INFLUENCE OF SALT STRESS ON SEED GERMINATION, GROWTH PERFORMANCE AND YIELD OF THREE POTATO (*Solanum tuberosum* L.) VARIETIES

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ABEBE MOLLA

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Influence of Salt Stress on Seed Germination, Growth Performance and Yield of Three Potato (*Solanumtuberosum*L.) Varieties

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AbebeMolla

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POSTGRADUATE PROGRAM DIRECTORATE

I here by certify that I have read and evaluated this Thesis, entitled **"Influence of Salt Stress on Seed Germination, Growth Performance and Yield of Three Potato (*Solanum tuberosum* L.) Varieties."** prepared under my guidance by AbebeMolla. I recommend that it be submitted as fulfilling the thesis requirement.

1. Meseret Chimdessa (PhD) _________________ _________________

Major Advisor Signature Date

2. Manikandan Muthusuwamy (PhD) __________________ _________________

Co-Advisor Signature Date

As a member of the Board of Examiners of the MSc Thesis Open Defense Examination, I certify that I have read and evaluated that Thesis prepared by AbebeMolla and examined the candidate. I recommend that the thesis be accepted as fulfilling the Thesis requirements for the degree of Master of Science in Biology.

1. __________________________ _________________ ________________

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DEDICATION

I dedicate this thesis to my parents for their dedicated partnership in the success of my life and whose constant encouragement and enduring love of inspiration and strength to achieve the level I have reached now. May God give them health and long life forever!

STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that, this Thesis is my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection and data analysis and compilation of this Thesis. Any scholarly matter that is included in the Thesis has been given recognition through citation.

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Name: AbebeMolla Signature: ________________

Date: October 2016

Department: Biology

BIOGRAPHICAL SKETCH

The author was born on April 26/1989 at the rural village of Kernewary, Hulet-EjjuEnebseWoreda of East Gojjam Zone in Amhara Regional State. He attended his elementary education at Kernewary Elementary School and his high school at Motta Senior Secondary and Preparatory School. In 2006, he joined Jijiga University and graduated with B.Sc in Biology in 2009. Since then, he has worked in Somali Regional State especially in Kebridahar Zone, Department of Biology until he joined the postgraduate program of Haramaya University on June 2011 to pursue his postgraduate studies in the field of Biology.

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ACRONYMS AND ABBREVIATIONS

AMP	Anti-Microbial Peptides
APC	Atlantic Potato Committee
CIP	International Potato Centre
CRD	Complete Random Design
CSA	Central Statistical Agency
DLS	Diffused Light Storage
FAO	Food and Agricultural Organization
HUPIP	Haramaya University Potato Improvement Program
m.a.s.l	meter above sea level
NGO	Non-Governmental Organization
OECD	Organization for Economic Cooperation and Development
PEG	Polyethylene Glycol
PLRV	Potato Leaf Roll Virus
PTM	Potato Tuber Moth
PVY	Potato Virus Y
RHSPC	Rare Hora Seed Producers' Cooperative
ROS	Reactive Oxygen Species
SNNPRs	Southern Nations Nationalities and Peoples Regional State
UVI	Ultra Violate Irradiation
WPC	World Potato Council

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ABSTRACT

In Ethiopia, salt affected soils are prevalent in the Rift Valley and lowland areas. Potatoes, which grow in different parts of Ethiopia, are salt sensitive. This experiment was conducted with the objective of screening potato varieties: namely Gabbissa, Chirro and Zemen for salt tolerance by the use of some agronomic traits such as days to seed germination, plant height, number of branches per plant, number of leaves per plant, days to flowering, number of flowers per plant, root length, number of tubers per plant, tuber weight and plant biomass. Three potato varieties were subjected to four salinity levels (0, 60, 120, and 180mM) under greenhouse condition. The experimental design was completely randomized design with three replications. Results showed that salinity negatively affected all measured parameters in a concentration dependent manner. Comparison between the varieties showed that variety Gabbissa performed better than the two varieties, suggesting this variety is relatively salt tolerant. Whereas variety Chirro is moderately salt sensitive and variety Zemen is highly salt sensitive compared to the rest.

***Key Words**: Growth, NaCl, Potato, Salinity level, Salt tolerant, Variety, Yield.*

1. INTRODUCTION

Potato (*Solanumtuberosum*L.) is the fourth most important productive food crop globally after rice, wheat and corn, and eighth most cultivated crop (FAO, 2008). It is a cheap source of vitamins, proteins, carbohydrates,and is a good source of phosphorous and magnesium, a moderate source of iron and rich in potassium (Horton and Sawyer, 1999). In some developed countries, it is used for starch and alcohol production (Horton and Sawyer, 2013). Approximately 60% of potato is consumed by humans, 25% is used as stock feed and in industry (starch and alcohol production), 10% is stored for seed and 5% is wasted (Horton and Sawyer, 1999).

Potato is an important food and cash crop in Eastern and Central Africa, playing a major role in national food security and nutrition, poverty alleviation and income generation, and; provides employment in the production, processing and marketing sub-sectors (Lungaho*et al*., 2007).

Potato, which was first introduced to Ethiopia by Schimper, a German Botanist in 1858, is now an important crop for smallholder farmers in the highlands (Tesfaye*et al*., 2010). Potato can potentially be grown on about 70% of the 10 million hectares of arable land in Ethiopia (FAO, 2008). In Ethiopia, potato is grown in four major areas, which together constitute approximately 83% of the potato production in the country namely, the North-Western Amhara region is the major potato growing area in the country, about 40% of the potato farmers are found in this area. The Southern and partial Oromia Regions also cover more than 30% of the total number of potato farmers. The Central (surrounding to Addis Ababa) About 10% of the potato farmers are located there and the Eastern Region only covers about 3% of the total number of potato growers in this area (CSA, 2008/2009).

The Eastern area of potato production in Ethiopia mainly covers the Eastern highlands, especially East Hararghe Zone (CSA, 2008/2009). The most important feature of potato production in this region is that the potatoes produced are market-oriented with considerable amounts being exported to Djibouti and Somalia (Adane*et al*., 2010).

Most potato-producing farmers in Eastern Ethiopia grow local potato varieties. However, some farmers accessing the research and extension system of Haramaya University and those targeted by NGO seed programs grow also improved varieties (Eshetu*et al*., 2005a).

Soil salinity is one of the main factors that limits the spread of plants in their natural habitats. It is an ever-increasing problem in arid and semi-arid regions that represent around 40% of the earth's area (Shanon, 1997).

Potatoes are classified as moderately salt-sensitive (Mass and Hoffman, 2001; Ahmad and Abdullah, 2005). A salinity level determined by the electrical conductivity of a saturated soil solution extract, in the range of 4.0 dS/m- or above, usually lowers tuber yields by more than 25% (Maianu, 2014). Responses of potatoes to salinity or soil moisture are generally assessed in terms of survival, vegetative growth, tuber size or total tuber production (Flowers and Hajibegheri, 2001). Potato leaves are very sensitive to saline water and are severely damaged by overhead irrigation with saline water (Maas, 1999).

In Ethiopia, salt affected soils are prevalent in the Rift Valley and the lowlands. The Awash Valley in general and the lower plains in particular are dominated by salt affected soils (Tadele, 1993). Moreover, of the 4000 ha irrigated land of the MelkaSadi Farm, 57% has been salt affected (Taddese and Bekele, 1996). Similarly, the occurrence of salinity problem in MelkaWerer Research Farm was reported (Haider*et al*., 2011). Moreover, entire Abaya State Farm, 30% of the land has already been salt affected (Hailay*et al*., 2000).

Salinity problem is expected to be severe in years to come. Because under the prevailing situation of the country, there is a tendency to introduce and implement large-scale irrigatio n agriculture to increase productivity (Tekalign *et al*., 1996). In the absence of efficient ways of irrigation water management, salt build up is an inevitable problem.

In this scenario, one of the most important strategies to increase the potato production in the salt affected area is to identify the salt stress effect on growth and yield of potato. Moreover, to exploit the salt tolerant genotypes that may sustain a reasonable yield on salt affected soils (Ashraf *et al*.,2006).

Therefore, this study was designed to identify the effect of salt stress on growth and yield performance on selected potato verities with the following objectives.

General Objective:

- ❖ To identify salt tolerant variety of potato plant under greenhouse conditions.

Specific Objectives are to:

- ☞ Assess the effect of different salt concentrations on growth performance of the three different potato varieties.
- ☞ Evaluate the effect of salt concentrations on potato yield.
- ☞ Identify the best salt resistant/tolerant potato variety.

2. LITERATURE REVIEW

2.1. General Description of Potato

Solanumtuberosum (Family, Solanaceae) is an herbaceous plant that grows to 0.4-1.4 m tall and may range from erect to fully prostrate (Spooner and Knapp, 2013). Stems may be green, purple, or mottled green and leaves are pinnate with a single terminal leaflet and three or four pairs of large, ovoid leaflets with smaller ones in between (Struik, 2007; Spooner and Knapp, 2013). The blades range in size from 8-22 x 5-13 cm with the petioles ranging from 2-6 cm. They are medium to dark green, and like the stems, may range in hairiness from nearly hairless to densely hairy on both sides.

Potatoes are best adapted to the cool temperature zones of the high altitudes in the Andes (2000-3500 m), at sea level in temperate regions of North America, Europe, South Chile and Argentina and at appropriate altitudes in intermediate latitudes (Hawkes, 1992b). Abiotic stress, especially salinity and drought are considered the most serious growth-limiting factors for crop plants (Boyer, 1982; Vinocur and Altman, 2005). An investigation by Rengasamy (2006)Suggested that 67% of agricultural area has potential for transient salinity, a type of ground water-associated salinity. The total area of salt-affected soils including saline and sodic is 831 million hectares (Martinez-Beltran and Manzur, 2005), extending over all the continents including Africa, Asia, Australia and the Americas (Schoups*et al*., 2005; Chaves *et al*., 2006; Rengasamy, 2006), Potato is relatively salt-sensitive; however, little research has been performed on salt stress resistance mechanisms in this crop.

Potato is mainly used for food production as a cheap source of vitamins, proteins and carbohydrates. However, in some developed countries such as Europe, potato is used as a source of food for animals (Anonymous, 2014). Potato is also used for starch and alcohol production (Horton and Sawyer, 1985). Approximately 60% of potato is consumed by humans, 25% is used as stock feed and in industry (starch and alcohol production), 10% is stored for seed and 5% is wasted (Horton and Sawyer, 2013). In terms of yield of edible energy and protein per hectare, the potato is near the top of the list of major world crops (Spooner and Salas, 2006) and is well balanced with regard to the ratio of protein to calories.

Potato tubers contain 75-80% water, 16-20% carbohydrates, 2.5-3.2% protein, 0.8-2% mineral (low sodium, high potassium), 0.6% fiber and 0.1-0.2% fat (Bajaj, 1987). The potato tuber contains high-quality protein and substantial amounts of essential vitamins, minerals and trace elements (Horton and Sawyer, 2013; Bajaj, 1987; Spooner and Salas, 2006). Potatoes are a good source of ascorbic acid (Vitamin C) and vitamin B, especially niacin, thiamine, vitamin B6 and riboflavin (Horton and Sawyer, 1999; Bajaj, 1987). The appreciable quantity of lysine in potato makes it a valuable supplement to cereals, which are limited in lysine. Potato is also a good source of phosphorous and magnesium, a moderate source of iron and rich in potassium (Horton and Sawyer, 1999).

Potato plants produce rhizomes (often called stolen) that have rudimentary leaves and are typically hooked at the tip. They originate from the basal stem nodes, typically below the ground, with up to three rhizomes per node. On the surface of the tuber are axillary buds with scars of scale leaves are called eyes (Struik, 2007). When tubers planted, the eyes develop into stems to form the next vegetative generation.

The terminal inflorescences are cymes that are 5-11 cm long and generally found in the distal half of the plant (Struik, 2007). The corolla may be a range of colours, including white, pink, lilac, blue, purple, and red-purple. The petals are fused to create a tubular flower (Sleper and Poehlman, 2006). The stamens have filaments that are 1-2 mm long and anthers that are 3-8 mm long (Spooner and Knapp, 2013).

The anthers form a cone-shaped structure through lateral joining, serving to conceal the ovary (Struik, 2007). They are typically bright yellow or orange with the exception of male-sterile plants in which the anthers are light yellow or yellow-green (Sleper and Poehlman, 2006). The style is 9-13 mm by approximately 1 mm (Spooner and Knapp, 2013).

They are green or green tinged with white or purple spots or bands when ripe (Spooner and Salas, 2006; Spooner and Knapp, 2013). The seeds are ovoid and approximately 2mm long, the lateral walls of the testa are thick and "hair-like" and cause the seeds to be mucilaginous when wet. Some cultivars may exhibit premature dropping of floral buds, male sterility, and/or inability to set fruit (Gopal, 1994).

2.2. Origin and Geographical Distribution of Potato

Potato *(Solanumtuberosum)* ultimately traces its origin to Andean and Chilean regions developed by the cultivators. These regions exhibit tremendous morphological and genetic diversity and are distributed throughout the Andes, from western Venezuela to Northern Argentina, and in southern Chile. (Grun, 1990; Miller and Spooner, 1999; Van den Berg *et al*., 1998).

Potatoes are grown in more than 150 countries on an estimated 180,000 square kilometers of farmland globally, with production of more than 323 million tons per year (FAO, 2006; CIP, 2007). Potatoes is grown in different climatic zones including temperate regions, subtropics and tropics under very different agro ecological conditions; in lowland as well as highland regions and from high-input agriculture by large-scale corporate farms to small holders (Struik and Wiersema, 1999).

The first record of *S. tuberosum* subsp. *andigena* outside South America was in the Canary Islands in 1567 (Hawkes and Francisco-Ortega, 1993; Rios *et al*., 2007), and shortly thereafter in continental Spain in 1573 (Hawkes, 1990; Hawkes and Francisco-Ortega, 1992; Romans, 2005). Forms of the introduced *S. tuberosum* subsp. *andigena* were adapted to the longer day lengths and climate of European latitudes through selection (OECD, 1997). These converted forms are known today as *S. tuberosum* subsp. *tuberosum.*

From Europe, potato was transported to North America. *S. tuberosum* may first have been transported from England to Bermuda in 1613 and then from Bermuda to the North American mainland in 1621, a hypothesis favoured by (Hawkes, 1990). Potato was present in India by 1610 and mainland China by 1700 and taken to New Zealand in 1769 by Captain Cook and gained agronomic significance for the native (Sauer, 1993).

Missionaries may have played a crucial role in the distribution of *S. tuberosum* from Europe throughout the world (Sauer, 1993). Potato is an herbaceous plant that is native to the Andes of South America. The leaves are pinnately divided, very lightly hairy and are usually dark green. The flowers are various shades of white, pink or purple have five petals and the stamens in a bright yellow cone in the middle of the flower. The fruits are shaped like a tomato, but is smaller, green and very bitter. The tubers we eat are the swollen underground stems of the plant; they too come in a wide variety of colours, shapes and sizes.

Potato first introduced to Ethiopia bySchimpera German Botanist in 1858 is now an important crop for smallholder farmers in the highlands, serving as both cash and food security crop. It is one of the crops with the highest growth rates in the country that serve to increase incomes and change in eating habits of the youth especially in urban areas, (Tesfaye*et al*., 2010) and the high yields it gives. This represents an opportunity for resource poor growers to generate additional income. Over one million households cultivate the crop for food and income generation in about 160,000 hectare (Gebremedhin*et al*., 2001).

2.3. Cultivation

Potato plant is cultivated around the world, although in the tropics it is grown in the cool highlands, typically at elevations over 1000 m, and in the subtropics it is grown during the cooler winter, autumn, and spring seasons or at mid-elevations (Simon *et al*., 2010; Hijmans, 2001). *S. tuberosum* grows best in cool climates, with higher temperatures favouring foliar development over tuberization (Haverkort, 1990).

Potato plant is not frost tolerant and will be killed at temperatures of -3°C or lower (Li, 1977). It can grow in a range of soil types, but is sensitive to drought stress and therefore can only be cultivated where there is adequate rainfall or the ability to irrigate (Bohl and Johnson 2010; Haverkort, 1990). Differences in tolerance to frost and drought occur within the species. Thus, cultivars have been selected with greater adaptation to these stresses.

2.4. Major Potato Growing Areas in Ethiopia

In Ethiopia, potato is grown in four major areas: the North-Western, the Southern, the Central, and the Eastern regions and they cover approximately 83% of the potato farmers (CSA, 2008/2009).

The North-Western Area: Amhara region is one of the major potato growing area in the country, making about 40% of the potato farmers (CSA, 2008/2009). South and North Gonder, East and West Gojjam, and AgewAwi are the major potato production zones. Farmers mainly grow 90% of local varieties (CSA, 2008/2009).

The Southern Area: Potato have grown mainly in the Southern Nations' Nationalities' and Peoples' Regional State (SNNPRs) and partly in the Oromiya region. The major potato producing zones in this area are Gurage, GamoGoffa, Hadiya, Wolayta, Kambata, Siltieand

Sidama in the SNNPRS and West Arsi zone in Oromiya. More than 30% of the total number of potato farmers is located in this area (CSA, 2008/2009). About six varieties have grown of which four are local and two are improved (Endale*et al*., 2008).

The Central Area: Potato production includes the highland areas surrounding Addis Ababa, within a 100–150 km radius. In this area, the major potato growing zones are West and North Shewa. About 10% of the potato farmers are located in this area (CSA, 2008/2009). In this area, potato is produced mainly in the "*belg*" (short rain season, February to May) and "*meher*" (long rain season, June to October) periods. Farmers grow about seven local varieties, eight improved varieties and six clones (that is, genetic material that have not officially released).

The Eastern Area: Potato production mainly covers the eastern highlands of Ethiopia, especially the East Harerghe zone. Only about 3% of the total number of potato growers is situated in this area (CSA, 2008/2009), but the area is identified specifically because the majority of the potato farmers in this area produce for the market and there is also some export to Djibouti and Somalia (Eshetu*et al*., 2005b). Most farmers grow local potato varieties such as*Zemen, Badhassa, Chirro, Gabbissa, Challa, Bubu, Gudene*tc. (Eshetu *et al*., 2005a). Farmers that cultivate local varieties that reported to get yields equivalent to those that cultivate improved varieties. This might be due to good farm management practices, which may be stimulated by the prospect of export market (Adane*et al*., 2010). However, in addition to the high yield potential, the local potato cultivars may have other agronomic, culinary, postharvest values by the farmers and consumers alike(Balkaya and Ergun, 2008).

Table 1: Released and local potato cultivars in Haramaya University.

No	Improved Varieties	Year of Release	Source of Planting Materials
1	Chirro (AL-111)	1998	HUPIP
2	Zemen (AL-105)	2001	HUPIP
3	Bedhasa (AL-114)	2001	HUPIP
4	Gabbisa (Cip-3870-96-11)	2005	HUPIP
5	Chala (Cip 387412-2)	2005	HUPIP
	Local Potato Varieties		
1	Batte	Local	RHSPC
2	Mashanadima	Local	RHSPC
3	Jarso	Local	RHSPC
4	Baddafa	Local	RHSPC

2.5. Phenological Features

Potato is an herbaceous C-3 annual plant, with wide genotypic differences in number of branching and pattern of branch development (Toosey, 1999). This results in differences in the number of stolons per plant, tubers per plant or tubers per stolon (Wurr, 2000). Stolon formation may start before or after plant emergence and stolon number per stem declines with increasing stem numbers. However, the quantity of assimilates available for growth also affects this relation (Struik and Wiersema, 1999). Early-maturing types tend to produce more nodes and subtending stolons than do late maturing types, but the ratio can be affected by environmental factors (Ewing, 2004).

Generally, it is common to distinguish between determinate types and indeterminate types of potato. Determinate types have a tendency to be early maturing, remain short, do not produce many successive orders within one main stem and produce short-cycle crops. Indeterminate types require a longer growing season (late maturing) to fully mature and have a higher yield potential if provided with an adequate duration of growing season (Struik and Wiersema, 1999).

Potato is the most widely cultivated vegetatively propagated crop in the world. Tubers are the organ harvested for consumption. Tuber formation requires a sequence of physiological events, which are internally regulated by plant hormones, triggered by photoperiod and modified by genetic and other environmental factors (Ewing and Struik, 1992). Short days and moderate temperature enhance tuber formation while long photoperiods enhance vegetative growth (Moreno, 2003).

Tuber formation takes place over a relatively short period, with the duration of this period depending on the maturity class of the potato (Jackson, 1999; Struik*et al*., 1999). Tuber development involves several stages, starting from induction, initiation, rapid growth and branching, cessation of longitudinal growth and swelling (Struik and Wiersema, 1999).

2.6. Effects of Salt Stress on Plant Development

Salinity affects plants in different ways such as osmotic effects, specific – ion toxicity and/or nutritional disorders (Lavchli and Epstein, 1990). One mechanism’s effect over the other depends on many factors including salinization solution.

Plant response to salinity stress occurs in two phases: an initial and rapid response to the elevation in external osmotic pressure and a slower response due to the build-up of Na+ inside the plant cells (Munns*et al*., 2006). Osmotic effect, which develops due to increasing salt concentration in the root medium, is a primary contributor in growth reduction in the initial stages of plant growth (Munns and Tester, 2008). This stage can be characterized by reduction in seed germination, generation of new leaves, leaf expansion, development of lateral buds leading to fewer branches or lateral shoots formation in plants (Munns and Tester, 2008). When salt concentration increases inside the plant, the salt starts to accumulate inside the older leaves and eventually they die (Munns, 2002).

Saline soils contain a high percentage of soluble salts, with one or more of these salt components being present in excess. Sodium chloride (NaCl) is the most commonly encountered source of salinity (Henry *et al*., 1987; Li *et al*., 2006). However, sulphate and bicarbonate anions and calcium and magnesium cations may contribute to salinity problems. Alkali soils are low in soluble salts but have high sodium content and characterized by high pH (Henry *et al*., 1987).

Salt stress arises from excessive uptake of salts by potato plants (Luttge and Smith, 1984). There are at least three components of salt stress in plants, including osmotic effects, nutritional effects and toxic effects (Leopold and Willing, 1984). The degree to which each one of these components of salinity stress influences growth is dependent upon many factors e.g., plant species, ionic composition of the saline water, humidity and stage of plant development. Levitt (1980) has drawn a line between ion stress and salt stress. He defined salt stress as a condition in which salt concentration is high enough to make the water potential in the plant excessively negative. Conversely, in ion stress conditions, salt concentration is not high enough to lower plant water potential. Ion imbalance specifically results from disturbed ionic ratios in the cells after an accumulation of ions present in the salt (Cheeseman, 1988).

Exposure of plants to extreme conditions such as high salinity causes a diverse set of physiological, morphological and developmental changes (Jensen *et al*., 1996). Much of the strain in salinity stress is related to water stress arising from excessive uptake of salts by the plants and the resulting reduction in water potential. This stress reduces leaf expansion due to reduction in leaf turgor, and can severely restrict crop yield (Addicott, 2007).

2.6.1. Effects of salinity on potato root

Salinity on root system can be significant and may directly affected its growth. High ions in leaves leads to osmotic damage and oxidative stress, affecting physiological and biochemical metabolism. In addition, more Cl accumulated in potato tissue than Na, indicating the absorption of Cl^- was higher than Na, which is similar to the findings in sunflower (Ebrahimi and Bhatla, 2011) and (Greenway and Munns, 1980). Higher Cl^- accumulation leads to more serious and instant damage under salt stress (Yao and Fang, 2008).

Salinity induced plant nutritional disorders, such as the suppression of K^+ uptake (Kader and Lindberg, 2005). Ebrahimi and Bhatla, (2011) Suggested that, more K^+ accumulated in roots is correlated with the salt tolerance of *Capsicum chinense*. In present study, salt stress dramatically reduced K^+ uptake and accumulation, especially in leaves, resulting in increased Na/K ratio in all tissues with the increase of external salt concentration and the duration of treatments.

2.6.2. Effects of salt stress on potato leaves

Potato leaves are very sensitive to saline water and severely damaged by overhead irrigation with saline water (Maas, 1985). Uptake of chlorine and sodium by leaves may induce toxicity, exhibited as leaf burn along the margins'. Potato leaves are most sensitive to salt applied at the beginning of tuber formation (Bruns and Caesar, 1990). Salt stress negatively affected relative water content, leaf stomata conductance and transpiration rate of the cultivar desire (pell*et al*., 2009).

2.6.3. Effects of salt stress on potato yield

About 74% of the normal yield of a cultivar can be obtained under surface irrigation with salinity of 2±4 dS/m (Paliwal and Yadav, 1980). In general, potato yields have been known to decrease as salinity increases with either surface irrigation (Paliwal and Yadav, 1980; Van Hoorn *et al*., 1993) or drip irrigation water (Levy, 1992).

However, the effect of salinity level of irrigation water depends on the cultivar that cause a problem of salt build-up in the crop root zone shouldbe considered (Zhang *et al*., 1993). In many semi-arid regions of the world, monsoon rains occur only for a few months, and no significant rainfalls thereafter. The monsoons can thus flush-out salts that would have accumulated in the crop root zone due to sub-irrigation with brackish water (Zhang *et al*., 1993).

The initial soil salinity is also an important factor that determines the salt build-up in the root zone under sub irrigation and, in turn, affects the crop yield. Potato (*Solanumtuberosum* L.) has been identified as moderately salt-sensitive or salt-tolerant (Katerji*et al*., 2000).

2.7. Biotic Factors

Late blight (*Phytophthorainfestans*) is common in all potato-growing areas of Ethiopia. In many parts of the country,Late blight is the cause for the shift of potato production from the long rainy season (*meher*) to off-season production, despite the high potential yield in the long rainy season (Bekele and Eshetu, 2008). Local varieties do not cope with the disease pressure in the main rainy season and often wiped out, particularly in the highlands (Bekele and Eshetu, 2008).

When seed tubers become infected by *Phytophthorainfestans* they may rot during storage or will fail to produce emerging and surviving plants. Viruses example, Potato leaf roll virus (PLRV) and Potato virus Y (PVY)] and bacterial wilt (*Ralstoniasolanacearum*) are causing potato plant and tuber degeneration in Ethiopia (Bekele and Eshetu, 2008).

The prevalence of these diseases is high in the low to medium altitudes (Bekele and Eshetu, 2008). On a seed degeneration experiment undertaken in Holetta Agricultural Research Centre from 1997 to 2000, percent yield reductions due to viruses (mainly PLRVand PVY) were recorded of 62, 45, 44 and 41 in the varieties *Tolcha, Genet*, *AL-624* and *Awash*, respectively (Bekele and Eshetu, 2008). Because these pathogens attack the foliage, root system and tubers, they are important throughout the crop cycle. Potato tuber moth, PTM (*Phthorimaeaoperculella*) is affecting seed potatoes in the field and stored in Diffused light storage (DLS) (Bayeh*et al*., 2008).

Are among the major constraints to potato yield, Interestingly, potato constitutively produces AMPs, called *Snakin 1* and *Snakin 2,* whose gene transcripts are up regulated by pathogen infection and wounding (Segura, *et al*., 1994, Berrocal*et al*., 2002). Transgenic research has demonstrated that when heterologous antimicrobial peptide variant, synthetic AMP, or other plant AMPs are introduced into plants including potato bring about a broad-spectrum resistance to diverse types of *phytopathogens* (Gao*et al*., 2000).

The over expression of potato *Snakin-1* in potato plants also enhanced resistance to *Rhizoctoniasolani* and *Erwiniacarotovora* (Almasia*et al*., 2005); however, when this gene was silenced in potato, it was found to affect growth and development processes such as cell division and primary metabolism (Nahimak*et al*., 2012). The biotic factors includes a number of plant pathogen includes bacteria, fungi, viruses and other micro – organisms are directly and indirectly cause a disease on potatoes plant.

2.8. Abiotic Factors

The common abiotic stress include high and low temperature, water deficit, salinity, sodicity, alkality, acidity and ion deficiencies and toxicity (Nuttal*et al*., 2003). It is important to recognize other physiological and biochemical factors, including toxic ions, osmotic potential, lack of elements and other physiological and chemical disorders, as well as the interactions between this various stresses (Munns, 1993, Munns, 2000).

Plants have to fight against abiotic stresses from the environment, such as drought, extreme temperature, salt, and UV irradiation, for growth and crop production (Pell *et al*., 2009). The degree to which flowering occurs, the duration of flowering, and the response of flowering behaviour to environmental conditions is greatly influenced by cultivar (Burton 1989). The environmental conditions that influence flower initiation and development include light intensity, quality and duration (day length), temperature, water supply, and available soil nutrients. Flowers of some varieties may abscise prematurely.

S. tuberosum can also suffer from a number of physiological disorders that are caused by a combination of poor environmental conditions and poor management decisions (APC, 2007; Bohl and Johnson, 2010; WPC, 2003). Exposure of the tubers to low temperatures in the field or in storage can cause low temperature injury, while high soil temperatures can cause tuber deformities, as can nutrient and water imbalances. If there is insufficient oxygen supplied to internal tuber tissues, blackheart can occur, and if the tuber grows too rapidly, for instance in poor stands, hollow heart can occur. These disorders are mostly preventable using proper crop management and storage conditions (WPC, 2003).

Water availability is one of the environmental factors that influence most the germinative process (Bewley and Black, 1994; Larson and Kiemnec, 1997). A threshold amount of rainfall is necessary for desert annuals to germinate in their growing season, though the seeds of some species germinate in low soil water potential. (Neffati, 1994) reported that, the seeds of desert plants germinate faster than those from other habitats. In these regions, germination occurs during rainy seasons when soil salinity levels are usually reduced (Gorai and Neffati, 2007).

2.9. Physiological Conditioning of Seed

The physiological age of seed tubers may affect their response to salinity. Plants developing from physiological `young` or physiological `old` seed tuber are more susceptible to salinity than that developing from seed tubers at the proper physiological age (Levy *et al*., 1993b).

Some of the signs we may see under salt stress: Slow stunted growth compared to an identical plant in a lower salinity area. increases succulence of the leaves, leaves may be darker green, or in some plants, take on a bluish green cast and leaves become yellowish, mottling, browning and leaves dropping off (Levy *et al*., 1993b).

The possibility of creating a physiological carryover effects by growing potato for seed tubers on saline soil prior to the next production cycle has been investigated (Zhang *et al*., 2001b). Commonly, the effect of salinity is widely spread on potatoes growth performance and affect its flowers, leaves, stem, reduce plant height and yield quality (Kumare, 1995). At the physiological level, salinity imposes an osmotic stress that limits water uptake and ion toxicity can cause nutrition (N, Ca, K, P, Fe, Zn) deficiency and oxidative stress (Munns, 1993).The adverse effects of salinity stress on potato plant can be: Reduced growth of stems (stunting), leaves and tubers, Leaf chlorosis (yellowing), tip burn and leaf burn, Restrict water uptake by root, Enhance plant senescence, Browning and cracking of tuber surface (Abdullah and Ahmed, 2005).

2.10. Germination and Seedling Emergence

Germination is a crucial stage in the life cycle of plants and tends to be highly unpredictable over space and time. Several environmental factors such as temperature, salinity, light, and soil moisture (Gorai and Neffati, 2007) interact in the soil interface, which regulate seed germination. In the semiarid regions of the Mediterranean basin, salinity stress is increasingly becoming primary limiting environmental condition that restricts successful establishment of crops.

Indeed, beside water scarcity, saline water used for irrigation or high soil salinity may exert an adverse effect upon seed germination in field, exposing the seeds to stress (Almodares*et al*., 2007). If water potential of the imbibition medium (ψ) is reduced, due to low water availability or high soil salt concentration and germination may be delayed or prevented depending upon the extent of reduction in ψ (Hegarty, 1987).

The depressive effects of an increased salt concentration or soil water deficit upon germination percentage and rate and following seedling emergence have been extensively shown in many crops (Kaya *et al*., 2006). Where polyethylene glycol (PEG 6000), has been used to simulate water-stress conditions. PEG is an inert osmotic agent, largely used in many studies on seed priming (Foti*et al*., 2002; Patane*et al*., 2009). Windauer*et al*., 2007), with high molecular weight, whose molecules are too large to penetrate into seed, thus preventing any toxic effects (Bradford, 1986).

Salts can affect seed germination either by restricting the supply of water (osmotic effect) or by causing specific injury through ions to the metabolic machinery (ionic effect). Studies have been carried out on the effect of various chloride and sulphate salts on the germination of halophytes where all the salts exhibited some osmotic effects but no specific ion effect (Mohammed and Sen, 1990) while others reported both osmotic and ionic effects.

2.11. Salinity Tolerance

Plants have to fight against abiotic stresses from the environment, such as drought, extreme temperature, salt, and UV irradiation, for growth and crop production (Pell *et al*., 2009). Low-molecular-weight antioxidants and antioxidant enzymes play important roles in scavenging and controlling the production and accumulation of reaction oxygen species (ROS) when plants are exposed to environmental stresses (Chalker-Soolt*et al*., 1999). Therefore, various metabolic pathways using secondary metabolites have evolved in plants to help them adapt to changing environments (Bewley and Black, 1994). The ability of plants to grow and survive under restrictive growth conditions imposed by salinity that known as salinity tolerance (Moller and Tester, 2007). These characteristics vary among plant species, and that can be accordingly classified as glycophytes or halophytes (Flowers and Flowers, 2005). Glycophytes are plants that are unable to complete their life cycle in elevated concentrations of salt whereas halophytes have the ability to tolerate the harsh condition imposed by salinity. Plants use two mechanisms to tolerate salinity, salt avoidance and tissue tolerance. Salt avoidance is the process whereby plants keep the ions away from their sensitive parts through the passive exclusion of ions by a permeable membrane, the active expelling of ions by ion pumps, and by dilution of ions in the tissue of plants (Munns, 2002). These plants adjust their osmotic pressure by producing compatible solute such as proline, glycine betaine and sugars (Munns and Tester, 2008).

Anthocyanin is also linked to stronger abiotic stress resistance (Bahron*et al*., 2004). Phenols, including flavonoids (flavonols, flavones, anthocyanins, etc.) and several classes of non-flavonoids (phenolic acids, lignins, stilbenes, terpenoids, etc.), have been found to determine the antioxidant activity and biosynthetic pathways appear to be mostly regulated at the transcriptional level (Qualttrocchio*et al*., 2006).

There are several techniques to enhance the endogenous proline accumulation for salt defense mechanism such as exogenous application (Santos *et al*., 1996; Hoque*et al*., 2007; Kaya *et al*., 2007), biosynthesis gene(s) overexpression (Zhu *et al*., 1998; Han and Hwang, 2003) and degradation gene(s) knockout (Nanjo *et al*., 1999).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The greenhouse experiment was conducted in Haramaya University greenhouse at *Rarre*station, Eastern Hararghe, Ethiopia. The station at *Rarre*is 1980m.a.s.l and located at 9° 26' N latitude and 42° 3' E longitude. It is situated in the semi-arid tropical belt of eastern Ethiopia and is characterized by a sub-humid type of climate with an average annual rainfall of about 790 mm, annual mean temperature of 17^{o}C with mean minimum and maximum temperatures of 3.8 and 25^{o}C, respectively (Tekalign and Hammes, 2005).

3.2. Plant Material and Chemical

Three available potato tubers (Gabbissa, Zemen and Chirro) were obtained from Haramaya University Agricultural Research Centre, *Rarre*, and pure sodium chloride (NaCl) was purchased from the Central Laboratory at Haramaya University.

3.3. Greenhouse Experiment

For the greenhouse experiment, sandy loam soil was collected from the research farm of Haramaya University and filled into each plastic pot. Tubers of potato varieties were surface sterilized in 6% sodium hypochlorite solution for five minutes and washed with distilled water. After surface sterilization, tubers of the three potato varieties were planted separately in 12 plastic pots (one seed per pot) of 380cm^2 (surface area) filled with sandy loam agricultural soil in a uniform depth. After germination and right after the emergence of the third leaf, seedlings were randomly assigned to three level salinity treatments (60mM, 120mM and 180mM) and control groups within three replications. Hundred milliliters of treatments and distilled water were applied on a weekly basis up to the end of flowering stage. Prior to salt treatments, salinity level of soils was also determined by measuring electrical conductivity of soil solutions to compare with salt build up after experiment. The following were data collected from the experiment and their means was recorded for all observations.

- ☞ **Days to Germination:** The mean days to germination of each potato varieties from each treatment was recorded starting from the sowing time until the emerging of shoot and root.
- ☞ **Plant height (cm):** Plants height was measured from the ground level to the shoot tip at the harvest and the averages of the three plants recorded.
- ☞ **Number of branches per plant:** The number of primary branches arising from the main stem was counted at the harvest time.
- ☞ **Number of leave per plant:** Total number of leaves on each potato varieties was counted at harvest.
- ☞ **Number of flowers per plant**: The number of flowers were counted from all plants of each variety and averaged for each treatment.
- ☞ **Average tuber weight (gm):** Tubers were weighed and averaged for each variety in each treatment after harvest.
- ☞ **Root length (cm):** The average length of adventitious root of each variety in each treatment was measured in centimeter at harvest.
- ☞ **Days to Flowering:** The mean number of days from sowing to the opening of first flower for all varieties and treatments was recorded.
- ☞ **Number of tubers per plant:** The number of tubers per plant was counted at th**e** harvesting stage.
- ☞ **Biomass:** It was determined by summing up the shoot fresh weight and root fresh weight at harvest stage.

3.3 Statistical Analysis

Statistical analyses were conducted with the statistical packages SPSS for Windows 16.0 (SPSS; Chicago, IL, USA). Data were first checked for normality of distribution from post-harvest observation, measurements and logarithmically transformed as necessary. One-way analysis of variance (one-way ANOVA) was employed to analyze data. Means were separated using List statistically significant difference (LSD) at P <0.05.

4. RESULTS AND DISCUSSION

4.1. The Effect of Salinity on Seed Germination

Mean days to germination significantly (P < 0.5) varied due to salinity treatment and between varieties (Table 2). All varieties germinated early under control treatment compared to salt treated ones and the time required to complete germination increased with salinity concentration. The greenhouse result showed that Gabbissa variety took shorter time to complete germination followed by Chirro and Zemen varieties at all treatment levels (Table 2), suggesting varietal difference in salt tolerance. Generally, with the increase of NaC1 level not all potato varieties germinated at the right time compared to the control (Table 2). Goudarzi and Pakniyat (2008) have studied effect of salinity on seed germination in many crops, maize and wheat for example. Similar to this result, germination was found to delay with increasing salt concentration.

Moreover, according to Karagiizel (2003), germination time in different plant species considerably increases with an increase in salt concentration.Salinity stress negatively affects seed germination, either osmotically through reduced water absorption or ionically through the accumulation of Na^+ and Cl^-, causing an imbalance in the nutrient uptake and toxicity effect (Dasgan*et al*., 2002).

Table 2: Mean germination days of potato varieties subjected to different salinity levels in the greenhouse experiment

Varieties	Salt Concentration in (mM)			
	0	60	120	180
Gabbissa	8.33^{Aa}	14.00^{Ab}	21.00^{Ac}	32.00^{Ad}
Chirro	9.66^{Aa}	17.00^{Bb}	25.33^{Bc}	36.33^{Bd}
Zemen	11.66^{Aa}	19.66^{Cb}	26.66^{Bc}	39.00^{Cd}
LSD(<0.05)	0.01			
CV(%)	13.04			

Where CV= Coefficient of variance; LSD= List of Significance Difference and mean values follow ed by the same capital letters in a column and small letters in a row are not significantly different at 5% level of significance

4.2. Effect of Salinity on Plant Height of Potato Varieties

Analyses of variance showed that there was significant (P<0.05) difference in plant height due to salinity treatments and varietal difference (Table 3). Plant height was gradually decreased with the increase of NaC1 level in all varieties compared with the control (Table 3). Under all treatments, variety Gabbissa was grew much more than the two varieties, whereas variety Chirro was salt sensitive and variety Zemen was highly sensitive to salinity stress compared to the control (Table 3).

Moreover, the present result is in close conformity with the finding of (Hadi*et al*., 2012) who reported similar results in potato and Hossain *et al*. (2008) in mung bean. Salinity may result in a significant decrease in photosynthesis and increase in transpiration rate leading to a shortage of assimilate to the developing organs, thus slowing down growth or stopping it entirely (El-Hendaway*et al*., 2005).

Table 3: Effect of different concentrations of (NaCl) on the plant height (cm) of potato plants.

Varieties	**Salt Concentration in (mM)**			
	0	60	120	180
Gabbissa	55.66^{Aa}	42.33^{Ab}	31.33^{Ac}	18.66^{Ad}
Chirro	48.00^{Aa}	37.66^{Bb}	29.33^{Ac}	14.33^{Bd}
Zemen	39.66^{Aa}	31.00^{Cb}	21.00^{Bc}	10.00^{Cd}
LSD(<0.05) 0.08				
CV(%) 18.99				

Where CV= Coefficient of variance; LSD= List of Significance Difference and mean values follow ed by the same capital letters in a column and small letters in a row are not significantly different at 5% level of significance

4.3. Effect of Salinity on Number of Branches per Potato Plant

The number of branches per plant ranged from 14.00-16.33, 11.00-12.66, 5.33-8.00, and 2.60-5.60 in 0, 60, 120, and 180mM of sodium chloride respectively. At the lowest salinity level, higher number of branches per plant was observed in all varieties and at the highest salt concentration; it was the reverse (Table 4). No significant difference was seen between the three varieties at 60mM of salinity. However, though no significant difference was observed between Gabbissa and Chirro varieties at 120 and 180mM salinity, these two varieties tolerated and produced higher number of branches compared to variety Zemen.

The present result showed that increasing NaCl concentration lead to reduction in number of branches per plant in all the tested varieties.

This result is in agreement with the finding of Tarinejad*et al.* (2013) who reported similar result in canola; Sohrabi*et al.* (2008) on potatoes.

Table 4: Mean number of branches per plant of potato varieties in different salinity levels during greenhouse experiment.

	Salt Concentration in (mM)			
Varieties	0	60	120	180
Gabbissa	16.33^{Aa}	12.66^{Ab}	8.00^{Ac}	5.00^{Ad}
Chirro	14.00^{Aa}	11.00^{Ab}	8.00^{Ac}	5.60^{Ad}
Zemen	16.33^{Aa}	11.33^{Ab}	5.33^{Bc}	2.60^{Bd}
LSD(<0.05)	0.01			
CV(%)	2.56			

Where CV= Coefficient of variance; LSD= List of Significance Difference and mean values follow ed by the same capital letters in a column and small letters in a row are not significantly different at 5% level of significance

4.4. Effect of Salinity on the Number of Leaves per Plant

Analyses of variance showed that there was significant ($P < 0.5$) difference in leaf number per plant due to salinity treatments and varietal difference (Table 5). Compared to the control, number of leaf per plant was decreased due to salinity in a concentration dependent manner. Under all treatments variety Gabbissa also had the highest number of leaf per plant compared to the two varieties (Table 5). This shows that, variety Gabbissa appears to be salt resistant as compared to the other potato varieties in all treatment groups. Gama *et al*., (2007) reported that harmful effect of salinity on leaf number increases with the increase in concentration of salinity levels. One of the studies that support these results also, is a study by Jamil *et al*., (2005). They reported that the treatment of Cabbage *Brassica oleracea capitata* L. and *Brassica oleracea botrytis* L. with the concentrations: zero, 4.7, 9.4, 14.1 dsm^{-1} NaCl, had a negative effect on leaf number of these plants.

Table 5: Effect of treatment with different concentrations of (NaCl) on the number of leaves of potato plants.

	Salt Concentration in (mM)			
Varieties	0	60	120	180
Gabbissa	152.00^{Aa}	103.00^{Ab}	86.00^{Ac}	44.33^{Ad}
Chirro	80.33^{Aa}	71.66^{Bb}	46.00^{Bc}	30.66^{Bd}
Zemen	76.66^{Aa}	71.33^{Bb}	44.3^{Bc}	25.6^{Cd}
LSD(<0.05)	0.05			
CV(%)	49.6			

Where CV= Coefficient of variance; LSD= List of Significance Difference and mean values follow ed by the same capital letters in a column and small letters in a row are not significantly different at 5% level of significance

4.5. Effect of Salinity on Flowering of Potato Varieties

Mean days to flowering significantly varied due to salinity treatment and between varieties (Table 6). All varieties flowered early under control treatment compared to salt treated ones and the time required to flower increased with salinity concentration. The Greenhouse result showed that, variety Gabbissa took shorter time to complete flowering compared to Chirro and Zemen varieties at all treatment levels (Table 6). However, variety Chirro was moderately salt tolerant, whereas variety Zemen took longer time to flower at all treatment, suggesting varietal difference in salt tolerance (Appendix Fig 1). Generally, with the increase of NaC1 level all plants bear no flowers at the right time and ultimately, affect the plant yield compared with the control (Table 6).

Goudarzi and Pakniyat (2008) have studied effect of salinity on seed germination in many crops, maize and wheat for example. Similar to this result, germination was found to delay with increasing salt concentration. This result agrees with that of Amador and Dieguez (2007) and Hadi*et al*., (2012) who reported that increase in salinity levels delays the flowering date in crops.

Table 6: Mean days to flowering of three potato varieties in different salinity levels during greenhouse experiment.

Varieties	**Salt Concentration in (mM)**			
	0	60	120	180
Gabbissa	43.33^{Aa}	55.00^{Ab}	66.0^{Ac}	74.0^{Ad}
Chirro	50.6^{Aa}	63.0^{Bb}	74.0^{Bc}	83.0^{Bd}
Zemen	61.33^{Aa}	71.33^{Cb}	83.66^{Cc}	90.33^{Cd}
LSD(<0.05)	0.071			
CV(%)	12.60			

Where CV= Coefficient of variance; LSD= List of Significance Difference and mean values follow ed by the same capital letters in a column and small letters in a row are not significantly different at 5% level of significance

4.6. Effect of Salinity on the Number of Flowers per Plant

No significant difference was observed in number of flowers per plant at 60mM and 120mM salinity between Gabbissa and Chirro varieties (Table 7). At 180mM salinity level, varieties Zemen and Chirro also the same is true. However, number of flowers per plant were decreased due to salinity increase with in a concentration dependent (Table 7). The Greenhouse experiment showed that, variety Gabbissa had more number of flowers, whereas varieties Chirro and Zemen had a lower number of flower per plant. Our finding agreed with Khan and Ungar (2000) who reported that, the reduction observed in flower number because of salt stress might be due to disruption of physiological processes in plants by salt stress.

Table 7: Mean number of flowers of three potato varieties in different salinity level during greenhouse experiment.

Varieties	**Salt Concentration in (mM)**			
	0	60	120	180
Gabbissa	18.6^{Aa}	11.00^{Ab}	7.33^{Ac}	5.00^{Ad}
Chirro	18.33^{Aa}	10.66^{Ab}	6.66^{Ac}	3.00^{Bd}
Zemen	16.33^{Aa}	8.33^{Bb}	4.33^{Bc}	2.00^{Bd}
LSD(<0.05)	2.78			
CV(%)	15.83			

Where CV= Coefficient of variance; LSD= List of Significance Difference and mean values follow ed by the same capital letters in a column and small letters in a row are not significantly different at 5% level of significance

4.7. Effect of Salinity on Root Length (RL) of Potato Varieties

Analyses of variance showed that there was significant (P < 0.5) difference in root length due to salinity treatments and varietal difference (Table 8). Compared to the control, root length was decreased due to the increment of NaCl concentration. Under all treatments variety Gabbissa grew much more than the two varieties with Zemen variety being the least (Table 8). The greenhouse experiment has showed that, the root length of variety Zemen were more decreased due to the gradual change of sodium chloride (60, 120 and 180mM) compared to the rest of potato varieties as well as the control (Table 8). This result is in agreement with the finding of Baghbani*et al*., (2013) on potato plant treated with different salinity level. Salinity affects both water absorption and biochemical process resulting in reduction of plant root growth (Parida and Das, 2005).

Moreover, reduction in root length and seedling growth under saline conditions may be either due to decrease in the availability of water or increase in sodium chloride toxicity, associated with increasing salinity **(**Moradi and Zavareh, 2013; Munns, 2002) also explains that salinity stress can result in hormonal imbalance and impair basic metabolic processes.

Table 8: Mean root length of potato varieties in different salinity levels during greenhouse experiment.

	Salt Concentration in (mM)			
Varieties	0	60	120	180
Gabbissa	39.66^{Aa}	28.00^{Ab}	21.33^{Ac}	14.33^{Ad}
Chirro	30.33^{Aa}	20.70^{Bb}	12.66^{Bc}	8.03^{Bd}
Zemen	19.50^{Aa}	11.50^{Cb}	4.86^{Cc}	3.93^{Cd}
LSD(<0.05)	0.056			
CV(%)	45.50			

Where CV= Coefficient of variance; LSD= List of Significance Difference and mean values follow ed by the same capital letters in a column and small letters in a row are not significantly different at 5% level of significance

4.8. Effect of Salinity on the Numbers of Tubers per Potato Varieties

At 60mM salinity levels, no significant difference was observed between varieties in number of tubers per plant. However, the effect was significant at 120 and 180mM salinity, with Gabbissa variety showing highest performance. On the other hand, varieties Zemenand Chirro were highly affected at 180mM salinity level (Table 9). However, number of tubers per plant subsequently decreased with increasing salinity in all varieties (Table 9).

At 180mM salinity level, variety Chirro and Zemen were highly affected and the number of tuber was decreased compared to the control (Table 9). These results agree with those of Paliwal and Yadav, (1980); Van Hoorn *et al*., (1993)who reported that, potato yields have been known to decrease as salinity increases with either surface irrigation water or drip irrigation water (Levy, 1992). Irrigation waters containing NaCl affect potato tubers production directly and disrupt the plants' growth (Sadegi*et al*., 2006).

Table 9: Mean number of tubers per plant of potato varieties subjected to different salinity levels during greenhouse experiment.

	Salt Concentration in (mM)			
Varieties	0	60	120	180
Gabbissa	5.66^{Aa}	3.66^{Ab}	3.33^{Ab}	2.00^{Ac}
Chirro	6.33^{Aa}	3.33^{Ab}	2.00^{Bc}	0.66^{Bd}
Zemen	5.00^{Aa}	2.33^{Ab}	1.00^{Cc}	0.66^{Bd}
LSD(<0.05)	0.02			
CV(%)	21.39			

Where CV= Coefficient of variance; LSD= List of Significance Difference and mean values follow ed by the same capital letters in a column and small letters in a row are not significantly different at 5% level of significance

4.9. Effect of Salinity on Tuber Weight of Potato Varieties

Analyses of variance showed that there was significant difference in tuber weight due to salinity treatments and varietal difference (Table 10). Compared to the control, tuber weight decreased due to salinity increase in a concentration dependent manner. Under all treatments variety Gabbissa also had the highest tuber weight compared to the two varieties with Zemen variety being the least (Table 10) and variety Chirro had moderately salt tolerate variety. Plant tuber weight was highly affected by 180mM NaC1 containing and generally, it was almost similar to all varieties compared to the control (Table 10). Moreover, tuber weight was gradually decreased with the increase of NaC1 level in all varieties compared with the control.

Results also agree with (Ahmad R and, Abdullah Z, 2005) as salinity concentration increase, potato is more sensitive due to a decrease in the average tuber size.

Table 10: Tuber weights of different potato varieties in different salinity levels during greenhouse experiment.

Varieties	**Salt Concentration in (mM)**			
	0	60	120	180
Gabbissa	194.29^{Aa}	159.66^{Ab}	143.00^{Ac}	126.26^{Ad}
Chirro	183.36^{Aa}	160.78^{Ab}	132.90^{Bc}	77.4^{Bd}
Zemen	159.77^{Aa}	134.58^{Bb}	127.66^{Bc}	55.1^{Cd}
LSD(<0.05)	0.051			
CV(%)	15.8			

Where CV= Coefficient of variance; LSD= List of Significance Difference and mean values followed by the same capital letters in a column and small letters in a row are not significantly different at 5% level of significance**.**

4.10. Biomass

Analyses of variance showed that there was significant difference in biomass due to salinity treatments and varietal difference (Table 11). Compared to the control, biomass decreased due to salinity increased in a concentration dependent manner. Under all treatments, variety Gabbissa had the highest biomass value compared to the two varieties being the least (Table 11). However, variety Gabbissa had salt tolerant variety even the highest (180mM) salt concentration compared with the rest two (Chirro and Zemen) varieties. This tolerance may be due to salt avoidance is the process whereby plants keep the ions away from their sensitive parts through the passive exclusion of ions by a permeable membrane, the active expelling of ions by ion pumps, and by dilution of ions in the tissue of plants (Munns, 2002).

Similarly, Taffouo*et al*., (2010) reported significant reduction in the total dry weight of potato plant when exposed to different concentration of NaCl under different water regimes.

Total dry biomass weight is frequently used as indicator of salinity tolerance under controlled environmental conditions. This is because salinity adversely affects important physiological and biochemical processes in plants ultimately leading to reduction in total biological yield (Munns, 2002).

Table 11: Mean biomass of potato varieties in different salinity levels during greenhouse experiment.

	Salt Concentration in (mM)			
Varieties	0	60	120	180
Gabbissa	191.0[Aa]	184.66[Ab]	139.03[Ac]	107.0[Ad]
Chirro	186.0[Aa]	161.0[Bb]	119.3[Bc]	56.00[Bd]
Zemen	151.66[Aa]	106.66[Cb]	51.66[Cc]	27.66[Cd]
LSD(<0.05)	0.027			
CV(%)	30.78			

Where CV= Coefficient of variance; LSD= List of Significance Difference and mean values followed by the same capital letters in a column and small letters in a row are not significantly different at 5% level of significance

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary

This study was mainly focused on the effects of salt stress on growth performance of selected potato varieties based on greenhouse experiments. To achieve the objectives, three available verities of potato were obtained from Haramaya University. The selected potato varieties (Gabbissa, Chirro and Zemen) were treated with different levels of salinity (0, 60, 120, 180mM) under greenhouse conditions. The treatments were arranged in CRD in factorial design with three replications. The control groups have treated with distilled water. In all parameters measured, salinity negatively affected all varieties as compared to the control. Comparison between each varieties showed that,Gabbissahad well performed under all salinity level, suggesting it has relatively salinity tolerance.

5.2. Conclusion

Plant injured and physiological responses of various potato varieties to salt stress differed depending on how the salt stress was applied. Salt stress regime applied has a significant impact on outcome and should be carefully considered when developing experimental practices and screening programs.Plants with higher germination date and low germination rate can establish themselves effectively on moderately saline soils.Thus, Variety Gabbissa has agricultural implication for the saline soil in a particular ways.

Every salt treatment delayed plant physiology compared to the control group and the delay was more marked at higher salt concentrations. The mean value indicated that the maximum and minimum result. However, the maximum mean value was observed on Gabbissa in all treatments at all characters. Whereas; the minimum mean value was seen on Zemen whereas, Chirro was scored a moderately mean value during the greenhouse experiment in all characters.

5.3. Recommendation

- This study mainly focused on morphological characters. Thus, I recommend that further investigation be undertaken through molecular markers in order to identify the genes that are responsible for salt tolerance.
- This study was carried out in the greenhouse experiment so further investigation under field condition is recommended.
- Out of three varieties of potato, Gabbissa showed salt tolerant in all treatments. Therefore, this salt tolerant potato varieties should be considered for breeding programs in salty areas.
- This finding was based on only three varieties of potato that makes it difficult to draw general conclusion for all varieties of potato found in Ethiopia for its salt tolerant. Therefore, further study is needed by increasing the number of varieties for salt tolerance study.

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7. APPENDIX

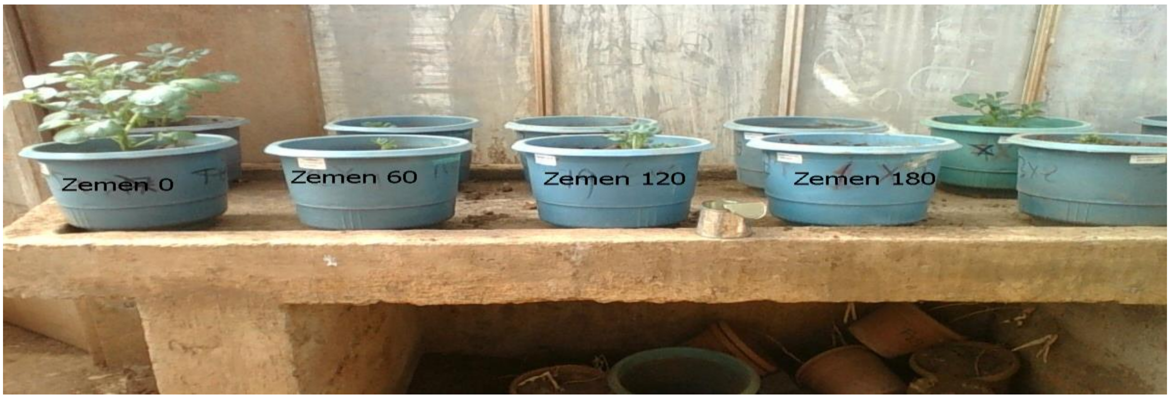
Appendix Table. 1: Physical and chemical characteristic of soils in the study area (0-20 cm depth)

Elements	Contents
Silt (%)	15.31
Sand (%)	71.60
Clay (%)	13.09
Ec (dS/m)	0.14

Appendix Fig 1: Three potato varieties (Gabbissa, Chirro and Zemen) at growth stage Withindifferent salt concentration (1-30 days)

Gabbissa

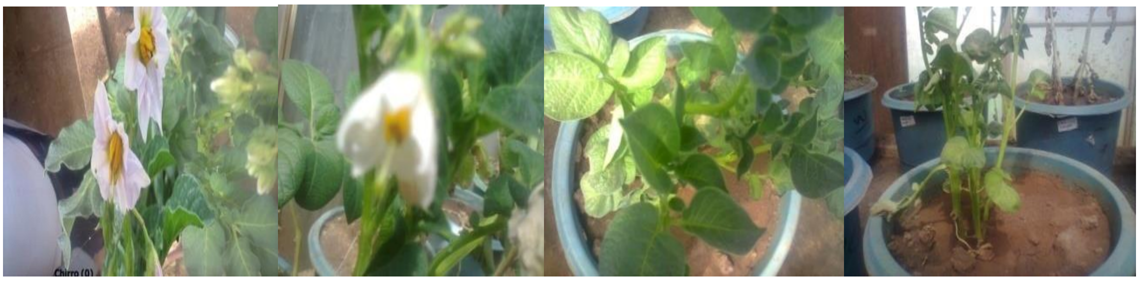
Chirro



Zemen

Appendix Fig 2: Potato varieties at flowering stage within different salt concentration (35-45 days)

Gabbissa (0-180Mm) NaCl concentration



Chirro (0-180mM) NaCl concentration

Zemen (0-180) NaCl concentration

Appendix Fig 3: Three Potato Varieties at Maturity and Harvesting Stage (50-75 days).

Appendix Fig .4: Limitations during Greenhouse Experiment