EVALUATING THE EFFECT OF LAKE BESEKA AND AWASH RIVER WATER MIX RATIOS ON GROWTH AND YIELD OF COWPEA (*VIGNA UNGUICULATA* [L.] WALP) FORAGE PRODUCTION

Abera Girma Niguse

A Thesis Submitted to the Department of Water Resources Engineering, School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Masters in Water Resources Engineering (Specialization in Irrigation Engineering)

Office of Graduate Studies
Adama Science and Technology University

October, 2020
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BOARD OF EXAMINERS APPROVAL SHEET

We, the undersigned, members of the Board of Examiners of the final open defense by Mr. **Abera Girma Niguse** have read and evaluated his thesis entitled "**Evaluating the effect of Lake Beseka and Awash River water mix ratios on growth and yield of Cowpea (*Vigna Unguiculata* [L.] Walp) Forage Production** " prepared, presented and defeated by Mr. Abera Girma Niguse.

This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Master's in Water Resources Engineering (Specialization in Irrigation Engineering)

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DECLARATION

I hereby declare that this MSc Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis/ dissertation have been duly acknowledged.

Name: Abera Girma Niguse

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This MSc Thesis has been submitted for examination with my approval as thesis advisor.

Name: Zelalem Biru (Ph.D.)

Signature: ___________________

Date of submission: … …..…

ADVISORS' APPROVAL SHEET

To: Water Resources Engineering Department

Subject: Thesis/Dissertation Submission

This is to certify that the thesis entitled "**Evaluating the effect of mix ratios of lake Beseka and Awash river water on growth, yield and quality of cowpea (*vigna unguiculata* [l.] Walp) forage production**" submitted in partial fulfillment of the requirements for the degree of Master's in Irrigation Engineering, the Graduate program of the department of Water Resources Engineering, and has been carried out by Abera Girma. Id. No Pgr/18141/11, under our supervision.

Therefore, we recommend that the student has fulfilled the requirements and hence hereby he can submit the thesis to the department.

Dr. Zelalem Biru	___________________	___________________
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Dr. Tilahun Hordofa	____________________	-------------------
Co-advisor	Signature	Date

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ABBREVIATION AND ACRONYMS

ABA	Awash Basin Authority
APH	Average Plant Height
BMC	Billion Metric Cubes
BN	Boll number
CEC	Cat ion Exchangeable Capacity
dS/m	deciSiemens per meter
ESP	Exchangeable Sodium Percentage
ECe	Electrical Conductivity
Eta	Actual Evapotranspiration
ETc	Crop Evapotranspiration
FC	Field Capacity
FAO	Food and Agricultural Organization
GIS	Geographic Information System
LSD	Least Significance Difference
masl	Meter above sea level
MARC	Melkessa Agricultural Research Center
MSE	Metehara Sugar Estate
MoA	Ministry of Agriculture
MoWR	Ministry of Water Resources
mg/L	Milli grams per liter
meq/L	Milli equivalents per liter
mmho/cm	Millimhos per centimeter
NPP	Number of pods per plant
PH	Plant Height
pH	Hydropower

ppm	Parts Per Million
PWP	Permanent Wilting Point
RAW	Readily Available Water
RCBD	Randomized Complete Block Design
RSC	Residual Sodium Carbonate
SAS	Statistical Analysis System
SAR	Sodium Adsorption Ratio
SPP	Number of seeds per pod
TDS	Total Dissolved Solid
UN	United Nations
USDA	United States Department of Agriculture
WARC	Werer Agricultural Research Centre
YKG	Yield Kilogram per Plot
YQHA	Yield Quintal per Hectare
µS/cm	Micro Siemens per centimeter

ABSTRACT

Irrigation water is one of the most critical and scarce resource for agricultural production in arid and semiarid regions. Poor quality of irrigation water has adverse effect on soil and crop performance. During the last five decades the lake level and surface area have been increasing contentiously and this continuous expansion of Lake Beseka poses risk to Awash River because of its saline water. This study was undertaken to evaluate the different mixed irrigation water on growth, yield and quality of cowpea and identify suitable mixing ratio of Lake Beseka and Awash River water on cowpea production. Five mixed irrigation levels of Lake Beseka and Awash River water (2:98, 3:97, 5:95, 8:92 and 10:90) and a control (0:100 of Awash River) were used as a treatment. The treatments were arranged in randomized complete block design with three replications. The water analyses for the Awash River water indicate ECw with 0.30 dS/m, Sodium with 7.39, pH with 7.64 and RSC with 0.24meq/l which was within safe limit for irrigation purpose. While Beseka water quality indicates ECw with 4.4 dS/m, pH with 9.50, sodium with 4 and RSC with 21.40 which was not safe for irrigation purpose. Mixed Lake Beseka and Awash River water affect growth of cowpea in treatment T_5 and T_6 for EC 0.94 ds/m and 0.98 ds/m respectively. There was a highly significant ($p<0.01$) difference among yield and yield parameters due to blended water applications. The control treatment gave higher crop yield, number of seed per pod and number of pods per plant and shows no significant difference with mix ration of 2:98, 3:97 and 5:95 Beseka to Awash river water, respectively. The lowest crop yield and yield parameters were obtained from mix ratio of 10:90 Beseka to Awash River water and shows no significant differences with mix ratio of 8:92 Beseka to Awash river water. From result it is clear that mixing Lake Beseka with Awash River is safe up to 2-5% based on the quality of Awash River.

Key Words: Awash River, Lake Beseka, Water quality, mix ratio, Cowpea

1. INTRODUCTION

1.1. Background

According to the United Nations (UN) estimation, by 2050, the world food supply would have to increase by up to 70% in developed and nearly 100% in developing countries to feed the world population of over nine billion people globally. Thus, the global food production should be steadily increased in order to meet the expected increase in the food demand (FAO, 2011). But staple crop production is globally threatened by a number of constrains such as abiotic stress expanded by climate change, erosion of natural resources, accelerated soil erosion, and land degradation. Therefore, attempt to feed the world's burgeoning global population necessitates the agricultural production to be extended into the marginal regions including saline soils (Henry *et al*., 2019).

Changing weather patterns also increase risks in crop production. Evidently, drought and high temperatures can affect the production of forage crops. Specifically, droughts can result in a reduced water supply, and thus limiting the amount of water needed for irrigation to support forage crop production (Swanckaert *et a*l., 2017). Therefore, planting crops mainly depends on irrigation water that is withdrawn from surface (54.46%) and groundwater (45.54%) sources as their use can vary from year to year (Chakwizira *et al*., 2019).

Agricultural water users must plan an annual water budget in semiarid and arid lands and areas where water usage is regulated due to ecological protection programs, limited resources and competitive demand (Barrett, 1999). It is reasonable to expect that improved crop water requirement estimate may make a substantial change in system specifications and profitability. Sustainability of irrigated agriculture both environmentally and economically depends primarily on the efficiency of irrigation water use, including crop water requirement and delivery and on-farm systems, management of degraded soils and water re-use (Howell, 2001). Therefore, a better management of water in irrigated agriculture is necessary to enhance crop production while preserving soil and water quality. Shortage of rainfall is normally reported as the cause of famine in Ethiopia. However, supplementary irrigation such as small-scale irrigation and water harvesting methods have been undertaken to cope with the water stress problem during crop growing (Degefie *et al*., 2004).

Salinity is a wide spread environmental stress for crop plant in arid coastal regions of the world more than 100 countries. The salinity reduced the crop yield by upsetting water and nutritional balance of plant. The use of saline irrigated water and application of fertilizer are the main factors for increasing soil salinity (Epstein *et al*., 1980; Patel *et al*., 2010). Excess salinity in the soil water can decrease water availability to plant and can cause plant stress. High level of soil salinity can significantly inhibit seed germination and seedling growth, due to the combined effects of high osmotic potential and specific ion toxicity (Grieve and Suarez, 1997; Munns, 2002; Azam *et al*., 2013). Salinity levels adversely affected growth and yield parameters of cowpea and many important crops (Silva *et al*., 2003; Allan *et al*., 2004). Cowpea is considered a moderately to fairly salt tolerant crop with a threshold level of 8.8 $(mmhos/cm)^2$ (FAO, 1985).

The expansion of Lake Beseka affects the surface and ground water dynamics and soil properties of the region and threatens the sustainability of Matahara Sugar Estate, Matahara town in particular, and Awash river in general. As a result, the yield of certain fields is decreasing and a significant area of cultivated lands are abandoning. The problem is believed to be the result of the expansion of saline Lake Basaka towards the plantation field. This would be disastrous as agricultural development downstream would be at risk (Dinka, 2017).

Untreated discharge from industries, domestic wastes, flower farms, and irrigation runoff are among the major sources of pollution in Awash River. The water quality of the Awash River water downstream of the Lake Beseka has shown a decreasing trend from 2013 to 2017. The quality of the river water is deteriorating due to the release of unregulated Lake water into the Awash River (Yimer and Jin., 2020).

During the last five decades the lake level and surface area have been increasing contentiously and this continuous expansion of Lake Beseka poses risk to Awash River because of its saline water. To overcome this problem, the Ministry of Water and Energy has so far spent 35 million ETB to dig drainage channels, discharging water into the Awash River (2% of Awash River by volume) from the lake water. The diluted Awash River water is discharged to the downstream irrigation farms; however, this cannot be a solution because of two reasons. First, the lake water rises much higher than the amount of discharging water into the river. Second the physiochemical property of the lake water changes periodically detailed hydrologic investigation is needed.

This study, therefore meant to classify suitability of mixing ratios of Lake Beseka and Awash River water for irrigation for selected forage crop production particularly cowpea, characterize physical and chemical constituents and achieve knowledge and information necessary for sustainable use of water resources thereby improving the wise use of irrigation water and improving water productivity of the river.

1.2. Statement of the Problem

In the twenty-first century, population, water scarcity, pollution, food insecurity and greenhouse gas emissions are accelerating across the globe. With these emerging conditions, billion people will face severe water shortage by 2050 (Obade *et al.*, 2013). Freshwater pollution is an environmental crisis caused mainly by anthropogenic activities. The water quality deterioration of Lake Beseka which is located in the Ethiopian portion of the East African Rift Valley is associated with rapid expansion that is not fully understood yet. This water quality impairment is the major cause of severe shortage of water supply for human consumption, irrigation use, and public health problems in that area (Fito *et al*., 2019).

Soil salinity and alkalinity problems are commonly found in the arid and semi-arid regions of the world due to insufficient annual rainfall to leach accumulated salts from the plants root zone. Besides, salt affected soils often occur in areas where soluble salts and sodium (Na) accumulate in soils through physical and chemical weathering of rocks or the pedogenic process of the soil development, atmospheric precipitation and fossil salts from marine or lacustrine environments and this occurs due to poor water management, heavy irrigation, high evaporation (Gogile *et al*., 2013; Haile, 2019).

In A wash Basin (i.e. Ethiopia) mixing of Lake Beseka's water with Awash River (relatively fresh water) was carried out not to reduce the problem of water scarcity in the basin rather to slow down the rapid expansion of Lake Beseka, before upsetting the surrounding environment and together with aim of diluting the Lake Beseka's water. Yet, in the basin, mixing Lake Beseka water with the Awash Water River has been taking place in the customary way, which is not based on scientific methods with the gauged and calibrated stations from 2007 up to now (Yimer and Jin., 2020)

If the Lake water continuously drains at its current rate, it would be difficult to control its water quality effects and environmental disasters in water and soil salinity downstream of the lake, human habitats and the irrigation farms. In-depth study is required to understand the impact of mixing ratio of Lake Beseka to Awash River water for appropriate agricultural irrigation at downstream.

1.3 Objective of the Study

1.3.1 General objective

The general objective of this research was to Evaluating the effect of Lake Beseka and Awash River water mix ratios on growth and yield of cowpea (*vigna unguiculata* [l.] Walp) forage production.

1.3.2. Specific objectives

The specific objectives of this study were:-

- To evaluate the physico-chemicals of Lake Beseka and Awash River Water quality,
- To evaluate the effect of mix ratios of Lake Beseka and Awash River water on growth, yield of cowpea and status of soil physico-chemical properties,
- To determine suitable mix ratios of the Lake Beseka water and Awash water river for irrigation.

1.4. Research Question

- What is the physico-chemical status of lake Beseka and Awash River water?
- To what extent do the mix ratios affect growth and yield of cowpea production and soil physico-chemical properties?
- What is the water quality of mixing Lake Beseka to Awash River for forage crop production and soil physico-chemicals?

1.5. Scope of the Study

This study was delimited to assess after mixing of Lake Beseka and Awash River water for cowpea forage production and also focused on physico-chemicals properties of soil after harvesting of cowpea in study area.

1.6 Significance of the Study

Research is concerned with new scientific information on quality of the mixed water of Lake Beseka and Awash River. It will also investigate its extent, contribution and impacts on cowpea yields and soil physico-chemical properties of the study area. This study is meant to classify suitability of mixed irrigation water for crop production, characterize physical and chemical constituents and achieve knowledge and information necessary for sustainable use of water resources. It is also beneficial for a better understanding of how to increase the yield of cowpea under different irrigation mixed ratio of saline water with fresh water in case of water limit, increase water productivity and help to identify the suitable mixed ratio of irrigation level where saline water stress does not significantly reduce yield. On the other hand, it is not only helpful for the study area but also helpful to other places with similar agro-climatic and soil condition.

1.7 Limitation of the Research

The Research has the following limitations:

- ✓ One cropping season experiment which luck a strong scientific conclusion.
- ✓ In ability to use greenhouse due to financial issues.
- ✓ Distance between Lake Beseka and experiment field (MARC) was far and trip for fetching water was very laborious.

2. LITERATURE REVIEW

2.1. Irrigation water Quality

One of the main problems in irrigation practice is salinity, this is because of all irrigation water contain soluble salts. The composition of salts in water varies according to the source of water and properties of constitute chemical compounds. The salt which found in the irrigation water may include substances gypsum (Calcium Sulphate, $CaSO4$, $2H2O$), table salt (Sodium Chloride, NaCl) and baking soda (Sodium bicarbonate ,$NaHCO2$). When these salts dissolved in water, salts separate in to ions, for example sodium chloride break down into Sodium and Chloride ions. Thus, it is customary to refer to ions rather than salts. The application of irrigation water to the soil introduces salts in to a root zone. plant roots take in to water but absorb very little salt from the soil solution, in a similar way when water evaporates from the soil surface, the salt remain behind. Gradually accumulation of salts in the root zone occurred. This happens even when the water has low salinity (Tahir *et al*., 2003).

The concentration and composition of soluble salts in water determines its quality for irrigation. Four basic criteria for evaluating water quality for irrigation purposes are described, including water salinity (EC), sodium hazard (sodium adsorption ratio-SAR), residual sodium carbonates (RSC) and ion toxicity (Zamanet *et al*., 2018). A good quality water has the potential to allow maximum yield under good soil and water management practices. However, with poor quality water, soil and cropping problems can be expected to develop which will reduce yields unless special management practices are adopted to maintain or restore maximum production capability under the given set of conditions (FAO, 1998).

Irrigation water quality and quantity have direct and indirect impact on soil characteristics (physical, biological and chemical) especially in arid and semi-arid regions that unfortunately depend on irrigation. The main cause of salinization and sodification is the use of poor quality irrigation water and continued use of this water leads inexorably to increasing salinization and sodification problems and ultimately results in increased cost of production and crop failures (Chemura *et al*., 2014).

The water with high RSC has high pH and land irrigated by such water becomes infertile owing to deposition of sodium carbonate as indicated by the black color of the soil (Eaton, 1950). The concentration of carbonates in natural waters is a function of dissolved carbon dioxide, temperature, pH, cat-ions and other dissolved salts. Carbonate is a salt of carbonic acid, which originates from dissolving of carbonate minerals. A carbonate salt is formed when a positively charged ion, attaches to the negatively charged oxygen atoms of the carbonate ion (Shakoor, 2017).

2.2. Mixing condition of Saline and Fresh Water

Mixing of saline water with fresh water used to solve water scarcity which an estimated 60% of the world's population is expected to face by the year 2025 is causing increasing reliance on various higher-salinity water sources as substitutes for freshwater irrigation (Kan and Rapaport-rom, 2012). Mixing of waters to an acceptable quality also results in improving the stream size and thus the uniformity in irrigation especially for the surface method practiced on sandy soils (Minhas, 2014). According to Hailu *et al*. (2016) and Leandro *et al*. (2015) the replacement of good quality water by the high salinity water, without negative impacts on crop yield was possible for irrigation purpose by mixing saline and fresh water to maximize water scarcity.

Competition for fresh water increases, water of better quality is primarily used for domestic purposes, whereas water of lower quality is often used for irrigation. Therefore, one challenge for the future will be to maintain or even increase crop production with less water that may often be of poor quality (Karlberg, 2005).

There are a number of factors to be considered when using fresh with saline water. These are plant tolerance, irrigation system, water management strategies, irrigation frequency and soil properties. Moreover growth and yield were high only in fresh water, whereas moderate saline irrigation water in mixed practice gave the highest values of yield productions and growth of crops (Malash *et al*., 2005). Therefore, mixing agricultural irrigation and saline water with good quality water in ratios to keep the salinity of the irrigation water below the threshold of the target crop is an acceptable practice (Al-ain *et al*., 2017). In fact mixing of the Lake water with Awash River without pertinent technology and regulated manner is a very complex action, however, MoWIE tried to discharge the lake water into Awash River using selected water quality parameters and mixing standards (Yimer and Jin., 2020).

2.3. Lake Beseka and Its Impact on Awash River Water

The Ethiopian Rift is characterized by a chain of lakes varying in size, hydrological and hydro geological settings. The rift lakes and Feeder Rivers are used for irrigation, soda extraction, commercial fish farming and recreation, and support a wide variety of endemic birds and wild animals. The level of Lake Beseka has expanded from an area of 2.5–40 km^2 over the same span of time. Changes in Lake Levels are accompanied by dilution in ionic concentration of Lake Beseka. Although the principal hydro geochemical process in the rift lakes is controlled by the input and output conditions and carbonate precipitation, anthropogenic factors such as water diversion for irrigation and soda ash extraction played important role. The recent changes appear to have grave environmental consequences on the fragile rift ecosystem, which demands an integrated basin-wide water management practice (Alemayehu *et al*., 2006).

Water level fluctuation of Lake Beseka due to climatic variability, climatic change as well as land use change impact, total discharge from agricultural land, surface runoff from different area, soil erosion which affect the quality of irrigation water and the impact of sedimentation on the storage capacity of the lakes (Belete e*t al*., 2016). Lake Beseka presents a completely different hydro chemical picture; from an extremely saline water body, it has changed to a nearly fresh lake over the last 40 years. The electrical conductivity has gone down from 74,170 to 7440 mS/cm between 1961 and 1991 corresponding to a change in size from 5 to 40 km^2 (Alemayehu *et al*., 2006).

Due to poor quality of Lake Beseka, the Awash River Basin is facing environmental problems of unprecedented magnitude due to degradation of the water quality of Awash River. This is due to of disposal of industrial effluents, municipal sewage, solid wastes, agricultural runoff, dumping of domestic wastes and natural agents like unregulated Lake Beseka's water discharge in to Awash River and it also deteriorated the water quality of the Awash River such as soil structure deformation, soil salinity, and sod-city effect (Kebede and Zewdu, 2019). The water quality degradation effect of Lake Beseka on Awash River was assessed using the last ten years water quality data from 2008 to 2017 (Yimer and Jin., 2020).

Lake Basaka water has excessively high salinity (EC ~ 6.3 dS/m), alkalinity (RSC ~ 80, pH ~9.5) and sodicity (SAR ~ 300). Lake Basaka are found to have relatively higher concentration of major ions dissolved constituents(Na$\cong 160\ me/l$). The excessively high Na content of Lake Basaka has a potential to destroy soil structure and aggregates ability to soil structure (Olumana and Loiskandl, 2015).

2.4. Effect of Using Saline and Non-saline Water on Crop Production and the Soil

Several crops are sensitive to salinity and the negative effect on growth leads to the decrease in potential profits. Irrigating saline water can also result in salt accumulation in soil, leading to the decrease in yield and deterioration in soil resource, in cowpea production in leading to the decrease in yield parameters, number of leaves per plant, number of branch per plant, the numbers of pods per plant and numbers of seeds were affected significantly when compared with the control. The reduction in the growth of cowpea might be related to osmotic, nutritional, and toxic effects, arising from the accumulation of salts in the root zone of the plant that affect net CO_2 assimilation, inhibit the leaf growth and accelerate senescence of mature leaves, thereby reducing the total production of photo assimilates (Mshelmbula *et al*., 2015; Leandro *et al*., 2015; Kim *et al*., 2016).

Salinity generally creates the following conditions for plants: a) ionic stress; b) osmotic stress; and c) disrupted homeostasis. In addition, a combination of different morphological, physiological and biochemical effects may occur, negatively affecting nutrient acquisition, transpiration and the photosynthetic function of plants and resulting in stunted growth or potential plant loss. Such effects are reflected as economic losses for producers (Patel *et al*., 2010; Afonso *et al*., 2017). Seed and pod yields of cowpea decreased significantly for the soil salinity values higher than 9.0 dS m^{-1}(Düzdemir *et al*., 2010; Salih *et al*., 2013).

Blended or mixed irrigation water had impact on soil properties, such as electrical conductivity (EC), exchangeable sodium percentage (ESP), as well as pH, increased due to blending effect of Beseka water to fresh water (Hailu *et al*., 2016). Furthermore, the water quality of Lake Beseka is not suitable for irrigation due to extremely high values of pH (10) and other parameters dominating in salt lakes (Fito *et al*., 2019). Researchers and farmers have established that these effects can be largely mitigated by incorporation of gypsum or other amendments that liberate free Ca^{2+} in the upper portion of the soil profile (Grattan *et al*., 2012).

The salt content of soils which plant growth is affected depends upon several factors, among which are the texture of soil, the distribution of salt in the profile, the composition of the salt, and the species of plant. Several arbitrary limits for salinity have been suggested for distinguishing saline from non-saline soils. In the case of irrigation, the salts are applied with the water and remain behind in the soil as water evaporates or is used by the crop. They originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. These salts are carried with the water to wherever it is used (Brown *et al*., 1990).

Yield reduction of some crops for various levels of soil salinity as measured by EC under normal growing conditions and gives potential yield reduction due to water salinity levels. The tolerance of crops to sodium is as measured by the exchangeable sodium percentage (ESP). Sodium Adsorption Ratio is also used to evaluate the suitability of water for irrigation. A high sodium ion in irrigation water affects the hydraulic conductivity (permeability) of soil and creates water infiltration problems. Due high value of SAR, the soil becomes hard and compact when dry and resultantly, reduces the infiltration rates of water and air into the soil affecting its structure If the chloride contamination in the leaves exceeds the tolerance of the crop, injury symptoms develop such as leaf burn or during leaf tissue. These symptoms occur when leaves accumulate from 0.3 to 1.0 percent chloride (Todd, 1980; FAO, 1985).

Sodium toxicity is not diagnosed quite easily as chloride toxicity. Typical toxicity symptoms are leaf burn, scorch and dead tissues along the outside edges of leaves in contrast to symptoms of chloride toxicity, which normally occur initially at the extreme leaf tip. For tree crops, sodium in the leaf tissue exceeding 0.25 – 0.50 percent is often associated with sodium toxicity. Boron is an essential element for plant growth. Boron is needed in relatively small amounts, however, and if present in amounts appreciably greater than needed, it becomes toxic (FAO, 1976).

2.5. Measuring Major Parameters of Irrigation Water Quality

The guidelines are practical and have been used successfully in general irrigated agriculture for evaluation of the common constituents in surface water, groundwater, drainage water, sewage effluent and wastewater (FAO, 1980). The chemical constituents of irrigation water can affect plant growth directly through toxicity or deficiency, or indirectly by altering plant availability of nutrients (Bartram *et al*., 1996). The suitability of water for irrigation is not dependent on soluble salts. Because, the low solubility salts precipitate in the soil and accumulate with each successive irrigation, the concentration of highly soluble salts increases the soil salinity (Doneen, 1964). Various measurements are used to characterize the salinity of irrigation water. The main parameters tested are:

2.5.1. Electrical Conductivity, EC

Electrical conductivity (EC) measurements are used as indication of total quantities of soluble salts in soils. Irrigation waters with ECw values of 0.7 to 3.0 dS/m may pose slight restrictions in use, with severe limitations being associated with waters having ECw values > 3.0 dS/m. EC is a good measurement of salinity hazard to crop when using groundwater for irrigation. According to FAO (1985), it classified as excellent (0-0.25 ds/m), Good (0.250-0.750 dS/m), high, (0.750-2.250 dS/m) and unsuitable (very high) (> 2.250 dS/m).

Table 2.1: Limits of some parameter indices for irrigation purposes

Quality Parameters	Unit	Interval	Classes	Source/Reference
EC	dSm^{-1}	0-0.25 0.25-0.75 0.75-2.25 > 2,25	Low Good High Very High	(FAO, 1985)
RSC	mel^{-1}	<1.25 1.25-2.5 >2.25	Safe Marginal Unsuitable	(Eaton, 1950)
SAR	$(mmhos)^{0.5}$	< 10 10-18 18-26 >26	Excellent Good Fair Poor	(Todd, 1995)
ESP (%)	-	<10 20-40 40-80 >80	Excellent Good Fair Poor	(Wilcox, 1955)

2.5.2. Total dissolved solid, TDS

Total dissolved solids (TDS), a measure of the bulk salinity often determined indirectly by measuring electrical conductivity of the water. In terms of 'Degree of restrictions on use' the TDS values <450, 450-2000 and >2000 mg/l represent the irrigation water as 'none'; 'slight to moderate' and 'severe', respectively (FAO, 1985; USSLS, 1954; Mass *et al.*, 1987; Bauder *et al.*, 2014).

TDS (mg/L) = EC ((mg/L or ppm) = EC (mmhos /cm or dS/m) x 640..........2.1

where, K is 640 in most cases (EC: 0.5 -5 dS/m) or K = 800 (EC > 5 dS/m)

2.5.3. Sodium adsorption ratio, SAR

It is the estimation of the degree at which Sodium will be absorbed by the soil. It also influences infiltration rate of water.

Table 2.2: Sod-city classes of irrigation water

SAR of irrigation water $(mmolesl^{-1})^{0.5}$	Sodicity class	Sodicity hazard
< 10	S1	Low
10 -18	S2	Medium
18 – 26	S3	High
> 26	S4	Very high

Source: (USSLS, 1954; Zaman *et al*., 2018).

The SAR is calculated from the ratio of the concentration of sodium to that of calcium and magnesium (Richard, 1954).

$$SAR = \frac{[Na^{+}]}{\sqrt{0.5\,(Mg^{+2} + Ca^{+2})}} \ldots\ldots\ldots\ldots\ldots 2.2$$

The concentrations of sodium, calcium, and magnesium ($[Na^{+}]$, $[Ca^{2+}]$, and $[Mg^{2+}]$) are in milliequivalents per liter (meq/L).

Table 2.3: SAR classes value for irrigation

Class	EC(mmhos/cm)	SAR	ESP
Normal	Below 4	Below 13	Below 15
Saline	Above 4	Below 13	Below 15
Sodic	Below 4	Above 13	Above 15
Saline- Sodic	Above 4	Above 13	Above 15

Source: (Horneck *et al*., 2007).

2.5.4. Residual sodium carbonate, RSC

Concentration levels of bicarbonate and carbonate affect the water suitability for irrigation. Water with high RSBC has a high pH. Soil irrigated with such water becomes infertile leading to deposition of sodium carbonate (Eaton, 1950).

The residual sodium bicarbonate (RSBC) was determined by using the equation (2.3) the obtained values of $CO^{2-}{}_{3}$, $HCO^{-}{}_{3}$ in me/l (Eaton, 1950).

$$RSC = (HCO_3^{-} + CO_3^{-}) - (Ca^{2+} + Mg^{2+}) \ldots\ldots\ldots\ldots\ldots 2.3$$

where, concentrations are in cmol(+)/kg of soil.

According to Eaton (1950) and Wilcox and Richard (1954) an RSC value less than 1.25 $meql^{-1}$ is safe for irrigation. A value between1.25 and $2.5meql^{-1}$ are marginal quality and value more than $2.5meq^{-1}$ is unsuitable for irrigation.

2.5.5. Sodium exchangeable percentage, ESP

Exchangeable Sodium Percentage (ESP) Another index that characterizes soil sodicity. As noted above, excess sodium causes poor water movement and poor aeration. By definition, sodic soil has an ESP greater than 15 (US Salinity Lab Staff, 1954).

Sodium reacts with soil to reduce its permeability. Sodium percent in water is a parameter computed to evaluate the suitability for irrigation. Usually little or only minor problems occur when ESP values are less than 15%. When ESP> 15%, reduced permeability will occur. Sodium percentage (ESP) determined by (USSL Staff, 1954; Horneck *et al*., 2007).

$$\text{ESP \%} = \frac{[Na^{+}]}{[Ca^{2+} + Mg^{2+} + K^{+} + Na^{+}]}\ x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 2.4$$

2.5.6. The pH

The pH of water is a measure of the acidity or basicity. The pH is the concentration of hydrogen ions (H+) and hydroxyl ions (OH-) in the water. It is used to determine the acidic, basic or neutral behaviors of water. The pH values range from 1 to 14, which means, if pH of water is less than 7 then it is called acidic water whereas, pH equal to 7 as neutral and more than 7 is called the basic nature water (USSL Staff, 1954). pH standard is (6–8.5) for irrigation purpose (FAO, 1985). The high pH value (>8.5) are often caused by high bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) concentrations, known as alkalinity (Bauder *et al*., 2014).

2.6. Salt Tolerant Forage Crops

Crop salt tolerance is based on the crop's ability to maintain yield and quality with increased salinity. The salt tolerance of crops can be described as a function of yield decline across a range of salt concentrations expressed as the average root zone salinity. Salt tolerance can be adequately characterized on the basis of two parameters: a "threshold "paramour (ECt), which is the maximum root zone salinity that crop can tolerate above which yields decline with increased soil salinity. Salt sensitive plants have low threshold and steep slopes, while salt tolerant plants have higher threshold and lower slopes. Many grass and forage corps is categorized as moderately to tolerant (Azam *et al*., 2013; Motawei, 2017).

Differences exist between plant species in their tolerance of salinity. These differences can be related to the salt content of the soil and/or water which causes an initial decline in growth (yield), and also to the rate of yield decline that occurs with increasing salinity. However, the salt tolerance values presented are not fixed and plant salt tolerance varies with water management practice (e.g. irrigation method, frequency, intensity, water logging); stage of plant growth; climatic conditions (e.g. temperature, humidity and light); and, soil type. Salt tolerance can also differ between cultivars of a species, such as for subterranean clover and white clover. However, these differences are usually much smaller than differences between species (James D, 2012).

2.7. Crop Water Requirement Relation to Salt Tolerant

As soil salinity increased, water consumption of cowpea decreased. Therefore, the effect of salinity in lowering evapotranspiration should be considered in irrigation planning and scheduling of cowpea. Either excessive or limited water applications caused decreases in seed and pod yields of cowpea. Cowpea is tolerant to water stress in terms of seed and pod yields (Düzdemir *et al*., 2010).

Water is the most limiting natural resources for agricultural production in arid and semi-arid regions. Therefore, by using more irrigation efficient methods, decreasing plant water consumption is best method to safe water. The total crop water requirement is the maximum amount of water that a crop can use productively when the soil water content is not limiting. Crops mainly need water for cooling purposes; most of the root’s water uptake is released back to the atmosphere through transpiration, and only a negligible fraction is retained for crop growth. In field experiments, partitioning transpiration from soil water evaporation is difficult (Abebe *et al*., 2013).

The hydrological cycle describes the constant movement of water above, on and below the Earth's surface. The cycle operates across all scales, from the global to the smallest stream catchment and involves the movement of water along evapotranspiration, precipitation, surface runoff, subsurface flow, and groundwater path ways (Hagos *et al*., 2019). Evapotranspiration (ET) is usually the largest component of the hydrologic cycle, given that most precipitation that falls on land is returned to the atmosphere. Globally, about 60% of the annual precipitation falling over the land surface is consumed by ET. Quantification of ET is used for many purposes, including crop production, water resources management, and environmental assessment. Irrigation requirement (IR) can be computed when ET is known using the following formula (Irmak, 2009).

$$IR = \left[\frac{ET_c\text{-}[P_e + D_{rz}(\theta_i\text{-}\ \theta_f)]\ x\ 100}{E_s}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.5$$

where; ETc- crop water requirement, Pe = effective rainfall, Drz- crop depth, θ_i= field capacity, θ_f – permanent wilting point, E_a – field application efficiency.

For the determination of crop water requirement, the effect of climate on crop water requirement, which is the reference crop evapotranspiration (ET_o) and the effect of crop characteristics (Kc) are important (Dorenbos and Pruitt, 1977).

The evapotranspiration from a reference surface not short of water is called the reference crop evapotranspiration and is denoted by ET_o. The only factors affecting ET_o are climatic parameters. As a result, ET_o is a climatic parameter and can be computed from weather data. Experimentally determined ratios of ET_c / ET_o, called crop coefficients (Kc) (FAO, 1985).

The updated values of crop coefficients are determined from FAO (1998) as follow.

2.8. Irrigated Agronomy of Cowpea Forage Crops to Salt Tolerant

Cowpea (Vigna unguiculata L. Walp.) is primarily grown in drier regions of the world, in the semi-arid tropics of Africa, Brazil and the United States where it is one of the most drought-resistant food legumes and heat loving forage crops. It is a crop of great economic importance, in addition to its importance in feeding low-income populations around the world *(*Dadson *et al*., 2005).

For all recommended plant spacing, sow 3seeds/hill and thin to 2plants/stand at two weeks after planting. Seeds requirement is about 12–25 kg/ha, depending on the variety, seed size, cropping system, and viability of the seeds. More seeds are required when erect varieties (25kg/ha) are used than when prostrate varieties are adopted, because of the closer spacing of the erect variety. Usually the number of seeds per pod may vary from 8 to 20. The seeds are weighed 5 to 30 g/100 seeds. yield of cowpea is 150-250 quantal per hectare under normal condition. Cowpea should be planted either on ridges or on flat beds, depending upon the field preparation. Being drought hardy deep rooted annual cowpea can penetrate soil up to 1.5-2 m under favourable soil conditions. Sowing time of cowpea thus, greatly varies depending on the season, place and purpose. In hills this crop is sown in April-May (Kumar and Narain, 2005; Dugje *et al*., 2009). Cowpea is salt tolerant forage crop next to cotton with threshold value of yield reduction at level of EC (3.3-6 mmhos/cm).

Cowpea is adapted to environments ranging from drought stress to waterlogged soil conditions and cowpea can be grown on wide variety of soils like sandy loam, red loam, coarse gravel, heavy loam, hilly tracts of sloppy land. It is well adapted to a variety of soil conditions ranging from drought- stressed to water logging soils and it usually grows about

60 to 90 cm and spacing between cowpea is 10-15 cm. For optimum yield, cowpeas should be planted late November to early December in lower rainfall areas in warm season. It thrives well between 21°C to 35°C. Cowpeas can be produced satisfactorily with an annual rainfall between 400 and 750 mm. It requires a soil pH of between 5.6 and 6.0. Cowpeas vary in growth habit from erect or semi-erect types with short (<100 days) growth duration, grown mostly for grain, to longer (>120 days) duration in semi-erect to trailing plants which are normally grown primarily for forage. At maturity, leaves will dry down but may not drop off completely. They need to be harvested when seed moisture content is 14 to 18 %, depending on the consumer's requirement (Ramesh *et al*., 2013; Mohamoud *et al*., 2019).

2.9. Irrigation scheduling to Salt Tolerant Crops

One method of conserving water would be to mine the plant-available soil water gradually during the irrigation season, in anticipation of recharge from precipitation during the off season. Yields were related linearly to irrigation and water use with a reduction in irrigation or water use reflected by a reduction in yield (Nelson *et al*., 1993). Proper irrigation scheduling is simply applying the appropriate amount of water at the correct time. Scheduling considers such physical factors as the water holding capacity of the soil, crop water use rate, and plant characteristics (e.g., root depth and sensitivity to water stress). Two reasons are often given for irrigation scheduling it saves water and it protects the environment (USDA, 2004).

Plant response to irrigation is influenced by the physical condition, fertility and biological status of the soil. Soil condition, texture, structure, depth, organic matter, bulk density, salinity, sodicity, acidity, drainage, topography, fertility and chemical characteristics all affect the extent to which a plant root system penetrates into and uses available moisture and nutrients in the soil (FAO, 2002).

Crop ET is generally computed using the reference crop ET (ETo or ETc) and a crop coefficient to relate actual crop water use to the reference crap. For many crops' irrigation should start when soil water content drops below 50 % of the total available soil moisture. The RAW is the amount of water that crops can extract from the root zone without experiencing any water stress (FAO, 1998; Jensen *et al*., 1990). Cowpea is more drought tolerant forage crops to water deficit, for high yield, soil water depletion is 40% (FAO, 1998).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted at Melkassa Agricultural Research Center experimental site during 2019/20 dry season. The center is located in the Central Rift Valley of Ethiopia, Oromia Regional State at 8°24′36” N - 8°26′24” N latitude, 39°19′12” E - 39°21′48” E longitude, and altitude of 1,550 m above sea level.

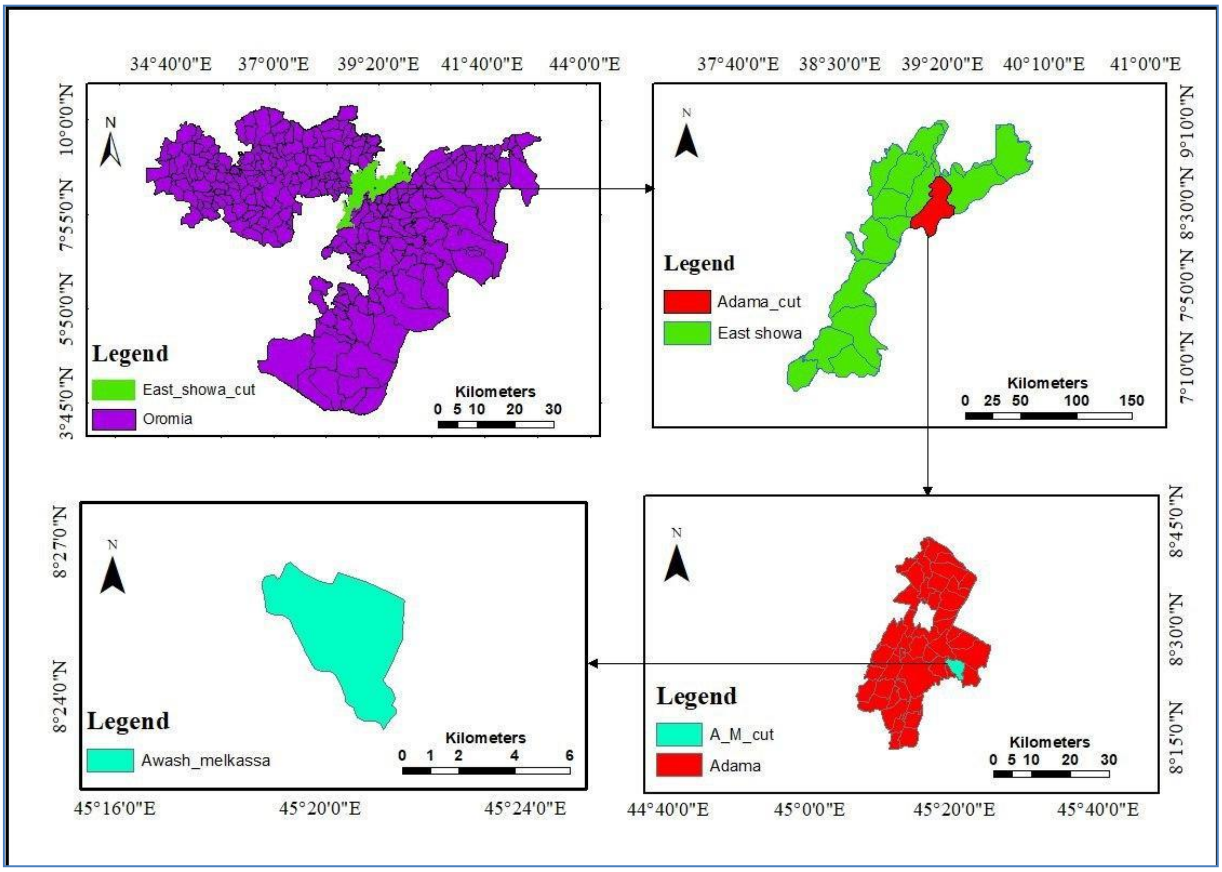

Figure 3.1 : Location map of the study area

The climate of the area is characterized as semi-arid with uni-modal low and erratic rainfall. Kiremt season has more rainfall and contribute about 67.4% of the total rainfall of the year occurring during June to September with peak on the months of July and August. From long-term (1977–2017) climatic record of Melkassa agro-meteorological observatory station indicted the average annual rainfall in the area was 824.9 mm and the mean maximum and minimum monthly rainfall were 204.2 mm and 9.6 mm occurs in the month of August and November, respectively. The mean maximum temperature varies from 26.3 ^{0}C to 31.0 0C while the mean minimum temperature varies from 10.4 ^{0}C to 16.4 ^{0}C, with the average of 21.3 ^{0}C. The source of irrigation water in the study area is Awash River that serves 27% of the total irrigated agriculture of the country (Zemede Abebe, 2011). The textural classification mainly varies from clay to clay loam.

3.2. Materials Use

Water sample was collected from Lake Beseka at sampling point by using tanker and travelled to Awash Research centre by using long vehicle. Water sample collection was mostly carried out on the material that collects water, procedures, and timing and transportation rate physiochemical water sample collection were employed. Samples were collected in 2000 ml plastic bottles to evaluate different physiochemical parameters at Melka Werera Agricultural Research Centre laboratory (WARC). Lake Beseka water was stored in tankers of containing 2000L at extremital site and mixed with Awash River water. Awash River was found in Melkessa Agricultural Research Centre and stored in ditch during application of water to the crop as per irrigation. After calculating crop water requirement based on volume basis, the mixed of Lake Beseka and Awash River were applied to plot based on their percentage. Then each treatment was multiplied with control treatment. The mixed water was measured by using cylinder. Then after the field were irrigated by using watering cane.

3.3. Soil Physical and Chemical Properties of Experimental Site

3.3.1. Soil sampling

The representative composite soils were collected for soil physical and chemical analysis from different location from four depths (0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm) by considering the effective root zone of cowpea from five points along the diagonal of experimental plot for physical and chemical analysis before sowing cowpea. The soil analysis was carried out following the standard procedure for soil physical and chemical analysis.

3.3.2. Soil physical characteristics

The soil samples collected were analyzed for soil physical soil properties at Werer Research soil laboratory following standard test procedures. Soil texture (particle size distribution), bulk density, particle density, total porosity, and water holding capacity at field capacity and permanent wilting point are some of the physical properties analyzed.

Particle size distribution was determined in the laboratory. Then, the soil textures were determined using the USDA textural triangle. In the field, soil infiltration measurements were made for the identified fields/plots/ using double ring infiltrometer.

3.3.3. Soil chemical characteristics

The soil chemical analyzed included soil pH, electrical conductivity, EC, CEC, exchangeable bases (Ca, Mg, K and Na), soluble bases ($Ca^{2+,}$ Mg^{2+}, Na^{+}, K^{+}) and anions (Cl^{-},HCO_3^{-}, CO_3^{2-}). The analyses for soil chemical were undertaken using standard procedure in soil laboratory. The TDS was computed based on Eq. 2.1. The value of SAR and ESP was calculated based on Eq. 2.4 and 2.2 respectively.

3.4. Water sampling

Sampling site from both Lake Beseka and Awash River were collected from Lake Beseka around Fentale and Awash River near Melkassa agricultural research center that used for irrigation purpose. This was based on the assumption that the sampling site requires consideration to make representative in respect to irrigation practice, which is very important for the water quality analysis and to evaluate the water quality changes (Table 4).

Table 3.1: Location of Sampling Site in Lake Beseka water

No	Sampling	Symbol	GPS		Elevation (masl)	Sub basin
			Easting	Northing		
1	Awash River	AW	39^{0} 52''20'	08^{0}51''52'	957	MARC
2	Lake Beseka	LB	39^{0} 54''22'	08^{0}53''55'	946	Beseka

3.5. Experimental Treatments and Design

The proportion selected based on the previous studies and of discharging Lake Beseka water to Awash River, on the first study the lake water discharged 2% by volume based on the flow of Awash River (MoWE, 2014). The treatments include five mixed irrigation water samples and control (0% Lake Beseka and 100% Awash River). The mixed water from Lake Beseka and Awash River water include 2:98, 3:97, 5:95, 8:92 and 10:90% by volume, respectively. The treatments were assigned randomly to the experimental plots within a replication and arranged in randomized complete block design, RCBD with three replications.

Table 3.2: Mixing Ratio of Awash River & Lake Beseka water used in this study area.

No	Sampling Name	Lake Beseka water (%)	Awash River (%)	Symbol
1	Treatment 1	0	100	L_0A_0
2	Treatment 2	2	98	L_2A_{98}
3	Treatment 3	3	97	L_3A_{97}
4	Treatment 4	5	95	L_5A_{95}
5	Treatment 5	8	92	L_8A_{92}
6	Treatment 6	10	90	$L_{10}A_{90}$

The six recommended mixes were:

1. L_0A_{0}-the mix of Lake Beseka and fresh water with a proportion of Lake Beseka and fresh water 0:100, this means the mix contains 0% of Lake Beseka and 100% fresh Awash River water.
2. L_2A_{98}-the mix of Lake Beseka and fresh water with a proportion of Lake Beseka and fresh water 2:98, this means the mix contains 2% of Lake Beseka and 98% fresh Awash water.
3. L_3A_{97}- the mix of Lake Beseka and fresh water with a proportion of Lake Beseka and fresh water 3:97, this means the mix contains 3% of Lake Beseka and 97% fresh Awash water.
4. L_5A_{95}- the mix of Lake Beseka and fresh water with a proportion of Lake Beseka and fresh water 3:97, this means the mix contains 5% of Lake Beseka and 95% fresh Awash water.
5. L_8A_{92}- the mix of Lake Beseka and fresh water with a proportion of Lake Beseka and fresh water 8:92, this means the mix contains 8% of Lake Beseka and 92% fresh Awash water.
6. $L_{10}A_{90}$- the mix of Lake Beseka and fresh water with a proportion of Lake Beseka and fresh water 3:97, this means the mix contains 10% of Lake Beseka and 90% fresh Awash water.

3.6. Treatment Combination

Treatment combination contains test crop level particularly cowpea and six irrigation treatments including control treatment. Treatment designation arranged with one factorial i.e. crop level particularly cowpea (C_1) and irrigation water with six levels.

Table 3.3: Treatment combination and layout of treatment in the experimental field

Treatments	Replications		
	Replication 1	Replication 2	Replication 3
T_1 (100%, 0%)	T_1C_1	T_4C_1	T_6C_1
T_2 (2%, 98%)	T_4C_1	T_6C_1	T_5C_1
T_3 (3%, 97%)	T_6C_1	T_5C_1	T_1C_1
T_4 (5%, 95%)	T_5C_1	T_3C_1	T_2C_1
T_5 (8%, 92%)	T_3C_1	T_2C_1	T_4C_1
T_6 (10%, 90%)	T_2C_1	T_1C_1	T_3C_1

3.7. Experimental Layout

The total area of experimental field had an area of A = 19.5 m x 12 m = 253.5 m^2. The experimental plot sizes were 2 x 3 m^2 dimensions with recommended plant spacing 10 cm 60 cm for cowpea between plants and hills (ridges) respectively. A total of 18 plots were arranged in RCBD in three replications. The distance between adjacent plot was 1.5 m whereas the distance between blocks was 2 m far apart. Working plot consisted of one row, 12 m with 120 plants, at a spacing of 0.1 m between plants. The total working area was 108 m^2, with only the central plants of each subplot being considered for data collection, where each subplot represented one replication. The treatments were representing the six irrigated production systems with Lake Beseka and Awash River water.

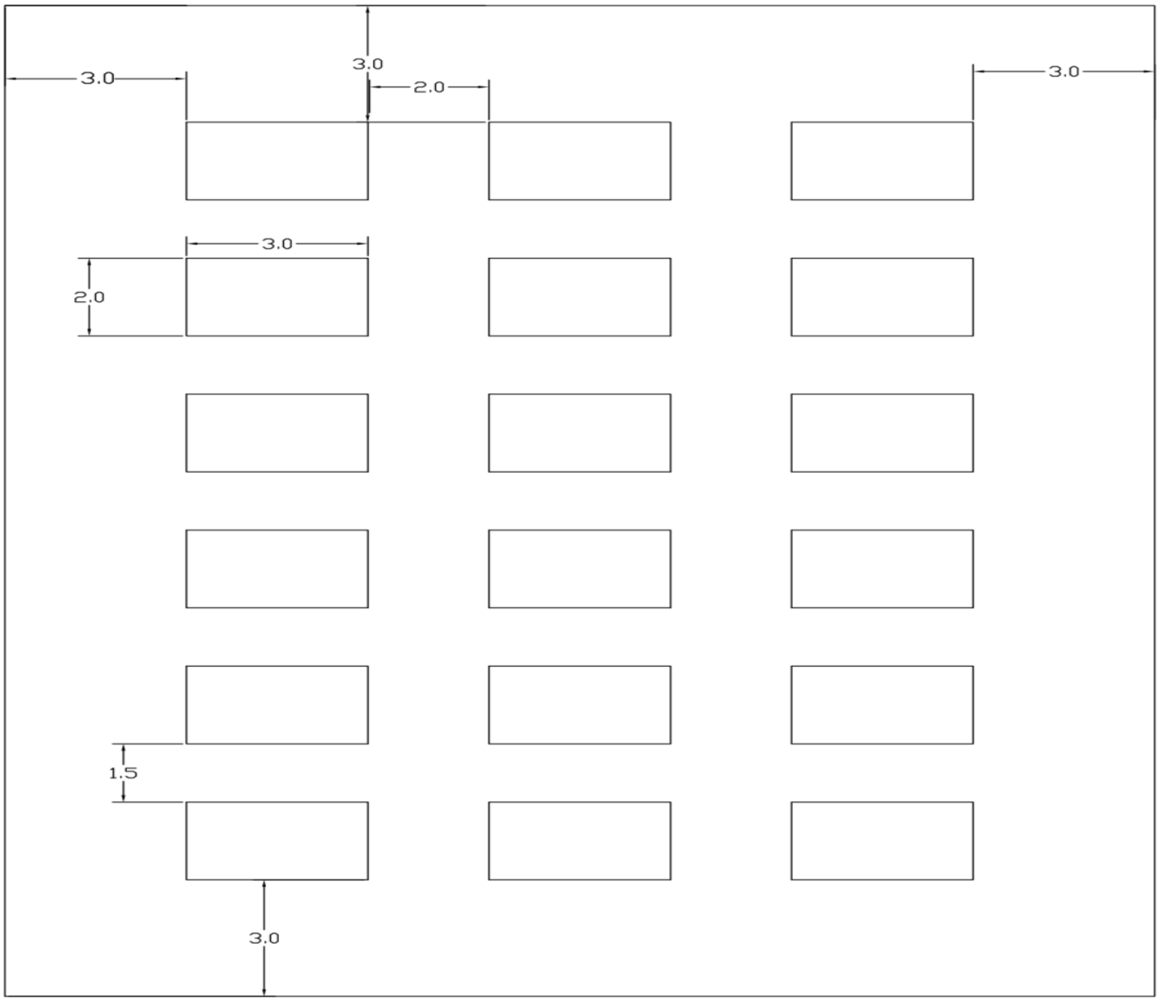

Figure 3.2: Experimental field layout

3.8. Water analysis and Interpretation

Water samples collected from Beseka and Awash River were analysed pH, EC, dissolved cat ions (Ca, Mg, Na and K), alkalinity (HCO_3^- and CO_3^{2-}), and Cl^{-1}, contents in the laboratory every time before irrigation. The collected water samples were subjected for the analysis of pH, EC, dissolved cat ions (Ca, Mg, Na and K), alkalinity (HCO_3^- and CO_3^{2-}), and Cl^{-1}, contents in the laboratory. EC and pH of the water samples were measured in the laboratory within 24 hours.

TDS was calculated based on Eq, 2.1 with the values obtained from water laboratory for EC in ds/m (FAO, 1985). The sodium adsorption ratio (SAR) was calculated based on Eq. 2.2 with the values obtained data from water laboratory for Na^+, Ca^{2+}, Mg^{2+} in me/l (Richards, 1954). The residual sodium bicarbonate (RSBC) was calculated based on Eq. 2.3 with the values obtained data from water laboratory for $CO^{2-}{}_3$, $HCO^-{}_3$ in me/l (Eaton, 1950). The soluble sodium percentage (ESP %) calculated based on Eq. 2.4 with the values obtained data from water laboratory for Na^+, K^+, Ca^{2+}, Mg^{2+} in me/l (USSL Staff, 1954; Horneck *et al*., 2007).

The analytical results were compared with FAO's, USSL's and related legislation classification criteria of irrigation water to interpret water quality characterization.

Table 3.4: Method used for water quality analysis in laboratory

Quality parameter	Unit	Symbol	Method Used
Hydropower	0-14	pH	Potentiometric (1:2.5 H_2O, v/v)
Electrical Conductivity	ds/m	EC	Conductometry (1:2.5 H_2O, v/v)
Calcium	mel^{-1}	C^{+2}	Spectrophotometer
Magnesium	mel^{-1}	Mg^{+2}	Spectrophotometer
Sodium	mel^{-1}	Na^+	Flame photometer
Potassium	mel^{-1}	K^+	Flame photometer
Chloride	mel^{-1}	Cl^{-1}	Mercuric nitrate titrimetric (with 0.05 N Ag NO_3)
Carbonate	mel^{-1}	CO_3^{2-}	Titrating with standard acid (pH of 4.5)
Bicarbonate	mel^{-1}	HCO_3^-	Titrating with standard acid (pH of 4.5)
Sulphate	mel^{-1}	SO_4	Turbidimetric or gravimetric

Source: from Melka Werera Agricultural Research Center (MARC) Laboratory

3.9. Agronomy Practices

The experimental field contained a total of 18 plots which had an area of 253.5 m^2 with 19.5 m by 12 m. The experimental plot size was 6.0 m^2 with 3.0 x 2.0 m. The recommended plant and row spacing for cowpea was 10 cm by 60 cm, respectively. The distance between adjacent plot was 1.5 m whereas the distance between replication was 2 m.

The experiment commenced on 25 March 2019/20 by sowing cowpea (*Vigna unguiculata* [L.] Walp) variety bunch type seeds on plot size of 3 m wide by 2 m long. Two weeks after germination, seedlings were thinned to recommend planting spacing to obtain a population of 133,333 plants ha^{-1}. Five plants from central two rows of each plot of the experimental area were randomly selected and tagged for data collecting on plant agronomy.

The experimental plots were pre-irrigated two days before sowing to bring current soil moisture to field capacity. Irrigation water was applied when 40 percent of the total available water was depleted. In every application, depth of irrigation water was based on the control treatment/ Awash River water (100%, 0%).

The recommended rate of 10 Kg/ha DAP was uniformly applied as per the recommendation made for the center. Cowpea irrigation was done manual by using watering can. One establishment irrigation was given seven days after germination. Treatment commenced after establishment irrigation when readily available water, RAW within 30 cm of soil depth was depleted. All other cultural practices other than treatment variables were done to all plots in accordance to the recommendations made for the area.

3.10. Crop water requirement

Crop water requirement was estimated using Eq. 3.1 and Cowpat 8.0 for windows was used for determination of reference evapotranspiration, ETo using FAO Penman-Month method. The daily climatic data, viz., maximum and minimum temperature, humidity and sunshine hours were used to calculate ETo. Excel sheet was used to compute crop water requirement using appropriate crop coefficient, Kc. Crop data were utilized as input in determination of crop water requirement. The calculation for crop water requirement was based on following Eq. 3.1.

$$ET_c = ET_o \times K_c \quad \text{..........} 3.1$$

where, ET_c is crop evapotranspiration (mm/day); Kc is crop coefficient and ET_o is reference evapotranspiration(mm/day)

Table 3.5: Date of cowpea growth stage and crop coefficient (kc)

	Days After Planting (DAP)	
Crop coefficient (kc)	Days	Stage
0.47	20	Initial
0.85	30	Development
1.2	30	Mid
1.15	20	Late

Source: (FAO, 1998)

3.11. Irrigation Water Management

The depth of water to be applied was based on allowable soil moisture depletion fraction (p) and irrigation water was applied at regular soil moisture observation when 40% (p) of the total available water, TAW depleted with in the root depth during the growing season.

The irrigation schedule was fixed based on readily available soil water, RAW, the fraction of TAW that a crop can extract from the root zone without suffering water stress. The RAW was obtained from the following expression.

$$RAW = p \times TAW \quad \ldots\ldots 3.2$$

where, RAW is the readily available water (mm), p is depletion fraction (fraction) and TAW is the total available water in the root depth (mm/ depth).

The total available water (TAW), stored in a unit volume of soil, was computed from the moisture content of field capacity and permanent wilting point and expressed as:

$$TAW = (FC - PWP) * BD * D_{rz} \quad \ldots\ldots 3.3$$

where, FC and PWP (% weight basis); Dzr is the maximum effective root zone depth (mm) and BD is the specific gravity.

The soil moisture depleted between irrigation at any time was computed using the equation

$$SMD = FC - SMC \quad \ldots\ldots 3.4$$

where, SMD is the soil moisture depleted before the next irrigation (mm), FC is the soil water content at field capacity (mm) and SMC is the soil moisture content before the next irrigation (mm)

The net irrigation depth applied for the control plot was also obtained from simplified water balance using Eq 3.5.

$$IR_n = ET_c - P_e \quad \ldots\ldots 3.5$$

where, IR_n is the net irrigation depth in mm, ET_C is the crop water requirement in mm and P_e is the effective rainfall in mm.

The effective rainfall estimated using dependable rain (FAO/AGLW formula) as given by FAO (1998).

$$P_{eff} = 0.6 \times P - \frac{10}{30/31} \text{ for month} \leq \frac{70}{30/31}\ mm \quad \ldots\ldots 3.6$$

$$P_{eff} = 0.8 \times P - \frac{24}{30/31} \text{ for month} > \frac{70}{30/31} mm \quad \ldots\ldots 3.7$$

where, P is daily rainfall (mm) and P_{eff} is effective rainfall (mm)

Irrigation water was applied as per the treatment to refill the crop root zone depth close to field capacity. The gross irrigation requirement was obtained from the following expression:

$$I_g = \frac{I_n}{E_a} \text{ x } 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.8$$

where; I_g is the gross irrigation depth (mm), I_n as obtained from Eq. (3.5) and Ea is the field application efficiency (%).

Field application efficiency was taken as 90% for can irrigation application. The irrigation frequency, f was determined by dividing calculated RAW by mean daily ETc.

$$f = \frac{RAW}{ET_c} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.9$$

where, f is irrigation frequency (day), RAW is readily available water (mm) and ETc is the mean daily crop water requirement (mm/day).

Moisture status of the soil profile for each treatment was observed before the next irrigation to starting the treatment from four soil depths of 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm. The wet soil samples were put in an oven set at a temperature of 105^{o}C and dried for 24 hours. Its gravimetric water content was determined using the following equation.

$$\theta_m \left(\frac{\text{gram}}{\text{gram}}\right) = \frac{\text{Weight of wet soil - Weight of dry soil}}{\text{Weight of dry soil}} \text{ x } 100 \ldots\ldots\ldots\ldots 3.10$$

Where, θ_m is water content expressed on weight basis (%).

The volumetric water content was calculated from the gravimetric water content using the following expression.

$$\theta_v \left(\frac{\text{gcm}^{-3}}{\text{gcm}^{-3}}\right) = \text{specific gravity x } \theta_m \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.11$$

where: θ_v is volumetric moisture content in (%).

3.12. Data Collection

3.12.1. Weather data

Data on daily weather of the site during crop growth period was collected from the Melkassa agricultural research center. The climatic data collected were maximum and minimum temperature (^{o}C), humidity (%), wind speed at 2 m (km/hr), sunshine hours (hr) and rainfall (mm). The data were used to compute ETo and effective rainfall.

3.12.2. Crop data

The crop data was collected and recorded from middle two rows of each plot. Five plants of each subplot of the experimental unit were used for data collection of different parameters for each subplot. These plots were first tagged from each eighteen subplots. The net harvest area in each plot was 1.68 m^2 (two row each 1.4 m long by leaving 3 plant from the borders from each central row or middle row). The following data was recorded from randomly selected plants of middle rows.

3.12.2.1. Plant height

Cowpea height was taken by measuring the main stem height from the ground level up to the tip of the leaf with the help of ruler. This measurement was taken when the cowpea pods were matured. All measurements were made from five representative samples.

3.12.2.2. Biomass

Biomass was recorded from the net central two rows. Moisture content of the samples was estimated after air drying the biomass collected.

3.13.2.3. Number of pods per plant

Number of pods per plant is recorded in plot base from each treatment by counting each pod from five selected plants.

3.13.2.4. Grain yield and yield parameters

Grain yield of cowpea was obtained from the net area in each plot separately. All of these plants were harvested when the pods were matured.

3.13. Statistical Analysis

The data were subjected to analysis of variance (ANOVA) appropriate to RCBD using SAS software (Statistical Analysis Institute, Inc.2002 version 9). Whenever treatment effects were found significant, treatment means were compared using the least significant difference, LSD and the LSD was used for mean comparisons.

4. RESULTS AND DISCUSSION

4.1. Physico-Chemicals Properties of Soil Before Harvesting

The result of laboratory soil analyses and field tests on physical and chemical characteristic, like soil infiltration, soil texture, BD, FC, PWP, TAW, soil pH, electrical conductivity (EC), organic carbon (OC) content and organic matter (OM) content, were given below.

The laboratory results of the average soil physical properties of the experimental site are presented in (Table 4.1) below. As depicted in the table, the particle size distribution showed loam texture was the dominant textural property. The average bulk density of the experimental soil showed a slight variation with depth. It varied from 1.29g/ cm^3 at the top root zone (0 – 15 cm) to 1.42 g/cm^3 at the lower root zone layer (60 – 90 cm).

Table 4.1: Soil physical property

Soil property		Soil depth (cm)				
		0-15	15-30	30-60	60-90	Mean
Particle size distribution	Sand (%)	23.7	29.6	23.6	21.6	54
	Silt (%)	48.7	40.8	44.8	42.8	10
	Clay (%)	27.6	29.6	31.6	35.6	36
Textural classes		Loam	loam	Sandy loam	loam	loam
Bulk density (g/cm^3)		1.29	1.39	1.41	1.42	1.37
FC (% wt bases)		29.8	31.1	31.3	33.7	31.5
PWP (%wt bases)		15.8	19.1	15.9	14.8	16.4
TAW (mm/m)		140	120	154	189	150
Nitrogen (%)		2.01	0.75	0.81	0.69	1.07
Organic Matter		12.2	12.43	13.2	12.4	12.56

This could be because of slight decrease of organic matter with depth and compaction due to the weight of the overlying soil layer. The top surface soil layer had slightly lower bulk density than the subsurface and this might be due to high organic matter contents in the top soil surface(Brady et al., 2002).The average weighted bulk density of the experimental site was 1.37g/cm^3. The representative value of TAW was 150 mm/m and this value is within the range of 100 – 175 mm/m and this characteristic for sandy loam soil (Goffeau, 1985).

As indicated in Table 4.2 the pH of the experimental site varied from 7.7 to 7.9 with an average pH-value of 7.53 that indicate the soil is slightly alkaline and suitable for most crops. Cowpea grows in a wide range of soil types. Best yields are obtained in well drained sandy loam to clay loam soils with a pH range of 6.0-7.9. The soil had an average electrical conductivity of soil 0. 6 dS/m through 90 cm profile which is below the threshold value for yield reduction, i.e. 1.2 dS/m (Smith et al, 2011). The OM content and TN of the soil had average values of 12.56% and 1.07% respectively. Cowpea is considered sensitive to salinity, the maximum soil EC level for cowpea without a significant yield loss being 1dS m^{-1} (FAO, 1998). SAR, ESP and RSC are within the FAO limit before sowing cowpea and adding saline Lake Beseka water to the soil of study area.

Table 4.2: Soil chemical properties of the experimental field before sowing cowpea

Water soluble cation and anion ($meql^{-1}$)								Exchangeable basic cation ($cmolkg^{-1}$)					
Soil depth (cm)	pH	EC(ds/m)	(Ca+Mg)	Na^+	K^+	Cl	HCO_3	(Ca + Mg)	Na	K	SAR	ESP (%)	RSC
0-15	7.7	0.5	2.3	4.6	6.7	2.6	2.5	18.4	2.4	6.5	4.3	8.8	0.25
15-30	7.5	0.3	0.7	4.1	4.4	2.3	1	17.0	2.5	5.5	7.0	9.8	0.30
30-60	7.8	0.4	1.0	4.8	4.5	1.7	1.5	21.0	2.6	5.3	6.7	9.0	0.48
60-90	7.9	0.6	1.6	5.2	4.8	1.7	2	26.2	2.7	5.3	6.0	8.0	0.45

4.2. Physico-chemical Properties of Lake Beseka and Awash River water

4.2.1. pH

Result showed (Table 4.3) the pH of Lake Beseka was 9.5. This value is out FAO limit. According Olumana and Loiskandl, (2015), pH value of Lake Beseka highly alkaline which is greater than 8.5 due to dominance of dissolved HCO_3 rather than CO_3 that affect pH of most water quality. This is due to hard minerals water and the release of basic industrial and agricultural effluents. The result of Physiochemical characteristics of Lake Beseka and Awash River water are given in Table 4.3.

Long data shown in appendix table 7 the pH value of Lake Beseka water increased from 2008 to 2011 and decreased from 2012 to 2013. Present findings uncorroborated that Fito *et al*. (2019), who reported that pH of Lake Beseka is greater than 10 and it is not suitable for irrigation. The pH value of Awash River in sampling site is 7.64 which fall within the limit of FAO standard (Table 4.3).

Table 4.3: FAO standard and physiochemical of water at the sampling sites

Parameters	Symbols	Unit	FAO (1985)	Awash River	Lake Beseka
pH	PH	-	6-8.5	7.64	9.50
Electrical conductivity	EC	dsm^{-1}	0-3	0.302	4.4
Total dissolved solid	TDS	mgl^{-1}	0-2000	1930	2812
Magnesium and Calcium	Mg^{+2}+ Ca^{+2}	mel^{-1}		2.06	0.40
Sodium	Na^{+}	mel^{-1}	0-40	7.39	46.09
Potassium	K^{+}	mel^{-1}	0-2	3.08	10.13
Carbonate	CO_3^{2-}	mel^{-1}	0 – 0.1	1.00	16.40
Bicarbonate	HCO_3^{-}	mel^{-1}	0 – 10	1.30	5.40
Chloride	Cl^{-}	mel^{-1}	0-30	0.79	13.11
Sodium adsorption ratio	SAR	$(mel^{-1})^{0.5}$	0-15	7.28	103.06
Residual sodium carbonate	RSC	mel^{-1}	1.25-2.5	0.24	21.40

4.2.2. Electrical conductivity, EC

The electrical conductivity (EC) values of water samples was 0.302- 4.4 ds/m in Awash River and Lake Beseka respectively (Table 4.3). According to Wilcox (1955) irrigation water quality classification standard, in terms of the 'degree of restriction on use', EC value less than 0.7 dsm^{-1} refers the water to 'none'; 0.7- 3 dsm^{-1} 'slight to moderate' and greater than 3 dsm^{-1} 'sever' (FAO,1985). From this point of view, referring to EC values of Awash River is suitable for irrigation and it can be classified as in 'none' whereas irrigation water quality of Lake Beseka is 'severe' category.

The allowable concentration for electrical conductivity as per FAO standards is 0-3ds/m. The higher value of EC (10.27 dS/m) of Lake Beseka is the indicator of higher ionic concentrations, probably due to high anthropogenic in the region and geological weathering condition acquiring high concentration of dissolved minerals (Olumana and Loiskandl, 2015). Long term data in appendix table 7 showed that the EC value of Lake Beseka decreased from 2009 to 2013.

4.2.3. Total dissolved solid, TDS

The present study indicated in Lake Beseka the value of TDS was 2812 $meql^{-1}$(Table 4.3). This indicated that irrigation water quality of Lake Beseka is salty water. The allowable TDS concentration of FAO is ranged 0 to 2000 mg/l. Thus, the obtained value of study area is beyond upper limit of FAO standards. The result obtained is similar with the findings of Olumana and Loiskandl (2015), they reported that some parts of Lake Beseka adjoining Abadir farms have extremely TDS (12000 ppm) and hence classified as salty water, almost similar to sea water which is the indication of the higher ionic concentration. The TDS values of Awash River water sample in present study was 1930 mgl^{-1}, which according to FAO (1985) suitable for irrigation.

According to USSLS (1954) and Mass *et al.* (1987) findings, in terms of 'degree of restrictions on use' of TDS values <450, 450-2000 and >2000 mgl^{-1} represent the irrigation water as 'none'; 'slight to moderate' and 'severe', respectively. From this point of view, referring to TDS values of Awash River and Lake Beseka, water of study can be classified as in 'slightly moderate' and 'severe' category respectively.

4.2.4. Carbonate and bicarbonate

According to the FAO standards of irrigation water the maximum limit of carbonate and bicarbonate are 0- 0.1 $meql^{-1}$ and 0 - 10$meql^{-1}$, respectively. The carbonate and bicarbonate of study area were 16.4 to 5.4$meql^{-1}$ in Lake Beseka respectively. The present value of carbonate is beyond the maximum limit of FAO standard classification whereas bicarbonate is within the range. Long term data indicated in appendix table 7 the values of carbonate are highest in 2008 whereas the minimum is 2011 year. The value of bicarbonate is decreased from 2008 to 2103 year (appendix 7). Present study indicated carbonate and bicarbonate of Awash River water were 1-1.3$meql^{-1}$ respectively. This result indicated that, carbonate is beyond the recommended value of FAO standard whereas the bicarbonate is within the limit of recommended range.

4.2.5. Sodium

According to FAO the standard range of sodium for irrigation water is between 0- 40$meql^{-1}$. In study area the value of sodium in Lake Beseka was 46.09$meql^{-1}$. This value is beyond the recommended value of FAO standard. The present study indicated that the value of sodium ion is the highest in Lake Beseka relative other cations and an ion (Table 4.3). According to Olumana and Loiskandl, (2015), sodium concentration is extremely in Lake Beseka (≅160meq/l) and this might be due to deposition of rock salts, weathering of rocks (limestone) and its displacement from absorbed complex of rocks and soils by Ca and Mg. The water quality of Lake Beseka is dominated by cations and ions (Yimar and Jin, 2020). Present study indicated the value of sodium in Awash River is 7.39$meql^{-1}$ (Table 4.3). This value is within the limit of FAO standard. Long term data showed in appendix 7 the values of increased from 2008-2011 year.

4.2.6. Potassium

FAO standard range of potassium for irrigation water is between 0-2 mgl^{-1}. From present study value of potassium in Lake Beseka water was 10.13$meql^{-1}$. This value is beyond upper limit of FAO standard classification for irrigation purpose. This lined with the findings of Olumana and Loiskandl, (2015), reported that high potassium in Lake Beseka is due to their high mineralogical origin. The present study indicated that the value of potassium in Awash River water was 3.08$meql^{-1}$, which is beyond upper limit of FAO.

4.2.7. Sodium adsorption ratio

FAO standards range of Sodium adsorption ratio for irrigation water is between 0 and 15 $(meql^{-1})^{0.5}$. The value of SAR in present study was 103.06 $(meql^{-1})^{0.5}$, in Lake Beseka. According to FAO (1985), it is not suitable for irrigation purpose. In Lake Beseka electrical concavity is very which increases the value of SAR and the value of sodium is very high relative to Ca and Mg this might be increases the value of SAR in Lake, since SAR is the ratio of sodium to summation of magnesium and calcium. According to findings of Tadesse (2019), reported that SAR is significantly correlated with sodium and electrical conductivity. Present study indicated SAR value of Awash River is suitable for irrigation purpose which is within limit of FAO standard.

4.2.8. Chloride

The maximum allowable of chloride for irrigation water is 0-30 $meql^{-1}$ as a FAO standard. Present study indicated that the value of chloride in Lake Beseka was 13.11 $meql^{-1}$. The value is within the limit of FAO standard (Table 4.3). According to Olumana and Loiskandl, (2015), the potential source of chloride ions in Lake Beseka might be the dissolution of halite, leaching of rocks, minerals from upper soils layers by weathering or erosion. Long data indicated in appendix 7 the highest chloride in Lake Beseka recorded in 2008 whereas the minimum value is obtained in 2013. In present study, the value of chloride in Awash River was 0.79 meq/l which is suitable for irrigation according to FAO standard (Table 4.3).

4.2.9. Residual sodium bicarbonate (RSC)

RSC values of Awash River and Lake Beseka water in study area 0.24 and 21.4 $meql^{-1}$ respectively. Present study indicated only Awash River is safe for irrigation since the RSC value are less than 3$meql^{-1}$, whereas the RSC value of Lake Beseka is beyond upper limit of FAO standard and Eaton. According to FAO (1985) and Eaton (1950), reported that maximum allowable value of RSC for irrigation is ranged from 1.25 – 2.5$meql^{-1}$. Present value showed that RSC is very high due to high concentrations of carbonate and bicarbonate with low concentration s of magnesium and calcium (Table 4.3). This in lined with the findings of Yimar and Jin (2020) and Olumana and Loiskandl (2015).

4.3. Irrigation Water Quality of Mixed Lake Beseka and Awash River Water

4.3.1. Physico-chemical properties of mixed ratio

4.3.1.1. The pH

The result of Physiochemical characteristics of Lake Beseka sample and Awash River water mixed water is given in Table 4.4. The pH value of mixed irrigation water of the samples ranges from 8.77 to 9.19. The maximum pH value of 9.19 was recorded by mixing 10% of Lake Beseka with Awash River water in treatment six (T_6) whereas the minimum value (8.77) was obtained by adding 2% of Lake Beseka to Awash River water in treatment two (T_2) (Table 4.4). Research has also shown that mixing saline water with fresh water increases pH value of irrigation water (Hailu *et al*, 2016; Al-ain *et al.*, 2017; Yimer and Jin, 2020). All the pH values of mixed irrigation water is beyond upper limit of FAO irrigation water standard (6-8.5) (FAO, 1985).

Table 4.4 : chemical and physical parameters of mixed water average over months.

Parameters	Unit	FAO	T_1	T_2	T_3	T_4	T_5	T_6
PH	-	6-8.5	7.93	8.77	8.86	9.08	9.15	9.19
EC	dsm^{-1}	0-3	0.302	0.55	0.65	0.74	0.94	0.98
TDS	mgl^{-1}	0-2000	193	352	416	473.6	601.6	627.8
Mg^{+2}+Ca^{+2}	mel^{-1}		2.19	2.23	2.31	2.36	2	1.99
Na^{+}	mel^{-1}	0-40	5.93	6	6.24	6.64	7.16	7.46
K^{+}	mel^{-1}	0-2	3.43	2.66	2.79	3.09	3.63	3.61
CO_3	mel^{-1}	0 – 0.1	1.15	1.2	1.45	1.75	2.6	2.65
HCO_3	mel^{-1}	0 –10	1.45	2.75	2.81	2.62	2.82	2.83
Cl -	mel^{-1}	0-30	0.84	1.70	1.62	2.17	3.59	5.07
SAR	(mel-^{1})	0-15	5.67	5.68	5.80	6.11	7.16	7.48
RSC	mel^{-1}	0.25-2.5	0.41	1.72	1.95	2.01	3.42	3.49

The result of the present study showed that all values of pH under different mixed ratio were greater than 8.5. This high pH value (>8.5) are often caused by high bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) concentrations, known as alkalinity (Bauder *et al*., 2014).

4.3.1.2. Total dissolved solid, TDS

The total amount of TDS of mixed Lake Beseka and Awash River water varies between 193 - 638.3 mgl^{-1} from lowest to highest mixed ratio. The findings of the present study indicated that all TDS values of mixed ratio is in line with FAO irrigation standard. According to USSLS (1954) and Mass *et al*. (1987) findings, in terms of 'degree of restrictions on use' of TDS values <450, 450-2000 and >2000 mgl^{-1} represent the irrigation water as 'none'; 'slight to moderate' and 'severe', respectively. In our treatment protocols, even though the value of TDS varies from treatment to treatment, some values are quite suitable for irrigation purpose (T_2 and T_3) as they are classified under 'none' and others are suitable under some restrictions as their values exceeded 450 mg/l (slight to moderate), particularly in T_4 to T_6 (Table 4.4).

4.3.1.3. Electrical conductivity, EC

The current study results showed that the EC value of mixed (Awash and Beseka) irrigation water of the study area ranges from 0.55 to 0.98 ds/m respectively. Maximum EC of mixed irrigation water was obtained from treatment T_6, 10% with value of 0.98 ds/m (Table 4.4). Similar to our study, other researchers had also reported increasing the mix ratio of Lake Beseka to Awash River water rapidly increased electrical conductivity in irrigation water under different irrigation treatments (Yimer and Jin, 2020; Hailu et al., 2016).

The allowable concentration for electrical conductivity is 0-3 ds/m, (FAO, 1985). Based on FAO (1985) and Aamir *et al.* (2017) categorization, it is easily presumable from the our study results, in terms of EC, all irrigation water under treatments (T_1, T_2, T_3 and T_4) were suitable for irrigation ; whereas T_5 and T_6 were high in EC range for irrigation purpose (Table 4.4).

4.3.1.4. Sodium absorption ratio, SAR

The range of SAR value of mixed water samples in the study area is ranged 5.68 - 7.48 (Table 12). Maximum SAR of mixed irrigation water was obtained from treatment T_6, 10% with value of 0.98 ds/m whereas the minimum was obtained in T_2 with the value of 6.68 (Table 12). In our study, as mixed ratio of Lake Beseka with Awash River water increases the value of SAR also increased. Similar to our study, Yimer and Jin. (2020), Tadesse (2019) and Hailu *et al*. (2016), stated that increasing mixed ratios of Lake Beseka with Awash River water increases the value of SAR.

The present study SAR values showed that all irrigation water samples were in 'excellent' category (Todd, 1980; Richard, 1985). These SAR values showed that the mixed ratios of 2%, 3%, 5%, 8% and 10% are in normal sod-city hazard category which is an indicative of suitability of these mixed ratios for agricultural irrigation (Horneck et al., 2007).

4.3.1.5. Residual sodium carbonate, RSC

RSC values of water samples in study area were varied from 0.41–3.49meql^{-1}. According to Eaton's (1950) classification, T_1 to T_4 is considered safe for irrigation since the RSC values are lower than 3meql^{-1} whereas T_5 and T_6 in mixed ratio irrigation water are beyond upper limit.

4.3.1.6. Carbonate and bicarbonate

According to the FAO (1985) standards of irrigation water, the maximum limit of carbonate and bicarbonate are 0-0.1 mg/l and 0-10 mg/l respectively. The present study results showed that the value of carbonate ranges from 1.15meql^{-1} (T_1) to 2.65meql^{-1} (T_6) (Table 4.4). As can be seen from Table 4.4, increasing mix ratios of Awash River water with Lake Beseka also increases the value of carbonate. So, the current mixed ratios are not safe for irrigation. The bicarbonate of study area was varied 1.45 to 2.83meql^{-1} and it is for irrigation according to the FAO (1985) standards of irrigation water.

4.3.1.7. Chloride

According to FAO (1985) standard, the maximum allowable chloride for irrigation water is 0-30mel^{-1}. The minimum and maximum the value of chloride is found in T_1 and T_6 respectively. The content of chloride ions (Cl^{-1}) in irrigation water increases with increase of electrical conductivity and sodium ions (Na^+) and many plants are sensitive to high chloride concentrations (FAO, 1985; Wilcox, 1955). It is evident that the all values of chloride obtained in study area are within the limit of FAO.

4.3.1.8. Sodium

The standard range of Sodium for irrigation water is between 0 - 40 mel^{-1} (FAO, 1985). The sodium values of mixed ratio of Lake Beseka and Awash River of the study area vary from 5.93 to 7.46mel^{-1}. All values of sodium are blow the maximum limit of FAO standard of (40meql^{-1}) even in maximum mixed ratio T_6 (Table 4.4). So, all mixed ratio of irrigation water in the current study is considered suitable for irrigation purposes.

4.3.1.9 Potassium

According to the FAO standards, the range of Potassium for irrigation water is between 0 and 2 mg/l. The concentration of potassium in mixed ratios of Lake Beseka and Awash water in the study area ranges from 3.08 to 3.609mgl^{-1} which is above the recommended limit for irrigation. Yimer and Jin (2020) also reported that as mixed ratio of Lake Beseka and Awash river increases, the potassium level increased.

4.4. Physico-Chemical Properties of Awash River Water Over Months

The flow of Awash River water varies from the rainy season to the dry season due to rain variability. This seasonal variation significantly affects the water quality of monitoring and mixing activities of Lake Beseka water. Irrigation water quality of control treatment or fresh Awash River water was taken as per irrigation and given in Table 4.5.

The physio-chemical values of Awash River over five months decreased slightly from March to July (dry to wet season). During dry season, the chemistry of Awash River water was raising up due to decrease in rainfall and surface runoff; whereas during wet season, the chemistry of water was diluted due to high rainfall and surface runoff. All the chemistries of Awash River water fell in FAO standard range. Therefore, Awash River can be considered safe for irrigation purpose (Table 4.5).

Table 4.5: Chemical and physical parameters average of Awash River water over months

Parameters	Unit	FAO standard	March	April	May	June	July
PH	1-14	6-8.5	7.72	7.64	7.63	7.32	7.14
EC	dsm^{-1}	0-3	0.41	0.43	0.42	0.38	0.34
TDS	mgl^{-1}	0-2000	263.3	279.5	273.0	247.0	221.0
$Mg^{+2}+Ca^{+2}$	mel^{-1}		2.10	2.20	2.11	2.06	2.03
Na	mel^{-1}	0-40	5.3	4.9	6.23	4.43	4.41
K	mel^{-1}	0-2	0.34	0.17	0.23	0.13	0.15
CO_3^{2-}	mel^{-1}	0 – 0.1	1.34	1.43	1.59	2.25	2.17
HCO_3	mel^{-1}	0 - 10	1.45	2.75	1.81	1.62	1.54
Cl	mel^{-1}	0-30	0.76	0.77	1.78	1.34	3.05
SAR	(mel^{-1})$^{0.5}$	0-15	5.17	4.67	6.07	4.37	4.38
RSC	mel^{-1}	1.25-2.5	0.69	1.981	1.29	1.81	1.68

This present result was similar from those reported by other authors that observed reduction of pH and EC during rainy season and increasing during dry season in May, June and July even including September (Hailu *et al*., 2016; Tadesse; 2019; Yimer and Jin, 2020). Seasonal variation flow of Awash River water (only fresh water of control treatment) per irrigation is given in table 4.5.

4.5. Effect of Mix Ratio on Cowpea Growth, Yield Quality and Properties of Soil.

4.5.1. Plant height

The plant height ranged from 156.5 –143.5 cm (Table 4.6). The highest plant was observed in control treatment receiving only Awash River water and lowest plant height was observed in T_6 (10% mix ratio). This shows that salinity greatly reduced plant height. However, the control treatment and treatment receiving 2-5% of Lake Beseka water gave plant height above the average whereas; the remaining treatments gave a value below the average. Similar results were obtained earlier by Salih *et al*, (2013) and Düzdemir *et al.*, (2010), even at the lowest treatment.

This study indicated that mixing Beseka to Awash River had significant ($P<0.001$) impact on plant height. T_5 and T_6 had been significant to each other, but control treatment (T_1), T_2, T_3 and T_4 were not significantly different from each other at $p = 0.05$ probability level. The decrease in plant height with increasing irrigation water salinity probably occurred due to the sodium chloride accumulation in the cell walls and in the root system (Mensah *et al*., 2015).

4.5.2. Number of leaves per plant

Number of leaves per plant was greatly reduced in the saline treated cowpeas compared to the control (untreated). The number of leaves per plant of cowpea was significantly affected ($p<0.01$) by mixing irrigation water i.e. Lake Beseka and Awash River water (Appendix 1). Furthermore, the number of leaves per plant was reduced as the percentage of mixing ratio increased (Table 4.6). This finding corroborates that of Silva *et al*. (2003) and Thiam *et al.* (2013), who reported that salinity induced reduction in the number of leaves in plants. The application of saline water for irrigation significantly decreased the number of leaves in cowpea at different stages compared to control treatment (Salih et al., 2013). This might be due to salinity which caused deficiency of potassium in cowpea plants (Mensah et al., 2015).

4.5.3. Biomass

The analysis of variance showed that mixed irrigation water of Lake Beseka and Awash River had significant effect on biomass production. In present study, the highest biomass was obtained in T_1 (59.52 qha^{-1}) and minimum was obtained in T_6 (50.02 qha^{-1}). There is no significant difference between untreated and treated cowpea with mixed ratios of 2%, 3%, 5% of Lake Beseka with Awash fresh water at $p = 5\%$ probability level. Eight (8%) and ten percent (10%) mixing ratios of Lake Beseka to Awash River water were not significant to each other. Thus, application of irrigation saline water significantly decreases dry biomass in cowpea compared to control treatment. The present study findings are in agreement with the findings of Düzdemir *et al*. (2010), Salih *et al*. (2013), Kim *et al*. (2016) and Mshelmbula *et al*. (2015), who reported that increasing the percentage mix ratios of saline water with non-saline water decreases dry mass. They concluded that this was due to the fact that saline water increases osmotic pressure, limits CO_2 assimilation, decreases the absorption and the water supply which are the major factors for reduction of dry matters.

4.5.4. Number of pods per plant

The number of pods per plant ranged from 7.27-14.87 (Table 4.6). The highest and lowest pod per plant was observed in control treatment receiving only Awash River water 100% and T_6 mixing 10% of Lake Beseka to Awash River water respectively. However, the control treatment, as well as treatments receiving 2%, 3% and 5% of Lake Beseka water gave pods per plant above average.

The analysis of variance showed that mixed Beseka to Awash water had significant effect on number of pods per plant. Mixing ratios of 8% and 10 % had a significant effect ($p< 0.01$) on number of pods per plant relative to control treatment. The present finding agrees with the findings of Mensah *et al*. (2015), Düzdemir *et al*. (2010), Salih *et al*. (2013) and Mshelmbula *et al*. (2015), who reported that the numbers of pods per plant were affected by increasing salinity level in fresh water.

4.5.5. Number of Seeds per Pod

The effect of mixing saline water of Beseka with fresh Awash River water on the numbers of seed per pod under different treatment of mixed ratio is displayed in Table 4.6. The highest number of seed per pod was recorded in control treatment (14.53). Minimum seeds per pod were obtained in T_6 (8.53).

Analysis of variance indicated that mixing Beseka water to Awash River water had significant difference ($P<0.001$) on number of seed per pod (Appendix 4). The control treatment had the maximum numbers of seed per pod (14.53), but was not significantly different from T_2, T_3 and T_4 (Table 4.6). Cowpea treated with T_5 and T_6 were not significantly different from each other at $P=0.05$, but significantly different from the rest treatment ($p< 0.001$). The significant decrease in seed per pod observed in the salt treated cowpeas would be related to a significant reduction of the foliar chlorophyll contents and potassium concentrations in saline medium (Kim *et al*., 2016; Mshelmbula *et al*., 2015 and Leandro *et al*., 2015).

4.5.6. Yield of Cowpea

Untreated (fresh Awash) irrigation water produced the highest yield than the mixed Lake Beseka and Awash River water in study area. The yield ranged from 18.228 – 14.153 qh^{-1}. The lowest yield was observed from treatment receiving 10% mixed ratio of Lake Beseka with fresh Awash River water. However, the control treatment and T_2 – T_4 produced above average yield of cowpea. This implies that the mix ratio of 2-5% is suitable for cowpea production. This is in line with MoWER (2014) recommendation (2-7.7%).

Table 4.6: Cowpea yield and growth parameters analysis

		Average of growth parameters and yield					
Irrigation treatments	Mixed ratios (%)	PH (cm)	NL	NPP	SPP	Yield (qha^{-1})	Biomass (qha^{-1})
T_1	0:100	156.50^a	73.20^a	14.87^a	14.53^a	18.228^a	59.52^a
T_2	2:98	155.50^a	72.80^a	14.47^a	14.70^a	18.222^a	59.48^a
T_3	3:97	155.30^a	72.70^a	14.27^a	14.07^a	18.213^a	59.40^a
T_4	5:95	154.90^a	72.40^a	12.80^b	13.80^a	18.212^a	59.25^a
T_5	8:92	150.50^b	37.20^b	7.60^c	9.07^b	16.173^b	53.01^b
T_6	10:90	143.50^c	34.60^b	7.27^c	8.53^b	14.153^c	50.02^b
Mean	**-**	**152.69**	**60.48**	**11.88**	**12.41**	**17.20**	**56.78**
LSD (5%)	**-**	**4.16**	**2.74**	**1.36**	**0.92**	**0.0183**	**3.91**
CV %	**-**	**1.5**	**2.49**	**6.3**	**4.09**	**0.06**	**3.78**

Means followed by the same letter in a column are not significantly different from each other at 5% probability level.PH- Plant height (cm), NL- numbers of leaves, NPP- numbers of pods per plant, SPP- seeds per pod.

As the mixed ratio of Lake Beseka to Awash River water increases the yield of cowpea decreased. This indicates that increasing the ratio of saline water decreased yield in cowpea production. The difference was not significant in the mixed ratio of T_2, T_3 and T_4 relative to control treatment, but T_5 and T_6 are significantly different from other treatments. There is significant difference between T_5 and T_6. These results are in good agreement with those reported by Salih and Keya, (2013) and Mshelmbula *et al.* (2015), who observed significant reduction in yield with increasing salinity of irrigation water for cowpea production.

As can be observed in Table 4.6, gradual increase of Lake Beseka ratio in Awash River water decreased the yield of cowpea. The present study also indicated that compared to the control treatment, mixing Lake Beseka (2-10%) to Awash River water in different treatments caused 0.033% to 22.4% yield reduction. This is in agreement with FAO report which stated that irrigation water salinity can reduce 0% to 50% cowpea yield potential (FAO, 1985). The present finding also agrees with the findings of Hailu *et al*. (2016), who reported that blending (mixing) Lake Beseka to Awash River water caused 5-40% yield reduction of cotton.

The lowest yield reduction was observed in lowest mixed ratio of Lake Beseka and Awash River water. Thus, Cowpea can be grown successfully even if irrigation water is mixed with Beseka water as nearly similar yields were obtained under T_2, T_3 and T_4 irrigation treatments which slightly different from control treatment. This present finding agreed with pervious found of Minhas *et al*. (1993), who stated that mixed irrigation water had a similar effect on yield and may be advantageous only with water of low to moderate salt content.

4.6. Effect of Lake Beseka and Awash River Water Mixed Ratio on Soil

The results showed that electrical conductivity (EC), sodium adsorption ratio (SAR), cation exchange capacity, (ECE), residual sodium carbonate **(**RSC) and exchangeable sodium percentage (ESP) of soil increased under different mixed irrigation relative to control treatment. This could be due to increase in sodium concentration of soil from lowest to highest mixed ratio of Lake Beseka to Awash River water under different irrigation treatments. Due to increasing salinity, soil in different mixed ratio was classified as non-saline and saline (FAO, 1985). According to Al-ain *et al*. (2017) and Salih and Keya (2013), this might be due to nutrient assimilation with increasing soil solution due to computation between ions, particularly nitrate (NO_3^{-1}) and Cl.

From study area chloride was increased under different mixed ratios from highest to lowest mixed ratio as compared to control treatment. A rapid increased of chloride indicated high concentration occurred in soil solution. On the other hand, the results showed a gradual increase in sodium, calcium, magnesium, bicarbonate and salinity levels in soils. Hailu *et al*. (2016), stated that mixing of saline Lake Beseka with fresh Awash River water could increase cation and an ion in soil solution. However, from the present study, we found that the concentration of potassium decreased slightly by increasing mixed ratios of Lake Beseka and Awash River water relative to control treatment (Table 4.7). According to Salih and Keya, (2013), the reduction in potassium could inhibit the growth by reducing capacity for osmotic adjustment and turgor maintenance or by adversely affecting metabolic functions whereas chloride does not affect chemical reactions in soil, but it will accumulate and can be considered as a good indication for accumulating salts in soils.

Table 4.7: Soil chemical properties after harvesting

Chemical properties	Unit	Treatment					
		T_1	T_2	T_3	T_4	T_5	T_6
Ph		7.8	7.8	7.9	8.1	8.3	8.5
EC(ds/m)	dm^{-1}	0.6	0.8	1.1	1.4	1.6	1.9
Ca + Mg	mel^{-1}	2.1	2.1	2.2	2.2	2	1.9
Na^+	mel^{-1}	4.3	4.5	4.8	5.6	6.6	7
K^+	mel^{-1}	3.1	2.7	2.5	2.3	2.2	2.1
Co_3^{2-}	mel^{-1}	1	1	1.2	1.6	2.4	2.4
HCo_3^-	mel^{-1}	1.3	2.7	2.8	2.6	2.8	2.8
Cl^-	mel^{-1}	0.8	1.7	1.4	2	3.7	5
Ca + Mg	mel^{-1}	20.5	18.2	19.8	25.8	28.5	23.1
Na	mel^{-1}	2.4	2.4	2.6	3	3.6	3.8
K	mel^{-1}	3	2.6	2.4	2.2	2.2	2.1
SAR		4.3	4.3	4.6	5.3	6.7	7.1
CEC		25.9	23.2	24.8	31.1	34.3	29
ESP (%)		9.1	10.5	10.6	9.8	10.5	13.1

The present result indicated that increasing of soil salinity and pH restrict the uptake of K^+, Ca^{+2}, and Na^+ ions. This high salinity might be reduced the uptake of Ca^{+2}, K^+, N^+, mainly in the leaves of plants. Accumulation of salts, cause plant growth problems and result in poor growth or death of plants. Also, pH affects the plant growth because it affects the availability of nutrients to the plants. Similar to the present findings, Afonso *et al*. (2011) point out that high soil salinity reduced the uptake of ion concentrations such as K^+, Ca^{+2}, Na^+ in plants leaves and pH reduces nutrient values to the plant.

Table 4.8: ANOVA table of selected soil analysis

Treatment	pH	EC	TDS	SAR
T_1	7.83^e	0.83^c	612^c	4.53^b
T_2	8.30^d	1.63^{ab}	1200.5^{ab}	6.4^a
T_3	8.80^c	1.43^b	1053.5^b	4.56^b
T_4	8.89^{bc}	1.50^b	1102.5^b	5.2^{ab}
T_5	9.14^b	1.63^{ab}	1188.3^b	4.47^b
T_6	9.73^a	1.83^a	1347.5^a	2.8^c
Mean	8.78	1.48	1084.1	4.6556
CV	1.70	6.40	8.37	17.29

The present study indicated that electrical conductivity increases 0.3-1.9 ds/m. Thus, increasing mixed ratio of Lake Beseka to Awash River water also increases EC in soil after harvesting of cowpea. This high alkaline soil may be restricting the movement of the water in soil, reduce infiltrations and soils becomes unfavorable for tillage. According to Richard (1954), continually using saline soil with high EC greater than 4 mmhoscm^{-1} to be a problem until the excess salt and exchangeable sodium are removed from root zone and a favorable physical condition of the soil reestablished.

5. CONCLUSIONS AND RECOMMENDATION

5.1 Conclusion

From laboratory result, mixing of Lake Beseka to Awash Fresh water, the quality of fresh water has shown change in chemical parameters. In spite of increasing mixed ratio, irrigation water quality under different treatments changed the quality of Awash River water. On other hand, soil salinity increased with increasing the amount of irrigation water with saline water i.e., increasing Lake Beseka in mixed ratio. This might decrease nutrients assimilation with increasing soil solution which decreases the quality of crop production, soil structure deformation and sod-city effect. All physico-chemicals of Lake Beseka water before any treatments are beyond upper limit of FAO standard that used for irrigation purpose.

Increasing Beseka water ratio decreased yield gradually; however, low saline water ratios T_2, 2%, T_3, 3%, and T_4, 5% mixed with Awash River produced the highest yield relative to control treatment. Thus, mixed ratio of Lake Beseka to Awash River is safe, if it is 2-5 % based on the quality of Awash River. The water quality of Awash River will get out of the allowable maximum limit as mixing more than 10% of Lake Beseka to Awash River water. Generally, mixing Lake Beseka water into Awash River will affect Awash River's water quality and reduce cowpea yield. Moreover, the result revealed that Lake Beseka is a great source of pollution for down streams agricultural farm and it is a great environmental concern that needs immediate attention.

5.2 Recommendation

- Irrigated agriculture could take place under mixing ratios of 2-5% of Lake Beseka and Awash River water.
- Further research is needed to undertake for more than one cropping season and during dry season to get sounding experimental output.

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7. APPENDICES

Appendix Tables 1:- Analysis of variance of number of leaves

Source variation	DF	SS	MS	F	P
Block	2	2.20	1.10		
Treatment	5	5447.74	1089.55	481.63	0.00
Error	10	22.62	2.26		
Total	17	5472.57			
LSD at (5%)	2.74				
Mean	60.48				
CV %	2.49				

Appendix Tables 2:-Analysis of variance of plant height

Source Variation	DF	SS	MS	F	P
Block	2	17.30	8.64		
Treatment	5	369.12	73.83	14.13	0.0003
Error	10	52.25	5.22		
Total	17	438.66			
LSD at (5%)	4.16				
Grand Mean	152.69				
CV	1.5				

Appendix Tables 3:-Analysis variance of pod per plant

Source variation	DF	SS	MS	F	P
Block	2	0.27	0.14		
Treatment	5	185.26	37.05	66.22	0.00
Error	10	5.60	0.56		
Total	17	191.13			
LSD at (5%)	1.36				
Mean	11.88				
CV %	6.30				

Appendix Tables 4:-Analysis variance of seed per pod

Source variation	DF	SS	MS	F	P
Block	2	0.75	0.38		
Treatment	5	118.86	23.77	92.06	0.00
Error	10	2.58	0.26		
Total	17	122.20			
LSD at (5%)	0.92				
Mean	12.41				
CV %	4.09				

Appendix Tables 5:-Analysis variance of biomass

Source variation	DF	SS	MS	F	P
Block	2	9.28	4.64		
Treatment	5	263.03	52.61	11.40	0.0007
Error	10	46.14	4.61		
Total	17	318.45			
Mean	56.78				
CV	3.78				
LSD (%5)	3.91				

Appendix Tables 6:-Analysis variance of yield

Source variation	DF	SS	MS	F	P
Block	2	0.001	0.000		
Treatment	5	43.470	8.694	85917.550	0.000
Error	10	0.001	0.000		
Total	17	43.471			
Mean	17.2				
CV	0.06				
LSD	0.0183				

Appendix Tables 7:- Laboratory result Lake Beseka water sample point (2008-2013)

Parameters	Unit	2008	2009	2010	2011	2012	2013
Total dissolved Solid 105oc	mg/l TDS	3877	3883	3526	3444	3387	3158
Electrical Conductivity	µs/cm	6057	6068	5510	5382	5292	4934
pH	0-14	9.4	9.4	9.5	9.5	9.3	9.2
Ammonia	mg/l NH_3	0.3	0.5	0.7	0.8	0.9	1.2
Sodium	mg/l Na^+	1565	1595	1613	1218	1286	1196
Potassium	mg/l K^+	65	59	49	47	47	44
Calcium	mg/l Ca	7.1	4.5	5.6	4.6	5.3	6.9
Magnesium	mg/l Mg	1.9	1.3	0.9	1.6	2.0	4.3
Chloride	mg/l Cl^{-1}	506	554	422	438	437	412
Alkalinity	mg/l $CaCO_3$	2210	2205	2100	2932	1754	1543
Carbonate	mg/l $CO^{-2}{}_3$	636	539	365	460	547	504
Bicarbonate	mg/l $HCO^-{}_3$	1471	1595	1557	1306	1028	892
Sulphate	mg/l SO_4^{-2}	564	554	792	427	374	473
Phosphate	Mg/l PO_4^{-3}	3.0	2.8	2.7	2.3	2.5	2.1

Source: Awash Authority Basin

Appendix Tables 8:- Irrigation water applied over five months (mm)

Irrigation event	Irrigation date	Growth stage	ETc (mm)	Peff (mm)	Net irrigation (ETc-Peff) mm	Lake Beseka (10^{2}) (L)	Awash water (10^{3}) (L)
First	Mar 25	PED	16.33	0	16.33	0.00	5.56
Second	Mar 31	initial	19.55	0	19.55	1.53	9.39
Third	Apr-06	initial	33.75	7.9	25.85	1.90	11.61
Fourth	Apr-18	dev’t	64.52	29.0	35.52	2.58	15.81
Fifth	May-06	dev’t	50.34	5.1	45.24	3.59	21.99
Sixth	May 15	dev’t	56.94	0	56.94	4.03	24.71
Seventh	May-24	mid	51.87	0	51.87	4.03	24.71
Eighth	June-01	mid	59.66	3.3	56.36	4.03	24.71
Ninth	June-10	mid	51.40	0	51.40	4.03	24.71
Tenth	June-18	late	51.12	0	51.12	4.03	24.71
Eleventh	June-26	late	45.99	0	45.99	4.03	24.71
Total amount of water			455.5	134	410.2	33.79	187.92

PED-Plant Establishment Date, L-litters, Volume of mixed was obtained through calculation of all these parameters. TWA = BD*DR*(Fc-Pw), In =TAW*depletion, Ig=In/Ea, V=A*Ig, A= l*w, where:- TAW- total available water, BD-bulk density, DR-root depth, Fc- field capacity, Pw- permanent wilting point, In- net irrigation applied, Ig-gross irrigation, Ea-application efficiency, V- volume, A- area of each plot, length of plot, w- width of plot.

Appendix Tables 9:- Randomized Complete Block
ANOVA of yield

Source variations	DF	SS	MS	F	P
Block	5	77.17	15.43		
Treatment	5	1575.17	315.03	88.8	0.0000
Error	7	24.83	3.55		
Total	17				
Mean	**1823.7**				
CV	**0.1**				
LSD (%)	**3.6365 to 6.0305**				

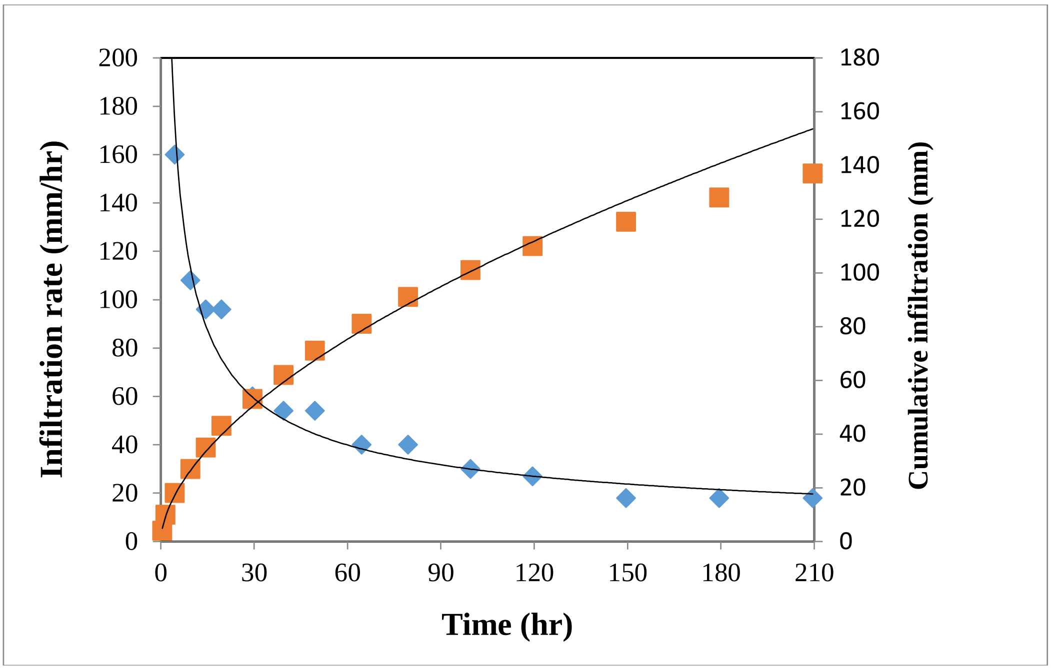

Figure 1: Infiltration graph

Figure 2: Collecting water from Lake Beseka at sampling point.

Figure 3: Mixing of Lake Beseka and Awash River water.

Figure 4: Taking soil moisture

Figure 5: Taking agronomy data and Harvesting