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COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES

CENTER FOR ENVIROMENTAL SCIENCE

FERTILIZING POTENTIAL OF BREWERY WASTEWATER SLUDGE FOR CULTIVATION OF LETTUCE AND TOMATO ON PLANOSOL AND VERTISOL SOILS

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ABSTRACT
Title: Fertilizing Potential of Brewery Wastewater Sludge for Cultivation of Lettuce and Tomato on Planosol and Vertisol Soils

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Alcohol and beverage factories produce large volume of wastewater sludge, which when applied to soil could have a fertilizing potential. However, before the sludge is used as soil amendment, the chemical property of the sludge need to examined. In Ethiopia brewery companies are growing rapidly producing large volume of wastewater sludge which can be used as fertilizer with proper technologies.The objective of this study was to determine the effect of brewery wastewater sludge on soil properties andgrowth and yield of vegetables. In this study two soil types are used, Planosol and Vertisol soils, and two vegetables, lettuce and tomato, as experimental plants. The experimental set-up was completed randomized design. Brewery wastewater sludge was prepared at 10, 20, 30 and 40%for addition as soil amendment. Two controls were used in the experimental treatment:no treatment control and inorganic fertilizer treatment. Our result indicate that the concentration of heavy metals of brewery wastewater sludge was within acceptable range of World Health Organization. And theaddition of wastewater sludgeincreases theamount of total Nitrogen, available potassium and organic carbon in the soil.WhileAvailable phosphorous decreased. The highest growth parameters were obtained in Vertisol soil amended with brewery wastewater sludge at 30% treatment rate for tomato and 20% of the sludge for lettuce. From this study we concluded Brewery wastewater sludge has fertilizing potential and it could be used as soil amendment for increasing productivity of vertisol soil.

Key words: wastewater, sludge, inorganic fertilizer, Planosol soil, vertisol soil, lettuce, tomato.

TABLE OF CONTENTS

Contents

LIST OF TABLES AND FIGURES
LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYM

ANOVA	Analysis of Variance
BOD	Biological Oxygen Demand
BWWS	Brewery wastewater sludge
COD	Chemical Oxygen demand
EC	Electrical conductivity
OC	Organic carbon
RPM	Rate per minute
P.BS	Planosol soil with brewery waste water sludge
P. PC	Planosol soil positive control
P.NC	Planosol soil negative control
PS	Planosol soil
TSS	Total Suspended Solid
V.S	Vertisol soil
V. NC	Vertisol negative control
V.PC	Vertisol positive control
V.BS	Vertisol with brewery waste water sludge
WHO	World Health Organization
GLBW	Germination of lettuce seeds before a week
GLAW	Germination of the lettuce seeds after a week
GTBW	Germination of tomato seeds before a week
GTAW	Germination of the tomato seeds after a week

1. INTRUDUCTION

1.1 Background

The use of organic matter such as animal manures, human waste, food wastes, yard wastes, sewage sludge and composts has long been recognized in agriculture as beneficial for plant growth and yield and the maintenance of soil fertility. The new approaches to the use of organic amendments in farming have proven to be effective means of improving soil structure, enhancing soil fertility and increasing crop yields (Mohimi, *et.al,* .2010) Organic matter is excellent source of plant-available nutrients and their addition to soil could maintain high microbial populations (Mary and Nithiya, 2015). Organic fertilizer is the end product obtained by converting various organic wastes such as crop residue, urban wastes, poultry droppings, animal dung, etc., into a usable fertilizer by a modified aerobic and anaerobic process of composting. Organic fertilizer has advantages which include: high nutrient content; suitability to a range of crops; fast biodegradability and safety. Crop yields have increased with the corresponding improvements in soil quality from additions of organic matter. Significant yield increases using mulches from coffee husks and increases in productivity using animal manures and hay residues have been reported (Mary and Nithiya, 2015). Their important roles in the soil and their potentially positive effect on crop yields have made organic amendments a valuable component of farm fertilization and management programs in alternative agriculture. (Norman *et.al*, .2005). The brewing industry is one of the largest industrial users of water. Even though substantial technological improvements have been made in the past, it has been documented that approximately 3 to 10 liters of waste effluent are generated per liter of beer produced in breweries. The malting and brewing industries use large volumes of water and 70% of the intake is discharged as effluent (Vriens, *et.al*. 1990). Chemical analysis on brewery sludge revealed that it has high N, P, K, volatile fatty acids and nutrients which are important requirement for plant growth (Ajmal and Khan. 1996). Brewery sludge is the sludge generated in brewing industry with high organic loading in terms of COD and BOD. The World Bank (1997) reported that untreated brewery effluent typically contained suspended solids (10 – 60 mg/L), Biological Oxygen Demand (BOD) (1000 – 1500 mg/L), Chemical Oxygen Demand (COD) (800 – 3000 mg/L), nitrogen (30 –100mg/L) and phosphorus (10 – 30 mg/L). However, not all of the organic materials are dissolved in the brewery sludge hence some organic materials will remain as particulate (Grolsch, 2000). The treatment of brewery sludge is a costly affair for the brewer in order to meet the government regulations and to practice environmentally friendly manufacturing (Guy *et.al,* 2002). The brewery sludge invariably produces a residual which must be disposed of into the environment. Most often this residual is a semisolid, auriferous, unmanageable and dangerous material commonly termed sludge in an effort to increase yields from a limited area, farmers tend to indiscriminately use more chemical fertilizers and pesticides (TewodrosTilahun, 2009). The brewery sludge can be directly applied to the soil for the agricultural purposes or it can be composted before utilizing for plant growth. Investigations by craft and nelson revealed that compost made with brewery sludge was suppressive against seedling and root diseases caused by the fungus Pythiumgraminicola.

This study was conducted to determine the soil type suitable for application of the sludge and effect of the brewery wastewater sludge on cultivation of vegetables by amending different proportion the brewery wastewater sludge with vertisol and Planosol soil in the green house experiment. To solve the soil fertility declination due to long term farming and using inorganic fertilizers and to increases the yield of the vegetables.

1.2 Statement of the problems and justification

The current global scenario firmly ascertains the need to adopt eco-friendly agricultural practices for sustainable agriculture (Ramya *et al*., 2015). To increase yields from a limited area, farmers tend to indiscriminately use more chemical fertilizers and pesticides. Such activity makes the soil poor of microorganisms. Due to this the soil loses its original structure and texture. Currently, there are lots of brewery factories built in our country. Among these some are regional, and rests are local. This indicates that sludge particularly that comes from brewery wastewater is increasing from day to daythissludge damped on the open land and it covers wide area of land cover. Thus, the environment highly polluted and the soil may loss its property and structure. The major problem arising in using of different types of sludge as fertilizer for land application is the presence of heavy metals. Though sewage sludge consists of high amounts of N, P, K and benefits the usage as fertilizer but heavy metals in them limits their usage (Kanagachandran and Jayaratne. 2006). Beer factory sludge consists of very low amount of heavy metals and even in below detectable levels which recommends to use as fertilizer (Kirk *et al.*, 1996). The application of brewery wastewater sludge and urea on soil can affect the nutrient content and heavy metal of the vegetable. The brewery wastewater sludge amendments improved pH of acidic soils and enhanced the Organic Carbon, total nitrogen, available phosphorous. In Ethiopia, the effect of brewery wastewater sludge on different soil type, soilPhysico-chemical properties and on growth of different vegetables not determined. This study conducted on two soils and vegetables to solve this problems.

1.3 Objective

1.3.1. General objective

- The general objective of the study is to evaluate fertilizing potential of brewery sludge on Planosol and Vertisol soils used for cultivation of vegetables in comparison with inorganic fertilizer (NPK) and to determine the effect of brewery waste water sludge on soil fertility.

1.3.2 Specific objectives

- To characterize brewery wastewater sludge in terms of the physic-chemical properties such as macro- nutrient contents and heavy metals.
- To determine the effect of brewery sludge on vegetable germination and growth.
- To compare biomass and fruit yield obtained using brewery sludge with inorganic fertilizer (NPK).
- To determine the effect of brewery sludge on soil physical-chemical properties and to determine the suitable soil type for brewery sludge application.

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2. LITERATURE REVIEW

Fertilizers and soil amendments are a wide array of materials added to soils to improve plant growth (Crohn, 2004) Soil amendmentsare anything mixed into topsoil to promote healthy plant growth. Their function we can see in several ways. For example, they may change the pH of soil or supply nutrients.

Fertilizers are primarily valued for their ability to supply nutrients. Plants use these nutrients to make components for plant growth such as proteins and carbohydrates. One sub-set of soil amendments, soil conditioners, like composted horse manure, improve soil structureby binding soil particles into larger aggregates (Kara, 2000). This increases the amount of pore space and enhances air exchange, water movement, and root growth. The main chemicals that must be supplied to plants are called Primary nutrients. Those required in the greatest amounts are nitrogen (N), phosphorus (P), and potassium (K) (Traunfeld 2013) Contributions of primary nutrients to plant health: Nitrogen (N) - strong leaf growth, dark green color. Phosphorous (P) - roots, early plant growth, seedformation. Potassium (K) - plant vigor, disease and stressresistance, and flavor and color enhancement. Organic fertilizers often supply other nutrients in addition to NPK release nutrients slowly over the growing season, and may double as soil conditioners (Traunfeld 2013).

2.1 Benefits of using organic fertilizers in agriculture

Research shows that organic fertilizer has an overriding importance, because it is not only supply the soil with nutrients, but improves the soil structure and induces useful microbiological processes (Singh and Agrawal, 2008). Therefore, every possible way of organic fertilizer has vital importance on the preservation of soil fertility. Organic fertilizer is the end product obtained by converting various organic wastes such as crop residue, urban wastes, poultry droppings, animal dung, etc., into a usable fertilizer by a modified aerobic and anaerobic process of composting. Sludge is one of the organic fertilizers used to increase the soil fertility. According to Eddy and Metcalf (1980) Sludge is the settleable solids separated from liquids during processing, the deposited foreign materials on the bottoms of streams or other bodies of water. According to Yale J.D., (1998) sludge was defined as a semi-solid or liquid waste derived from municipal, commercial or industrial treatment facilities, wastewater treatment plants and air pollution control. Sludge was also defined as an accumulation of solids removed from sewage during waste treatment (Spinosa L. and Wichmann K., 2004). According to Ekman, (1993) Sludge acts as a soil conditioner to facilitate nutrient transport, increase water retention and improve soil fertility. Sewage sludge/biosolids are by-products of municipal and industrial wastewater treatment and a rich source of organic nutrients. Land application of sewage sludge has a great incentive in view of its fertilizer and soil conditioning properties. And also used for crop production in both the developed and developing countries as important organic fertilizer of the world. Due to its high content of organic matter, macro- and micro-nutrients, it can be used as fertilizer/soil Conditioner for food, vegetable crop, horticultural plants and pasture, which in most cases can be beneficially recycled. This biosolids are rich in organic matter it contains more than half of organic nutrients, therefore, biosolids can be utilized as a soil conditioner to improve physical, chemical, and biological properties of soils, especially those degraded or disturbed soils (Krause, 1985). In addition to that act as a food source for microorganisms, organic materials are the major binding agents for aggregate formation and stabilization (Krause, 1985) Sewage sludge characteristically contain high levels of the major plant nutrients such as nitrogen, phosphorus and potassium, contain valuable micro nutrients such as Fe, Mn, Cu, Zn, Mo and Cl and are often enriched in organic matter (Foeken and Mwangi, 2000). Land application of the sewage sludge is becoming more popular due to the possibility of recycling valuable components such as organic matter, N, P and other plant nutrients (Martinez *et al.*, 2002). According to Haynes *et.al*. (2009). Due to population increase and urbanization, biosolids production would be rise. To reuse this biosolids or to minimize byproduct accumulation on environment, land application is generally considered as the most economical and beneficial way of biosolids disposal. The use of sewage sludge for soil amendment and land reclamation is not only to solve the final disposal problems but it also improves the soil physical properties and increases soil organic matter content.

2.2 Benefit of using brewery waste water sludge for agriculture

Brewery is a traditional industry with an important economic value in the agro-food sector. Brewery Wastewater is one of the most significant waste products of brewery operations. Brewery consumes large volumes of water and at the same time it also discharges large volumes of effluent throughout the year. Even though substantial technological improvements have been made in the past, it has been estimated that approximately 3 - 10 L of wastewater is generated per liter of beer produced in breweries (Kanagachandran and Jayaratne, 2006).Many technologies have been developed to achieve pollutant removal from wastewater. Both aerobic and anaerobic wastewater treatment systems are currently in use. They can be seen as complementary to each other, since in some situations anaerobic systems cannot fulfill the requirements of effluent quality. Anaerobic treatment of wastewater is a process that takes place in the absence of electron acceptor. The overall basic reactions during anaerobic system can be summarized as: - Organic matter $\rightarrow CH_4$ +

CO_2 + Anaerobic Biomass. This process is characterized by biological conversion of organic compound into biogas (methane 70-85 % and carbon dioxide 15-30 % with traces of hydrogen sulphide (Metcalf and Eddy, 2003). The interest in the use of anaerobic treatment processes can be addressed by considering the advantages and disadvantages of these processes. Anaerobic treatment is the fact that the process is net energy producer instead of an energy user, its low biomass production, the low nutrient requirements and the high volumetric loadings possible. The aerobic treatment processes were predominant in the biological treatment of wastewater in this process the Organic material is converted into CO_2 and sludge (biomass) through aerobic treatment. The conversion is done with O_2 supplied to the reactor tank either mechanically or by diffusion from the atmosphere. For aerobic processes molecular oxygen (O_2) is the electron acceptor. The overall basic reactions during aerobic treatment can be summarized as: -

Organic matter + $O_2 \rightarrow CO_2 + H_2O$ + Aerobic Biomass. Since it is an oxidative biological reaction, large amounts of biomass are produced which settle as sludge which requires further disposal. This biomass/sludge which is the byproduct of aerobic waste water treatment can be used as organic fertilizer. Brewery sludge can be directly amended with soil without any further treatment. Composting and Co-Composting is also not required for brewery waste water sludge. Sun dried brewery waste water sludge can be directly applied to soil as it is a high source of nutrients and no detrimental effects in soil and plant because the heavy metals were below detectable levels (Karuna, 2015).

According to Dominica *et al*., (2009), land application of brewery sludge is divided in to four categories; for agricultural, forest, land reclamation and land dedicated to sludge application. According to EPA, (2000) land application of threatened brewery sludge for soil amendment and land reclamation purposes has increased over the past decade rather than other disposal option such as incineration, damp on land and ocean dumping. Brewery sludge, as organic manure, should be regarded as valuable commodity especially in warm arid and semi-arid regions particularly where soil fertility depletion and soil degradation are most serious problems. Since the sludge is a rich source of organic manure which is an important property for moisture retention, it can be used to reclaim desert soils. According to the study conducted on comparison of organic and inorganic fertilizer effect on performance of legume plants at Arba Minch University. Organic fertilizer (cow dung) showed high frequency of 92-96% germination when compared with inorganic fertilizer (urea and potassium chloride) of (80-86%) after 35 days of germination over the control of only 82% in faba bean and pea (Bhaskarrao, *et.al* 2015). According to Nithiya (2015)Table 1: Effect of organic and inorganic fertilizer on morphological traits of *Solanum nigrum*the organic fertilizer shows the great difference on plant height, leaf length and leaf area than the inorganic fertilizers. Sewage sludge can be a valuable resource if used as a fertilizer and soil conditioner. Generally, sewage sludge is composed of organic compounds, macronutrients, and a wide range of micronutrients, non-essential trace metals, organic micro pollutants and microorganisms (Kulling, 2001). South African farmers using sewage sludge as a fertilizer amendment reported a 20% increase in the yield of cultivated maize and 40% saving on inorganic fertilizer. According to Mohimi *et.al*, *(*2010) land application and use of sludge as a soil conditioner appear to be the most acceptable way to dispose industrial sludge.

2.3 Characteristics of brewery waste water sludge

Chemical analysis on brewery waste water sludge revealed that it has high N, P, K and nutrients which are important requirement for plant growth (Mohammad, 1996). The pH of the brewery sludge was almost neutral according to Luque *et.al,* (1990). But according to Driessen and Vereijken (2003) pH ranges from 6.5 to 11.5. This difference in pH is due to raw water used and certain process variations in wastewater treated plants. The usage of acids and caustic soda for the cleaning of process equipment and reuse bottles results in large variation of the pH in the wastewater. Some researches done in our country shows that the pH of the brewery waste water sludge is almost neutral for example kebenebula in (2014) the pH of the BGI Ethiopia brewery waste water was 7.8±0.3. The pH analysis for brewery waste water sludge were found between 7.12±0.47-7.17±0.35 indicating the suitability of the brewery sludge as a source of fertilizer since most crops grow best when the soil pH is between 6.5-7.0 and a high moisture content was obtained. As World health organization standard the pH of the brewery waste water ranges from 6.5-8.5and theElectrical conductivity (EC) of brewery waste water sludge at final effluent tank was 1741.08. Nitrogen (N) according to the study conducted at BGI Ethiopia by (keben bula 2014) the total nitrogen was 34.6±8 mg/l the content of total nitrogen did not vary that much. According to the brewery sludge collected is a rich source of Nitrogen the available Nitrogen was 420.25kg/ha. Chemical oxygen demands (COD); according to the study conducted at BGI Ethiopia by Keben Bula (2014) the COD (mg/L) of the waste water was 209±92 table 2. The total COD of brewery waste water sludge discharge limit of South Africa beer factory is 75 while the EU discharge limit is 125. Biological oxygen demands (BOD); according to the study conducted at BGI Ethiopia by Keben Bula (2014) the BOD (mg/L) was 79±24.Phosphorous (P) according to the study conducted by Osaro *et al*. (2012) the available Phosphorous of the brewery sludge was PO4mg /g was 14.05 ± 0.48. The brewery waste water sludge is rich in Potassium were very high 840.00kg/ha.

Table 3.1 Characteristics of brewery effluent.

Parameter	**Unit**	**Brewery effluent Composition**	**Typical brewery Benchmarks**
COD	mg/l	2000-6000	0.5-3 kg COD/hl beer
BOD	mg/l	1200-3600	0.2-2 KG BOD/hl beer
TSS	mg/l	200-1000	0.1-0.5 TSS/hl beer
Temperature	^{0}C	18-40	
Ph		4.5-12	
Total Nitrogen (TN)	mg/l	25-80	
Phosphorous	mg/l	10-50	

According to the study conducted in India by Ramya *et al* (*2015*) the amount of heavy metal in brewery waste water sludge is negligible. In our country different research were conducted on the characterization of the brewery waste water sludge. According to the study conducted in Addis Ababa University at center of environmental science by (Edeget, 2016) the heavy metal of the brewery sludge was negligible, so it can be applicable for agriculture. The content of the heavy metal was; Lead, Pb (mg/Kg) 0.62±0.01, Cadmium, Cd (mg/Kg) 0.04±0.01, Nickel, Ni (mg/Kg) 13.93±0.00, Chromium, Cr (mg/Kg) 34.09±0.00.

Table 3.2 Heavy metal concentrations in seepage and EU standards for admissible levels in sludge used in agriculture.

Heavy metal (g/kg)	Bangkok	Manila	US	EU Standard
Cd	2.5	5.3	18	20-24
Pb	6.8	84	215	750-1200
Cu	289	289	165	1000-1750
Cr	20	16	28	1000-1500

Source: Martin Strauss, 2000 cited by (Jenifer, 2002)

2.4 Effect of brewery wastewater sludge on growth of plants

The major benefits of sludge application are; increased supply of major plant nutrients; provision of some of the essential micronutrients (Zn, Cu, Mo, and Mn) and; improvement in the soil physical properties, i.e. better soil structure, increased water holding capacity, and improved soil water transmission characteristics. According to Bhaskarrao *et al*., (2015) the average accumulative germination percentage with organic and inorganic fertilizer on figure 1(a) shows that the organic fertilizer showed high frequency of 92-96% germination when inorganic fertilizer 80-86%.(Kumudha and Gomathinayagam 2007; Dawari, and Sharma, 2014) also proved that as organic fertilizer maximize seed germination. This suggests that brewery sludge would be a positive input for yield increase in relation to poor and semi-arid soils. Concentrations of metals and toxic constituents' sludge can be a valuable resource if used as a fertilizer and soil conditioner. South African farmers using sewage sludge as a fertilizer amendment reported a 20% increase in the yield of cultivated maize and 40% saving on inorganic fertilizer. According toRamya et al. (2015) the brewery waste water sludge enhanced growth with increasing proportions of brewery sludge. According toDriessen and Vereijken (2003) increase in sludge led to a significant increase in plant height and yield. Organic fertilizer is primarily responsible for the increase in biomass, the length of the shoot and root length increases with increasing rate of application. Increased leaf area and leaf length implies higher light interception and dry matter product which invariably promotes plant growth. The average values of fresh weight and dry weight biomass of faba bean and pea plants treated with organic are higher than those with inorganic and control.

2.4 Effect of brewery waste water sludge on Soil Physic-Chemical properties

The application of sewage sludge to agricultural soil not only enables nutrients to be recycled, but may eliminate the need for commercial fertilization of cropland (Sommers 1977; Singh 2007 and Agrawal, 2009). Land application of sludge is considered a beneficial alternative to land filling or incineration. Agricultural use of sludge is an effective management practice that can provide a source of revenue. In U.S. dried biosolids can have value between $25 and $40 per ton; depending on the quality therefore municipal sludge is processed into agricultural fertilizers and soil conditioners in most major U.S. cities (Jenifer, 2002). Digestive quality can be asses on chemical, biological and physical aspects (Metcalf and Eddy, 2003). The chemical aspects of quality management of digestive are related to the presence of Heavy metals and other inorganic contaminant, Persistent organic contaminants, Nutrients (NPK).pH is a measure of the soils acidity and alkalinity that gives an indication of the activity of the hydrogen ion (H+) and hydroxyl ion in (OH-) in a water solution. According to Garcia and Barco (2000) study on using brewery wastewater and effects on soil physical and chemical properties under greenhouse condition. The result showed that the soil pH gradually decreased as the rate of application of BW is increased. Moreover, and other researcher also shown that pH of the soil decreases with increasing rate of application of brewery wastewater sludge (Epstein *et al*. 1976; Moreno *et al.,*1997 and Nielson *et al.,*1998).EC is reliable way to assess how salts are affecting plant growth. The EC of soil or water is influenced by the concentration and composition of dissolved salts. Salts increase the ability of a solution to conduct an electrical current, so a high EC value indicates a high salinity level. The electrical conductivity was not affected by application rate of the brewery waste water sludge increase. Cation exchange capacity is the capacity of the soil to hold and exchange cations. The CEC depends on the amount and kinds of clay and organic matter that are present in the soil. Organic carbon will vary with soil texture and rainfall zone. A lower CEC soil will have a lower organic carbon level. Increasing OC levels will increase the soils CEC and nutrient holding capacity resulting in increased productive capacity in some soils. Higher rainfall or finer texture will generally have higher OC levels. The organic carbon of the soil after amendment of the brewery effluent shows increasing in concentration (Orhue, *et al* 2005). According to Kladivko and Nelson (1975) and Ramya, (2015) Brewery sludge addition improved the organic carbon content of the soils significantly and the higher water retention capacity is linked to high Organic Matter, high cation exchange capacity and other nutrients. Potassium is one of the most abundant elements in soil. The total K in soil will be dependent on soil parent material, the extent of weathering and leaching of soil minerals, the type of clay minerals, soil texture, organic matter content and K fertilizer history. Much of the potassium occurring in soils is not available to plants and crops, therefore soils containing high levels of K can still be responsive to K fertilizers. According to Ramya *et.al,* (2015) table 2 and 3 result the amount of potassium in the soil increases with the increasing rate of the sludge. Nitrogen in soil is largely depends on soil organic matter and microbial activity (Kara 2000) which founds in both organic and inorganic forms. Organic nitrogen (N) present in various forms, including plant and microbial proteins, amino acids and nucleic acid in the soil and enters to the soil in the form of crop residue and amendments (e.g., manures, composts, and specialty products (Crohn 2004). And Inorganic N, mostly ammonium (NH+4) and nitrate (NO3), crops can only assimilate these two inorganic forms of nitrogen. Therefore, before organic N can be taken up, it must first be converted to inorganic forms (Dinnes 2000). Organic amendments had strongly influenced 'N' uptake and crop productivity than inorganic fertilizer additions. According to *Ramya et al. (2015 table 2, 3, 4* with different soil types, with increasing rate of brewery waste water sludge application the nitrogen content of the soil also increased but the concentration of Phosphorous decrease with increased application rate of sludge.

3. MATERIALS AND METHODS

3.1 Experimental design used in the study

The fertilizing potential of the brewery wastewater sludge was evaluated for the two different types of soils such as the vertisol and Planosol soil. Each soil was evaluated using two different vegetables tomato and lettuce. The study was conducted using Completely Randomized Design (CRD) in triplicate. The experiment was conducted in two control group and four different treatments groups for each type of soil and vegetable. One control group was without any fertilizer and sludge which was used as negative control. Other control group was with inorganic fertilizer (NPK) was used positive control. The four different treatments used in the experiments were 10, 20, 30 and 40% of the sludge. A total of 72 pots were used for the four different setsof experiments. The experiment was conducted in a greenhouse at the college of natural and computational science, Addis Ababa University.

3.2 Sample and Sampling Site selection

To carry out this thesis the vertisol and Planosol soil sample were used. The sampling sites of the two soils were first selected based on the abundance of the soil and the nutrient contents. The Planosol soil sample was collected from mojo area which is found around 200km from Addis Ababa. And the vertisol soil was collected form Akaki kality sub city the place called Berta/ whalimate. The brewery waste water sludge sampling site was selected randomly based on their willingness of the chief of the organization to give their sludge for the research purpose.and the sludge was selected based on the heavy metal level of contamination. The brewery waste water sludge was collected from BGI Ethiopia which found in Hawassa branch.

3.3 Soil and brewery waste water sludge sample collection

3.3.1. Soil samples collection

The 150 kg of Planosol soil sample was collected from mojo farm land at 25cm depth from 5 randomly selected sampling points and similarly 150 kg of vertisol soil sample was collected from Addis Ababa Akaki Kality sub city at 25cm depth from randomly selected 5 sampling points. After collection were homogenized and sieved well before using for green house experiment.

3.3.2. The brewery wastewater sludge sample collection

The sludge was collected from St. George beer (BGI) Ethiopia which found in Hawassa from aerobic waste water treatment plants with 3 hours interval in one working day to get the representative sludge sample that produced in one day.

3.4 Laboratory analysis of Soil and brewery sludge

The selected Physico-chemical parameters of brewery wastewater sludge such as pH, organic carbon (OC), total nitrogen (TN), available phosphorous (AP) and potassium (K) were analyzed in the laboratory of the Center for Environmental Sciences. The heavy metal content in the sludge such Cd, Cr, Cu, Ni and Pd were analyzed in the laboratory of leather industry developmental institute. The pHof the soil and brewery waste water sludge were determined in 1:2.5 soil/water suspensions.10g of air dried soil and brewery waste water sludge were measured by 0.001g sensitivity electronic balance and transferred to 500ml of approx. bottle and 25ml of distilled water was added and shacked for 2 hours by shaker in 150h/min and settled for 1 hour the pH determined using pH meter model sx711

3.4.1 Heavy metal analysis

The brewery wastewater sludge was analyzed for the presence of heavy metals by using Atomic absorption spectrophotometer. The heavy metals were determined according to the standard procedures at Ethiopian leather industry laboratory ICP.

3.4.2 Organic carbon

Organic carbons of soil and brewery waste water sludge were determined by Walkley-Black, (1934) procedure. After all reagents prepared 0.5g of air dried soil and brewery waste water sludge were weighted by electrical balance sensitivity 0.001g and transferred to 500ml flask, 10ml of 1 N potassium dichromate ($K_2CR_2O_7$) was added and 200ml of distilled water was added, 20ml of concentrated sulfuric acid [H_2SO_4]was added slowly and cooled for 30 min then 10ml of orthophosphoric acid was added and shacked. Then titrated with titrant solution of 0.5 N ferrous sulfateuntil the color changes to purple or blue, then add ferrous sulfate solution drop by drop until the color flashes to green then continue to a light green end point.

$$\%C = \frac{N \times V_1 - V_2 \times 0.39 \times mcf}{S} \qquad \ldots\ldots 3.1$$

Where:

N= Normality of ferrous sulfate solution (from blank titration), V_1 = Volume of ferrous sulfate solution used for blank, ml,V_2= Volume of ferrous sulfate solution used for sample, ml,S = Weight of air-dry sample in gram,0.39 = $3 \times 10^{-3} \times 100\% \times 1.3$ (3 = equivalent weight of carbon), mcf = moisture correction factor.

3.4.3 Available phosphorus was determined by Olsen method

Extracting solution was prepared from 0.5M of sodium bicarbonate with pH 8.5 the pH was adjusted with 1M sodium hydroxide. The 100mg/l standard phosphate solution was prepared by weighting 4g of phosphate in one liter of volumetric flask and make to volume with distilled water.4mg/l standard phosphate was prepared in

250ml of volumetric flask from 100mg/l of standard phosphate solution and filled with extracting solution. The standard series was prepared from 4mg/l P standard solution 0, 10, 20, 30, 40; 50ml was pipetted in 100ml of volumetric flask and make to volume with extracting solution which means 0, 0.4, 0.8, 1.2, 1.6, and 2,0mg/L p Mixed reagent was prepared from 50ml of 4M H_2SO_4, 15ml of NH4 molybdate solution, 30ml of ascorbic acid solution, 200ml of distilled water and 5ml of potassium antimony tartrate solution. 5g of soil sample and the brewery waste water sludge were weighted and transferred to 250ml polythene shaking bottle including to the blank and 100ml of $NaHCO_3$ solution added and shacked for 30 minon mechanical shaker at 175 RPM. The solutions were Filtered through Whitman no 1 filter paper and 3ml of standard series, the blank and the extracted sample solution were measured and pipetted to the short test tubes and 3ml of mixed reagent was added to each of test tube including the blank then the solutions were stand for 1 hour until the blue color was developed and absorbed by spectrophotometer at 882 nm. The calibration graph was plotted absorbance against P concentration for standard series the concentration of the sample read from the graph the of

P ppm/mg/kg = $\frac{(a-b)\times 100\times mcf}{S}$ ………………………………………….. 3.2

Where a=mg/l P in sample extracted, b= mg/l P in blank, S= sample weight in gram, Mcf= moisture correction factor, 100= ml of extracting solution, Conversion factor $P_2O_5 = 2.29 \times P$

3.4.4Total Nitrogen by Kjeldahl Method

After the all necessary reagents such as concentrated sulfuric acid, Catalyst mixture, 40% of Sodium hydroxide, 2% of Boric acid solution, Mixed indicator, 0.1N of Sulfuric acid solution , 0.05M of Oxalic acid, 0.1% of Phenolphthalein indicator, 0.1

N of Sodium hydroxide, prepared 1g soil sample weighted which sieved through 0.5mm sieve and the soil sample transferred in to digestion tube, 2gm of catalyst mixture was added then rinsed with water, 7ml of concentrated H_2SO_4 was added and mixed by swirling. The digestion tube stands with the samples beside the block digester and fit the exhaust manifold on top of it. Place the tubes with rack and exhaust manifold on the digestion block, preheated in the fume-hood. The samples Digested for 3 hours or until the digest is white or pale yellow on a block digester preheated to 380°C, after cooling for minutes cautiously 50ml of distilled water was added. The acid digest quantitatively transferred to the macro-Kjeldahl flasks and rinsed with distilled water.20ml boric acid solution from a dispenser into a receiver Erlenmeyer flask corresponding to the number of samples. 2 drops of indicator solution was added and placed under the condenser. 75 ml of 40% NaOH poured carefully down the neck of the distillation flasks and mixed gently. The prepared 250ml Kjeldahl distillation flasks was fitted to the corresponding holder, after the distillation is completed, i.e. when about 100ml of distillate has been collected, remove the receiver flask. The stirrer bar was added and titrate the receiver flask solution from green to a pink end point with 0.1N H2SO4.The reading of the burette was recorded.

Calculation

% N = (a-b) x N x 0.014 x 100 xmcf/s……………………………………………3.3

Where; a = Volume of H_2SO_4 required for titration of sample, ml, b= Volume of H_2SO_4 required for titration of blank, ml, s = air-dry sample weight in gram, N= Normality of H_2SO_4 (0.1N), 0.014 = weight of nitrogen in g, mcf = moisture correction factor

3.4.5 Available potassium were determined by Morgan methods

100g sodium acetate ($CH_3COONa.3H_2O$) was Dissolved in 900ml distilled water. And the pH of extracting solution adjusted to 4.8 and dilute to 1 liter with distilled water. Accurately 1.91g of potassium chloride was measured and added into a 100ml beaker and Wash into a 1 liter volumetric flask, and make to mark with distilled water and mix well to dissolve. Then standards was prepared by100ml of the potassium stock solution, 1000ppm K into1 liter volumetric flask and dilute to volume with distilled water Standard series working solution of 0 – 2 – 4 – 6 – 8 - 10 mg/1 K: Pipette into 250ml volumetric flasks, respectively 0 – 5 – 10 – 15 – 20 - 25ml of the diluted 100mg/1 standard solution diluted to volume with Morgan's extracting solution.10g of soil passed through 2mm sieve was weighted and transferred into 100ml of shaking bottle and 50ml of extracting solution added then shacked for 30 minutes at 180 rpm and filtered in 100ml of Erlenmeyer flask and Diluted extracts 5 times for sandy soils and 10 times for vertisol soils, using the extracting solution K measured by Flame photometer

Available K (mg/kg soil) = $(a-b)\times Z\times\frac{50}{1000}\times\frac{1000}{S}\times df\times mcf$

$$= \frac{(a-b)}{S}\times 50\times Z\times df\times mcf \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.4$$

Where: a = concentration of K, measured in the sample (mg/1), b = concentration of K, measured in the blank (mg/1), S = air- dry soil sample weight in g (10g), mcf = moisture correction factor, df = dilution factor, 50 = ml of extractant used/ sample, Z = standard reading for K

3.5 Estimation of the height of shoot, root and leaves and yields

The lettuce and the tomatoes were harvested together with their roots after eight and thirteen weeks, respectively. The height was measured using meter and the leave areas were calculated using the formula below.

$A = L \times W$ …………………………………………………………. 3.5

Where A is area, L is leaf length, W is leaf width.

The number of leaves and number of fruits were determined by physical counting.

3.6 The fresh and dry biomass of the vegetables

The fresh and dry biomass of the vegetables were determined; after the vegetables harvested carefully and washed to remove soil particles adhering to them then the shoot part separated from the root by using seizers. Fresh biomass of the vegetables was measured by digital balance and the dry biomass of the vegetables was determined by drying fresh weighted vegetables in oven- at 70 °C for 24 hours then the dry weight was measured by digital balance.

3.7 Data analysis

The experiment was in completely randomized design with three replicates maintained for each of six treatments. Data were analyzed by one-way ANOVA to compare the mean of the control groups with soil amended with the sludge. The significant difference (at P level of 0.05) values were calculated for comparisons of treatment means. Analysis of variance (ANOVA) was performed by statistical package for social studies (SPSS) software version 20.0 to know the presence of significant difference between the controls groups and treatment groups. The figures drown on excel sheet.

4 Result and discussion

4.1 The characteristics of brewery wastewater sludge.

The Physico-chemical characteristic of the sludge used in this study is shown in Table 4.1. The results found in the laboratory analysis revealed that brewery wastewater sludge has pH value of 7.4 which is in the accepted range to be used as fertilizer for agriculture According to Luque et.al. (1990) the pH of the brewery wastewater sludge is almost neutral which is in agreement with the results of the present study. However, Driessen and Vereijken (2003) has reported pH values ranges from 6.5 to 11.5. These discrepancy in the value of pH might be attributed to the variation of raw material used in the production and the chemical used during washing of the bottle and to purify the wastes.

Table 4.1 Selected Physico- chemical characteristics of brewery sludge.
A.P; (available phosphorus). A.K (available potassium), TN (total nitrogen) and OC (organic carbon)

Parameters	Units	Concentration
pH	**-**	**7.**4
A.P	ppm	763.6
A.K	mg/kg	1275
T N	%	0.25
OC	%	29
Pb	mg/kg	3.5
Cd	mg/kg	1.04
Ni	mg/kg	10.85
Cr	mg/kg	20.95

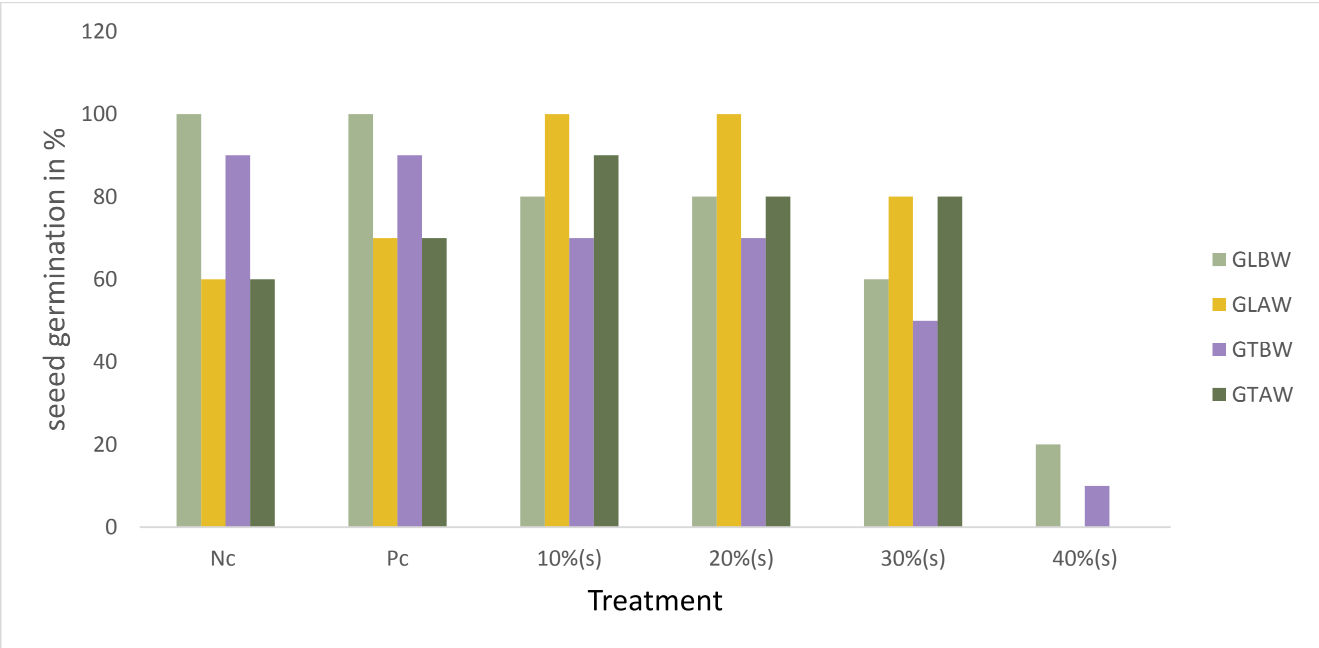
The results found in this study also revealed that the sludge was rich in NPK nutrients and OC. The available phosphorous in the sludge was 763.6 ppm and potassium was

1275 mg/kg while the total nitrogen and organic carbon were 0.25 and 29%, respectively. Other researchers have also confirmed that the sludge are rich in nutrients such as NPK which is very important to increase the soil fertility, growth and yield of the plants (Krause1985). The sludge has also contained heavy metals with a concentration of 5mg/kg for lead, 1.04mg/kg for cadmium, 10.85mg/kg for Nickel (Ni) and 20.95 mg/kg for Chromium (Cr). The concentration of heavy metals in the sludge is negligible when compared with the results of other studies like, Martin Strauss, 2000 cited by (Jenifer, 2002), and Ajmal and Khan (1996). Moreover, the heavy metal levels were also within the EU permission levels for the application of the sludge for agriculture.

4.2 Effect of the sludge on germination of lettuce and tomato seeds

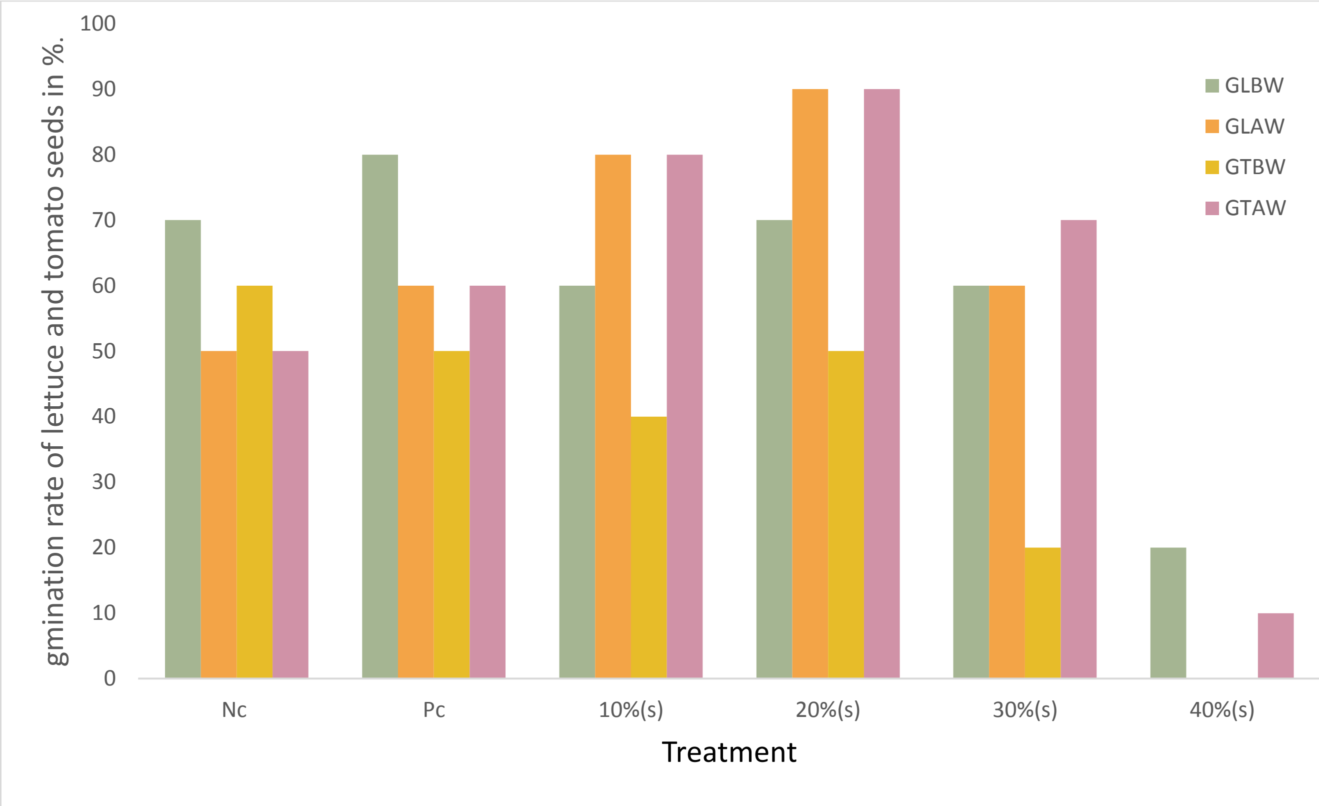
4.2.1 Effect of the sludge on seeds germination of lettuce and tomato in vertisol soil.

The result found on variation of germination percent of the lettuce and tomato seeds in vertisol soil are shown on figure 4.1 and in Planosol soil are shown on figure 4.2. The seeds of the lettuce and tomato were started to germinate after 4 and 7 days respectively. The seed germination was varied with variation of the treatment group and the inorganic fertilizer. The seed germination of lettuce in vertisol soil before a week was 100% in the soil without inorganic fertilizer and sludge and in soil amended with inorganic fertilizer. When the soil amended with different proportion of the sludge shown variation with variation of the sludge proportion. 80% of the seeds were germinated in the soil amended with 10 and 20% of the sludge, 60% in the soil amended with 30% of the sludge and 20% of the seeds germinated in the amended with 40% of the sludge. For tomato 90% of the seeds were germinated in the soil amended with NPK fertilizer and in the soil amended without the sludge and inorganic fertilizer. And in the soil amended with different proportion of the sludge shown variation with variation of the sludge proportion.70% of the seeds were germinated in the amended with 10 and 20% of the sludge,50% of the tomato seeds were germinated in the soil amended with 30% of the sludge and 10% of the seed was germinated in the soil amended with 40% of the sludge. But after a week the result was reversed the highest germination percent was recorded in the soil amended with different proportion of the sludge than the controls. where100% of the seeds germinated in the soil amended in10 and 20% of the sludge, 80% of the seeds were germinated in the soil amended with30% of the sludge and 60 and 70% of the seeds were germinated in the soil amended with NPK fertilizer and soil without any fertilizer there was no seeds germination in 40 % of the sludge, the 20% germinated seeds were dried. This result might be due to the shortage of homogenization period of the sludge with the soil. For tomato 90% of seeds germination observed in the soil amended with 10% of the sludge and 80% of seeds germination for 20 and 39% of the sludge for NPK fertilizer and soil without any fertilizer was 70 and 60% of the seeds were germinated



GLBW; Germination of lettuce before a week, GLAW germination of lettuce after a week. GTBW germination of tomato before a week GTAW germination of the tomato after a week.

Figure 4.1 Germination of lettuce and tomato seeds in vertisol soil before and after a week



GLBW; Germination of lettuce before a week, GLAW germination of lettuce after a week. GTBW germination of tomato before a week GTAW germination of the tomato after a week.Figure 4.2 Germination of lettuce and tomato seeds in Planosol soil before and after a week.

Figure 4.2 illustrates the germination of the lettuce and tomato seeds in Planosol soil.The germination percent of the lettuce seeds in Planosol soil was 70%, 80%, 60%, 70%, 60% and 20% in the soil without any fertilizer, in the soil amended with NPK fertilizer, 10, 20, 30, and 40% of the sludge respectively after one week the result was changed 90% of the seeds were germinated in the soil amended with20%

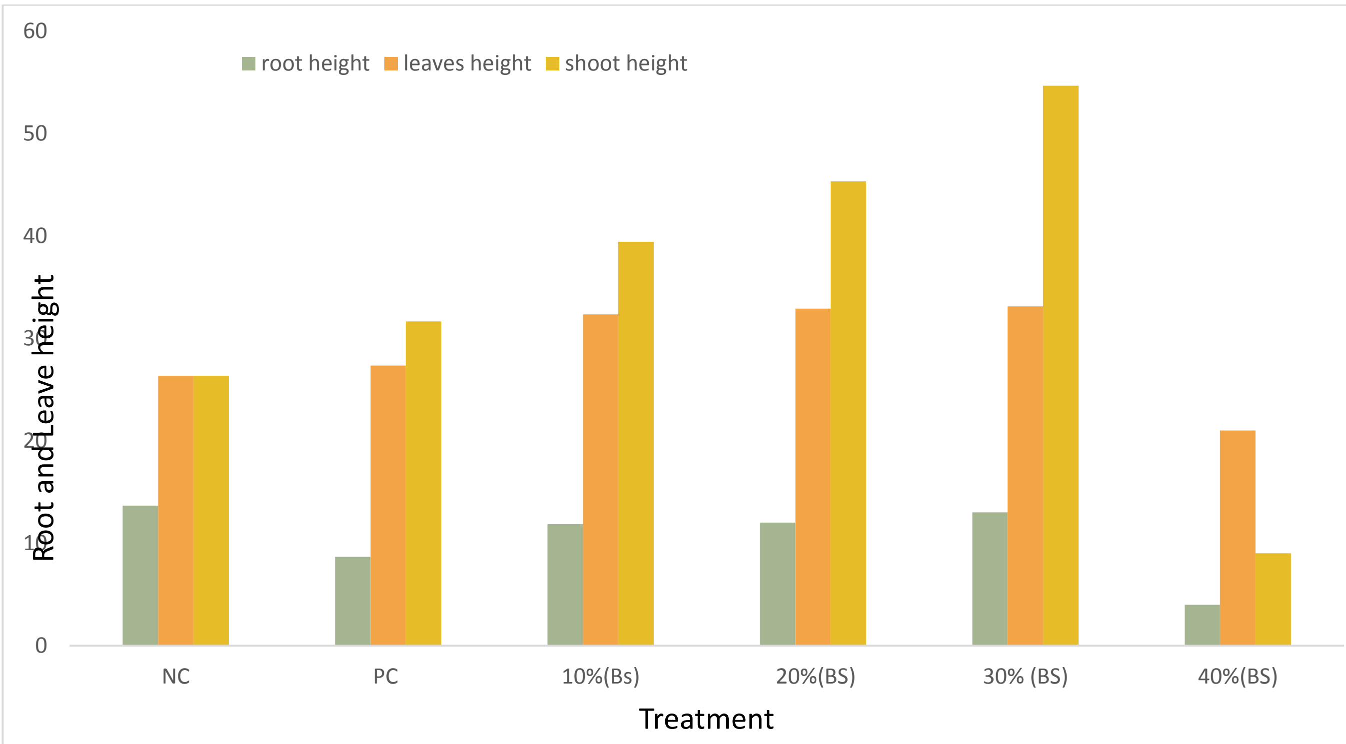
of the sludge and 80% of the seeds germinated in the soil amended with 10% of the sludge and 60% of the seeds were germinated in the soil amended with NPK fertilizer and 30% of the sludge. In the soil without any fertilizer 50% of the seeds were germinated. For tomatoes seed before a week the highest seeds were germinated in the soil without any fertilizer and the lowest was in the soil amended with 30% of the sludge. But after a week the highest germinated seeds were in the soil amended with 20% of the sludge where 90% of the seeds were germinated and the lowest was in the soil amended with 40% of the sludge where 10% of the seed were germinated. This study results also agree with Bhaskarrao *et al*., (2015) the average accumulative germination percentage with organic and inorganic fertilizer shows that the organic fertilizer showed high frequency of 92-96% germination when inorganic fertilizer 80-86. And (Kumudha and Gomathinayagam 2007) and (Dawari, and Sharma, 2014) also proved that as organic fertilizer maximizes seed germination.

4.3 Effect of the sludge on the growth of Lettuce and Tomato

4.3.1 The effect the sludge on vegetables grown in vertisol soil

The result found on the variation of length of lettuce leave, shoot and root with variation of sludge treatment were shown in Figure 4.3 and the variation of leave area with sludge proportion indicated in Figure 4.5. The lettuce shoot lengths were varied in the range from 9 to 54.67cm. The length of shoot was increased with increasing rate of sludge application until the proportion of the sludge was 30%. The highest shoot length was observed in the soil amended with 30% sludge while the lowest was in the soil amended with 40% sludge. The reason for this might be the excess mount of sludge has a negative effect on shoot length due to high amount of nutrient lead to reduce the growth. And the nature of sludge also affects the growth the sludge. The sludge was in powdered form that leads to decrease aeration and water penetration.

There was significant variation in the length of shoot between the negative control and positive control and different treatment groups (p<0.05). And the length of leaf was varied in the range 21 to 33.11cm. The highest was 33.11cm in the soil amended with30% of the sludge. While the lowest was obtained in the soil amended with 40% sludge. Unlike shoot length there was no significance variation in leaf length among the treatment groups as well as between control groups (p <0.05). The root length was varied in the range from 4 to 13.67cm. The longest root was measured in the soil without sludge and inorganic fertilizer. The result found in this study showed that increasing sludge up to 30% in the soil increase the growth of lettuce.



NC: control, PC: positive control, BS: brewery sludge

Figure 4.3: The length of root, leave and shoot of the lettuce on vertisol soil.

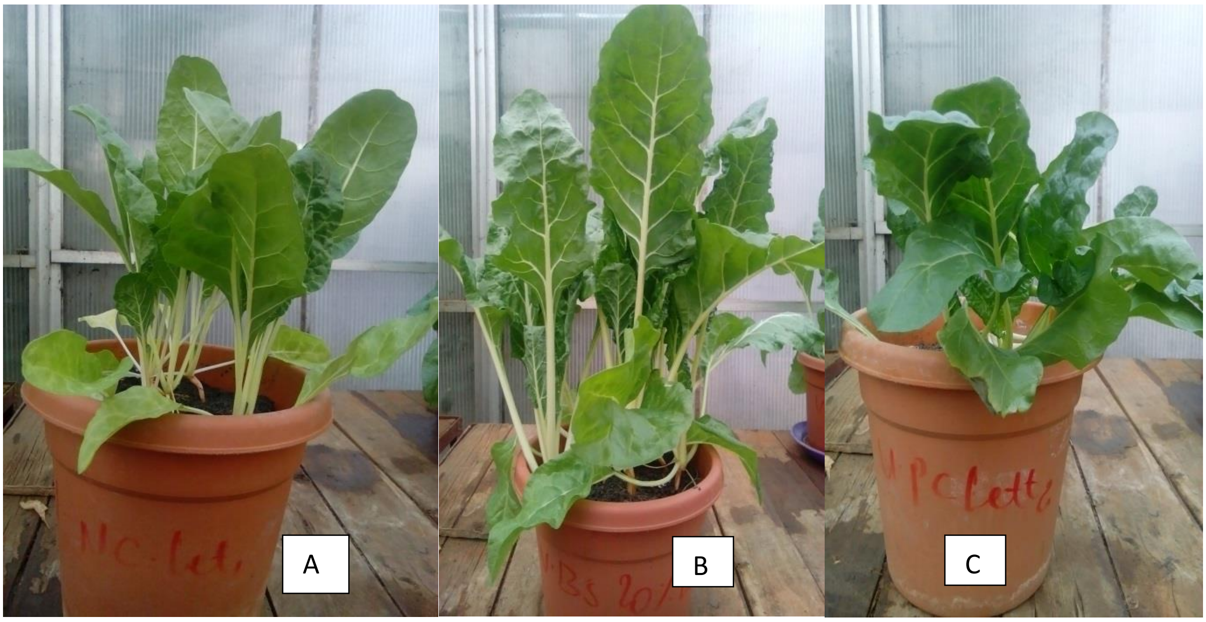
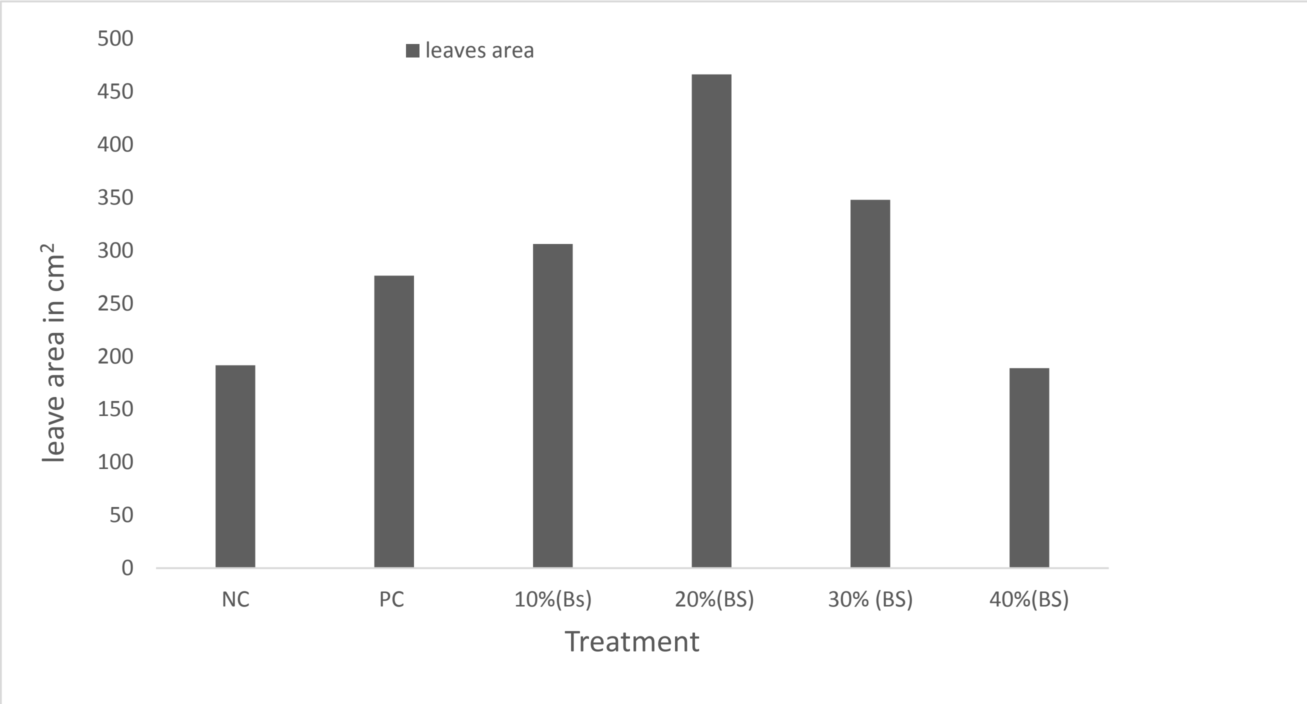


Figure 4.4 “A” NC (vertisol negative control), “B” 20% Sludge and “C” PC (vertisol positive control)

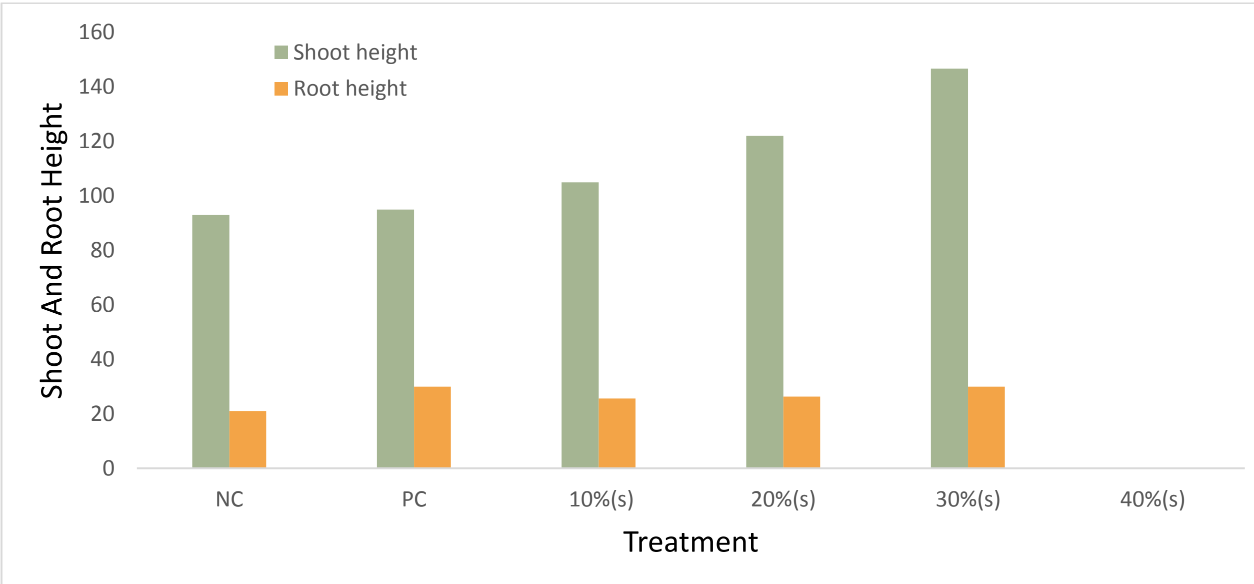
Photo by Alemnesh Bejiga

The sludge has the potential to enhance soil productivity because it contains high organic matter and plant nutrient content. As displayed on Figure 4.4B a soil amended with 20% sludge totally different from negative control shown in figure 4.4A and in the soil having NPK fertilizer as shown in figure 4.4C, in all aspects such as leaves no, leaves height, and leaves color. This shows that the application of sludge has a positive effect on growth of lettuce.



NC: Negative control, PC: positive control, BS: brewery sludge

Figure 4.5 the leave area of the lettuce on vertisol soil.



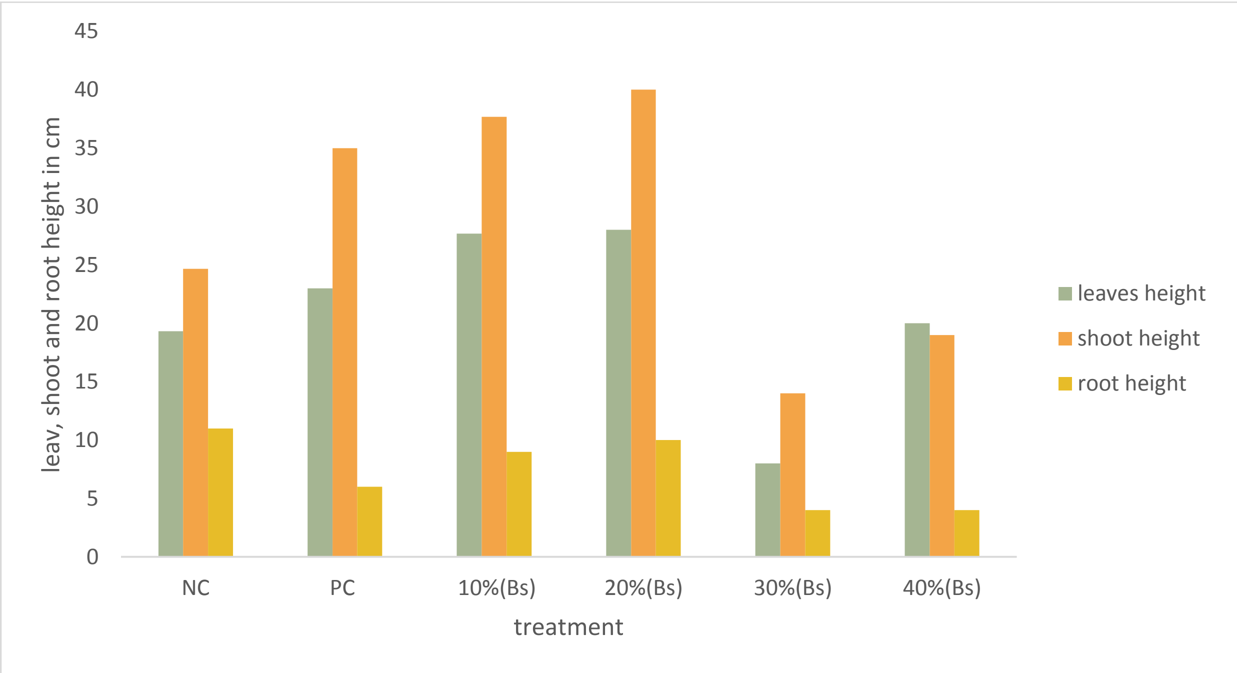
NC: control, PC: positive control, BS: brewery sludge

Figure 4.6The effect of sludge on growth of the tomato on vertisol soil

Figure 4.6 shows the variation of shoot and root length of tomato grown in vertisol soil amended with inorganic fertilizer and different amount of sludge. The length of shoot ranges from 93 to 146.67cm and the length of root was varied in the range from 21 to 30cm. the longest shoot and root length were recorded for the tomato grown in the soil amended with 30% of the sludge. The lowest shoot and root were recorded in the soil without both inorganic fertilizer and sludge. The tomatoes in the soil amended with 40% sludge were dried after germination. There was significant variation of shoot length with variation of sludge proportion used to amend the soil ($p<0.05$). This study also agrees with Driessen and Vereijken (2003) increasing sludge (organic fertilizer) led to a significant increase in plant height and yield. Organic fertilizer is primarily responsible for the increase in biomass, the length of the shoot and root length increases with increasing rate of sludge application

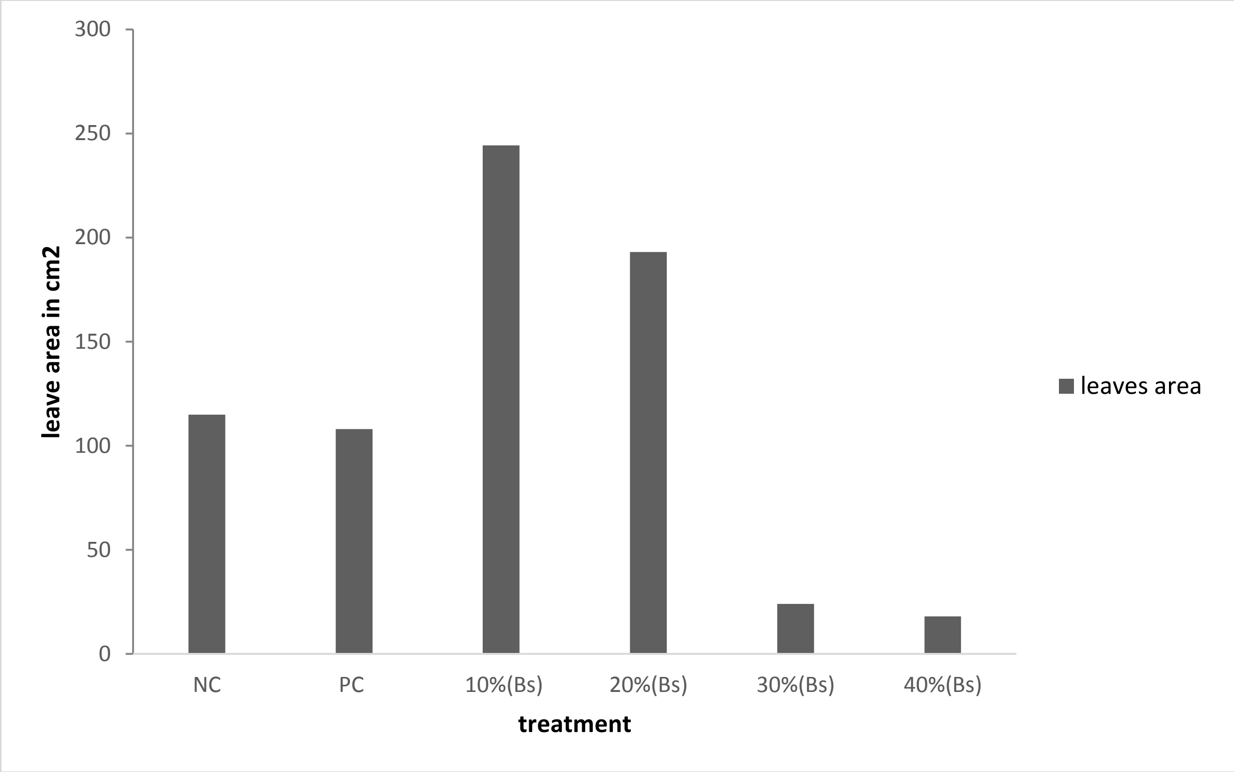
4.3.2 The effect the sludge on vegetables grown in Planosol soil

The result found on the variation of length of lettuces leaves, shoot and root with variation of sludge treatment were shown in Figure 4.7 and the variation of leave area with sludge proportion indicated in Fig 4.8. The lettuce shoot length varied in the range from 40 to 14cm. the highest shoot length recorded in the soil amended with 20% sludge while the lowest shoot length was recorded in the soil amended with 30% sludge. The analysis of variance showed that there was no variation of shoot length with variation of sludge proportion used to amend the soil ($P< 0.05$).The leave length of lettuce varied in the range from 28 to 8cm. The longest leave length recorded in the soil amended with 20% sludge while the lowest leave length recorded in the soil amended with 30% of sludge. This result indicate that the soil amended with sludge was more effective in leave length of lettuce than the soil amended with inorganic fertilizer. This finding also agrees with Nithiya; (2006**)** the organic fertilizer shows the great difference on plant height, leaf length and leaf area than the inorganic fertilizers. The leave length was not significantly varied with variation of sludge used to amend the soil ($p < 0.05$).But there was significant variation between the treatment group (soil amended with sludge) and the negative and positive control. And the root length of the lettuce varied in the range from 11 to 4cm unlikely the shoot and leave length the highest root length was recorded in the soil without inorganic fertilizer. This might be due to technical error during harvesting the lettuce or during separating the root from the soil or the vegetable elongated the root to get nutrient. The lowest root length was 4cm in the soil amended with 30 and 40% of the sludge this was might be due to the sludge amended in to the soil aggregate or tie the soil particles and difficult to separate the root from the soil. There was significant variation of the root length with variation of sludge proportion used to amend the soil ($p < 0.05$).



NC: control, PC: positive control, BS: brewery sludge

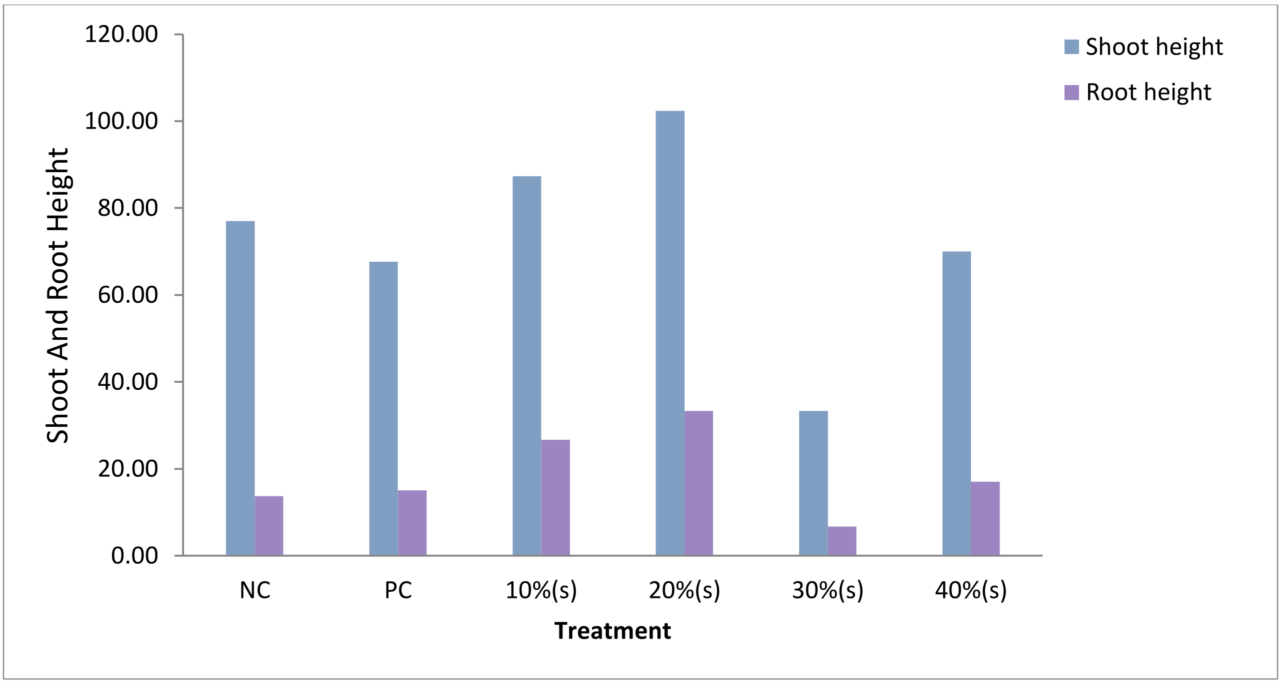
Figure 4.7 the effect of sludge on growth of the lettuces on Planosol soil.



NC: NC Negative control, PC: positive control, BS: brewery sludge

Figure 4.8: The leave area of the lettuce grown in the Planosol soil.

The result found on Figure 4.8 the leave area of the lettuce varied in the range from 244.33 to 18cm^2. The highest leave area (244.33cm^2) was recorded in the soil amended with 10% sludge while the lowest was in the soil amended with 40% sludge.



NC: Negativecontrol, PC: positive control, BS: brewery sludge

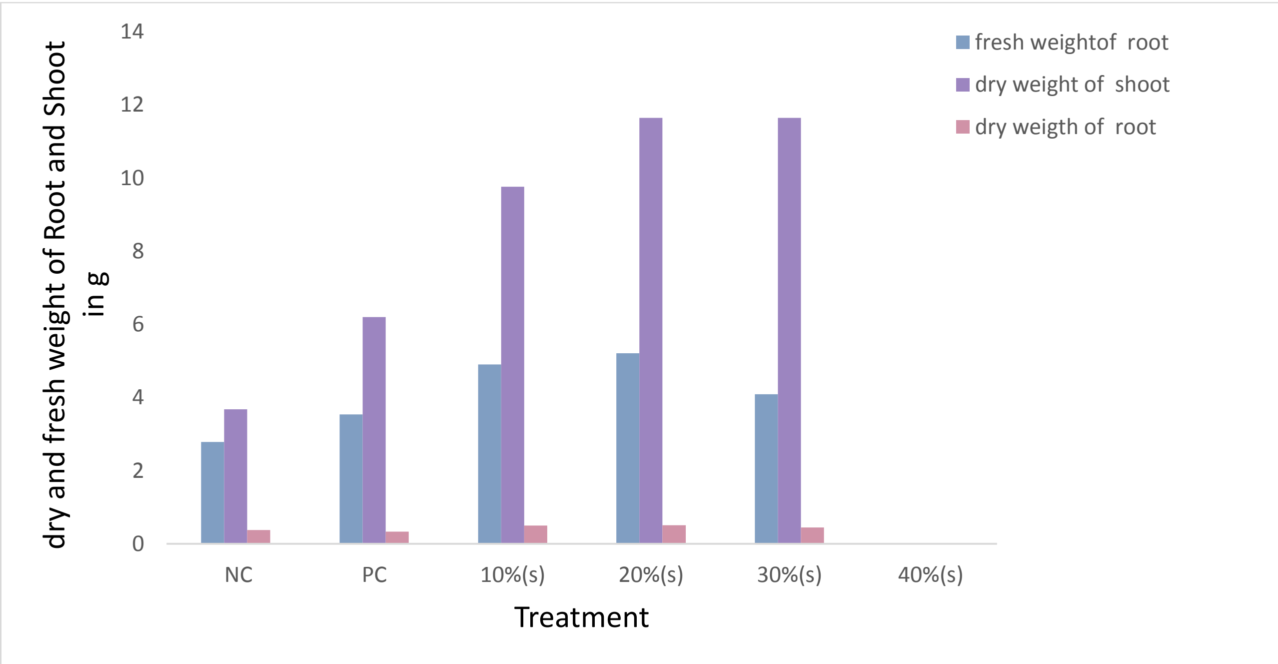
Figure 4.9 the effect of sludge on growth of the tomato in Planosol soil

Figure 4.9 shows the variation of the shoot and the root length of tomato grown in the Planosol soil amended with inorganic fertilizer and different amount of the sludge. The shoot length of tomato was varied in the range from 102.33 to 33.33cm. And the length of root was varied in the range from 33.33 to 6.67cm. The longest shoot and root length were recorded in the soil amended with 20% sludge. The lowest shoot and root length was recorded in the soil amended with 30% sludge. The analysis of variance showed that there was significant variation of shoot and root length with variation of sludge proportion used to amend the soil. ($P < 0.05$). This study also revealed that the application of sludge had a positive impact on growth of lettuce and tomatoes in Planosol soil and vertisol soil and the growth increases with increasing rate of sludge. This study result also agree with Ramya et al., (2015) the brewery waste water sludge enhanced growth with increasing proportions of brewery sludge.

4.4 The effect of sludge on fresh and dry biomass and yield of the vegetables.

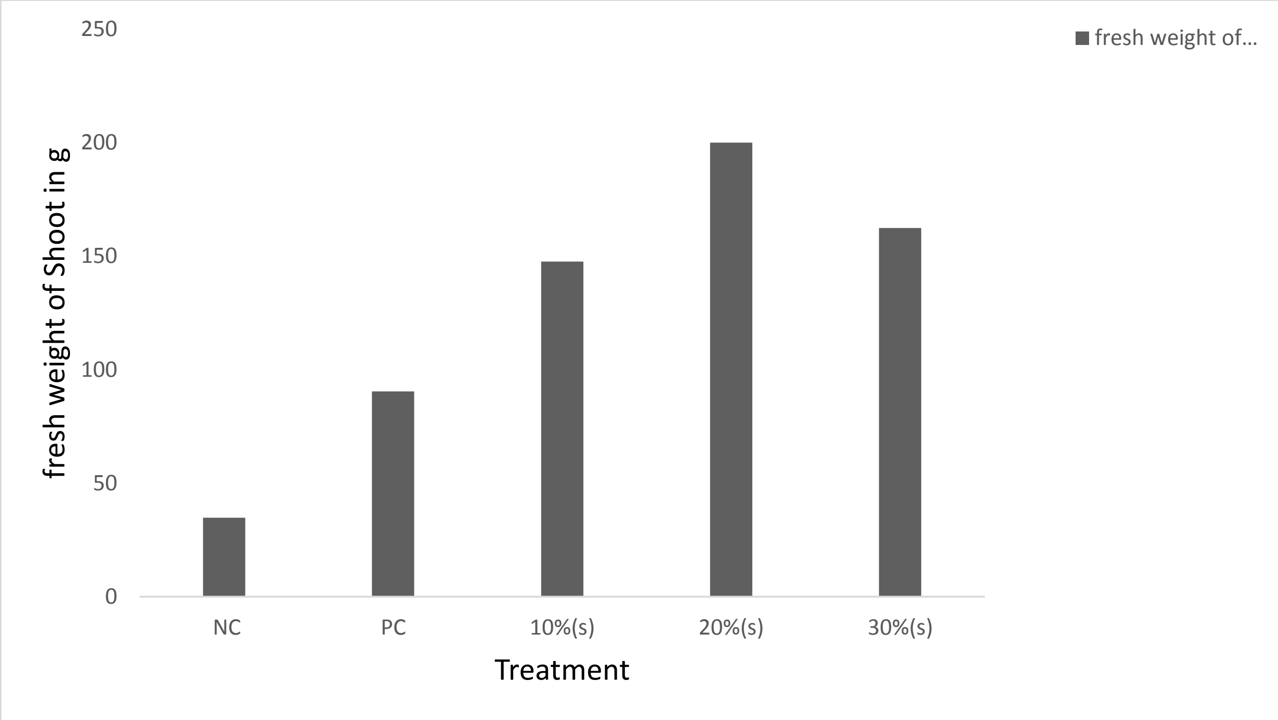
4.4.1 Fresh and dry biomass of lettuce in vertisol soil

The result found in variation of fresh and dry biomass of lettuce root and dry biomass of lettuce shoot with variation of sludge treatment was shown in figure 4.10 and the fresh weight of lettuce shoot with variation of sludge treatment shown in figure 4.11. The fresh weight of lettuce shoot found in the range from 200.12 to 34.82g. The highest fresh weight of lettuce shoot was recorded in the soil amended with 20% of sludge and the lowest was recorded in the soil without sludge and inorganic fertilizer. The dry weight of lettuce shoot found in the range from 11.64 to 3.67g. The highest dry weight of lettuce shoot was recorded in the soil amended with 20 and 30% of the sludge. While the lowest dry weight of lettuce shoot was recorded in the soil without any fertilizer (without the sludge and inorganic fertilizer). The fresh root weight of lettuce found in the range from 5.20 to 2.78g. The highest fresh root weight of lettuce was recorded in the soil amended with 20% of sludge and the lowest fresh weight of the lettuce root was in the soil without any fertilizer such as inorganic fertilizer and the sludge. Similarly, the highest dry weight of the root was recorded in the soil amended with 20% of the sludge. this study also agree with Bhaskarrao Chinthapalli*et, al.* (2015) the average values of fresh weight and dry weight biomass of faba bean and pea plants treated with organic are higher than those with inorganic and control. There was significance difference between the groups of fresh and dry weight of lettuce. But there is no significant difference between the fresh and dry weight of roots. At $P<0.05$.



NC: control, PC: positive control, BS: brewery sludge

Figure 4.10 Fresh and dry weight of lettuce shoots and roots on vertisol soil.

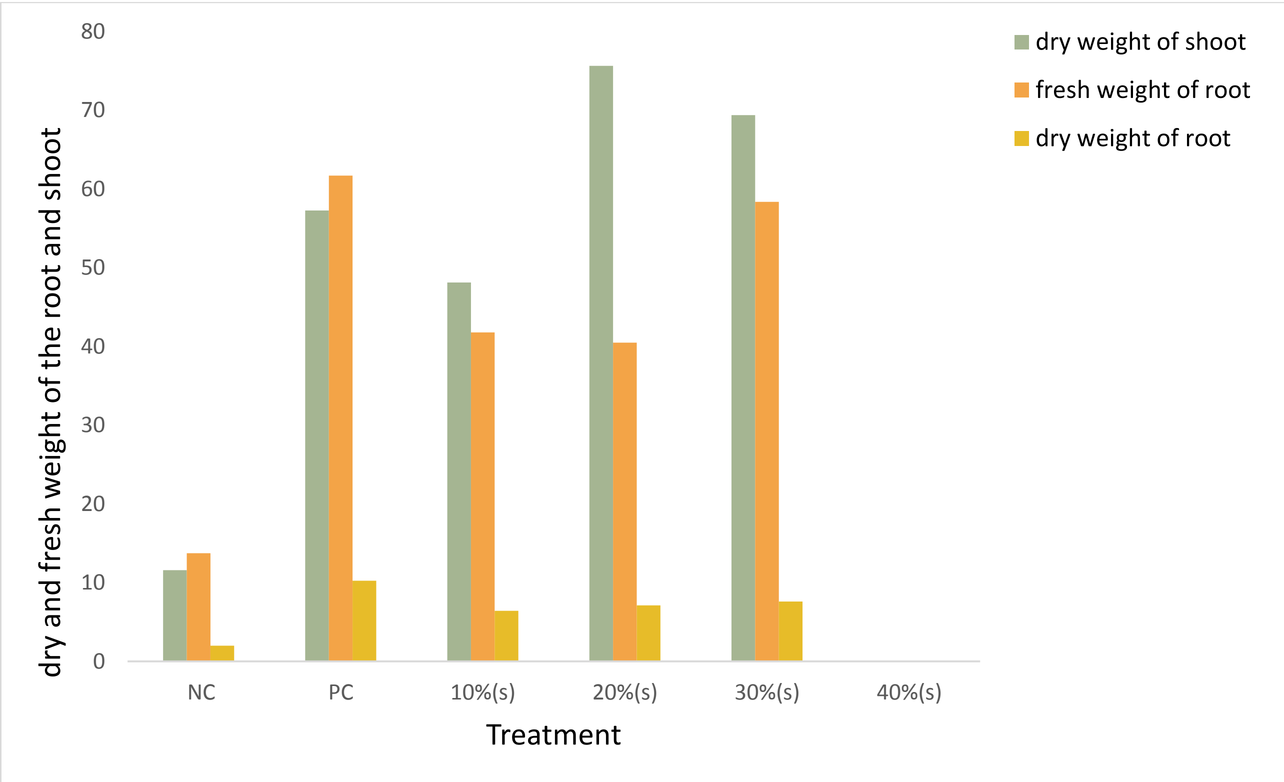


NC: control, PC: positive control, BS: brewery sludge

Figure 4.11 Fresh shoot weight of lettuce in vertisol soil

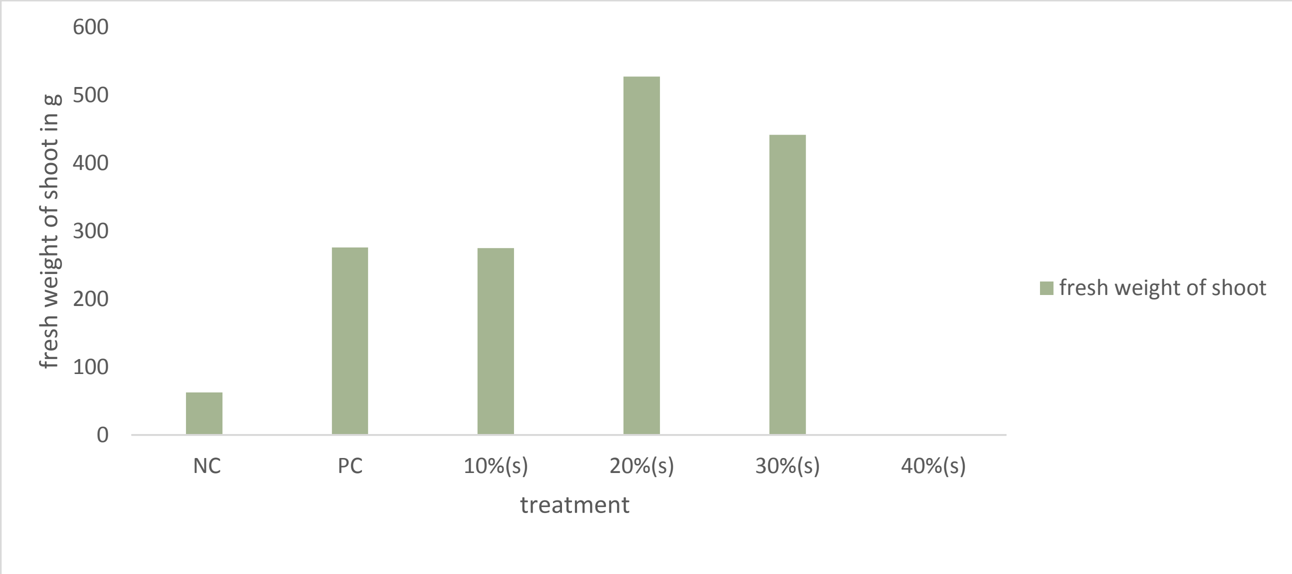
4.4.2 Fresh and dry biomass of tomato in vertisol soil

The result variation found in fresh and dry biomass of tomato root and dry weight of tomato shoot shown in figure 4.12 and the fresh weight of tomato shoot shown in figure 4.13. The fresh weight of the tomato shoot found in the range from 527. 24 To 62.48g. The highest fresh weight of tomato shoot was recorded in the soil amended with 20% of the sludge while the lowest was in the soil without the sludge and inorganic fertilizer.And the dry weight of the tomato shoot found in the range from 75.64 to 11.56g. The highest dry weight of the tomato shoot was recorded in the soil amended with 20% of the sludge while the lowest shoot weight was in the soil without any fertilizer the sludge and NPK fertilizer. This result indicates that the sludge has important nutrient to increases the shoot biomass than inorganic fertilizer. This study also agrees with Kumudha and Gomathinayagam (2007) finding. As the concentration of the sludge or organic fertilizer increases the biomass of the plant also increases and start decreasing after half amount of the sludge applied. The fresh shoot biomass was significantly varied with the variation of the sludge proportion used to amend the soil ($p < 0.05$). The fresh weight of tomato root values found in the range from 61.71 to 13.75g. The highest fresh weight of the root was recorded in the soil amended with NPK fertilizer when the lowest was recorded in the soil without the sludge and the NPK fertilizer. While the dry weight of the root result found in the range from 10.23 to 1.97g. the highest dry weight of the root was recorded in the soil amended with NPK fertilizer when the lowest was recorded in the soil without the sludge and NPK fertilizer. The dominance of the soil amended with the NPK fertilizer might be due to the sludge effect in the soil particles aggregation that was caused difficulties during harvesting the vegetables. There was no significant variation of dry and fresh weight of root with the variation of the sludge proportion.



NC: control, PC: positive control, S: brewery sludge

Figure 4.12 Fresh and dry weight of tomato shoots and roots in vertisol soil.

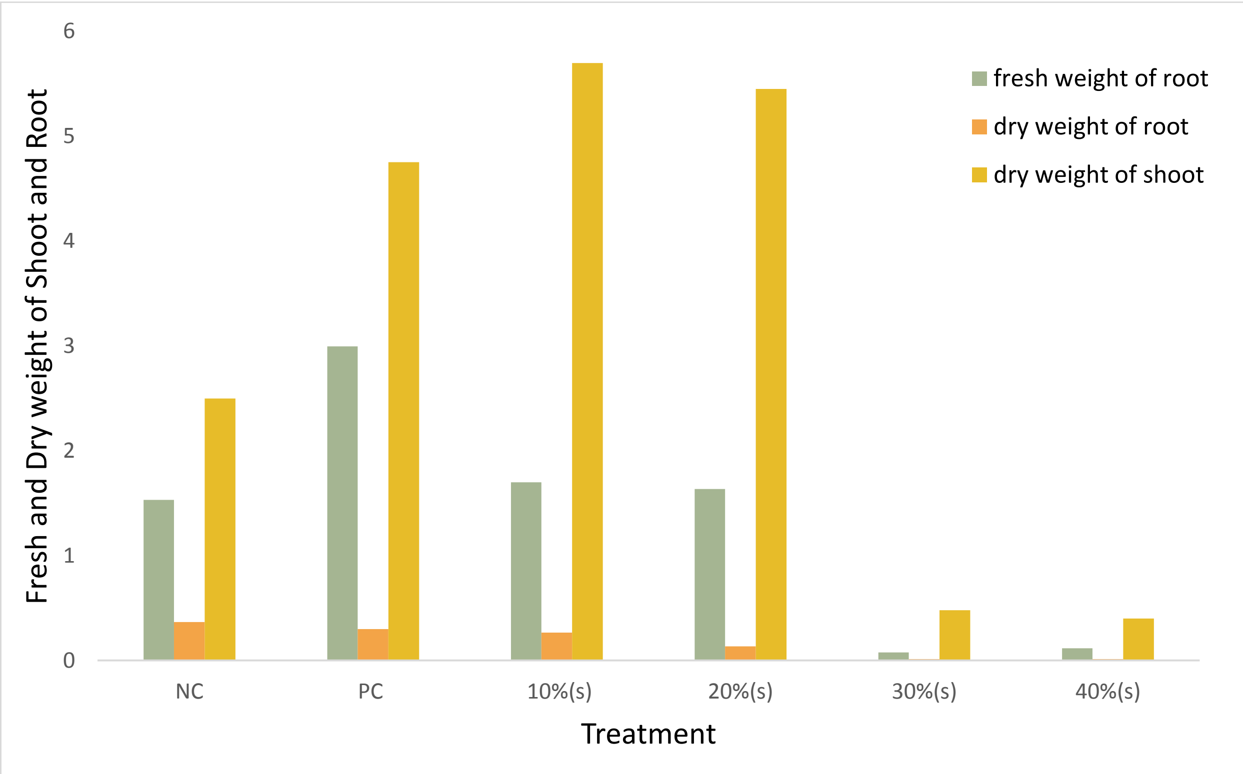


NC: control, PC: positive control, S: brewery sludge

Figure 4.13 Fresh shoot weight of tomato in vertisol soil.

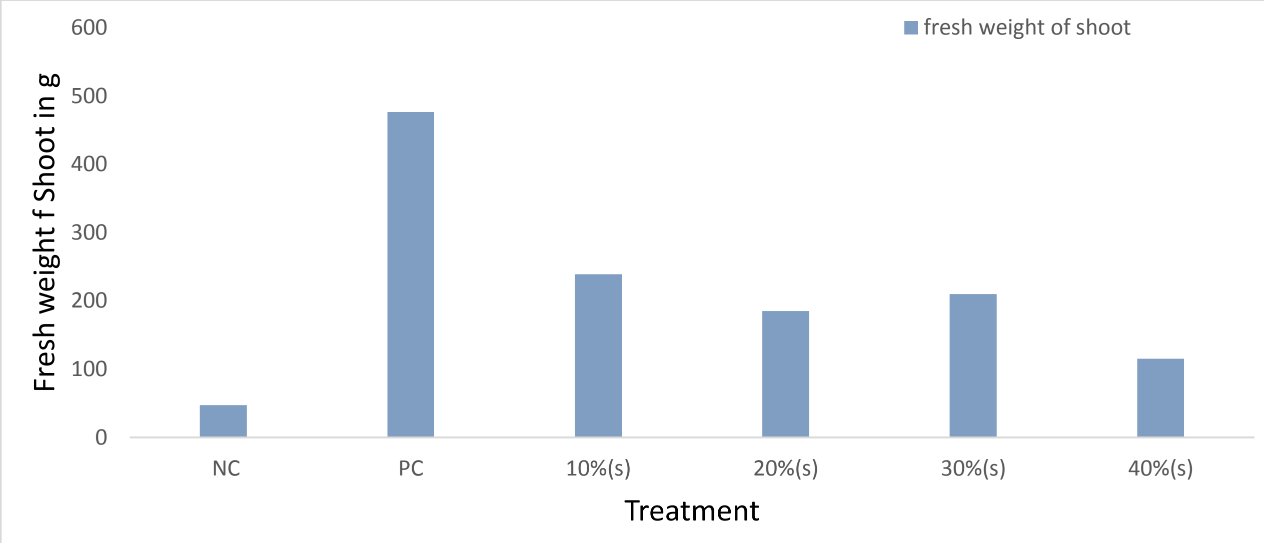
4.4.3 Fresh and dry biomass of lettuce in Planosol soil

The result variation found in fresh and dry weight of the lettuce root and dry weight of lettuces shoot were shown in figure 4.14 and the fresh shoot weight of the lettuce was shown in the figure 4.15. The fresh weight of the shoot result found in the range from 476.55 to 47.43g. The highest fresh weight of the shoot of lettuce was recorded in the soil amended with NPK fertilizer when the lowest was in the soil without the sludge and NPK fertilizer. This result might be due to the externaleffects of the sunlight at the end of the green house experiment the soil amended with the sludge were exposed to the sun light the leaves of the lettuce were started to dry that might be contributed for the decreasing in biomass of the shoot fresh weight in the soil amended with different proportion of the sludge. The dry weight of the lettuce shoot was found in the range from 5.69 to 0.4g. The highest dry weight of the shoot was recorded with soil amended with 10% of the sludge while the lowest was in the soil amended with 40% of the sludge. The analysis of variance showed that there was variation of fresh shoot weight with the variation of the sludge proportion used to amend the soil (P< 0.05 <). The fresh weight of the root result found in the range from 2.99 to 0.07g. The highest fresh weight of the root was recorded in the soil amended with NPK fertilizer when the lowest was in the soil amended with 30% of the sludge. And the dry weight of the root result found in the range from 0.36 to 0.012g. The highest dry weight of the root was recorded in the soil amended with inorganic fertilizer while the lowest was recorded in the soil amended with 30% of the sludge.



NC: control, PC: positive control, BS: brewery sludge

Figure 4.14 Fresh and dry weights of the shoot and root of lettuce on Planosol soil

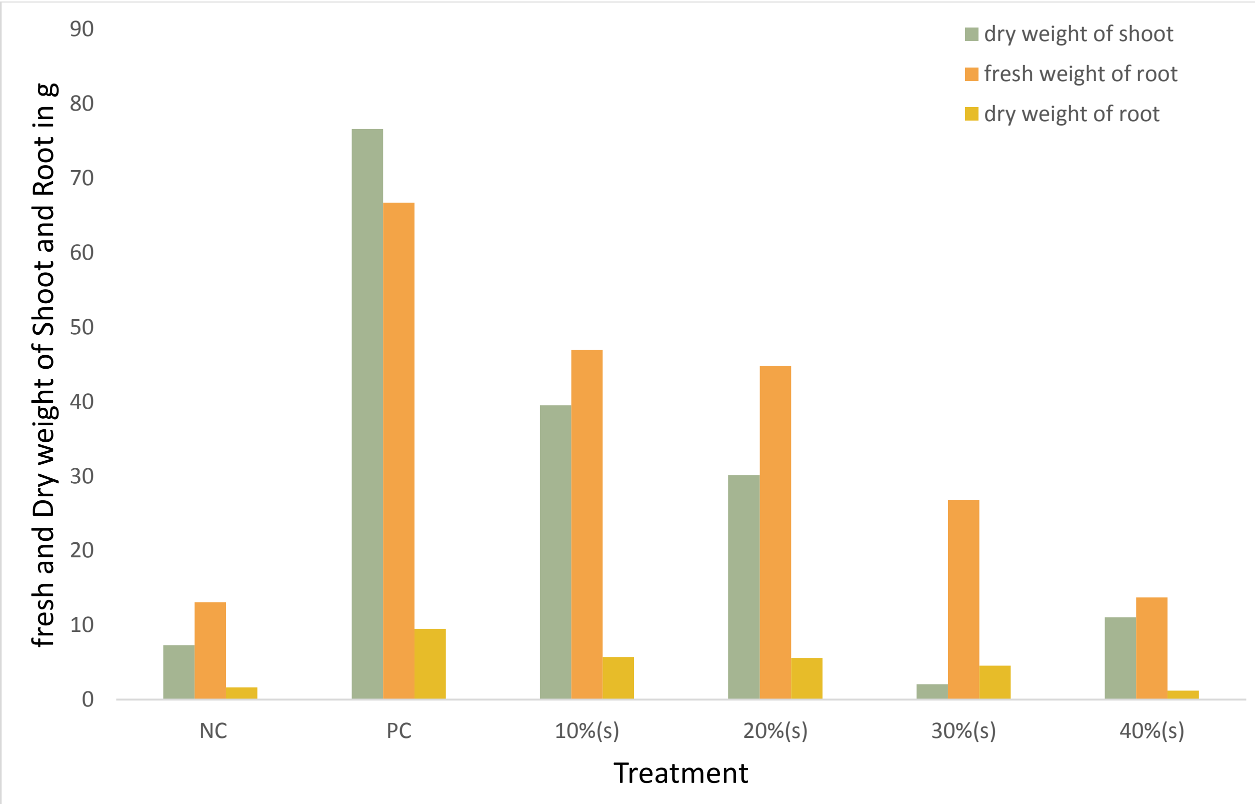


NC: control, PC: positive control, BS: brewery sludge

Figure 4.15 Fresh weight of lettuce shoot in Planosol soil.

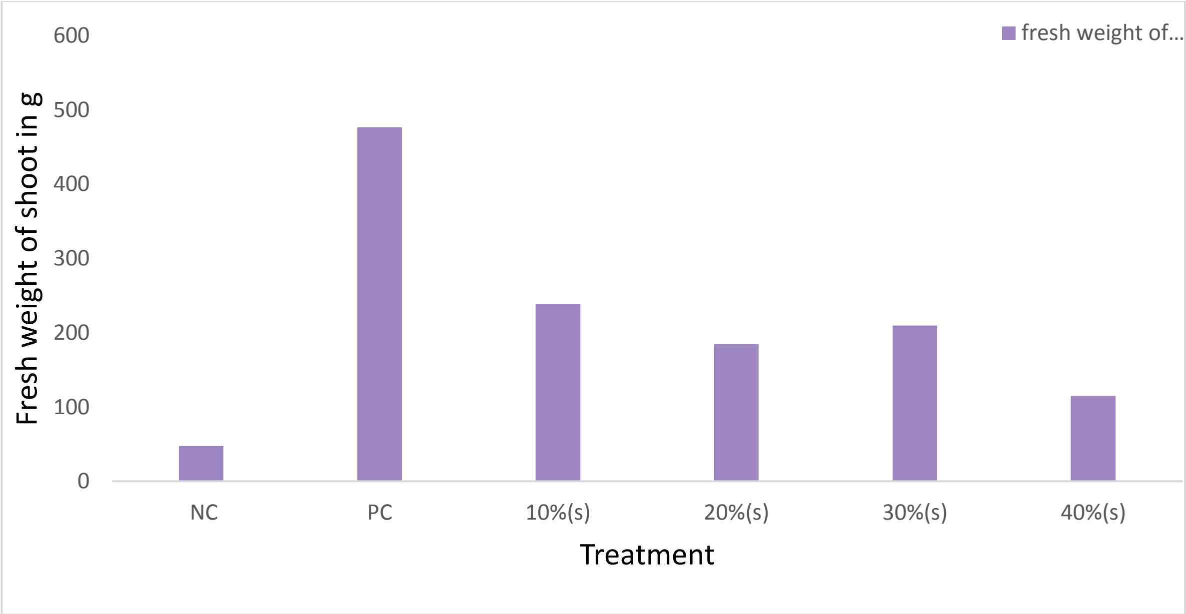
4.4.4 Fresh and dry biomass of tomato in Planosol soil

The result variation found on fresh and dry weight of tomato root and dry weight of tomato shoot were shown in figure 4.16 and the fresh weight of the tomato shoot were shown in figure 4.17. The fresh weight of the tomato shoot result was found in the range from 476.55 to 43.47g. The highest fresh weight of the tomato shoot was recorded in the soil amended with NPK fertilizer when the lowest was recorded in the soil without the sludge and the NPK fertilizer. While the dry weight of tomato shoot result found in the range from 76.62 to 2.06g. The highest dry weight of the shoot was recorded in the soil amended with NPK fertilizer while the lowest shoot weight was recorded in the soil amended with 30% of the sludge. This result indicates that the sludge was not much effective than the inorganic fertilizer in the Planosol soil. But the sludge was more effective than the soil without the sludge. The fresh weight of the tomato root result found in the range from 66.74 to 13.08g. The highest fresh weight of the tomato root was recorded in the soil amended with NPK fertilizer when the lowest was recorded in the soil without the sludge and NPK fertilizer. Similarly, the highest dry weight of root was recorded in the soil amended with NPK fertilizer which was 9.51g and the lowest was recorded in the soil amended with 40% of the sludge which was 1.22g. In general, the Planosol soil was more effective in the soil amended with inorganic fertilizer than the soil amended with the sludge, but the sludge was effective when compared with the soil without sludge.



NC: control, PC: positive control, BS: brewery sludge

Figure 4.16 Fresh and dry weight of tomatoes shoots and roots on Planosol soil.

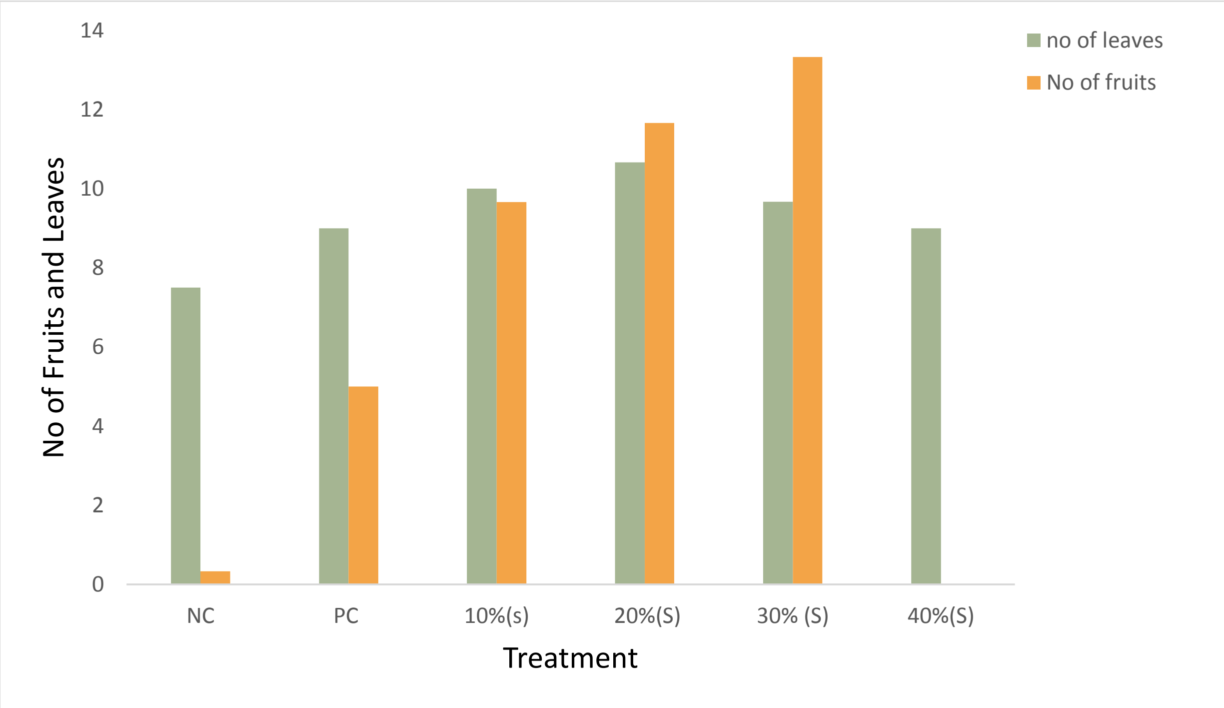


NC: control, PC: positive control, BS: brewery sludge

Figure 4.17 Fresh weight of tomato shoot in Planosol soil.

4.5. Effect of sludge on yield of vegetables in vertisol and Planosol soil

According to this study the yield of the vegetables was estimated in number of leave and number of fruit for lettuce and tomato respectively. The yield of lettuce and tomato in vertisol soil shown in figure 4.18 and the yield of lettuce and tomato in Planosol soil shown in figure 4.20. The yield of tomato in vertisol soil found in the range from 13.33 to 0.33. The highest tomato yield in vertisol soil was recorded in the soil amended with 30% of the sludge while the lowest was recorded in the soil without the sludge and inorganic fertilizer. Unlikely the yield of tomato the lettuce yield in vertisol soil found in the range from 10.66 to 7.5. The highest lettuce yield recorded in the vertisol soil was in the soil amended with 20% of sludge when the lowest was in the soil without the sludge and inorganic fertilizer. The analysis of variance showed that there was variation of the yield of tomato in vertisol soil with the variation sludge proportion used to amend the soil at ($p< 0.05$). This result also agrees with South African farmers using sewage sludge as a fertilizer amendment reported a 20% increase in the yield of cultivated maize and 40% saving on inorganic fertilizer. According to this study the application of sludge increases the yield of tomato and lettuce with increasing proportion of the sludge until 30%. In Planosol soil the yield of tomato and lettuce as illustrated on figure 4.20 the yield of lettuce was found in the range from 9 to 7. The highest yield was recorded in the soil amended with 10% of the sludge when the lowest was in the soil without sludge and inorganic fertilizer. The yield of tomato in the Planosol was found in the range from 5.33 to 1.33. the highest yield was recorded in the soil amended with NPK fertilizer and the lowest was in the soil amended with 30 and 10% of the sludge.



NC: control, PC: positive control, BS: brewery sludge

Figure 4.18 Number of the leaves of lettuces and fruit no of tomatoes on vertisol soil

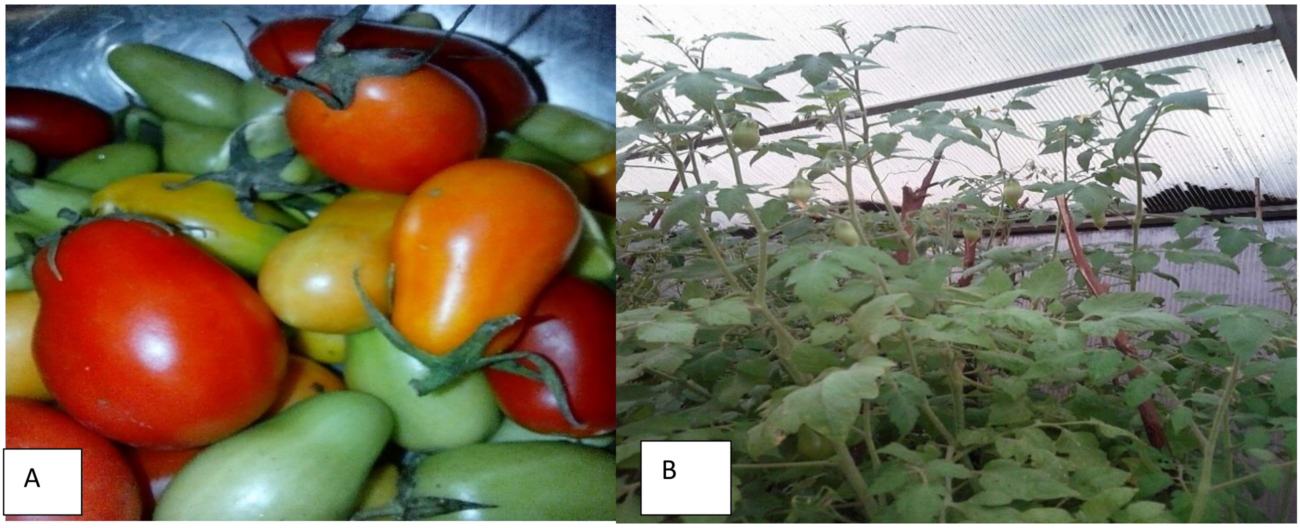
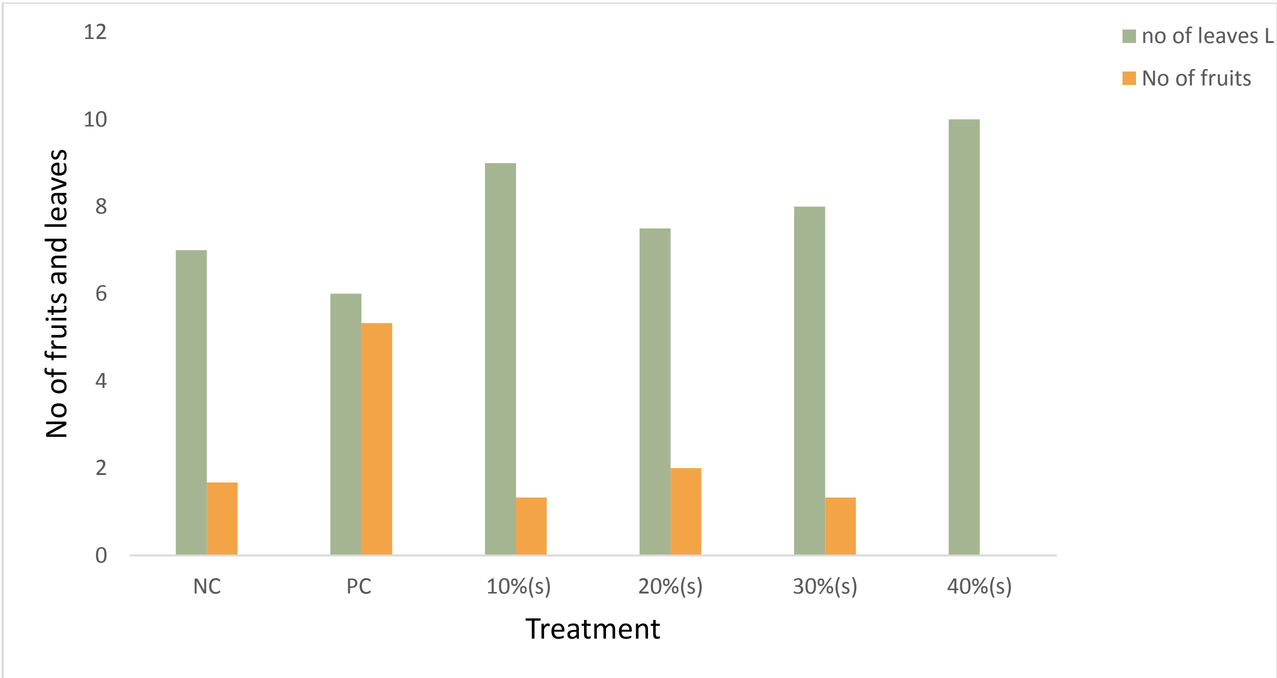


Figure 4.19"A" and "B" Represent the fruit of tomatoes before and after harvesting respectively. Picture by Alemnesh Bejiga



NC: control, PC: positive control, BS: brewery sludge

Figure 4.20 Number of leaves of lettuce and fruit number of tomatoes vegetables in Planosol soil.

4.6 The suitable soil type for application of brewery waste water sludge.

4.6.1 The suitable soil type for application of sludge in terms of seeds germination

The seeds sown on vertisol soil and Planosol soil as displayed in figure 4.1 and 4.2. The seeds germination was high in controls groups for the first 4 and 7 days for lettuce and tomato seeds respectively. But After the first week the germination on the controls group were decreased while the soil amended with the sludge accelerated. After a week 100 to 90% of the seeds of the lettuce and tomato were germinated in vertisol soil amended with the sludge when 90 to 80% of the seeds were germinated in Planosol soil amended with the sludge. This result indicates that the vertisol soil was more selective to amend the sludge than the Planosol soil.

4.6.2. The suitable soil type for application of sludge in terms of vegetables growth

4.6.2.1 The suitable soil type for application of the sludge in terms of the lettuce growth

The result variation found in growth of lettuce in the Planosol soil and vertisol soil shown in figure 4.21A and 4.21B respectively. Both soils amended with 30% of the sludge but the best growth was observed in the vertisol soil amended with 30% of the sludge. This might be due to the soil nature and the sludge in Planosol soil. The Planosol soil afteramendment of the sludge the soil forms cements that reduce aeration and water penetration.

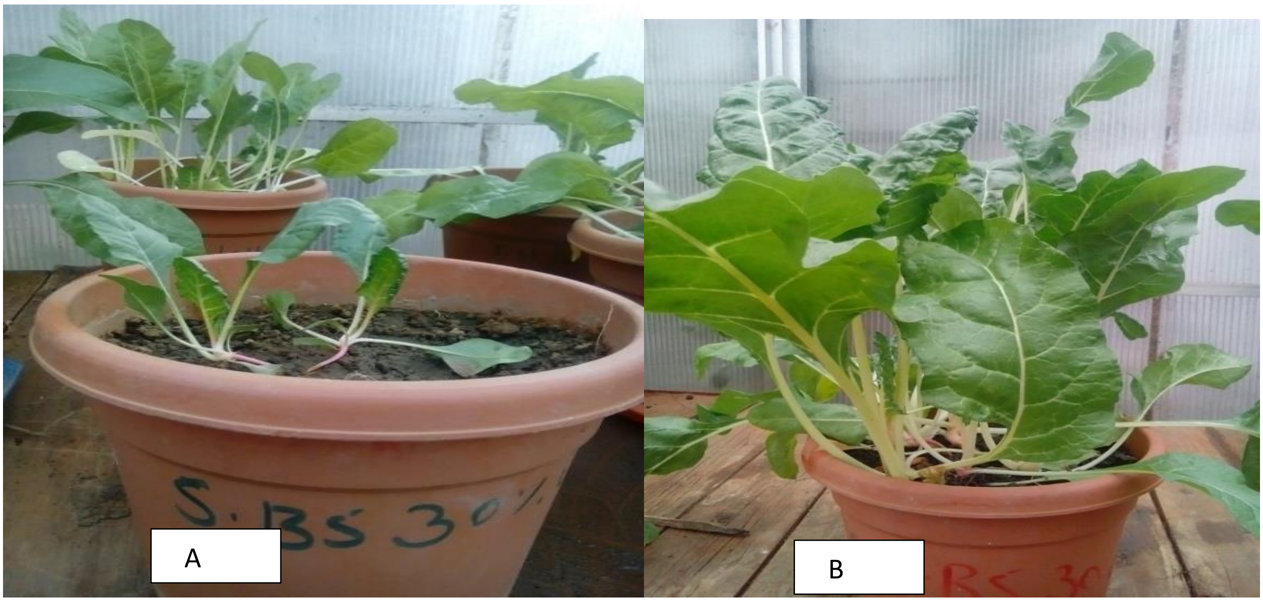
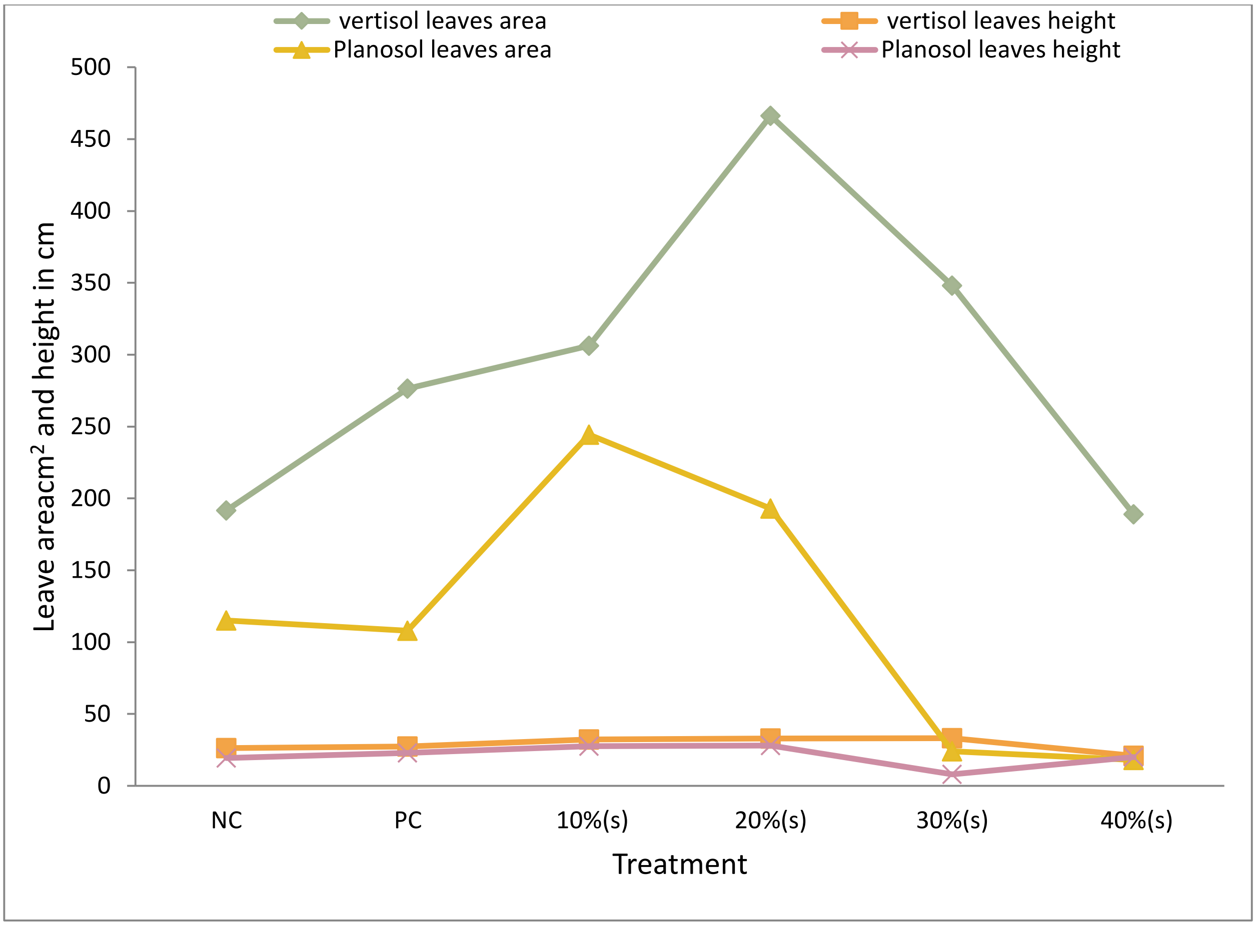


Figure 4.21 Suitable soil type for application of sludge the growths of lettuce on Planosol (a) and vertisol (b).

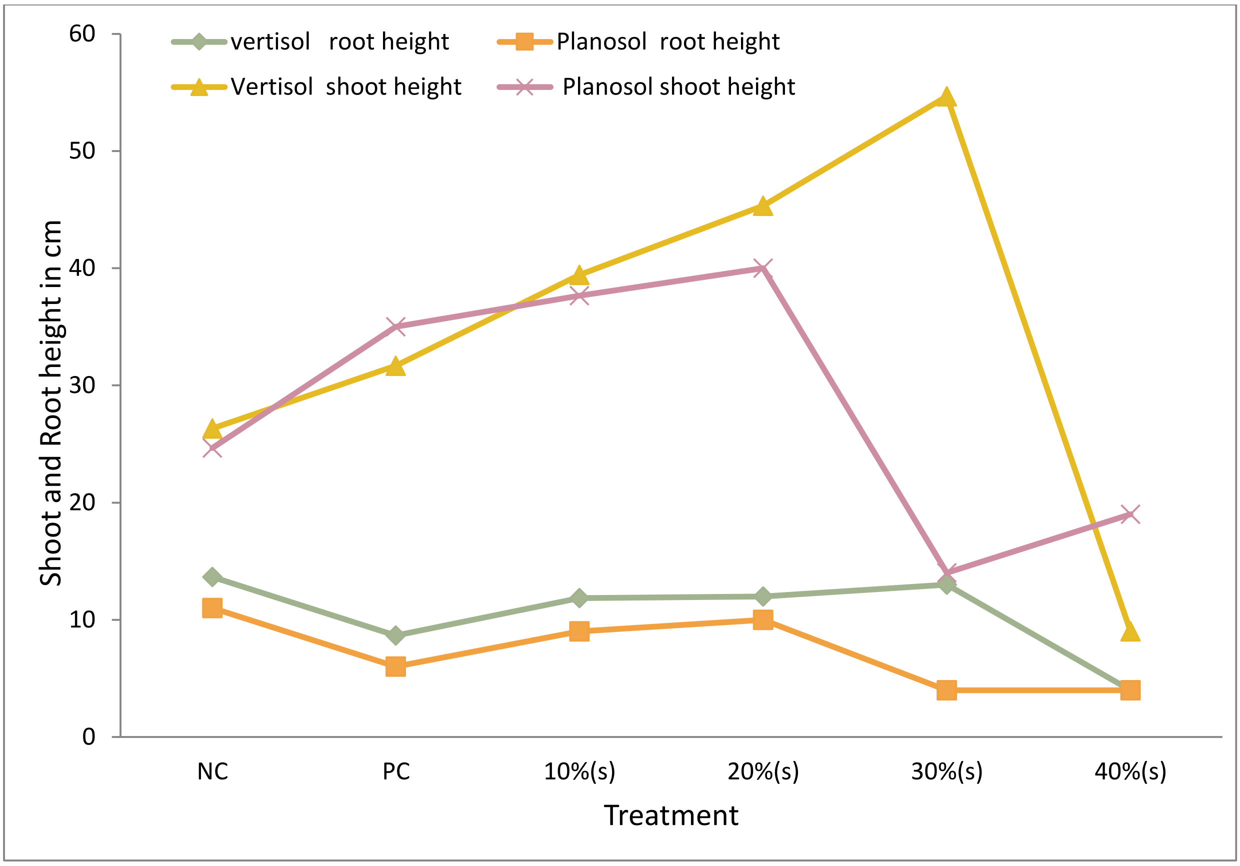
The below Figure 4.22 discusses about suitable soil for application of sludge in terms of the leaves area and leaves height of the lettuce in vertisol soil and Planosol soil. The highest leaves area in vertisol soil was 466.33cm^2 while the Planosol soil was 244.33cm^2 at treatment rate of 20% and 10% respectively. And the lowest result of leaves area was 189cm^2 in vertisol soil when the Planosol soil was18cm^2 in the soil amended with 40% of the sludge for both type of soil, On the other hand the highest leave height was 33.11cm in vertisol soil amended with 30% of the sludge when the Planosol soil highest leave height was 28cm and the lowest leave height in vertisol soil was 20cm in the soil amended with 40% of the sludge but the Planosol soil was 8cm in the soil amended with 30% of the sludge. This big gap between the soils was may be due to the nature of the soil this means the Planosol soil has sandy when this soil amended with the sludge the soil for a kind of cement that prevents water penetration and aeration.



NC: control, PC: positive control, BS: brewery sludge

Figure 4.22 Suitable soil type for amendment of the sludge in terms lettuces growth.

Figure 4.23 illustrates the shoot and root height of lettuce in Planosol and vertisol soil. The highest shoot height was 54.66cm recorded in vertisol soil amended with 30% of the sludge. While in Planosol soil highest shoot height was 40cm in the soil amended with 20%.and 40% of the sludge. The Planosol soil shown same increments in shoot and root height when compared with the negative control and Positive control but the Planosol soil compared with vertisol soil the vertisol soil was the most effective in root and shoot height of the lettuce.

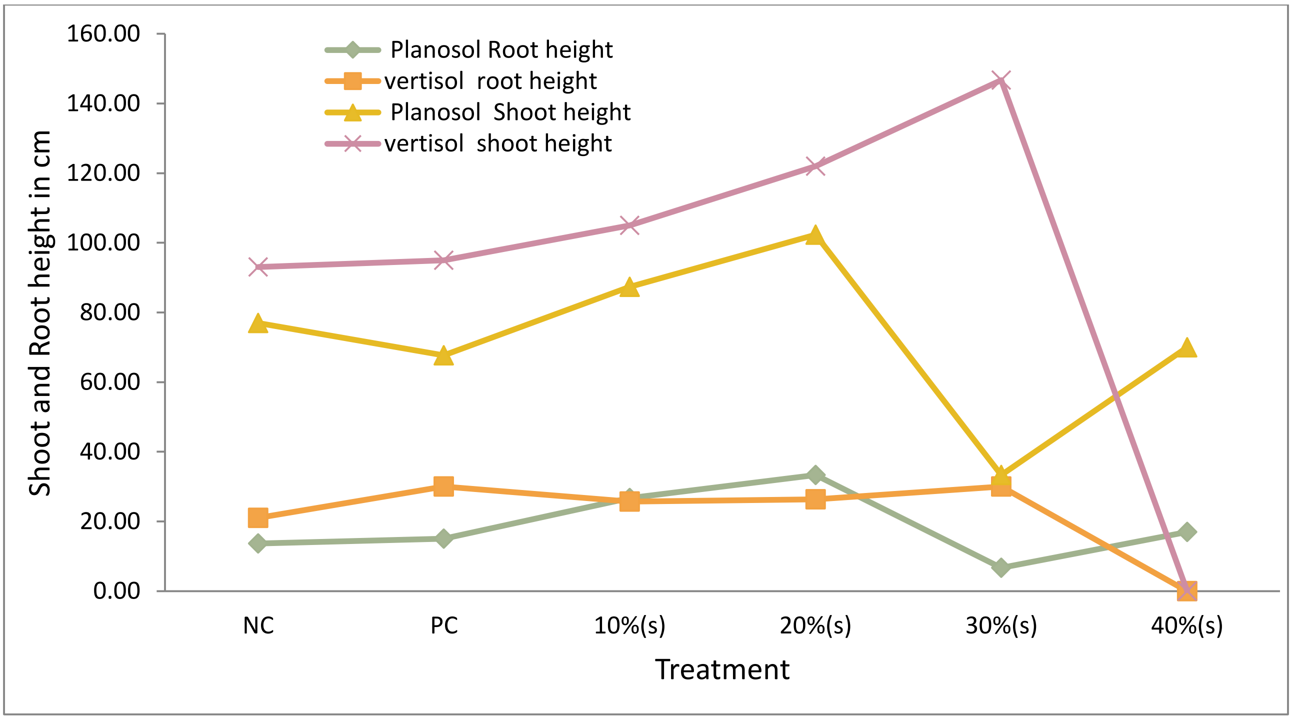


NC: control, PC: positive control, BS: brewery sludge

Figure 4.23 Suitable soil types in terms of shoots and root height of lettuce

4.6.2.2 The suitable soil type for application of the sludge in terms of the tomato growth.

The Figure 4.24 below illustrates that the suitable soil types for amendment of sludge in terms of shoot height and root height of tomato. The highest shoot height in vertisol soil was 146.66cm while the Planosol soil was 102.33cm in the soil amended with 30 and 20% of the sludge respectively. And the highest root height was 30cm in vertisol soil and in Planosol soil was 33.33cm in the soil amended with 30 and 20% of the sludge respectively. The dominance of Planosol soil in root length might be due technical error during separation of the root from the soil. The sandiness of the Planosol soil may contribute for the easily removal of the root from the soil but in vertisol soil removal of the root part from the soil was difficult. According to the result of this study the suitable soil type was the vertisol soil in all aspects the reason for its suitability was the first one was the nature of the soil and the initial nutrient content of the soil. Even if the effect of the sludge was less in Planosol soil but it is better than the soil amended with inorganic fertilizer and soil without the sludge and inorganic fertilizer.This suggests that brewery sludge is the positive input to increase the yield of less fertile and semi-arid soils.



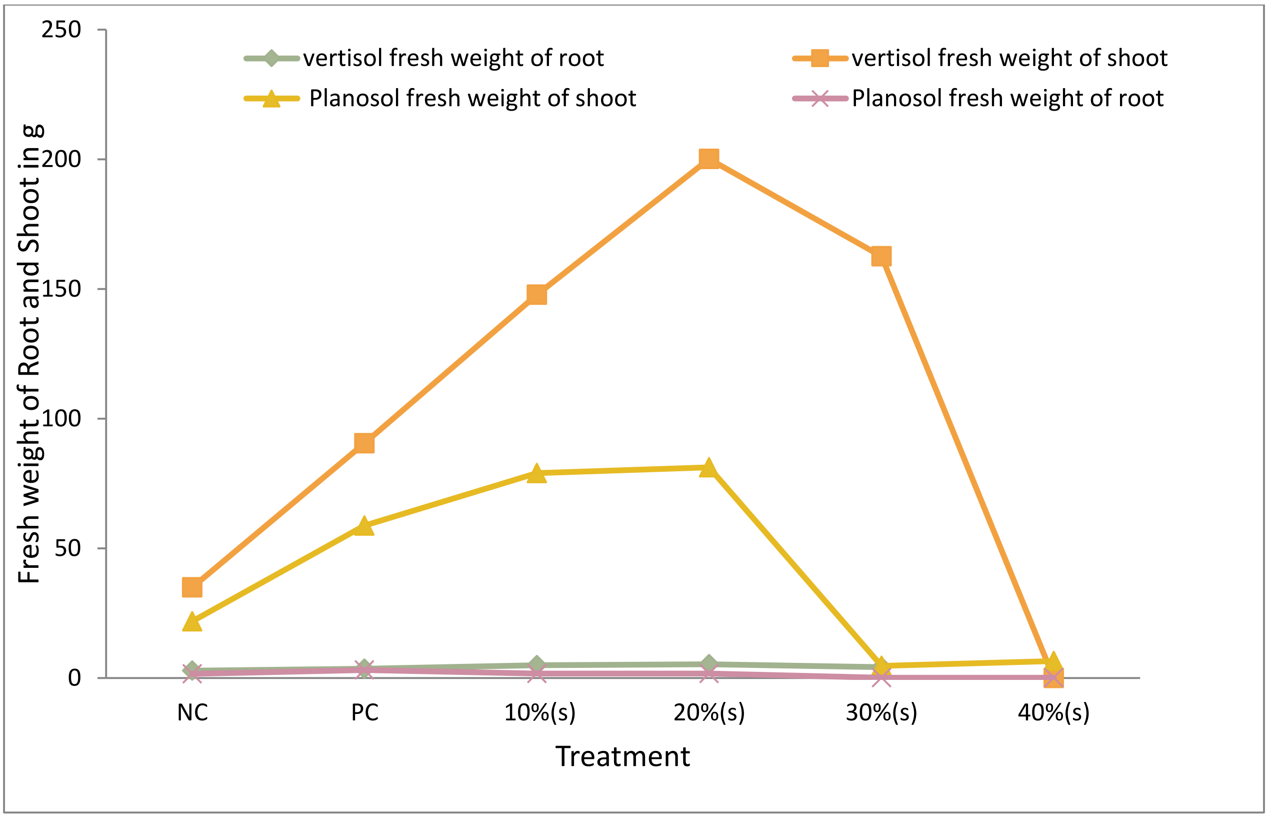
NC: control, PC: positive control, BS: brewery sludge

Figure 4.24 Suitable soil type for application of sludge in terms of shoots and root height of tomato.

4.7. The suitable soil types for application of sludge in terms of vegetables biomass.

4.7.1 The suitable soil types for application of sludge in terms of fresh biomasslettuce.

The below figure 4.25 illustrates the suitable soil types in terms of the lettuces fresh weight. The highest fresh shoot weight of lettuce was 200g in the vertisol soil amended with20% of the sludge. While the highest fresh weight of the lettuce in Planosol soil was 81.19g in the soil amended with 20% of the sludge. The vertisol soil fresh biomass was greater than the Planosol soil by more than half. The highest fresh root weight of the lettuce was 1.69g in the Planosol soil amended with 10% of the sludge while the lowest was 0.07g in the soil amended with the 30% of the sludge. The highest fresh root weight in vertisol soil was 5.20g in the soil amended with 20% of the sludge. When the lowest was 4.09g in the soil amended with 30% of the sludge.

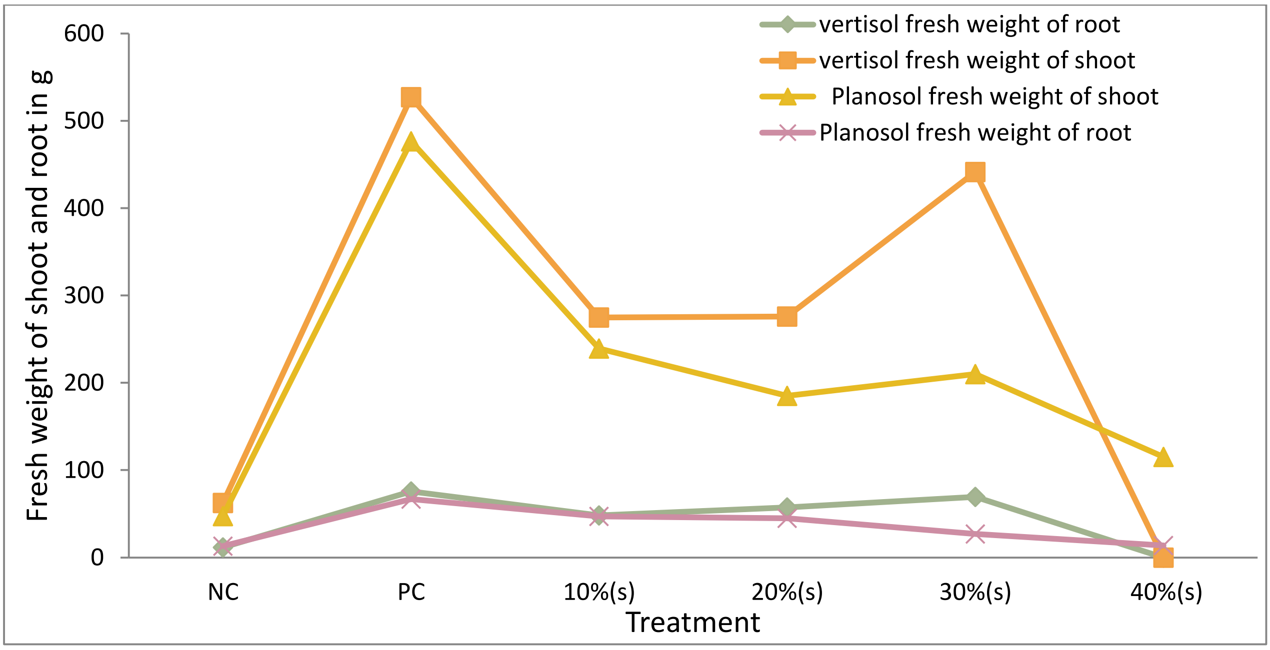


NC: control, PC: positive control, BS: brewery sludge

Figure 4.25 Suitable soil types for application of sludge in terms of lettuce biomass.

4.7.2 The suitable soil types for application of sludge in terms of fresh tomato biomass.

Figure 4.26 shows the variation of the tomato fresh weight of shoot grown in vertisol and Planosol soil amended with inorganic fertilizer and different amount of the sludge. The highest tomato fresh weight of the shoot was 441.47g in the vertisol soil amended with 30% of the sludge. The Planosol soil was 239.11g in the soil amended with 10% of the sludge. While the lowest fresh weight of the shoot was 274.64g and 115.09 in the soil amended with 10% and 40% of the sludge in vertisol and Planosol soil respectively. The highest tomato fresh weight of the root was 69.35g in the vertisol soil amended with 30% of the sludge. While the Planosol soil was 46.93g in the soil amended with 10% of the sludge. The lowest tomato fresh weight of the root was 13.71g in the Planosol soil amended with 40% of the sludge when the vertisol soil was 0g in the soil amended with 40% of the sludge. Similarly, the dominant soil type was the vertisol soil amended with the sludge only the Planosol soil was dominate in fresh weight of the root.

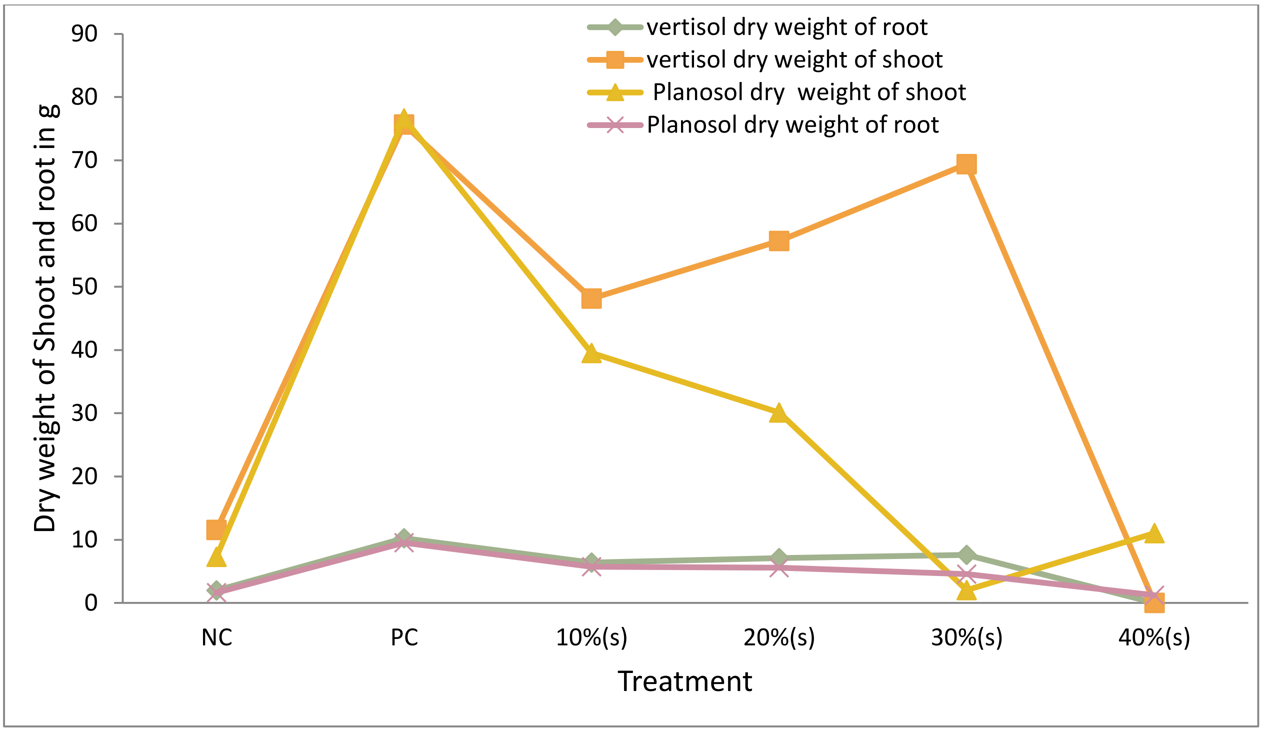


NC: Negative control, PC: positive control, BS: brewery sludge

Figure 4.26 Suitable soil types for application of sludge in terms of tomatoes biomass.

4.7.3 The suitable soil types for application of sludge in terms of dry biomass of tomato.

Figure 4.27 shown the variation of the tomato dry weight of shoot grown in vertisol and Planosol soil amended with inorganic fertilizer and different amount of the sludge. The highest dry weight of the tomato shoot was 69.38g while the lowest was 0g in vertisol soil amended with 30and 40% of the sludge respectively. The highest Planosol soil dry weight of the tomato shoot was 39.51 g and the lowest was 2.06g in the soil amended with 10% of the sludge and in the soil amended with 30% of the sludge respectively.in Planosol soil the highest biomass was recorded with the soil amended with 10% than the soil amended with other proportion of the sludge and but if the dry biomass of the tomato was compared with the soil without any fertilizer and the soil amended with different proportion of the sludge the soil amended with the sludge recorded the highest dry biomass. The highest dry weight of the root of tomato was 39.42g in vertisol soil amended with 10% of the sludge while the lowest was 2.02g in the soil amended with 40% of the sludge. In Planosol soil the highest dry weight of the root was 5.71g while the lowest dry weight of the root of tomato was 1.22g in the Planosol soil amended with 10% of the sludge and in the soil amended with 40% of the sludge. The all above results shows that the vertisol soil was more suitable for the amendment of the sludge. This result also agrees with the finding of EPA (2000) Brewery sludge, as organic manure, should be regarded as valuable commodity especially in warm arid and semi-arid regions particularly where soil fertility depletion and soil degradation are most serious problems.

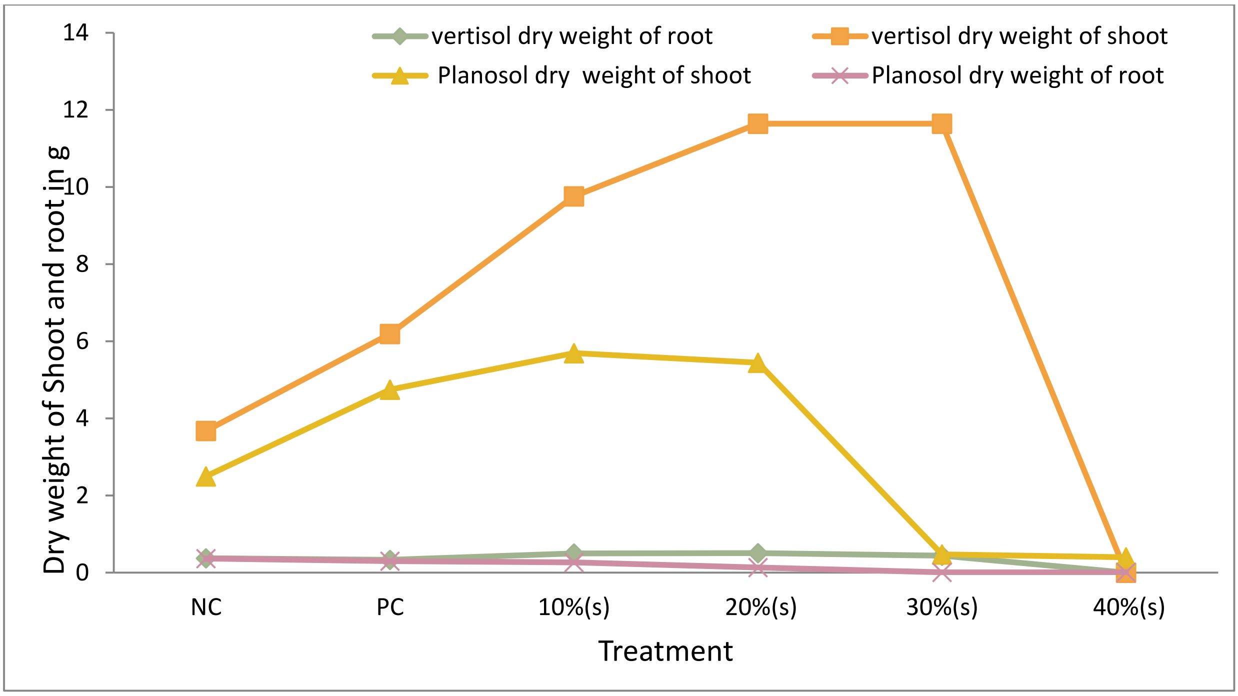


NC: control, PC: positive control, BS: brewery sludge

Figure 4.27 Suitable soil types for application of the sludge in terms of dry weight of the tomatoes.

4.7.4 The suitable soil types for application of sludge in terms of dry biomass of lettuce.

Figure 4.28 shown the variation of the dry weight of the lettuce with the variation of the soil type. The highest dry weight of the shoot of lettuce in vertisol soil was 11.64g in the soil amended with 20 and 30% of the sludge. While the lowest was 0g in the soil amended with 40% of the sludge. The highest Planosol soil dry weight of the shoot was 5.69g in the soil amended with 10% of the sludge while the lowest was 0.4g in the soil amended with 40% of the sludge. The highest dry weight of the root of the lettuce was 0.51g in vertisol soil amended with 20% of the sludge. While the lowest was 0g in the soil amended with 40% of the sludge. The highest dry weight of the root of the lettuce grown in Planosol soil was 0.26g in the soil amended with 10% of the sludge while the lowest was 0.01g in the soil amended with 30% of the sludge.



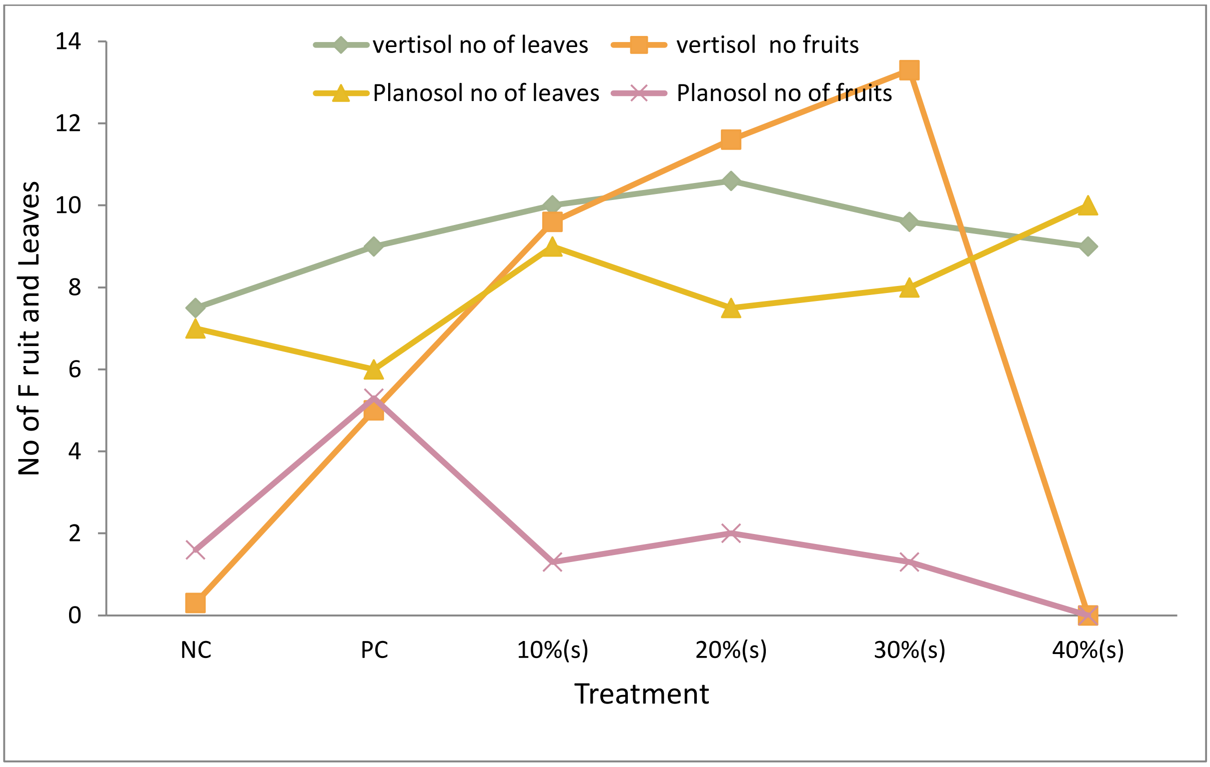
NC: control, PC: positive control, BS: brewery sludge

Figure 4.28 Suitable soil types for application of BWWS in terms of dry biomass of the lettuce.

But on lettuce the dominant soil type was the vertisol soil shown the highest dry weight of the shoot and the root. There is significance difference between the dry weight of shoots of lettuce and tomato while no significance difference between the dry weights of root at $P < 0.05$

4.8 The suitable soil types for application of sludge in terms of yield.

As illustrated on the below figure 4.29 the yield of tomato and lettuce in vertisol and Planosol soil. Thehighest yield of tomato was 13.3 fruits in the vertisol soil amended with 30% of the sludge while the lowest yield of tomato was 9.6 in the soil in the soil amended with 10% of the sludge. The Planosol soil highest yield of tomato was 2 in the soil amended with 20% of the sludge. Whilethe lowest was 1.3 fruits of tomato in the Planosol soil amended with 10 and 30% of the sludge. From this study the yield of tomato was high in vertisol soil than the Planosol soil. The highest yield of the lettuce was 10.6 leaves in vertisol soil amended with 20% of the sludge. While the lowest was 9 leaves in the soil amended with 40% of the sludge. The highest yield of the lettuce in Planosol soil was 10 leaves in the soil amended with 40% of the sludge while the lowest was 7.7 leaves in the soil amended with 20% of the sludge.



NC: control, PC: positive control, BS: brewery sludge

Figure 4.29 Types of suitable soil for application of sludge in terms of yields.

4.9 The effect of the sludge on selected physical-chemical properties of the soils.

4.9.1The effect of the sludge on pH of the soils

The PH value of the Planosol soil and vertisol soil before amendment of the BWWS was 8.50±0.01 and 7.64±0.07, respectively as displayed on table 4.2. The pH of the Planosol and vertisol soil of positive and negative control shows slightly decreases in soil pH and the soil amended with BWWS also show decreasing in soil pH with increasing rate of BWWS application. in vertisol soil from (7.64±0.07 to 5.89±0.12 and 7.02±0.02 of lettuce and tomato). And in Planosol soil from (8.50±0.01 to 6.73 ±0.07and 6.11±.01 of tomato and lettuce) This result also agree with Epstein et al. (1976, Moreno et al. 1997 and Nielson *et al*. 1998, result. as the pH of the soil decreases with increasing rate of the brewery waste water sludge.

Table 4.2 Effects of the sludge on pH of the soils

NC: control, PC: positive control, BS: brewery sludge VS (vertisol soil), PS (Planosol soil), L (lettuce), T (tomato),

Treatment	VS. L pH	VS.T pH	PS.L pH	PS.T pH
Before	7.64±0.07	7.64±0.07	8.50±0.01	8.50±0.01
NC	7.78±0.08	7.67±0.02	7.82±0.05	7.65±0.02
PC	7.69±0.02	7.58±0.00	6.97±0.01	7.55±0.04
BS 10%	7.55±0.09	7.5±0.07	7.2±0.01	7.80±0.06
BS 20%	7.46±0.02	7.54±0.04	6.94±0.01	7.76±0.06
BS 30%	6.52±0.08	7.31±0.03	6.17±0.04	6.95±0.04
BS 40%	5.89±0.12	7.02±0.02	6.11±.01	6.73±0.07

4.9.2 The effect of sludge on total Nitrogen (TN) of soils

The total nitrogen content of the soil before amendment of the sludge and after vegetables cultivated are shown in table 4.3. The total nitrogen content before the amendment of the sludge was 0.16% in vertisol soil and 0.10% in Planosol soil.

According to Tisdall andOades (1982) soil with TN < 0.05 is categorized as very low in nitrogen content, in the range from 0.05 to 0.15%. The TN in the range from 0.15 to 0.25 is categorized as medium while from 0.25 to 0.50% is categorized as high and soil with $> 0.50\%$ is very high. The total nitrogen in the Planosol soil was considered as low while the total nitrogen in the vertisol soil was medium.

The total nitrogen content was shown improvement in the both soils type amended with the sludge as well as inorganic fertilizer when compared with the soil without amendment (table 4.5). In comparison with the soil amended with inorganic fertilizer, the soil amended with the sludge shown improvement in content of total of total nitrogen. The nitrogen content was increased in the soils with increasing rate of the sludge application, the highest was observed in the soil amended with 40% of the sludge. Ramya *et al* (2015) was also found similar results with the application of brewery wastewater sludge for different types of soil the TN increases with increasing rate of the sludge. The total nitrogen in the soil amended with 20% of the sludge was lower than others treatment this was might be due to the vegetables grown in 20% of sludge was more cultivated than others this resulted with observation of more Nitrogen and decrease nitrogen content in the soil. But in 40% of the sludge the vegetables in same treatment did not grown at all and only a few grown. In comparison with the soil planted with lettuce, the total nitrogen content showed significant reduction in tomato planted soil with similar rate of sludge application ($p < 0.05$). The variation of nitrogen content between the soils planted with different vegetables might be attributed to the variation of nitrogen uptake rate. Tomato might take more than lettuce.

Table 4.3 Effects of sludge on total Nitrogen in the soils.

TN (total nitrogen), VS (vertisol soil), PS (Planosol soil), L (lettuce), T (tomato), NC: control, PC: positive control, BS: brewery sludge

Treatment	VS. L (TN)%	VS.T(TN) %	PS.L (TN)%	PS.T (TN)%
Before	0.16	0.16	0.10	0.10
NC	0.14	0.07	0.13	0.05
PC	0.17	0.15	0.15	0.11
BS 10%	0.20	0.18	0.13	0.12
BS 20%	0.24	0.15	0.15	0.10
BS 30%	0.21	0.17	0.28	0.12
BS 40%	0.30	0.19	0.30	0.12

4.9.3 The effect of the sludge on Available phosphorous (AP)ofthe soils.

The Available phosphorous content in the soil before amendment of sludge and after vegetables cultivated are shown in the table 4.4. The Available phosphorous content before the amendment of the sludge was 19.72 ppm in vertisol soil and 10.72ppm in Planosol soil. The Available phosphorous content in the soil amended with the sludge increased in the negative control when decreased in positive control and decreased in the soil amended with the sludge.this result agrees with Ramya *et al*. (2015) with different soil types, with increasing rate of brewery waste water sludge application the content of available Phosphorous decrease with increased application rate of sludge. But in 20% of the sludge amendment the Available phosphorous was increased. These results agree with the conclusions reported by Ahmadi et.al. (2010) who reported that application of high N rates decreased the Phosphorous in spinach plants. Phosphorus uptake is in the form of H_2Po4 and HPO_4anions. Nitrate increment might have a competitive effect with Phosphate anions and thus cause the inhibition of both anions absorption.

Table 4.4 Effects of sludge on available phosphorous (AP) in the soils
A.P; (available phosphorus). VS (vertisol soil), PS (Planosol soil), L (lettuce), T (tomato), and NC: control, PC: positive control, BS: brewery sludge

Treatment	VS. L (AP)ppm	VS.T(AP)ppm	PS.L (AP)ppm	PS.T (AP)ppm
Before	19.72	19.72	10.72	10.72
NC	21.24	7.15	9.09	1.38
PC	13.49	26.87	23.98	3.98
BS 10%	21.04	19.25	276.26	30.22
BS 20%	396.26	127.10	175.45	19.32
BS 30%	29.67	25.67	134.84	127
BS 40%	121.25	22.32	126.01	168.86

4.9.4 The effect of the sludge on Available potassium (AK) of the soils.

The available potassium content in the soil before amendment of sludge and after vegetables cultivated are shown in the table 4.5. TheAvailable potassium before the amendment with the sludge was 180mg/kg in vertisol soil and 310mg/kg in Planosol soil. The result indicated that the Planosol soil had high available potassium content than vertisol soil. The application of the sludge had a positive effect in the available potassium content of the soil. It increased the amount of available potassium in the soil when compared with negative and positive controls. The highest available potassium was obtained in the soil amended with 40% of the sludge which was 460mg/kg. This might be due to the less vegetable growth in the soil amended with 40% of the sludge.

Table 4.5 Effects of sludge on available potassium (AK) in the soils.
A.K (available potassium), VS (vertisol soil), PS (Planosol soil), L (lettuce), and T (tomato NC: control, PC: positive control, BS: brewery sludge

Treatment	VS. L (AK)mg/kg	VS.T(AK)mg/kg	PS.L (AK)mg/kg	PS.T (AK)mg/kg
Before	180	180	310	310
NC	55	105	245	275
PC	125	25	255	145
BS 10%	65	25	250	235
BS 20%	55	35	275	215
BS 30%	95	70	300	175
BS 40%	235	90	460	350

4.9.5 The effect of the sludge on organic carbon (OC) of soils.

The organic carbon content in the soils was shown in table 4.6.the organic carbon before amendment of the sludge was 1.8%in vertisol soil where as it was 0.98 in Planosol soil. This result indicated that vertisol soil has high organic content than Planosol soil. This might be due to the high organic carbon retention capacity of the vertisol soil in comparison with Planosol soil. The application of the sludge had positive effect in the organic carbon content of the soils.it increases the amount of OC in the soil when compared with the negative and positive controls. The highest OC content was 2.09% in the soil amended with 40% of the sludge.

Table 4.6 effect of the sludge on organic carbon content in the soils.

OC (organic carbon),VS (vertisol soil), PS (Planosol soil), L (lettuce), T (tomato), NC: control, PC: positive control, BS: brewery sludge

Treatment	VS. L (OC)%	VS.T(OC)%	PS.L (OC)%	PS.T (OC)%
Before	1.80	1.80	0.98	0.99
NC	0.98	0.45	0.71	0.49
PC	1.00	0.40	0.65	0.39
BS 10%	1.53	1.01	0.97	0.75
BS 20%	1.90	0.99	0.99	0.88
BS 30%	1.95	1.54	0.97	0.94
BS 40%	2.09	1.78	1.00	1.05

5 CONCLUSIONS AND RECOMMENDATION

5.1 CONCLUSIONS

The BWWS contained nutrient that is important for growth of plants such as N, P, K and OC and has negligible amount of heavy metal. The heavy metals which limit the sludge to use as fertilizers is not found in BWWS. Might contributed for BWWS is suitable for agricultural purposes. The BWWS has a positive effect on growth of two vegetables on Planosol soil and vertisol soil. The lettuce on sandy and vertisol soil shown the great performance on growth and yield when compared with tomato. The lettuce shoot, root, leaves height and leaves area were high on soil amended with BWWS than the positive and negative controls. And the same was true for tomato on both soil types. According to this study the two-soil type amended with BWWS recorded the highest yield than the positive and negative control for the two kinds of vegetables. The highest yield was recorded at treatment rate of 20% of BWWS and the lowest yield were recorded on negative control. The vegetables growth parameters and the yield increase with increasing rate of BWWS. The application of BWWS in soil shown the positive effect on content of nutrients. This means the soil physic-chemical properties such as the N, K and C content increases with increasing rate of BWWS. While the P decreases. This macronutrient is very important for plants growth and soil fertility so BWWS can be used for agricultural purpose to increases the yield and biomass of the plants and also to increases the fertility. From this study we concluded Brewery wastewater sludge has fertilizing potential and it could be used as soil amendment for increasing productivity of Ethiopian highland soils.

5.2 RECOMMENDATION

- This study was conducted only in two soil types and two vegetables further studies needed to be done in other plant and soil types.
- During this research the duration of homogenization of BWWS with the soil was only for two weeks if the homogenization period is extended.
- This experiment was carried out in green house have to done on field
- Further study is needed to determine the exact amount of the sludge have to be added to rich the maximum nutrient content of the soil.

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Appendix

The leave area, root, shoot and leave height of lettuce on vertisol soil

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
leaves area	Between Groups	137740.771	5	27548.154	6.796	.005
	Within Groups	40534.667	10	4053.467		
	Total	178275.437	15			
root height	Between Groups	115.438	5	23.088	3.981	.030
	Within Groups	58.000	10	5.800		
	Total	173.438	15			
shoot height	Between Groups	2412.271	5	482.454	27.003	.000
	Within Groups	178.667	10	17.867		
	Total	2590.937	15			
leaves height	Between Groups	239.604	5	47.921	2.380	.114
	Within Groups	201.333	10	20.133		
	Total	440.938	15			

The shoot and root height of tomatoes on vertisol soil two table below.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Root height	Between Groups	718.267	4	179.567	2.575	.103
	Within Groups	697.333	10	69.733		
	Total	1415.600	14			
Shoot height	Between Groups	22214.000	4	5553.500	8.189	.003
	Within Groups	6781.333	10	678.133		
	Total	28995.333	14			

The root, shoot and no of fruit of tomato on sandy soil.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Root height	Between Groups	718.267	4	179.567	2.575	.103
	Within Groups	697.333	10	69.733		
	Total	1415.600	14			
Shoot height	Between Groups	22214.000	4	5553.500	8.189	.003
	Within Groups	6781.333	10	678.133		
	Total	28995.333	14			
No of fruits	Between Groups	424.000	4	106.000	5.911	.010
	Within Groups	179.333	10	17.933		
	Total	603.333	14			

ANOV Asandy soil root shoot leave height and leave area of lettuce

		Sum of Squares	Df	Mean Square	F	Sig.
root height	Between Groups	186.923	5	37.385	10.065	.004
	Within Groups	26.000	7	3.714		
	Total	212.923	12			
shoot height	Between Groups	1614.308	5	322.862	2.678	.116
	Within Groups	844.000	7	120.571		
	Total	2458.308	12			
leaves height	Between Groups	894.923	5	178.985	2.955	.095
	Within Groups	424.000	7	60.571		
	Total	1318.923	12			
leaves area	Between Groups	97673.026	5	19534.605	6.206	.016
	Within Groups	22032.667	7	3147.524		
	Total	119705.692	12			

Root and shoot height of tomatoes on sandy soil.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Root height	Between Groups	853.333	5	170.667	3.060	.069
	Within Groups	502.000	9	55.778		
	Total	1355.333	14			
Shoot height	Between Groups	2617.733	5	523.547	.575	.718
	Within Groups	8188.000	9	909.778		
	Total	10805.733	14			

Dry and fresh biomass of lettuce in vertisol soil

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
fresh w biomass shoot	Between Groups	65198.863	5	13039.773	7.438	.004
	Within Groups	17531.536	10	1753.154		
	Total	82730.399	15			
dry w biomass root	Between Groups	.241	5	.048	1.554	.258
	Within Groups	.311	10	.031		
	Total	.552	15			
dry w biomass shoot	Between Groups	218.426	5	43.685	6.911	.005
	Within Groups	63.213	10	6.321		
	Total	281.639	15			
fresh w biomass root	Between Groups	26.944	5	5.389	2.247	.129
	Within Groups	23.986	10	2.399		
	Total	50.930	15			

Biomass of lettuce on sandy soil

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
DRY W SHOOT	Between Groups	53.370	5	10.674	3.357	.073
	Within Groups	22.256	7	3.179		
	Total	75.626	12			
F W SHOOT	Between Groups	12551.384	5	2510.277	5.720	.020
	Within Groups	3072.140	7	438.877		
	Total	15623.523	12			
DRY W ROOT	Between Groups	.197	5	.039	1.959	.202
	Within Groups	.141	7	.020		
	Total	.337	12			
F W ROOTS	Between Groups	3.989	5	.798	.677	.655
	Within Groups	8.256	7	1.179		
	Total	12.245	12			