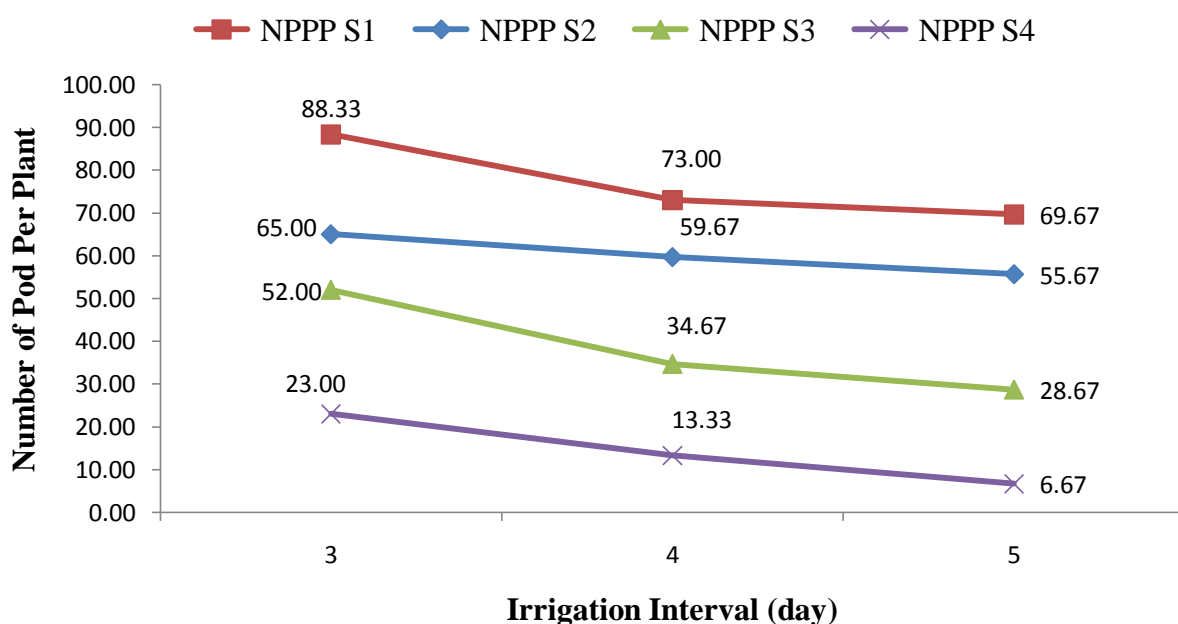


Figure 3: Effects of saline water and irrigation interval number of pod per plant

4.2.2 Number of Seed per Plant of Soybean

The salinity, irrigation interval and interaction of salinity with irrigation interval showed highly significance ($P < 0.001$) effect on number of seed per plant (Appendix Table 9).

The highest number of seed per plant (172.3) was recorded from treatment S_1I_1 , while the lowest number of seed per plant (12.67) was recorded from treatment (Figure 4). The result also showed irrigation with fresh water (S_1) in interaction with (I_1) increased the number of seed per plant by 10.97 and 11.97% over four (I_2) and five day of irrigation interval (I_3) respectively. Irrigation by fresh water with irrigation interval three (five days) decreased number of seed per plant by 1.81% over four days of irrigation interval. Irrigation by salinity level two with interaction of irrigation interval one increased number of seed per pod by 2.15% over irrigation interval two and 2.97% over irrigation interval three and irrigation by salinity level two water with irrigation interval two increase number of seed per plant by 0.8 % over irrigation interval three. Irrigation by salinity level three with interaction of irrigation interval one increased number of seed per pod by 10.15% and 23.23% over irrigation interval two and three respectively. Irrigation by salinity level four with interaction of irrigation interval one also increased number of seed per plant by 7.20% over irrigation interval two and 30.79% over irrigation interval three and irrigation by salinity level four (S_4) water with irrigation interval two increase number of seed per plant by 23.59 % over irrigation interval three (Figure 4).

The reason for decreased in the number of seed per pods within increased of Salinity and irrigation interval may due to increased irrigation interval causes to hold a altered moisture content in the soil. Thus, more of the salts are then kept in the soil and difficult for leaching process.

The study is in line with Nahar and Hasanuzzaman(2009) who studied that Number of pods per plant, seeds per plant and seed weight was negatively correlated with salinity levels. Ghassemi-Golezani *et al.* (2010) also reported reduction in seed yield of Soybean due to salinity stress. According to Muhammad and Hussain (2010), disturbed water and nutritional imbalance of plants may cause reduced crop yield in saline conditions.

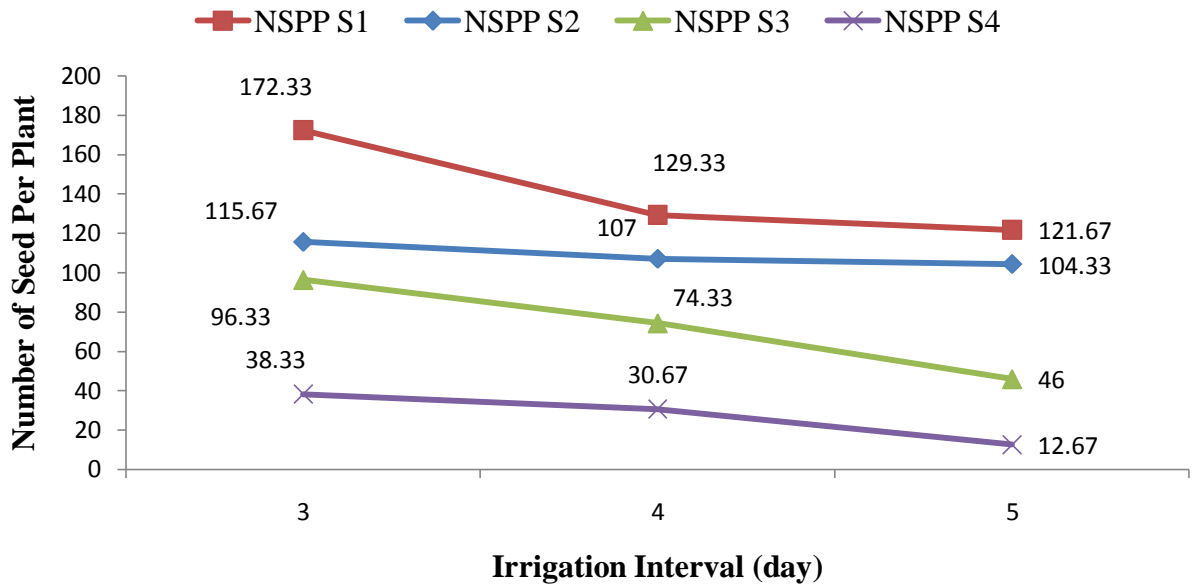


Figure 4: Effects of Saline Water and Irrigation Interval on Number of Seed per Plant of Soybean

4.2.3 Grain Yield of Soybean

The results of statistical analysis showed that irrigation interval, saline water and the interaction of salinity and irrigation interval had highly significance effect ($p < 0.001$) on grain yield (Appendix Table 9). The maximum grain yield 2.31 ton/ha was obtained from S_1I_1 and minimum grain yield 0.034 ton/ha was obtained at treatment S_4I_3 . It is found that irrigation with fresh water (S_1) in interaction with (I_1) increased the grain yield by 10.5 and 14.6% over four (I_2) and five day of irrigation interval (I_3), respectively. Irrigation with 4 dS/m salinity level (S_2) in interaction with three day irrigation interval (I_1) increased the grain yield by 9.2% over four day irrigation interval (I_2) and 13.4 % over five day of irrigation interval (I_3). The grain yield was decreased by 15.9% and 20.2% for I_2 and I_3 treatments in compare to the I_1 treatment in interaction with high salinity level treatment (S_3). In addition, the grain yield was decreased by 13.8% for I_2 and 40% for I_3 in compared to the I_1 treatment in interaction with high salinity level of S_4 (Figure 5).

The reason for decreasing of grain yield within increasing of irrigation interval with increasing of salinity level was due to concentration of salts in the root zone reduces soil water potential causing water deficit, phytotoxicity of ions such as Na^+ and Cl^- and nutrient imbalance depressing uptake and transport of nutrients. Excess salt concentration also enhances the osmotic potential of soil matrix, which restricts the water uptake by plants. Consequently, plant cannot uptake water freely from the soil, and the deficiency of water causes reduction of yield.

According to Lesley *et al.*, (2003), salinity stresses may reduce the seed filling rate and decrease grain filling duration. This can influence final yield of Soybean because final seed weight is the result of seed filling rate.

The results agree with Ayman El Sabagh(2015) who reported that the grain decreased significantly under saline stress and irrigation interval on soybean crop. Grain yields reduction of rice varieties due to salt stress also reported by Linghe and Shannon(2000) and Gain *et al.*(2004).The results in this study was substantiate findings of Kabir *et al.*(2009) and Ali *et al.* (2007) who also noted similar effects of irrigation on grain yield while working on wheat crop. Erkan Boydak (2007) also found the highest yield in narrow irrigation interval in sesame crop.

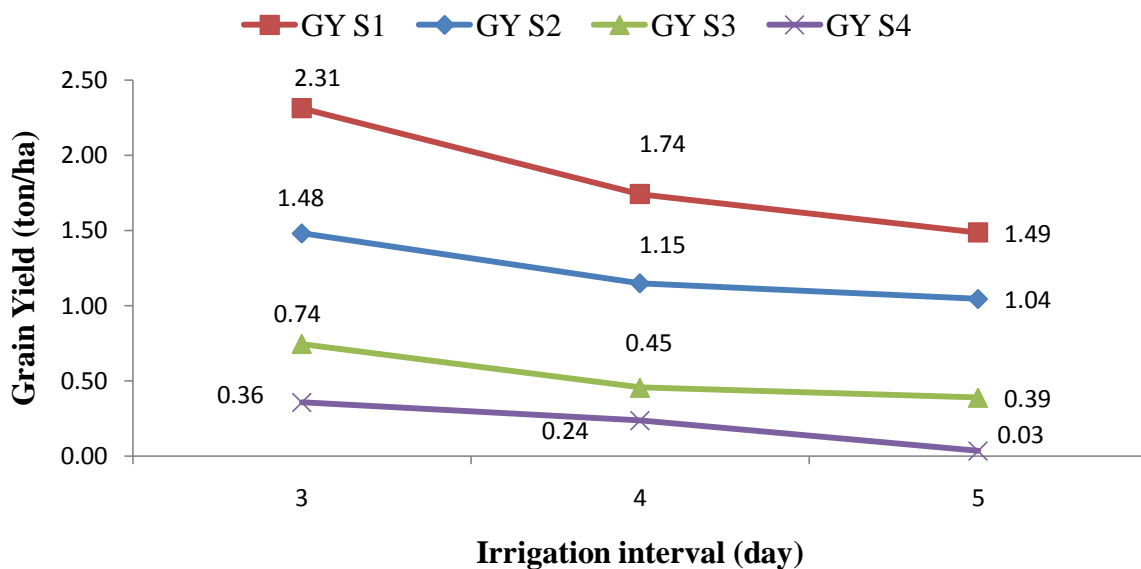


Figure 5: Effects of Saline Water and Irrigation Interval on Grain Yield (GY) of Soybean

4.3 Effects of salinity and Irrigation Interval on Soil Physical Properties

The result showed that salinity and irrigation interval has not significance effect on bulky density soil texture and water holding capacity (Table 8).

The reason for the non significance of soil physical properties was due to the soil irrigated by saline water was for one season (three month) this is short period of time ,but to change the soil physical properties it takes long period of time.

Table 8: Mean value of soil bulky density with different saline water and irrigation interval

Soil property	Before planting	Treatment	After harvesting	Difference
Bulky density	1.3	S ₁ I ₁	1.32	0.02
	1.3	S ₁ I ₂	1.32	0.02
	1.3	S ₁ I ₃	1.32	0.02
	1.3	S ₂ I ₁	1.32	0.02
	1.3	S ₂ I ₂	1.31	0.01
	1.3	S ₂ I ₃	1.31	0.01
	1.3	S ₃ I ₁	1.31	0.01
	1.3	S ₃ I ₂	1.31	0.01
	1.3	S ₃ I ₃	1.31	0.01
	1.3	S ₄ I ₁	1.31	0.01
	1.3	S ₄ I ₂	1.31	0.01
	1.3	S ₄ I ₃	1.30	0.00

Means in column followed by the same letters are not significantly different at 5% level of significant according to LSD test.

4.4 Soil Chemical Properties

4.4.1 Effects of salinity and Irrigation Interval on Soil Electrical Conductivity (EC)

The result of current study showed that the electrical conductivity of the soil was significantly ($P < 0.001$) affected by salinity, irrigation interval and interaction of salinity and irrigation interval (Appendix Table 10).

The electrical conductivity of soil before planting showed 0.41 $\mu\text{S}/\text{cm}$. The higher electrical conductivity was recorded (15.12 $\mu\text{S}/\text{cm}$) from treatment S₄I₃. This was 14.73 $\mu\text{S}/\text{cm}$ greater

than from soil electrical conductivity before planting. While the lowest electrical conductivity was observed (1.2 $\mu\text{S}/\text{cm}$) from treatment S_1I_1 .

Electrical conductivity increases from 0.41 $\mu\text{S}/\text{cm}$ before planting to 13.73 $\mu\text{S}/\text{cm}$ and to 12.63 $\mu\text{S}/\text{cm}$ after harvesting at treatment S_4I_2 and S_4I_1 respectively. EC increase from 0.4 to 6.43 $\mu\text{S}/\text{cm}$ 5.32 $\mu\text{S}/\text{cm}$ 4.69 $\mu\text{S}/\text{cm}$ in treatment S_3I_3 , S_3I_2 and S_3I_1 . EC also increase from 0.4 to 3.18 $\mu\text{S}/\text{cm}$, 2.54 $\mu\text{S}/\text{cm}$ and 2.4 $\mu\text{S}/\text{cm}$ in treatment S_2I_3 , S_2I_2 and S_1I_1 respectively. In salinity level one (S_1) EC increase from 0.41 to 1.83 $\mu\text{S}/\text{cm}$ interact with I_3 (S_1I_3), 1.31 $\mu\text{S}/\text{cm}$ interact with I_2 (S_1I_2) (Figure 6).

Increase of EC in the soil due to increase of salinity of irrigation water and irrigation interval may due to the high irrigation intervals and the high saline irrigation water imposed a more rapid salt accumulation in the root zone, which was the cause to restriction of the volume of drainage . This may be recognized to the higher direct evaporation rates leading to an increase in salt accumulation in the soil.

The result in line with Geerts *et al.*(2008) who found that reducing soil moisture content by deficit irrigation can increased soil salinity due to lack of leaching. The study is also in line with Abedinpour (2016) who recorded that increase electrical conductivity of the soil with increased of salinity level of water and irrigation interval. The study also in agreement with those obtained by Abd El-Nour (1989) who found that the significant increases in soil EC was comparative to the salts concentration in the irrigation water.

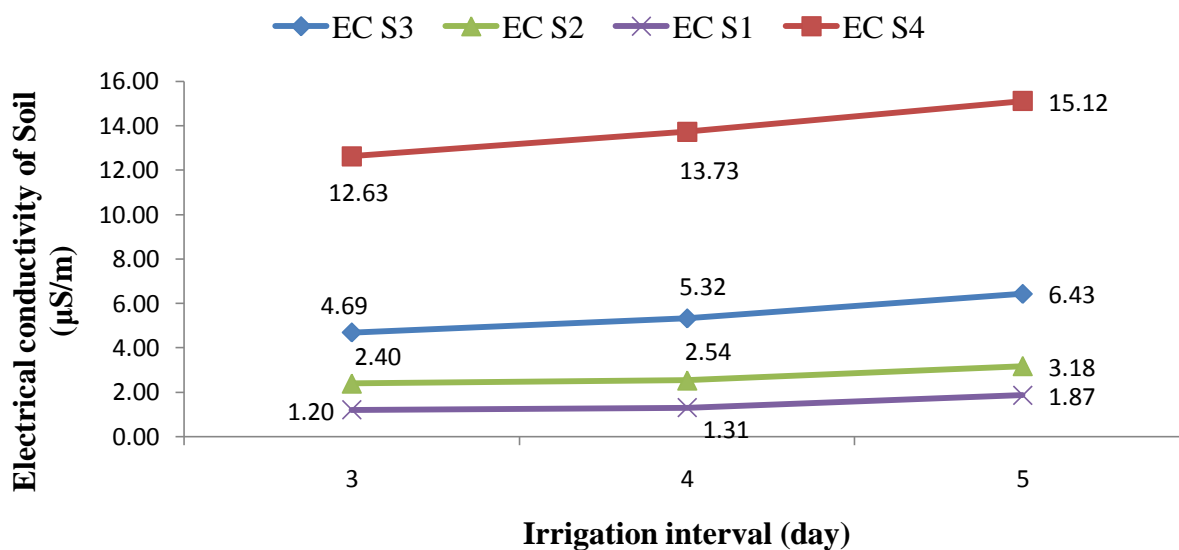


Figure 6: The effects of saline water and irrigation interval on soil electrical conductivity (EC)

4.4.2 Effects of salinity and Irrigation Interval on Soil P^H

The result showed that salinity and irrigation interval has not significance effect on soil PH (Appendix Table10).The result agreed with Meysam Abedinpour, (2016) who reported that the soil pH was not affected by the saline irrigation water during the growing period.

4.4.3 Exchangeable Sodium (Na) Content

The result of this study indicated that exchangeable Sodium significantly ($P < 0.001$) affected by salinity, irrigation interval (Appendix Table 10), despite interaction of salinity and irrigation interval was not affect exchangeable Sodium. The soil analysis showed the initial amount of Sodium in the soil was 0.2 cmol/kg. The higher exchangeable Sodium was found from treatment S₄I₃ (0.87) cmol/kg which was greater than by 0.67 cmol/kg from soil before plating .While the lowest exchangeable Sodium was found from treatment S₁I₁ which was 0.21cmol/kg (Table 9).

The quality of irrigation water directly related to salt accumulation in the soil. Therefore increased of salinity in irrigation water it increase soil salinity. The study in lined with Ragab

(2008) who found that soluble Sodium content in the soil was increased by increasing Sodium content in irrigation water.

4.4.4 Exchangeable Calcium and Magnesium Content

The results of statistical analysis of this study indicated that saline irrigation water, irrigation interval significantly ($P < 0.001$) affect exchangeable Calcium and Magnesium of the soil despite their interaction effect was not significant (Appendix Table 10).

The results of soil analysis before planting showed that the initial exchangeable Calcium of the soil was 7.86 cmol/Kg and Magnesium 3.02 coml/kg. At the end the experiment, the exchangeable Calcium and exchangeable Magnesium of the soil reduced to 3.7cmol/Kg and 0.47 coml/kg in treatment S_4I_3 respectively (Table 9).

The lower Ca content due increase of salinity and irrigation interval may be due to changes in osmotic and ion-specific effects that can produce imbalances in plant nutrients, including deficiencies of some nutrients or excessive levels of Na^+ . The result agreed with Kaya, *et al* .(2001)who reported that the increase of Na^+ decrease the exchangeable Calcium in the soil due to osmotic and ion-specific effect.

4.4.5 Organic Matter and Organic Carbon

The results of statistical analysis of this study indicated that saline irrigation water and irrigation interval significantly affect of the soil Organic Matter and soil Organic Carbon ($P < 0.001$), despite their interaction effect was not significant effect (Appendix Table11).

According to Tekalign (1991), the highest soil Organic Matter (6.48 %) and Organic Carbon (3.85 %) was observed from treatment S_1I_1 . While the lowest soil Organic Matter and Organic Carbon (1.33 %) and (0.83%) was found from treatment S_4I_3 and salinity respectively (Table 9).

The possible reason for significant difference in Organic Matter and Organic Carbon among salinity difference might be due to the effect of decomposition and may increase the loss of dissolved Organic Carbon from the soil by dissolving Organic Matter or changing the soil to a

more dispersed form.

In this study, Soil Organic Matter also decreased with increased of irrigation interval. But all soil irrigate with in irrigation interval one, two and three found in moderate Organic Matter.

The result was in agreement with the result from Yuan *et al.* (2007) who suggested that SOC decreased with increasing salinity. Ghollarata and Raiesi, (2007) also recommended that the high salinity inhibited Organic Matter by decomposition of Organic Matter and release of nutrients.

4.4.6 Phosphorus, Nitrogen and Potassium

The result of current study showed that the Phosphorus Nitrogen and Potassium of the soil was significantly affected by salinity and irrigation interval ($P < 0.001$) despite interaction of salinity and irrigation interval not significantly affect Phosphorus and Potassium (Appendix Table11).

The highest value of Phosphorus (19.98 ppm) was found treatment S_1I_1 after harvesting. On the other hand the lowest value of Phosphorus (8.99 ppm) was observed from treatment S_4I_3 after harvesting (Table 9).

The result of the study showed the amount of Potassium in the soil decreases from 0.8 cmol/Kg to 0.71 cmol/Kg in treatment S_1I_1 after harvesting. The result also showed that Potassium in the soil reduced by 0.53 cmol/Kg in treatment S_4I_3 after harvesting (Table 8).

The amount of Nitrogen on the soil before planting indicated 0.35% but after harvesting or at the end of the experiment decreased to 0.33, in treatment S_1I_1 and to 0.07 in treatment S_4I_3 (Table 9).

Decrease of amount of Phosphorus, Nitrogen and Potassium in the soil among increase of salinity and irrigation interval might be due to the highest immobilization of ions to the soil and fixation of available Phosphorus at higher salinities.

The result agree with Prapagar *et.al.*, (2015) who reported that the availability of N and P nutrients was reduced with the increasing salt concentration. Gupta *et al.* (2001) also reported

a slight decrease in available Phosphorus was observed with the increase in salt concentration. Saqib *et al.*, (2000) recorded that with increasing salt concentration decreases K availability due to this at higher salt concentration obtained low K^+ value in soil. He also reported an increased concentration of Na^+ and Cl^- , decreased the concentration K^+ .

Table 9 : The mean value of soil Organic Matter, Organic Carbon and Potassium

Soil property	Before planting	Treatment	After harvesting	Difference
pH				
	6.9	S ₁ I ₁	7.33	0.43
	6.9	S ₁ I ₂	7.13	0.23
	6.9	S ₁ I ₃	7.13	0.23
	6.9	S ₂ I ₁	7.10	0.20
	6.9	S ₂ I ₂	7.10	0.20
	6.9	S ₂ I ₃	7.10	0.20
	6.9	S ₃ I ₁	7.07	0.17
	6.9	S ₃ I ₂	7.00	0.10
	6.9	S ₃ I ₃	7.00	0.10
	6.9	S ₄ I ₁	7.00	0.10
	6.9	S ₄ I ₂	6.97	0.07
	6.9	S ₄ I ₃	6.97	0.07
EC				
	0.4	S ₁ I ₁	1.20	0.80
	0.4	S ₁ I ₂	1.30	0.90
	0.4	S ₁ I ₃	1.87	1.47
	0.4	S ₂ I ₁	2.40	2.00
	0.4	S ₂ I ₂	2.57	2.17
	0.4	S ₂ I ₃	3.17	2.77
	0.4	S ₃ I ₁	4.70	4.30
	0.4	S ₃ I ₂	5.30	4.90
	0.4	S ₃ I ₃	6.43	6.03
	0.4	S ₄ I ₁	12.63	12.23
	0.4	S ₄ I ₂	13.73	13.33
	0.4	S ₄ I ₃	15.13	14.73
Na				
	0.2	S ₁ I ₁	0.21	0.01
	0.2	S ₁ I ₂	0.32	0.12
	0.2	S ₁ I ₃	0.35	0.15
	0.2	S ₂ I ₁	0.40	0.20
	0.2	S ₂ I ₂	0.46	0.26
	0.2	S ₂ I ₃	0.51	0.31
	0.2	S ₃ I ₁	0.59	0.39
	0.2	S ₃ I ₂	0.62	0.42
	0.2	S ₃ I ₃	0.73	0.53

	0.2	S ₄ I ₁	0.76	0.56
	0.2	S ₄ I ₂	0.83	0.63
	0.2	S ₄ I ₃	0.87	0.67
OM				
	7.01	S ₁ I ₁	6.48	0.53
	7.01	S ₁ I ₂	6.24	0.77
	7.01	S ₁ I ₃	6.12	0.89
	7.01	S ₂ I ₁	4.74	2.27
	7.01	S ₂ I ₂	4.67	2.34
	7.01	S ₂ I ₃	4.45	2.56
	7.01	S ₃ I ₁	2.47	4.54
	7.01	S ₃ I ₂	2.37	4.64
	7.01	S ₃ I ₃	2.30	4.71
	7.01	S ₄ I ₁	2.00	5.01
	7.01	S ₄ I ₂	1.78	5.23
	7.01	S ₄ I ₃	1.33	5.68
OC				
	4.04	S ₁ I ₁	3.85	0.19
	4.04	S ₁ I ₂	3.62	0.42
	4.04	S ₁ I ₃	3.53	0.51
	4.04	S ₂ I ₁	2.70	1.34
	4.04	S ₂ I ₂	2.52	1.52
	4.04	S ₂ I ₃	2.28	1.76
	4.04	S ₃ I ₁	1.48	2.56
	4.04	S ₃ I ₂	1.33	2.71
	4.04	S ₃ I ₃	1.26	2.78
	4.04	S ₄ I ₁	1.05	2.99
	4.04	S ₄ I ₂	0.90	3.14
	4.04	S ₄ I ₃	0.83	3.21
Mg				
	3.02	S ₁ I ₁	2.83	0.19
	3.02	S ₁ I ₂	2.53	0.49
	3.02	S ₁ I ₃	2.37	0.65
	3.02	S ₂ I ₁	2.10	0.92
	3.02	S ₂ I ₂	2.03	0.99
	3.02	S ₂ I ₃	1.80	1.22
	3.02	S ₃ I ₁	1.73	1.29
	3.02	S ₃ I ₂	1.63	1.39
	3.02	S ₃ I ₃	1.57	1.45
	3.02	S ₄ I ₁	0.80	2.22
	3.02	S ₄ I ₂	0.63	2.39
	3.02	S ₄ I ₃	0.47	2.55
K				
	0.8	S ₁ I ₁	0.71	0.09
	0.8	S ₁ I ₂	0.70	0.10

0.8	S ₁ I ₃	0.69	0.11	
0.8	S ₂ I ₁	0.55	0.25	
0.8	S ₂ I ₂	0.51	0.29	
0.8	S ₂ I ₃	0.50	0.30	
0.8	S ₃ I ₁	0.33	0.47	
0.8	S ₃ I ₂	0.32	0.48	
0.8	S ₃ I ₃	0.32	0.48	
0.8	S ₄ I ₁	0.31	0.49	
0.8	S ₄ I ₂	0.30	0.50	
0.8	S ₄ I ₃	0.27	0.53	
<hr/>				
N				
0.35	S ₁ I ₁	0.33	0.02	
0.35	S ₁ I ₂	0.31	0.04	
0.35	S ₁ I ₃	0.31	0.04	
0.35	S ₂ I ₁	0.24	0.11	
0.35	S ₂ I ₂	0.24	0.11	
0.35	S ₂ I ₃	0.22	0.13	
0.35	S ₃ I ₁	0.13	0.22	
0.35	S ₃ I ₂	0.12	0.23	
0.35	S ₃ I ₃	0.12	0.23	
0.35	S ₄ I ₁	0.10	0.25	
0.35	S ₄ I ₂	0.09	0.26	
0.35	S ₄ I ₃	0.07	0.28	
<hr/>				
P				
21.5	S ₁ I ₁	19.98	1.52	
21.5	S ₁ I ₂	19.69	1.81	
21.5	S ₁ I ₃	19.55	1.95	
21.5	S ₂ I ₁	15.41	6.09	
21.5	S ₂ I ₂	15.35	6.15	
21.5	S ₂ I ₃	15.04	6.46	
21.5	S ₃ I ₁	10.03	11.47	
21.5	S ₃ I ₂	9.81	11.69	
21.5	S ₃ I ₃	9.48	12.02	
21.5	S ₄ I ₁	9.35	12.15	
21.5	S ₄ I ₂	9.15	12.35	
21.5	S ₄ I ₃	8.99	12.51	

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The analysis of the study showed that, there were significant differences on the Soybean grain yield, number of seed per plant and number of pod per plant under different irrigation intervals and salinity level. Grain yield, number of seed per plant and number of pod per plant in treatment S₁I₁ were 2.313ton/ha, 172.33, and 88.33 respectively. On the other hand minimum grain yield (0.034 ton /ha), minimum number of pod per plant (6.67) and number of seed per plant (12.67) were found in treatment S₄I₃. When highly saline water is used for irrigation, it is recommended to use short irrigation interval (3 days interval) instead of applying irrigation every 4 or 5days. However, the short irrigation interval practice normally reduces the plant stress under saline irrigation.

Regarding the salt accumulation in the root zone, the results of this study showed an increase in soil salinity with increase of salinity of irrigation water and irrigation interval .Soil salinity reached up to 15.12 μ S/cm at the end of the growing period, particularly under highly saline water and relatively high irrigation interval. With increasing salt concentration, nutrient availability was significantly decreased. Among the treatments, S₁I₁ had highest Nitrogen (N), Phosphorus (P) and Potassium (K) content. Lowest K, N and P content were observed from treatment S₄I₃. From this study, we can conclude that release of nutrients required continuing soil productivity were increased due to high salinity and relatively high irrigation interval. This indicated that need for give attention for soil in addition to the production of Soybean. Increase of salinity and irrigation intervals not only reduce the production of soybean but also reduce nutrients that required for continuing use of soil productivity

5.2 Recommendation

From the study using 3 days irrigation interval with 3 dS/m of water salinity for soybean production and for continue use of soil for production was good relatively using 4, 5, and 6 dS/m. however this study was based on only one season, one location and using pot experiment, thus requires further study on diversified location year and field experiment to fully recommend the salinity level and irrigation interval.

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7. APPENDICES

Appendix Table 1: Long term Rain fall data of the study area (2006-2017)

Year	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2006	1.7	9	139	146	74.4	108	171	169	195	56.9	79.2	48	1198
2007	18	55	76	112	166	225	129	104	234	32.7	3.7	0.0	1157
2008	34	8.3	3.4	57.8	121	118	121	124	160	66.1	97.1	5.8	915
2009	33	9.0	60.3	45.6	103	51.6	92.6	112	81.7	41.6	4.1	70	704
2010	27	58	125	96.1	174	53.1	133	137	96.1	53.1	32.0	56	1039
2011	2.3	7.1	55.5	73.7	194	65.5	151	155	126	5.5	88.2	0.2	923
2012	0.0	2.4	13.0	211	91.3	89.8	153	87.2	86.8	15.2	23.2	13	785
2013	23	1.0	104	78.8	143	132	209	163	118	77.5	22.0	0.0	1072
2014	23	26	91	104	198	98.4	105	207	164	105	19.1	5.8	1148
2015	0.0	2.5	38.2	28.9	56.1	147	113	85.3	104	34.1	23.3	39	671
2016	54	4.7	33.5	173	226	101	70.9	79.8	71.7	101	53.1	0.0	969
2017	0.0	88	91.0	88.5	226	54.7	154	115	174	129			1120
Total	216	272	831	1216	1773	1245	1601	1538	1610	718	445	238	11702

Source: Hawassa Meteorological Agency

Appendix Table 2: Long term Maximum Temperature of the study area (2006-2017)

Year	Month												Mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2006	30	31	29.3	27.3	27.7	26.2	24.5	24.7	25.2	26.7	27.6	28	27.3
2007	29	29	30.0	28.2	27.7	25.3	24.6	24.2	25.1	26.7	27.8	28	27.1
2008	30	29	31.5	29.4	26.3	25.6	24.4	24.8	25.7	26.6	26.6	28	27.3
2009	28	30	31.3	29.2	29.0	27.7	26.0	26.0	26.3	27.5	29.5	28	28.3
2010	29	28	28	28.0	26.9	26.2	24.4	25.0	25.3	27.7	28.7	28	27.1
2011	29	31	30.2	30.7	27.6	26.2	25.6	24.6	25.3	28.2	27.8	28	27.8
2012	30	30	31.8	28.0	28.3	26.6	24.9	24.9	25.1	27.8	29.1	29	28.0
2013	30	31	30.3	28.8	26.7	26.1	24.3	24.7	26.2	26.8	28.0	28	27.6
2014	30	30	29.6	28.7	27.1	26.7	25.2	25.2	25.3	26.3	27.4	28	27.4
2015	29	31	31.5	30.8	28.5	28.5	26.1	26.8	27.1	28.5	29.0	28	28.8
2016	29	31	32.3	28.7	26.7	26.0	25.3	25.3	26.6	27.4	28.1	28	27.8
2017	29	30	31.6	31.6	28.4	28.1	26.1	26.6	26.3	27.9	28.5	28	28.5
Mean	29	30	30.6	29.1	27.6	26.6	25.1	25.2	25.8	27.3	28.2	28	27.7

Source: Hawassa Meteorological Agency

Appendix Table 3: Long term Minimum Temperature of the study area (2006-2017)

Year	Month												Mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2006	11.8	12.4	13.8	14.6	13.9	14.3	15.0	14.7	14.5	14.2	11.4	12.4	13.6
2007	12.7	12.9	12.4	14.2	14.8	15.0	14.8	14.6	14.3	11.1	10.9	9.0	13.1
2008	10.5	11.7	11.4	14.1	14.6	14.4	14.9	14.5	14.2	13.0	11.1	10.3	12.9
2009	11.8	12.4	12.9	14.3	14.4	13.9	14.2	14.7	14.8	13.2	10.7	13.6	13.4
2010	13.0	15.3	14.7	15.6	16.3	15.1	15.2	15.3	14.4	13.5	11.1	10.9	14.2
2011	12.6	11.8	13.4	14.3	15.1	15.3	14.7	14.9	14.7	12.3	13.0	10.0	13.5
2012	10.2	11.7	13.5	15.1	14.4	15.1	15.3	15.0	14.4	12.2	12.3	11.3	13.4
2013	12.2	12.2	15.6	15.1	15.1	15.4	15.1	14.9	14.2	13.5	12.0	9.4	13.7
2014	12.2	13.5	13.4	13.1	14.1	14.0	15.3	14.9	14.7	14.2	12.3	10.7	13.5
2015	11.2	13.0	14.5	14.8	15.4	15.8	14.8	15.3	15.3	14.7	13.9	13.5	14.3
2016	15.3	14.7	15.4	16.7	16.1	14.7	15.8	15.4	15.3	14.9	13.1	11.2	14.9
2017	9.7	14.5	14.5	14.8	15.8	15.6	15.5	16.0	15.6	27.9	11.7	9.4	15.1
Mean	12.0	13.0	13.8	14.7	15.0	14.9	15.0	15.0	14.7	14.6	12.0	11.0	13.8

Source: Hawassa Meteorological Agency

Appendix Table 4: Long term Wind speed of the study area (2006-2017)

Year	Month												Mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2006	0.92	0.84	0.67	0.63	0.82	0.91	0.93	0.97	0.87	0.72	0.80	0.83	0.83
2007	0.95	0.82	0.79	0.79	0.90	1.07	0.98	0.93	0.82	0.64	0.87	0.92	0.87
2008	0.84	1.05	0.93	0.98	1.05	1.10	0.96	0.88	0.72	0.66	0.74	0.84	0.90
2009	0.83	0.91	0.83	0.78	0.99	1.01	0.98	0.98	0.75	0.75	0.80	0.73	0.86
2010	0.79	0.77	0.84	0.71	0.84	1.03	0.92	0.88	0.75	0.64	0.64	0.68	0.79
2011	0.67	0.72	0.74	0.64	0.68	0.78	0.68	0.65	0.57	0.55	0.50	0.60	0.65
2012	0.61	0.74	0.72	0.54	0.60	0.82	0.57	0.56	0.46	0.46	0.50	0.57	0.60
2013	0.65	0.64	0.60	0.56	0.60	0.74	0.49	0.53	0.48	0.37	0.42	0.49	0.55
2014	0.51	0.52	0.51	0.47	0.46	0.63	0.53	0.47	0.42	0.38	0.45	0.52	0.49
2015	0.63	0.61	0.71	0.57	0.60	0.63	0.65	0.63	0.51	0.46	0.56	0.69	0.60
2016	0.55	0.66	0.62	0.44	0.52	0.58	0.53	0.61	0.48	0.45	0.54	0.69	0.56
2017	0.75	2.66	0.65	0.63	0.49	0.70							0.98
Mean	0.73	0.91	0.72	0.65	0.71	0.84	0.75	0.74	0.62	0.55	0.62	0.69	0.71

Source: Hawassa Meteorological Agency

Appendix Table 5: Long term relative humidity of the study area (2006-2017)

Year	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
2006	47	50	59	69	68	68	74	77	75	72	59	64	65
2007	58	58	53	69	72	74	73	77	77	61	54	47	64
2008	48	44	37	58	71	70	74	74	74	66	60	49	60
2009	54	47	49	64	62	65	67	69	70	63	42	59	59
2010	55	62	64	69	74	70	74	74	75	63	52	50	65
2011	49	44	50	57	72	74	74	77	77	61	63	57	63
2012	49	44	39	68	67	68	76	72	77	61	53	51	60
2013	50	42	58	65	69	68	75	73	71	66	59	48	62
2014	50	58	59	64	71	68	70	72	73	68	57	51	63
2015	50	45	44	53	66	70	67	70	68	60	56	58	59
2016	57	45	51	60	70	60	72		67	64	54	48	59
2017	31	46	40	42	61	60	67	80	66	58	55	42	54
Mean	50	49	50	62	69	68	72	74	73	64	55	52	61

Appendix Table 6: Irrigation schedule and amount of NaCl (gm) per pot for 3 days of irrigation interval

Month	Growth Satge	KC	ETo mm/day	Etc mm/day	Etc mm/period	Peff mm	IR mm/period	NIR mm/period	Peff	GIR mm/period	NaCl(gm)			
											S ₁	S ₂	S ₃	S ₄
4-Feb	Init	0.15	4.65	0.71	2.12	0.00	2.12	2.1	0	2.2	0.0	0.12	0.24	0.36
7-Feb	Init	0.15	4.65	0.71	2.12	0.00	2.12	2.1	0	2.2	0.0	0.12	0.24	0.36
10-Feb	Init	0.15	4.65	0.71	2.12	0.00	2.12	2.1	0	2.2	0.0	0.12	0.24	0.36
13-Feb	Init	0.19	4.65	0.89	2.68	0.00	2.68	2.6	0	2.7	0.0	0.14	0.29	0.43
16-Feb	Init	0.19	4.65	0.89	2.68	0.00	2.68	2.6	0	2.7	0.0	0.14	0.29	0.43
19-Feb	Dev	0.19	4.65	0.89	2.68	0.00	2.68	2.6	0	2.7	0.0	0.14	0.29	0.43
22-Feb	Dev	0.6	4.65	2.82	8.46	0.00	8.46	6.5	0	6.8	0.0	0.32	0.64	0.96
25-Feb	Dev	0.6	4.65	2.82	8.46	0.00	8.46	8.4	0	8.9	0.0	0.41	0.82	1.23
28-Feb	Dev	0.6	4.65	2.82	8.46	0.00	8.46	8.4	0	8.9	0.0	0.41	0.82	1.23
3-Mar	Dev	1.04	4.87	5.10	15.29	0.00	15.29	15	0	15.8	0.0	0.69	1.39	2.08
6-Mar	Mid	1.04	4.87	5.10	15.29	0.00	15.29	15	0	15.8	0.0	0.68	1.36	2.04
9-Mar	Mid	1.04	4.87	5.10	15.29	0.00	15.29	15	0	15.8	0.0	0.67	1.34	2.01
12-Mar	Mid	1.1	4.87	5.39	16.17	0.00	16.17	15.7	0	16.5	0.0	0.69	1.39	2.08
15-Mar	Mid	1.1	4.87	5.39	16.17	0.00	16.17	16.1	0	16.9	0.0	0.71	1.42	2.13
18-Mar	Mid	1.1	4.87	5.39	16.17	0.00	16.17	16.1	0	16.9	0.0	0.71	1.42	2.13
21-Mar	Mid	1.1	4.87	5.39	16.17	0.00	16.17	15.9	0	16.7	0.0	0.70	1.41	2.11
24-Mar	Mid	1.1	4.87	5.39	16.17	0.00	16.17	15.6	0	16.4	0.0	0.69	1.38	2.07
27-Mar	Mid	1.1	4.87	5.39	16.17	0.00	16.17	15.6	0	16.4	0.0	0.69	1.38	2.07
30-Mar	Mid	1.1	4.87	5.39	16.17	0.00	16.17	15.6	0	16.4	0.0	0.69	1.38	2.07
2-Apr	Mid	1.1	4.41	4.73	14.19	0.00	14.19	15.2	0	16	0.0	0.68	1.36	2.04
5-Apr	Mid	1.1	4.41	4.73	14.19	0.00	14.19	15.1	0	15.9	0.0	0.68	1.35	2.03
8-Apr	Mid	1.1	4.41	4.73	14.19	0.00	14.19	15.1	0	15.9	0.0	0.68	1.35	2.03
11-Apr	Mid	1.05	4.41	4.52	13.55	0.00	13.55	14.7	0	15.4	0.0	0.66	1.31	1.97
14-Apr	Mid	1.05	4.41	4.52	13.55	0.00	13.55	13.9	0	14.6	0.0	0.62	1.25	1.87
17-Apr	End	1.05	4.41	4.52	13.55	0.00	13.55	13.9	0	14.6	0.0	0.62	1.25	1.87

20-Apr	End	1.05	4.41	4.52	13.55	0.00	13.55	13.9	0	14.6	0.0	0.62	1.25	1.87
23-Apr	End	0.63	4.41	2.71	8.13	0.00	8.13	8	0	8.4	0.0	0.37	0.73	1.10
26-Apr	End	0.63	4.41	2.71	8.13	0.00	8.13	8	0	8.4	0.0	0.37	0.73	1.10
29-Apr	End	0.63	4.41	2.71	8.13	0.00	8.13	8	0	8.4	0.0	0.37	0.73	1.10
2-May	End	0.32	3.96	1.27	3.80	0.00	3.80							
Total					323.75		323.75	323.75	0	335.1	0.0	14.52	29.03	43.55

Appendix Table 7: Irrigation schedule and amount of NaCl (gm) per pot at 4 days of irrigation interval

Date	Day	Growth Stage	Kc	ET _o	ET _c	ET _c	NIR	Pe _{ff}	GIR	NaCl (gm)			
				mm/day	mm/day	mm/period	mm/period	mm	mm/period	S ₁	S ₂	S ₃	S ₄
5-Feb	4	Init	0.15	4.65	0.70	2.79	2.8	0.00	2.95	0.00	0.74	1.47	2.21
9-Feb	8	Init	0.15	4.65	0.70	2.79	2.8	0.00	2.95	0.00	0.17	0.33	0.5
13-Feb	12	Init	0.19	4.65	0.88	3.53	3.3	0.00	3.47	0.00	0.19	0.39	0.58
17-Feb	16	Init	0.19	4.65	0.88	3.53	3.5	0.00	3.68	0.00	0.2	0.41	0.61
21-Feb	20	Dev	0.6	4.65	2.79	11.16	5.4	0.00	5.68	0.00	0.3	0.6	0.89
25-Feb	24	Dev	0.6	4.65	2.79	11.16	11.3	0.00	11.89	0.00	0.57	1.15	1.72
1-Mar	28	Dev	1.04	4.87	5.06	20.26	13.4	0.00	14.11	0.00	0.68	1.36	2.03
5-Mar	32	Dev	1.04	4.87	5.06	20.26	20	0.00	21.05	0.00	0.93	1.86	2.79
9-Mar	36	Mid	1.04	4.87	5.06	20.26	20	0.00	21.05	0.00	0.91	1.82	2.72
13-Mar	40	Mid	1.1	4.87	5.36	21.43	21.1	0.00	22.21	0.00	0.94	1.88	2.82
17-Mar	44	Mid	1.1	4.87	5.36	21.43	21.4	0.00	22.53	0.00	0.95	1.91	2.86
21-Mar	48	Mid	1.1	4.87	5.36	21.43	21.3	0.00	22.42	0.00	0.95	1.9	2.85
25-Mar	52	Mid	1.1	4.87	5.36	21.43	20.8	0.00	21.89	0.00	0.93	1.86	2.79
29-Mar	56	Mid	1.1	4.87	5.36	21.43	20.8	0.00	21.89	0.00	0.93	1.86	2.79
2-Apr	60	Mid	1.1	4.41	4.85	19.40	20.4	0.00	21.47	0.00	0.92	1.84	2.77
6-Apr	64	Mid	1.1	4.41	4.85	19.40	20.1	0.00	21.16	0.00	0.91	1.82	2.72
10-Apr	68	Mid	1.1	4.41	4.85	19.40	20.1	0.00	21.16	0.00	0.91	1.82	2.72
14-Apr	72	Mid	1.05	4.41	4.63	18.52	18.5	0.00	19.47	0.00	0.85	1.71	2.56
18-Apr	76	End	1.05	4.41	4.63	18.52	18.5	0.00	19.47	0.00	0.86	1.73	2.59
22-Apr	80	End	0.63	4.41	2.78	11.11	14.6	0.00	15.37	0.00	0.69	1.39	2.09
26-Apr	84	End	0.63	4.41	2.78	11.11	10.7	0.00	11.26	0.00	0.52	1.03	1.55
30-Apr	88	End	0.63	4.41	2.78	11.11	10.7	0.00	11.26	0.00	0.52	1.03	1.55
Total				102.14	82.87	331.48	321.5	0.00	338.42	0.00	15.57	31.17	46.71

Appendix Table8: Irrigation schedule and amount of NaCl (gm) per pot at 5 days of irrigation interval

Date	Day	Stage	KC	ETo	ETc	ETc	NIR	Peff	GIR	S ₁	NaCl (gm)			
				mm/day	mm/day	mm/period	mm/period	mm	mm/period		S ₂	S ₃	S ₄	
6-Feb	5	Init	0.15	4.65	0.70	3.49	3.50	0.00	3.60	0.00	0.16	1.55	2.32	
11-Feb	10	Init	0.19	4.65	0.88	4.42	3.60	0.00	3.80	0.00	0.17	0.44	0.66	
16-Feb	15	Init	0.19	4.65	0.88	4.42	4.30	0.00	4.50	0.00	0.20	0.52	0.77	
21-Feb	20	Dev	0.60	4.65	2.79	13.95	6.30	0.00	6.60	0.00	0.30	0.70	1.04	
26-Feb	25	Dev	0.60	4.65	2.79	13.95	14.10	0.00	14.80	0.00	0.67	1.44	2.16	
3-Mar	30	Dev	1.04	4.87	5.06	25.32	20.60	0.00	21.70	0.00	0.98	1.95	2.93	
8-Mar	35	Mid	1.04	4.87	5.06	25.32	25.00	0.00	26.30	0.00	1.19	2.15	3.23	
13-Mar	40	Mid	1.10	4.87	5.36	26.79	26.10	0.00	27.40	0.00	1.24	2.19	3.28	
18-Mar	45	Mid	1.10	4.87	5.36	26.79	26.80	0.00	28.20	0.00	1.28	2.22	3.34	
23-Mar	50	Mid	1.10	4.87	5.36	26.79	26.30	0.00	27.70	0.00	1.25	2.20	3.30	
28-Mar	55	Mid	1.10	4.87	5.36	26.79	25.90	0.00	27.30	0.00	1.23	2.19	3.28	
2-Apr	60	Mid	1.10	4.41	4.85	24.26	25.60	0.00	27.00	0.00	1.22	2.17	3.26	
7-Apr	65	Mid	1.10	4.41	4.85	24.26	25.10	0.00	26.40	0.00	1.19	2.14	3.21	
12-Apr	70	Mid	1.05	4.41	4.63	23.15	24.30	0.00	25.60	0.00	1.16	2.10	3.15	
17-Apr	75	End	1.05	4.41	4.63	23.15	23.20	0.00	24.40	0.00	1.10	2.03	3.05	
22-Apr	80	End	0.63	4.41	2.78	13.89	19.20	0.00	20.20	0.00	0.91	1.79	2.70	
27-Apr	85	End	0.63	4.41	2.78	13.89	13.30	0.00	14.00	0.00	9.09	1.28	1.93	
2-May	End	End	0.32	3.99	1.28	6.38								
Total			14.09	82.92	65.40	326.99	313.20	0.00	329.50	0.00	23.35	29.06	43.61	

Appendix Table 9: Mean square values for total number of pod number of seed per pod and grain yield

Source	Degree of Freedom	NPPP	NSPP	GY
S	3	6633.95***	21338.8***	4.85414***
I	2	906.36***	3509.2***	0.64082***
SXI	6	33.18***	418.0***	0.05670***
Error	22	2.26	43.7	0.00852
CV (%)		3.17	7.56	9.82
P S		0.000	0.000	0.000
P I		0.000	0.000	0.000
P SXI		0.000	0.001	0.001

*** indicate highly significance at $P < 0.001$, 'ns,'= not significant, S=salinity, I=irrigation interval and S x I=salinity with irrigation interval, NPPP = number of pod per plant, NSPP = number of seed per plant and GY= grain yield, P S =p value for salinity, P I=P Value for irrigation interval and P SXI= P value for interaction of salinity with interval.

Appendix Table10: Mean square values for electrical conductivity, exchangeable Sodium, Calcium PH and exchangeable Potassium

Source	Degree of Freedom	EC	Na	Ca	pH	Mg
S	3	279.10***	0.47***	15.25***	0.06 ^{ns}	5.96***
I	2	6.209***	0.047***	0.39**	0.02 ^{ns}	0.27***
SXI	6	0.567***	0.001 ^{ns}	0.07 ^{ns}	0.02 ^{ns}	0.02 ^{ns}
Error	22	0.066	0.001	0.05	0.04	0.01
P S		0.0000	0.0000	0.0000	0.2141	0.0000
P I		0.0000	0.0000	0.0033	0.6244	0.0000
P SXI		0.0001	0.3002	0.2386	0.7094	0.0680

*** indicate significance at $P < 0.001$, **=significance at $P < 0.05$, 'ns,'= not significant, S=salinity, I=irrigation interval and Sx I= Interaction of salinity with irrigation interval, P S =p value for salinity, P I=P value for irrigation interval and P SXI= P value for interaction of salinity with interval.

Appendix Table11: Mean square values for Organic Matter, Organic Carbon, Phosphorus and Potassium

Source	Degree of Freedom	Organic Matter (%)	Organic Carbon (%)	Nitrogen (%)	Phosphorus (ppm)	Potassium (ppm)
S	3	39.670 ^{***}	13.67 ^{***}	0.0985 ^{***}	224.23 ^{***}	0.322 ^{***}
I	2	0.415 ^{***}	0.26 ^{***}	0.0012 ^{***}	0.55 ^{**}	0.0012 ^{**}
SXI	6	0.040 ^{ns}	0.009 ^{ns}	0.0001 ^{ns}	0.01 ^{ns}	0.001 ^{ns}
Error	22	0.023	0.005	0.00006	0.16	0.0003
P S		0.000	0.000	0.0000	0.000	0.0000
P I		0.000	0.000	0.0000	0.041	0.0078
P SXI		0.155	0.157	0.2572	0.997	0.0950

*** indicate significance at $P < 0.001$, **=significance at $P < 0.05$, 'ns,'= not significant, S=salinity, I=irrigation interval and S x I= Interaction of salinity with irrigation interval, P S =p value for salinity, P I=P value for irrigation interval and P SXI= P value for interaction of salinity with irrigation interval.