EFFECT OF SALT INDUSTRIES BYPRODUCT AS A LIQUID FERTILIZER ON GROWTH AND YIELD OF LETTUCE IN SOILLESS CULTURE

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BY

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CERTIFICATE

*This is to certify that the thesis entitled **"Effect of salt industries byproduct as a liquid fertilizer on growth and yield of lettuce in soilless culture"** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE**, embodies the result of a piece of bona fide research work carried out by **Md. Shariful Islam**, Registration No. **09-03629** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

***Dated:** June, 2015*

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LIST OF ABBREVIATED TERMS

SIB	=	Salt Industries Byproduct
DAT	=	Days After Transplanting
DAS	=	Days After Sowing
EC	=	Electrical Conductivity
LA	=	Leaf Area
LWD	=	Leaf Dry Weight
RDW	=	Root Dry Weight
LMR	=	Leaf Mass Ratio
RWR	=	Root Weight Ratio
RGR	=	Relative Growth Rate
NAR	=	Net Assimilation Rate

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ABSTRACT

An experiment was conducted at the Central Laboratory in Sher-e-Bangla Agricultural University, Dhaka; during September 2014 to March 2015 to identify the effect of salt industries byproduct on growth and yield of lettuce in soilless culture. Three nutrient solutions were considered as treatments, viz. T_1 – ½ Rahman and Inden (2012) + 0 ml of salt industries byproduct (SIB), T_2 – ½ Rahman and Inden (2012) + 0.5 ml of SIB, T_3 – ½ Rahman and Inden (2012) + 0.75 ml of SIB. The experiment was conducted in a completely randomized design (CRD). Salt industries byproduct showed significant variation in most of the parameters. The highest plant height (19.53 cm) was recorded from T_1 while the lowest plant height (15.61 cm) was found in T_3. Number of leaves per plant was maximum (10.61) from T_1 whereas minimum (8.80) was recorded T_3. Higher leaf breadth (11.36 cm) was recorded from T_1 which was statistically similar to T_2 and lower (9.56 cm) was from T_3, higher leaf length (17.61 cm) was found in T_1 and lower (13.90 cm) was in $T_{3.}$ Maximum fresh weight of lettuce (48.81g/plant) was recorded from T_1 which was statistically similar to T_2 and minimum (27.94 g/plant) was in T_1. In case of ascorbic acid content, the maximum amount of ascorbic acid content (157.61 mg/100g fresh weight) was recorded from T_3 and the minimum (127.41 mg/100g fresh weight of lettuce) was in T_1. In case of β-carotene content, the maximum amount of β-carotene content (3207 µg/100g fresh weight of lettuce) was recorded from T_3 and the minimum (3100 µg/100g fresh weight) was in $T_{1.}$ Similar trend was also found in other growth analytical parameters (viz. leaf area, leaf area ratio, leaf mass ratio, root weight ratio, net assimilation ratio and relative growth rate), which was the best from T_1 but LA, RGR and NAR were statistically similar to that of T_2. Meanwhile all the physiological parameters were lowest in T_3.Therefore, T_2 (½ Rahman and Inden (2012) + 0.5 ml of SIB) can be used to get higher amount of ascorbic acid and β-carotene content with moderate yield.

CHAPTER I

INTRODUCTION

Hydroponic crop production has significantly increased worldwide in recent years worldwide which is the growing of plants in a soilless medium, or an aquatic based environment. Hydroponic growing uses mineral nutrient solutions to feed the plants in water, without soil. Soilless culture is the modern cultivation system of plants that use either inert organic or inorganic substrate through nutrient solution nourishment. PossSIBly it is the most intensive culture system utilizing all the resources efficiently for maximizing yield of crops and the most intense form of agricultural enterprises for commercial production of greenhouse vegetables. Several studies suggested soilless culture in the greenhouse as an alternative to traditional field production for high-value vegetable crops. This protected cultivation system can control the growing environment through management of weather factors, amount and composition of nutrient solution and also the growing medium. Therefore, quality of horticultural crops grown through soilless culture improves significantly compared to conventional soil culture. This artificial growing system provides plants with mechanical water and mineral nutrient for higher growth and development. Over the years, hydroponics has been used sporadically throughout the world as a commercial means of growing both food and ornamental plants. Now a days, it has also been used as the standard methodology for plant biological researches in different disciplines, as it allows a more efficient use of water and fertilizers, as well as a better control of climate and pest factors. Furthermore, hydroponic production increases crop quality and productivity, which results in higher competitiveness and economic incomes. Hydroponics culture is becoming increasingly popular all over the world. It is highly productive, conservative of water and land, and protective of the environment. Hydroponics has proved to be an excellent alternative crop production system (Savvas, 2003). The cultivation of vegetable crops and the achievement of high yields and high quality are posSIBle with hydroponics even in saline or acidic soils, or non-arable soils with poor structure, which represent a major proportion of cultivable land throughout the world. A further advantage of hydroponics is the precise control of plant nutrition. Furthermore, the preparation of the soil is avoided in hydroponics, thereby increasing the potential length of cultivation time, which is an effective means of increasing the total yield in greenhouses. The reason, imposing a switch over to hydroponics is increasingly associated with environmental policies as well. A hydroponic system enables a considerable reduction of fertilizer application and a drastic restriction or even a complete elimination of nutrient leaching from greenhouses to the environment (Avidan, 2000). It provides an instant as well as long-term solution to the problem of inability of a household to produce its own vegetables under urban settings. Hydroponics offers a means of control over soil-borne diseases and pests, which is especially desirable in the tropics, where infestations are major concern. Despite the considerable advantages of commercial hydroponics, there are still some disadvantages, which restrict the further expansion of soilless cultivation. Nowadays, the main disadvantages of hydroponics, relative to conventional open-field agriculture, are the high costs of capital and energy inputs, and the high degree of management skills required for successful production. Lettuce is regarded as a winter crop and optimal nutrient solution concentration, water and nutrient supply in hydroponics depend on the environmental conditions (Fallovo *et al.,* 2009). Leafy lettuce grown in soilless condition require careful management of fertilizer concentrations, therefore, optimization of the nutrient solution concentration is critical for the farmer in order to maximize yield and quality. Fallovo *et al.* (2009a) mentioned that the total nutrient concentration of the solution used in soilless culture is one of the most important aspects for successful vegetable production. It is also an important tool to determine the nutrient requirements of crops in order to avoid probable toxicities due to over fertilization and also to monitor the growth and the productivity under different climatic conditions (Samarakoon *et al.,* 2006). Furthermore, the soilless vegetables growers have the opportunity to reduce plant nutrition in proper way that do not negatively affect yield of the crops. Lettuce is an important vegetable commodity and in demand by the local markets throughout the year. This popularity has led to an increase in lettuce production and consumption in urban areas, since it has become popular as a vegetable salad (Maboko and Du Plooy, 2008). Lettuce is normally consumed raw and has a high nutrient value, being rich in calcium, iron and vitamin A. It is a good source of vitamins and a popular food for weight conscious consumers because of its low kilo joule content (Niederwieser, 2001; Maboko, 2007). A soilless technique refers to the method of applying nutrient solution to the plant roots. However, an optimal nutrient solution composition for vegetable crops in floating system under non-circulating methods also depends on environmental conditions (Fallovo *et al.,* 2009b).Higher temperature is also known to cause faster crop growth which enhance tip burn incidence, and when this happens it normally affect quality. The absorption of N ions (NH_4^+& NO_3^-) was increased at high root and air temperatures, while Gosselin and Trudel (1983) reported that an increase in root temperature from 12^0C to 24^oC increased P. K, Ca and Mg content of lettuce plant. The total nutrient concentration of the nutrient solution used in soilless culture is one of the most important aspects for successful vegetable production. Too high levels of nutrients induce osmotic stress, ion toxicity and nutrient imbalance, while too low levels generally lead to nutrient deficiencies (Fallovo *et al.,* 2009). Although there is a lot of research being done on nutrient concentration levels of lettuce in hydroponic system in the world but, there is very little information on research done on the nutrient solution concentrations in our country

Considering the above mentioned facts, the present research work was aimed to study with the following objectives:

a) To find the effect of industries byproduct as a liquid fertilizer in lettuce.

b) To identify the suitable dose of industries byproduct as a liquid fertilizer in hydroponic system.

CHAPTER II
REVIEW OF LITERATURE

Some of the research findings related to the effect of nutrient solution on physiological growth and yield in hydroponic lettuce so far have been reviewed here.

Cometti *et al.* (2013) reported that the temperature of the nutrient solution influenced the behaviour of lettuce changing the electrical conductivity (EC). They found that the increased in EC did not reduce lettuce productivity when the maximum temperature of the nutrient solution was limited at 26^{o}C. They also found that cooling of the nutrient solution provided greater accumulation of biomass and higher water content in plants, increasing the productivity of hydroponic lettuce in the tropics.

Dyśko *et al.* (2008) studied that in the root zone this element can be found as PO_4^{3-},HPO_4^{2-} and $H_2PO_4^{-}$ ions; the last two ions are the main forms of P taken by plants. On inert substrates, the largest amount of P available in a nutrient solution is presented when its pH is slightly acidic (pH 5). In alkaline and highly acidic solutions the concentration of P decreases in a significant way.

Tyson *et al.* (2007) conducted a study to determine the nitrification rate response in a perlite trickling biofilter (root growth medium) exposed to hydroponic nutrient solution, varying NO_3^{-} concentrations and two pH levels (6.5 and 8.5), founded that nitrification was significantly impacted by water pH. The increased ammonia oxidation rate (1.75) compared to nitrite oxidation rate (1.3) at pH 8.5 resulted in accumulation of NO_2^{-} to levels near those harmful to plants. The potential for increased levels of un-ionized ammonia, which reduced plant nutrient uptake from micronutrient precipitation, are additional problems associated with pH 8.5. Phosphorus is an element which occurs in forms that are strongly dependent on environment pH.

Trejo-Téllez *et al.* (2007) reported that with the exception of carbon and oxygen, which are supplied from the atmosphere, the essential elements are obtained from the growth medium. Other elements such as sodium, silicon, vanadium, selenium, cobalt, aluminium and iodine among others, are considered beneficial because some of them can stimulate the growth, or can compensate the toxic effects of other elements, or may replace essential nutrients in a less specific role. The most basic nutrient solutions consider in its composition only nitrogen, phosphorus, potassium, calcium, magnesium and sulphur and they are supplemented with micronutrients. The nutrient composition determines electrical conductivity and osmotic potential of the solution.

Samarakoon *et al.* (2006) reported that toxicities could occur in nutrient solutions over time, as solution gets concentrated due to rapid water absorption. Therefore, estimation of individual nutrient requirements in different growth stages is needed for the replacement of the nutrient solutions during the growth period. Leaf number of lettuce was not significantly affected by the treatments, since it did not either increase or decrease with increasing nutrient solution concentration.

Samarakoon *et. al.* (2006) produced leafy lettuce in stationary (trough) culture of hydroponics successfully under tropical greenhouse conditions (38.5^{o}C). A solution concentration of 0.5 g/L of Albert's solution (having an EC of l.4 dS/m) with renewal at 2 weeks intervals could be identified as the best fertigation strategy under hot and humid conditions. Increasing solution concentrations above that level upto 2 dS/m increased the plant uptake of N, P, K and Ca but, without a significant increase in leaf growth and yield.

Dufour and Guérin (2005) reported that when a nutrient solution is applied continuously, plants can uptake ions at very low concentrations. So, it has been reported than a high proportion of the nutrients are not used by plants or their uptake does not impact the production. It was determined that in anthurium, 60% of nutrients are lost in the leachate. Andriolo *et al.* (2005) found the results whereby leaf number was not affected by salinity levels. Fresh mass decreased with increasing nutrient solution concentration but there was no significant difference between the treatments. This decreases meant that there was a decline in yield of lettuce during the spring season.

Andriolo *et al.* (2005) reported that there was no significant difference on root dry mass among treatments because it did not show any specific tendency of either increasing or decreasing with increasing nutrient solution concentration. However, there was contrasting results between fresh mass and leaf dry mass whereby fresh mass was decreasing with an increase in nutrient concentration while leaf dry mass was increasing with increasing nutrient concentration. This could be attrSIButed to the fact that plants grown at 1 mS/cm had more water content whereas plants grown a higher EC level (4 mS/cm) had less water content but more dry matter content. This indicate that there was very little nutrients (nutrient deficiency) in the lower EC (1 mS/cm) while high salt content resulted in low chlorophyll content in the higher EC levels (4 mS/cm). Nitrogen significantly increased with increasing nutrient solution concentration. Phosphorus is good for root development but there was conflicting relationship between the P content in the leaves and the dry root mass which could not be explained. Calcium (Ca) decreased with increasing the EC level while magnesium (Mg) remained constant, but both were slightly lower than the recommended range. However, potassium (K) was below the recommended range although it did not affect lettuce quality/taste.

Kang and Van Iersel (2004) reported that high concentrated nutrient solutions lead to excessive nutrient uptake and therefore toxic effects may be expected. Conversely, there are evidences of positive effects of high concentrations of nutrient solution. In salvia, the increase of Hoagland concentration at 200% caused that plants flowered 8 days previous to the plants at low concentrations, increasing total dry weight and leaf area.

Timmons *et al.* (2002) reported that iron, copper, zinc, boron, and manganese, become unavailable at pH higher than 6.5 in nutrient solution of Hydroponic system.

Voogt (2002) studied that in closed systems of hydroponic nutrient solution, the loss of nutrients from the root environment is brought to a minimum.

Voogt (2002) indicates that the nutrient solution composition must reflect the uptake ratios of individual elements by the crop and as the demand between species differs, the basic composition of a nutrient solution is specific for each crop. It must also be taken into account that the uptake differs between elements and the system used. For instance, in open-systems with free drainage, much of the nutrient solution is lost by leachate.

Serio *et al.* (2001) found decreasing fresh shoot mass with increasing nutrient solution concentration.

De Rijck and Schrevens (1999) reported that each nutrient shows differential responses to changes in pH of the nutrient solution as descrSIBed below. In the nutrient solution, NH_3 only forms a complex with H^+. For a pH range between 2 and 7, NH_3^+ is completely present as NH_4^+. Increasing the pH above 7 the concentration ofNH_4^+ decreases, while the concentration of NH_3^+ augments.

De Rijck and Schrevens (1998a) studied that the pH is a parameter that measures the acidity or alkalinity of a solution. This value indicates the relationship between the concentration of free ions H^+ and OH^-present in a solution and ranges between 0 and 14. Changing the pH of a nutrient solution affects its composition, elemental speciation and bioavailability. The term “speciation” indicates the distrSIBution of elements among their various chemical and physical forms like: free ions, soluble complexes, chelates, ion pairs, solid and gaseous phases and different oxidation states.

De Rijck and Schrevens (1998b) reported that Sulphate also forms relatively strong complexes with Ca^{2+} and Mg^{2+} in Nutrient solution in Hydroponic system.

De Rijck and Schrevens (1998c) investigated the effects of the mineral composition of the nutrient solution and the moisture content of the substrate on the mineral content of hydroponically grown tomato fruits, using "design and analysis of mixture systems'', a (3.1) simplex lattice design extended with the overall centroid set-up in the cation factor-space (K^+, Ca^{2+} and $Mg^{2+)}$ of the nutrient solution. For each nutritional composition two moisture contents (40 and 80% of volume) of the substrates were investigated. After this short sample illustrates some aspects to be considered in the preparation of nutrient solutions.

Taiz and Zeiger (1998) studied that an essential elements of nutrient solution for hydroponic lettuce have physiological role and its absence prevents the complete plant life cycle.

Wheeler *et al.* (1998) conducted an experiment on lettuce (*Lactuca sativa* L., cv. Ostinata) under three light levels and three nutrient solution nitrate contents which represented a range of adequate and inadequate environments. Larger, fastergrowing plants should have a larger demand for nitrate and hence larger uptake rates than smaller, environmentally stressed plants. Results showed higher sustained levels of nitrate uptake by larger plants. Neither the severity of stress under which a plant was grown nor the plant sizes were the sole determinants of maximum potential uptake behaviour, however. Increased light level was related to an increased ability to transport nitrate on a short-term basis. Increased light level was associated with increased maximum nitrate uptake rates. The effects of environmental light and nitrate levels on nitrate uptake were incorporated into a power relationship where the maximum uptake velocity was determined in relation to the shoot growth rate.

De Rijck and Schreven (1997) found that with pH 5, 100% of P is present as HPO_4^{2}; this form converts into HPO_4^{-} at pH 7.3, reaching 100% at pH 10. The pH range that dominates the ion HPO_4^{2}on HPO_4^{-} is between 5 and 6. Potassium is almost completely present as a free ion in a nutrient solution with pH values from 2 to 9; only small amounts of K^+ can form a soluble complex with SO_4^{2-} or can be bound to Cl^-. Like potassium, calcium and magnesium are available to plants in a wide range of pH; however, the presence of other ions interferes in their availability due to the formation of compounds with different grade of solubility.

Chen *et al.* (1997) found that the growth of lettuce was significantly increased when the NO_3 concentration of the solution was reduced below the highest concentration being used by a local commercial hydroponic grower.

Marschner (1995) reported that an important feature of the nutrient solutions is that they must contain the ions in solution and in chemical forms that can be absorbed by plants, so in hydroponic systems the plant productivity is closely related with to nutrient uptake and the pH regulation.

Van Labeke *et al.* (1995) studied Eustomagrandiflorum responses to different nutrient solutions differing in ion ratios using an experimental as a (3.1) simplex centroid design, one in the cation factor-space and the other in the anion factorspace.

Salisbury and Ross (1992) reported that currently 17 elements are considered essential for most plants, these are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, copper, zinc, manganese, molybdenum, boron, chlorine and nickel which must be present in nutrient solution in case of growing Lettuce.

Ayers and Westcot (1987) found that as water naturally contains HCO_3^-, this anion turns into CO_3^{2-} when the pH is higher than 8.3 or to H_2CO_3 when it is less than 3.5; the H_2CO_3 is in chemical equilSIBrium with the carbon dioxide in the atmosphere.

Steiner (1984) found that at a pH above 8.3, Ca^{2+} and Mg^{2+} ions easily precipitate as carbonates (Also, as mentioned above, when the pH of the nutrient solution increases, the HPO_4^{2-} ion predominates,which precipitates with Ca^{2+} when the product of the concentration of these ions is greater than 2.2, expressed in mol m-

Hansen (1978) indicated that the addition of plant nutrients to hydroponic systems may be performed according to the plant nutrient requirement. Application of nutrients may be performed according to analyses of a specific crop stage that may descrSIBe the consumption of the various typical nutrients of the particular crop or by means of analyses of the total plant needs quantitatively adjusted to the rate of growth and the amounts of water supplied.

Coic and Steiner (1973) studied that the composition and concentration of the nutrient solution are dependent on culture system, crop development stage, and environmental conditions.

Steiner (1968) reported that a nutrient solution for hydroponic systems is an aqueous solution containing mainly inorganic ions from soluble salts of essential elements for higher plants. Eventually, some organic compounds such as iron chelates may be present. Steiner (1968) studied that nutrient solutions usually contain six essential nutrients: N, P, S, K, Ca and Mg. There by Steiner created the concept of ionic mutual ratio which is based on the mutual ratio of anions: NO_3^-, HPO_4^2 and SO_4^{2-}, and the mutual ratio of cations K^+, Ca^{2+}, Mg^{2+}. Such a relationship is not just about the total amount of each ion in the solution, but in the quantitative relationship that keep the ions together; if improper relationship between them take place, plan performance can be negatively affect.

Steiner (1968) proposed that in soilless cultures any ionic ratio and any total concentration of ions can be given, as precipitation limits for certain combinations of ions are considered. Thus, the selection the concentration of a nutrient solution should be such that water and total ions are absorbed by the plant in the same proportion in which those are present in the solution.

Hewitt (1966) studied that the ionic balance constraint makes it imposSIBle to supply one ion in nutrient solution without introducing a counter ion. A change in the concentration of one ion must be accompanied by either a corresponding change for an ion of the opposite charge, a complementary change for other ions of the same charge, or both. Steiner (1966) reported that the ratio 3:1 between Ca^{2+} and Mg^{2+} is constant in nutrient solution. Similarly, the ratio HPO_4^- :SO_4^{2-} (1:9) is constant, while the changes in the NO_3^- concentration are produced at expense of the $H_2PO_4^-$ and SO_4^{2-} concentrations. Steiner (1961) developed a method to calculate a formula for the composition of a nutrient solution, which satisfies certain requirements. Later on the evaluated five different ratios of NO_3^-: anions (NO_3^-+$H_2PO_4^-$+SO_4^{2-}) and three of K^+: cations (K^++Ca^{2+}+Mg^{2+}), combining also the two groups, resulting in a full factorial design; all solutions had the same osmotic pressure and pH value. In this system, the relative concentration of K^+ increases at the expense of Ca^{2+} and Mg^{2+} concentrations.

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental Site

The experiment was conducted at the Central Laboratory in the Sher-e Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh during September 2014 to March 2015. The experimental site is situated between $23^{0}41/$ N latitude and $90^{o}22/$ E longitude.

3.2 Plant materials and other materials

The seeds of lettuce cv. ‘Lolorossa’ were used in the experiment. The seeds were kept in a sealed packet which was collected from Siddikbazar, Dhaka. The styrofoam, air pump, air stone etc were collected from Katabon Market, Dhaka. Experimental chemicals were bought from Tikatolli, Dhaka.The industries byproduct was collected from Nitaigonj, Narayanganj.There are six white lights and some red color polythene paper were collected from boubazar from SAU. Different types of daily instruments also used for many purposes to complete the experiment

3.3 Experimental design and treatment

The experiment was conducted in a completely randomized design (CRD) with three replications. Three nutrient solutions were considered as treatments viz.:

T_1 – ½ Rahman and Inden (2012) + 0 ml of SIB

T_2 – ½ Rahman and Inden (2012) + 0.5 ml of SIB

T_3 –½ Rahman and Inden (2012) + 0.75 ml of SIB

The ratio of Rahman and Inden (2012) solution were NO_3^-N, P, K, Ca, Mg, and S of 17.05, 7.86, 8.94, 9.95, 6.0 and 6.0 meq·L^{-1}, respectively. The rates of micronutrients were Fe, B, Zn, Cu, Mo and Mn of 3.0, 0.5, 0.1, 0.03, 0.025 and 1.0 mg·L^{-1}, respectively for both the nutrient solutions. All the treatments were started at half strength from the first day of the seedlings when transferred into the boxes. Full strength of the treatments was started from the second week of the experiment.

The pH approximately 6.0 was maintained in the nutrient solutions. These solutions were used in different boxes. After one week of lettuce seedlings transplantation 1/4strength of nutrient solution was used. Treatments were applied from the second week of the transplantation. Fifteen plants were considered as an experimental unit.

3.4 Growing Environment

Non-circulating floating technique was used for culturing the plants. Nutrient solution was reserved in the styrofoam boxes. Styrofoam boxes were prepared as 60 cm x 40 cm x 20 cm. Polythene sheet was placed in the inner side of box so that the nutrient solution could not pass through the styrofoam box. For each box lids was prepared with styrofoam sheet and 15 small holes were made with sharp knife. In these holes 20 mL plastic cups containing the mixture of coco peat and broken bricks at the ratio of 70%**:**30% were inserted those holes and the lid was placed on the styrofoam box after transplanting of lettuce seedlings. Roots were suspended in the nutrient solution. Air stone was placed on the nutrient solution boxes for proper aeration. One air pump was set with two air stone which were set in different boxes. The experiment was conducted in a room under intensive care. Red and white lights were supplied during the experiment. Energy bulbs which supplied white light, There are some rod lights which are covered with foiling paper. The room was kept clean and tidy during the time of experiment. Daily supervision was maintained to protect the plant.

3.5 Preparation of nutrient solutions

In this experiment Rahman and Inden (2012) solution was used. The concentrations T_1 – ½ Rahman and Inden (2012) + 0 ml of SIB, T_2 – ½ Rahman and Inden (2012) + 0.5 ml of SIB, T_3 –½ Rahman and Inden (2012) + 0.75 ml of SIB. In the solution industries byproduct was added according to their composition.

3.6 Growing media preparation for seedling rising

The mixture of coco peat and broken bricks at the ratio of 70%**:**30% (v/v). Coco peat was soaked in a big bowl for 24 hours. It was washed well with water and spread in a polythene sheet for 3 hours. Then they are mixed with khoa. Plastic sauce cups of 20 ml were filled with this mixture for raising seedlings.

Plate1. Preparing the growing media for seedling raising

3.7 Seed sowing

The seeds were soaked in water for 24 hours and then wrapped with piece of thin cloth. The socked seed were then spreaded over polythene sheet for 2 hours to dry out the surface water. After that seeds were shown in plastic sauce cups and covered with newspaper under room temperature for germination.

3.8 Transplanting of lettuce seedling

Lettuce seedlings were transplanted into the main boxes containing nutrient solution after two weeks of emerging. The cup contains the mixture of coco peat and khoa. One healthy lettuce plant was selected for each cup. Lettuce plants were transplanted carefully so that roots were not damaged. After transplanting of lettuce plant in the cup, light watering was done with sprayers.

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Plate2. Lettuce culture in hydroponic system at the 20 days after transplanting in the laboratory.

Plate3. Different stages of lettuce plant

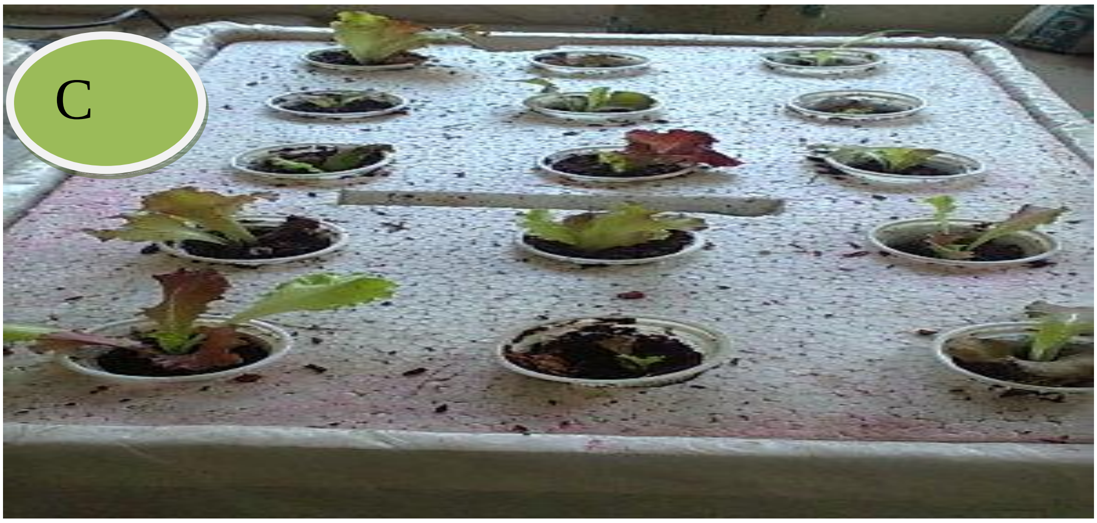

Plate4. Different stages of lettuce plant

3.9 Weeding

No weeding was done in the experiment.

3.10 Pest management

Cockroach attacked in the boxes and started to cut the lettuce plants. So Insecticides was applied around the boxes to protect the plant. No other pesticides were applied in the experiment.

3.11 Diseases management

Lettuce plants were grown in controlled environment in hydroponic system and all nutrients required for plant were supplied artificially to the plants. The growing environment was clean and no disease attacked to the plants.

3.12 Harvesting

The crop was harvested after 40 days of sowing. Harvesting of the crop was done box wise. It was done by uprooting the plants by hand carefully. The growing media and fSIBrous roots adhering to the roots were removed and cleaned

.

3.13 Data collection

Data on the following parameters were recorded from the plants during the experiment. Data were collected from each plant. Each box was regarded as an experimental unit. Data were collected on different growth and yield components.

3.13.1 Plant height

Plant height was measured in centimetre (cm) by a meter scale at 0, 10, 20, 30, and 40 DAT (days after transplanting) from the point of attachment of growing media up to the tip of the longest leaf.

3.13.2 Breadth of leaves

Breadth of leaves were measured in centimetre (cm) by a meter scale at 0, 10, 20, 30, and 40 DAT. Fourth leaf was selected for measurement of breadth.

3.13.3 Length of leaves

Length of leaves were measured in centimetre (cm) by a meter scale at 0, 10, 20, 30, and 40 DAT. Fourth leaf was selected for measurement of length.

3.13.4 Number of leaves per plant

Number of leaves per plant were counted at 0, 10, 20, 30, and 40 DAT. All the leaves of each plant were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from the counting and the average number was recorded

3.13.5 Fresh weight of plant

Leaves were detached by a sharp knife and fresh weight (g) of the plant was taken by an electric balance at harvest (40 DAT) and was recorded.

3.13.6 Percent dry matter of plant

From the random samples of plants weighing then sun dried for seven days. After drying, plants were weighed. An electric balance was used to record the dry weight of plant and it was calculated on percentage basis. The percentage of dry matter of plant was calculated by the following formula.

$$\% \text{ Dry matter of plant} = \frac{\text{Constant dry weight of plant}}{\text{Fresh weight of plant}} \times 100$$

3.13.7 Measurement of ascorbic acid

Ascorbic acid content in lettuce was measured from Bangladesh Council of Scientific and Industrial Research (BCSIR).

3.13.8 Measurement of β- carotene

β- Carotene content in lettuce was measured from Bangladesh Council of Scientific and Industrial Research

3.13.9 Physiological parameters

Growth parameters (dry weights of stem, leaf and root), and different physiological parameters [Leaf area (LA), leaf area ratio (LAR), leaf mass ratio (LMR), root weight ratio (RWR), relative growth rate (RGR), and net assimilation rate (NAR)] were determined in the experiments. The parameters were measured as descrSIBed below:

$$LAR=\frac{LA}{PDW}$$

Where, LAR = leaf area ratio, LA = Leaf area (cm2), PDW = plant dry weight (g).

$$LMR =\frac{LDW}{PDW}$$

Where, LMR = leaf mass ratio, LDW = leaf dry weight (g).

$$RWR= \frac{RDW}{PDW}$$

Where, RWR = root weight ratio, RDW = root dry weight (g).

$$RGR= \frac{PDW1-PDW0}{t1-t0\ PDW0}$$

Where, t = time. Subscripts 0 and 1 refer to the transplanting and final harvest (days), respectively.

$$NAR = \frac{RGR}{LAR}$$

3.13.8 Statistical analysis of data

The data obtained for different characters were statistically analyzed with SPSS version 19.0 and means separation were done by Tukey's test at $P \leq 0.05$.

CHAPTER IV

RESULTS AND DISCUSSION

A summary of the analysis of variances in respect of all the parameters have been shown on Appendices. The recorded data have been expressed in figures. Results are presented under the following heads.

4.1 Plant height

Plant height of lettuce showed statistically significant differences for the application of salt industries byproducts at 30 and 40 DAT (Figure 1).Plant height of lettuce showed a gradual increasing trend with different days after transplanting for different salt industries byproducts application. The tallest plant at 0 DAT (5.90 cm), 10 DAT (10.51 cm), 20 DAT (14.41 cm), 30 DAT (17.71 cm) and 40 DAT (19.53 cm) was recorded from T_1(½ Rahman and Inden (2012) + 0ml of SIB) treatment. Meanwhile , the shortest plant at 0 DAT (5.30 cm), 10 DAT (8.82 cm), 20 DAT (11.88 cm), 30 DAT (14.33 cm) and 40 DAT (15.61 cm) was obtained from T_3(½ Rahman and Inden (2012) + 0.75 ml of SIB) treatment. This might be due to the proportion of nutrient supply in the plants. In case of closed hydroponic system, proper nutrient solution management in the root zone is the first consideration for the adoption of the plants. Andriolo *et al*. (2005) stated that lettuce growth was affected by different strength of nutrient solutions. The present finding was consisted with the findings of Andriolo *et al*. (2005). In the present study, T_1(½ Rahman and Inden (2012) + 0ml of SIB) can supply proper amount of nutrients to the plant resulting higher plant height.

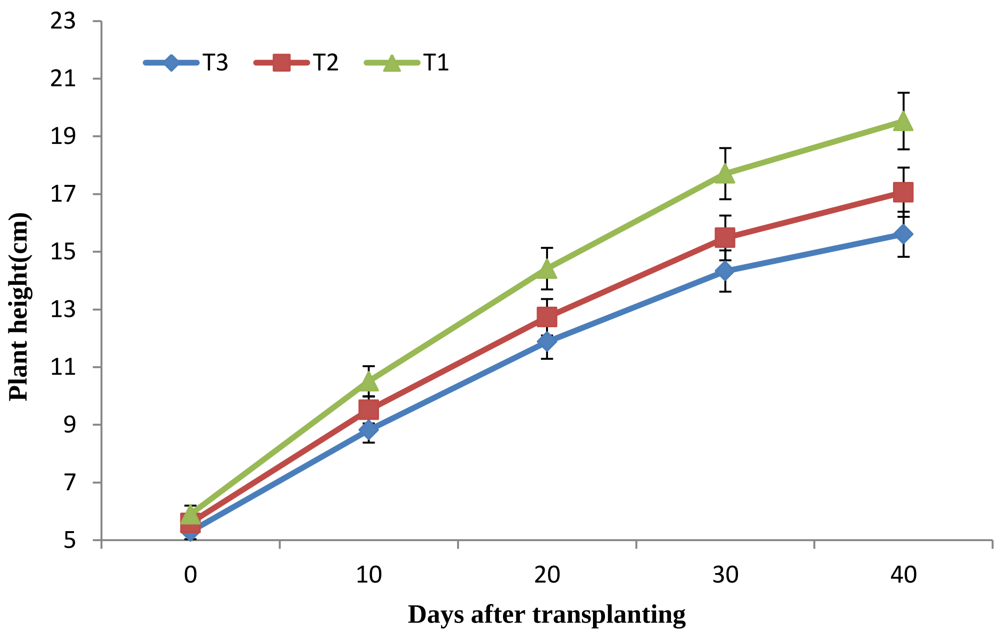

Figure 1.Effect of salt industries byproduct as a liquid fertilizer on plant height of lettuce at different DAT (days after transplanting).

T_1 : ½ Rahman and Inden (2012) + 0 ml of SIB; T_2 : ½ Rahman and Inden (2012) + 0.5 ml of SIB; T_3: ½ Rahman and Inden (2012) + 0.75 ml of SIB.

Vertical bars represents the error bars with percentage.

4.2 Number of leaves per plant

Leaves number of lettuce exposed statistically significant inequality for the application of salt industries byproducts at 20, 30and 40 DAT (Figure2).The maximum leaf no. at 0 DAT (3.34 cm), 10 DAT (6.31 cm), 20 DAT (8.21 cm), 30 DAT (9.83 cm) and 40 DAT (10.65 cm) was recorded from T_1 (½ Rahman and Inden (2012) + 0ml of SIB) and also the leaf no. at 0 DAT (3.19 cm), 10 DAT (6.11 cm), 20 DAT (7.89 cm), 30 DAT (9.63 cm) and 40 DAT (10.36cm) was recorded from T_2 (½ Rahman and Inden (2012) + 0.5ml of SIB) Meanwhile, the minimumleaf no. at 0 DAT (2.15 cm), 10 DAT (5.50 cm), 20 DAT (6.98 cm), 30 DAT (8.15 cm) and 40 DAT (8.80 cm) was obtained from T_3(½ Rahman and Inden (2012) + 0 .75 ml of SIB) treatment. This might be because of proper supply of nutrient in the plants. Andriolo *et al.* (2005) stated that lettuce growth was affected by different strength of nutrient solutions. In the present study, T_1 and T_2 can supply proper amount in available forms of nutrients to the plants resulting higher leaves per plant.

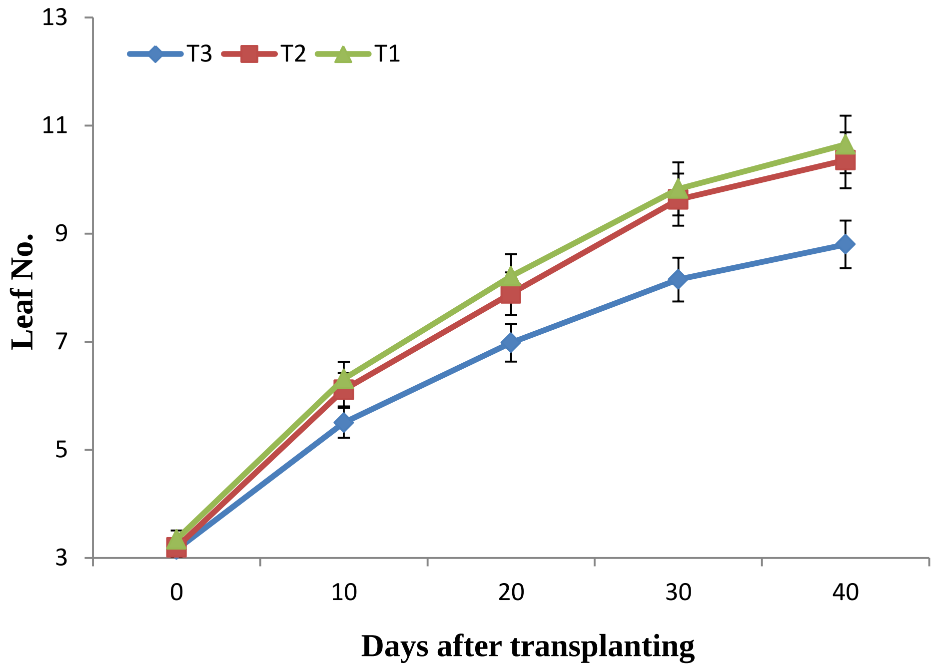

Figure 2. Effect of salt industries byproduct as a liquid fertilizer on number of leaves at different DAT (days after transplanting)

T_1 : ½ Rahman and Inden (2012) + 0 ml of SIB; T_2 : ½ Rahman and Inden (2012) + 0.5 ml of SIB; T_3: ½ Rahman and Inden (2012) + 0.75 ml of SIB.

Vertical bars represents the error bars with percentage.

4.3 Leaf breadth

Significant difference was not found in leaf breadth at 0 DAT to 20 DAT, but leaf breadth increased significantly at 30 DAT and 40 DAT due to the application of different strength nutrient solutions (Figure 3). The highest leaf breadth at 0 DAT (2.65 cm), 10 DAT (6.35 cm), 20 DAT (8.63 cm), 30 DAT (10.34 cm) and 40 DAT (11.36 cm) were recorded from T_1 (½ Rahman and Inden (2012) + 0ml of SIB) and similar the highest leaf breadth at 0 DAT (2.45 cm), 10 DAT (5.86 cm), 20 DAT (8.31 cm), 30 DAT (10.11 cm) and 40 DAT (11.01 cm) were recorded from T_2(½ Rahman and Inden (2012) + 0.5 ml of SIB) Meanwhile, the lowest plant at 0 DAT (2.30 cm), 10 DAT (5.25 cm), 20 DAT (7.70 cm), 30 DAT (9.15 cm) and 40 DAT (9.56 cm) was obtained from T_3(½ Rahman and Inden (2012) + 0.75 ml of SIB) treatment. This might be because of the proportion of nutrient supply in the plants. Andriolo *et al.* (2005) stated that lettuce growth was affected by different strength of nutrient solution. The present finding was consisted with the findings of Andriolo *etal.* (2005). In the present study, T_1 and T_2 can supply proper amount in available forms of nutrients to the plants resulting higher leaf breadth.

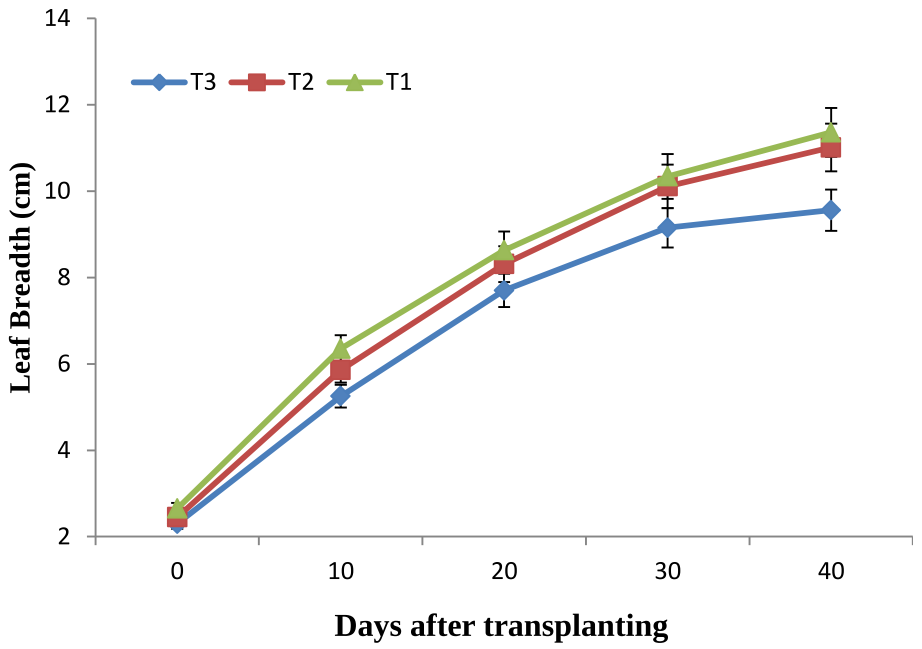

Figure 3. Effect of salt industries byproduct as a liquid fertilizer on leaf breadth of lettuce at different DAT (days after transplanting);

T_1 : ½ Rahman and Inden (2012) + 0 ml of SIB; T_2 : ½ Rahman and Inden (2012) + 0.5 ml of SIB; T_3: ½ Rahman and Inden (2012) + 0.75 ml of SIB.

Vertical bars represents the error bars with percentage.

4.4 Leaf length

Leaf length was not exposed significant by application of salt industries by-product until 30 DAT, significant difference found only at 40 DAT among the treatments of the experiments (Figure 4).The highest plant at 0 DAT (5.19 cm), 10 DAT (9.31 cm), 20 DAT (13.21 cm), 30 DAT (15.83 cm) and 40 DAT (17.61 cm) were recorded from T_1(½ Rahman and Inden (2012) + 0ml of SIB) which was similar to the T_2. Meanwhile, the lowest plant at 0 DAT (5.14 cm), 10 DAT (7.80 cm), 20 DAT (10.30 cm), 30 DAT (12.65 cm) and 40 DAT (13.90 cm) was obtained from T_3 (½ Rahman and Inden (2012) + 0.75 ml of SIB) treatment. Andriolo *et al.* (2005) stated that lettuce growth was affected by different strength of nutrient solution with industries byproduct.

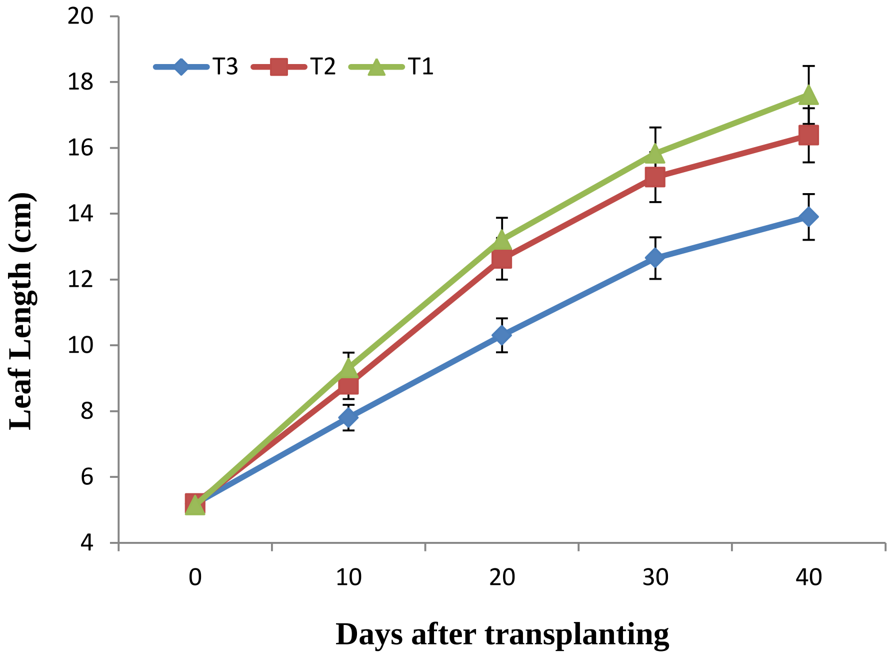

Figure 4. Effect of salt industries byproduct as a liquid fertilizer on leaf length of lettuce at different DAT(days after transplanting)

T_1 : ½ Rahman and Inden (2012) + 0 ml of SIB; T_2 : ½ Rahman and Inden (2012) + 0.5 ml of SIB; T_3: ½ Rahman and Inden (2012) + 0.75 ml of SIB.

Vertical bars represents the error bars with percentage.

4.5 Fresh weight of lettuce plant

Marketable quality of lettuce is determined mainly by plant size, which depends on fresh weight. Significant difference in growth were observed among the three treatments. At 40 days after transplantation of lettuce plant we weight and noticed that lettuce gave greater fresh weight (48.81g/plant) in T_1 which was similar to T_2 (45.63 g/plant) and lowest fresh weight (27.41 g/plant) was found due to application of T_3 (Figure 5). In fact, plants were able to grow higher shoot and roots with ½ Rahman and Inden (2012) + 0 ml of SIB in a closed floating hydroponic system. It can improve the total marketable fresh weight of lettuce. Physiological quality of fruiting horticultural crops such as capsicum, tomato, strawberry, etc. can be improved at high electrical conductivity (EC) (Cuartero and Fernandez-Muñoz, 1999; Li and Stanghellini, 2001). Andriolo *etal.* (2005) also stated that EC levels above 2.0 and 2.6 dS m^{-1} reduced fresh yield and plant growth, respectively in lettuce. In the present experiment, EC of ½ Rahman and Inden (2012) + 0 ml of SIB was less than 2 dS m^{-1} and it might have contributed to supply proper amount of nutrient in available form.

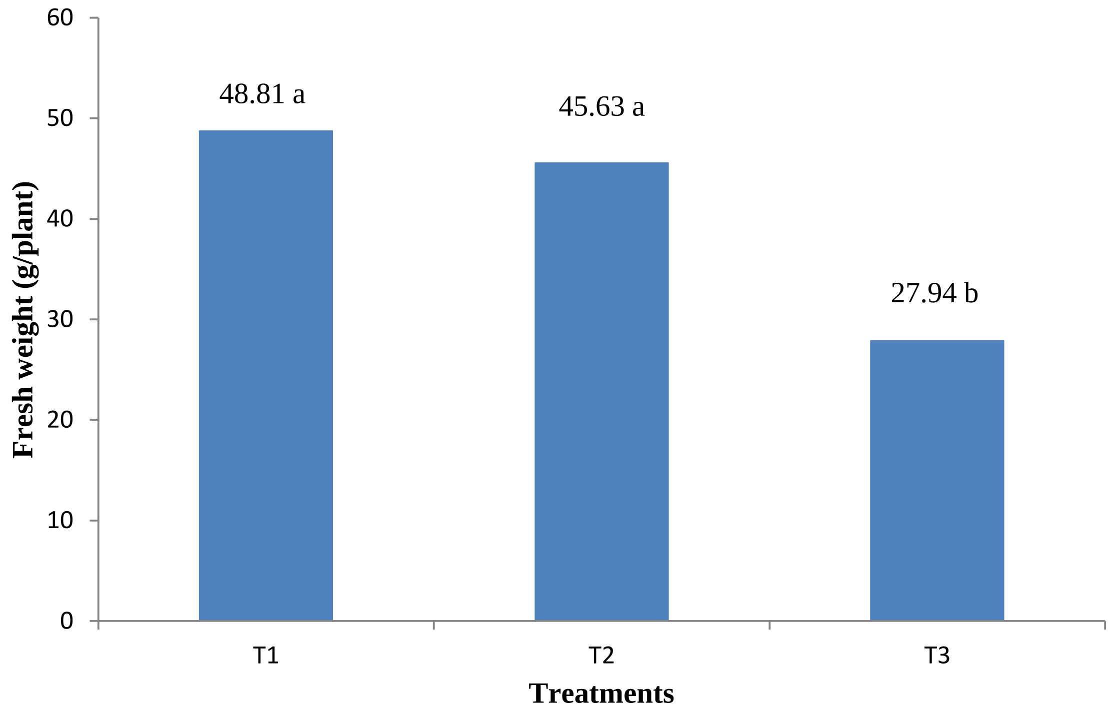

Figure 5. Effect of salt industries byproduct as a liquid fertilizer on fresh weight of lettuce at different treatments.

T_1 : ½ Rahman and Inden (2012) + 0 ml of SIB; T_2 : ½ Rahman and Inden (2012) + 0.5 ml of SIB; T_3: ½ Rahman and Inden (2012) + 0.75 ml of SIB. Vertical bar represents the standard error.

4.6 Plant dry weight

Plant dry weights of lettuce were varied significantly by three treatments (Figure 6). The highest dry weights of leaf and root were found in T_1 similar to $T_{2.}$ Meanwhile, dry weights of plants drastically decreased at T_3. This might be due to proper supply of industries byproduct due to application of T_1 solution containing higher Ca^{2+} compared to the control, which contributed to higher dry weights. On the contrary, nutrient solution of T_3 contains the lowest amount of Ca^{2+} compared to the other treatments. Epstein and Bloom (2005) reported that Ca^{2+} increased the root dry weight and calcium content in plant tissues. Bar-Tal *et al.*(2001) found that the shoot and root dry weights decreased with increasing Ca^{2+} in sweet pepper. The present findings consisted with the other findings.

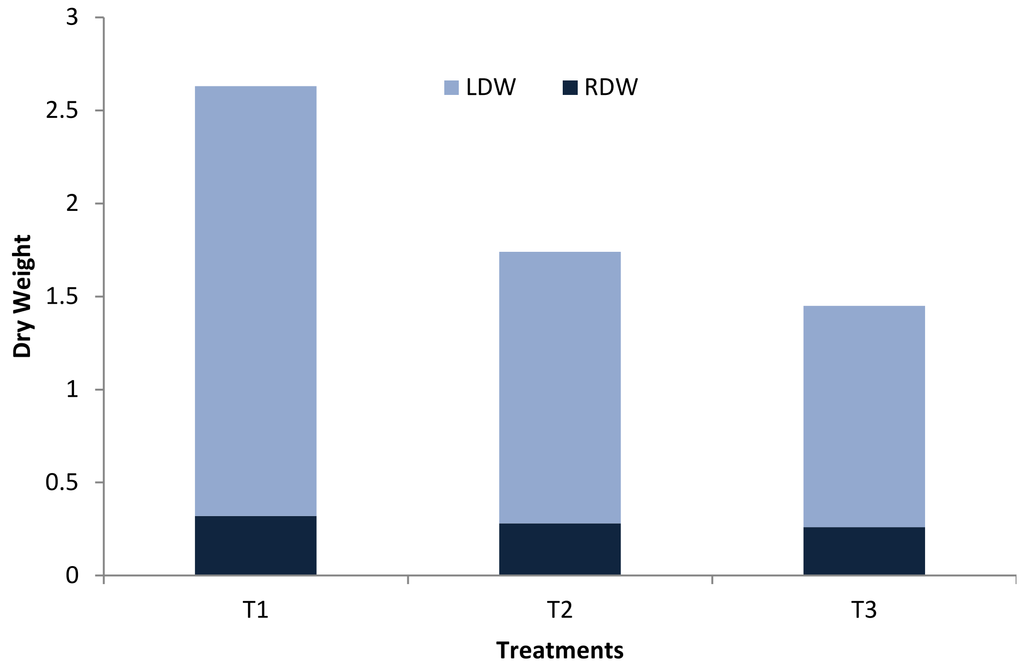

Figure 6. Effect of salt industries byproduct as a liquid fertilizer on plant dry weight of lettuce at different Treatments.

T_1 : ½ Rahman and Inden (2012) + 0 ml of SIB; T_2 : ½ Rahman and Inden (2012) + 0.5 ml of SIB; T_3: ½ Rahman and Inden (2012) + 0.75 ml of SIB.

4.7 Ascorbic acid content

In Figure 7 the effect of treatments on the ascorbic acid content was observed. Ascorbic acid content increased markedly with the increasing levels of nutrient solution with industries byproduct. Ascorbic acid content was higher in the plants grown in ½ Rahman and Inden (2012) + 0.75 ml of SIB than those grown in ½ Rahman and Inden (2012) + 0.5 ml of SIB and ½ Rahman and Inden (2012)+0 ml of SIB .There are some reports concerning the effect of nutrient solutions on ascorbic acid in lettuce. In this experiment, the effect of strength of nutrient solution was studied using hydroponics to control the root zone conditions precisely. Shinohara *et al.*(1978) reported that ascorbic acid content of lettuce was increased when grown in ¼strength nutrient solutions compared to the ½ strength nutrient solutions. In the present experiment, ascorbic acid content increased with increased concentration which was not consistent with the others findings. However, it was significant that ascorbic acid content increased in the same treatment with higher yield. On the other hand, when the plants were grown in low nutrient concentrations, leaf constituents implied not to be metabolized sufficiently under low concentration of nutrient solution because of insufficient supply of inorganic matter from roots (Shinohara and Suzuki, 1981). The present result was consistent with their findings. Fanasca *et al.*(2006) stated that the total antioxidant activity increased in tomato with increased supply of Mg^{2+} and K^{+} in the nutrient solution. In the present study, T_3 (½ Rahman and Inden (2012) + 0.75 ml of SIB)contained the higher amount of Mg^{2+} and K^{+} which enhanced the bio synthesis of higher amount of ascorbic acid in lettuce.

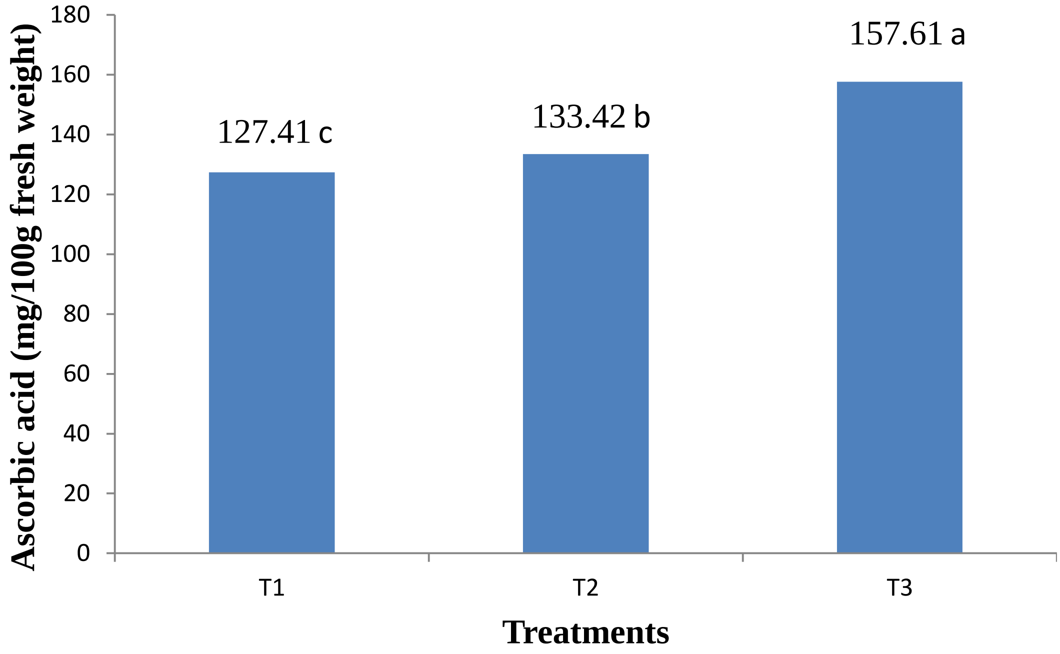

Figure 7. Effect of salt industries byproduct as a liquid fertilizer on ascorbic acid content of lettuce at different treatments.

T_1 : ½ Rahman and Inden (2012) + 0 ml of SIB; T_2 : ½ Rahman and Inden (2012) + 0.5 ml of SIB; T_3: ½ Rahman and Inden (2012) + 0.75 ml of SIB. Vertical bars represents the standard errors.

4.8 β- carotene content

In Figure 8 β- carotene content in lettuce plant increased with the increasing levels of ½ Rahman and Inden (2012) solution + SIB. Plant carotenoids are the primary dietary source of provitamin A worldwide, with β- carotene as the most well-known provitamin A carotenoid. β- carotene content was higher in the plants grown in ½ Rahman and Inden (2012) + 0.75 ml of SIB than those grown in ½ Rahman and Inden (2012) + 0.5 ml of SIB and ½ Rahman and Inden (2012) + 0 ml of SIB. Amin Ismail and Cheah Sook Fun (2003) showed that many organically grown vegetables were higher in vitamins than that conventionally grown and the findings of β- carotene content was 2006 μg/100 g. In the present study, T_3 (½ Rahman and Inden (2012) + 0.75 ml of SIB) contained the higher amount of β- carotene content.

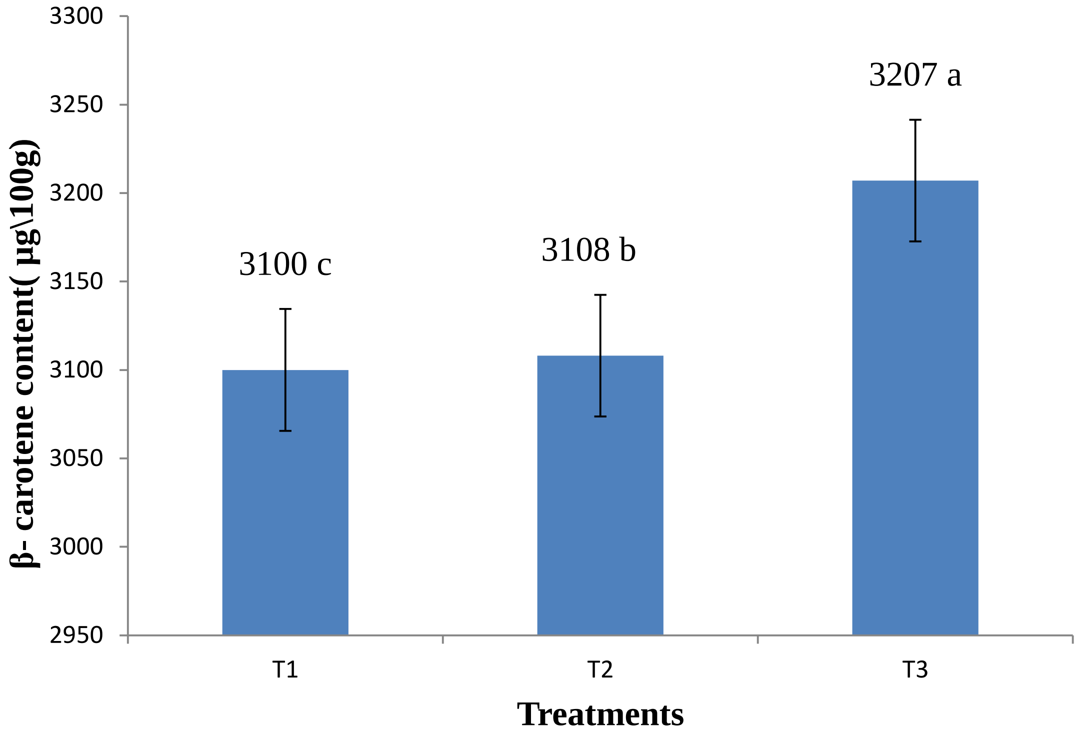

Figure 8. Effect of salt industries byproduct as an alternative liquid fertilizer on β- carotene content of lettuce at different Treatments.

T_1 : ½ Rahman and Inden (2012) + 0 ml of SIB; T_2 : ½ Rahman and Inden (2012) + 0.5 ml of SIB; T_3: ½ Rahman and Inden (2012) + 0.75 ml of SIB.

Vertical bars represents the standard errors.

4.9 Growth analysis

4.9.1 Leaf Area (LA)

Leaf area of lettuce showed statistically significant variation among the different treatments at 0,10, 20, 30 and 40 DAT. The highest leaf area at 0 DAT (11.20 cm^2), 10 DAT (83.30 cm^2), 20 DAT (125.30 cm^2), 30 DAT (162.20 cm^2) and 40 DAT (187.40 cm^2) was recorded from T_1(½ Rahman and Inden (2012) + 0 ml of SIB) which was similar to T_2. In comparison, the lowest plant at 0 DAT (10.10 cm^2), 10 DAT (49.20 cm^2), 20 DAT (87.70 cm^2), 30 DAT (113.20 cm^2) and 40 DAT (143.2 cm^2) was obtained from T_3(½ Rahman and Inden (2012) + 0.75 ml of SIB) treatment. Prieto *et al.* (2007) reported that increased LA gave the plants an increased ability to intercept light. Higher LA was found due to application of T_1 (½ Rahman and Inden (2012) + 0 ml of SIB) that may have the ability to produce higher metabolites in lettuce.

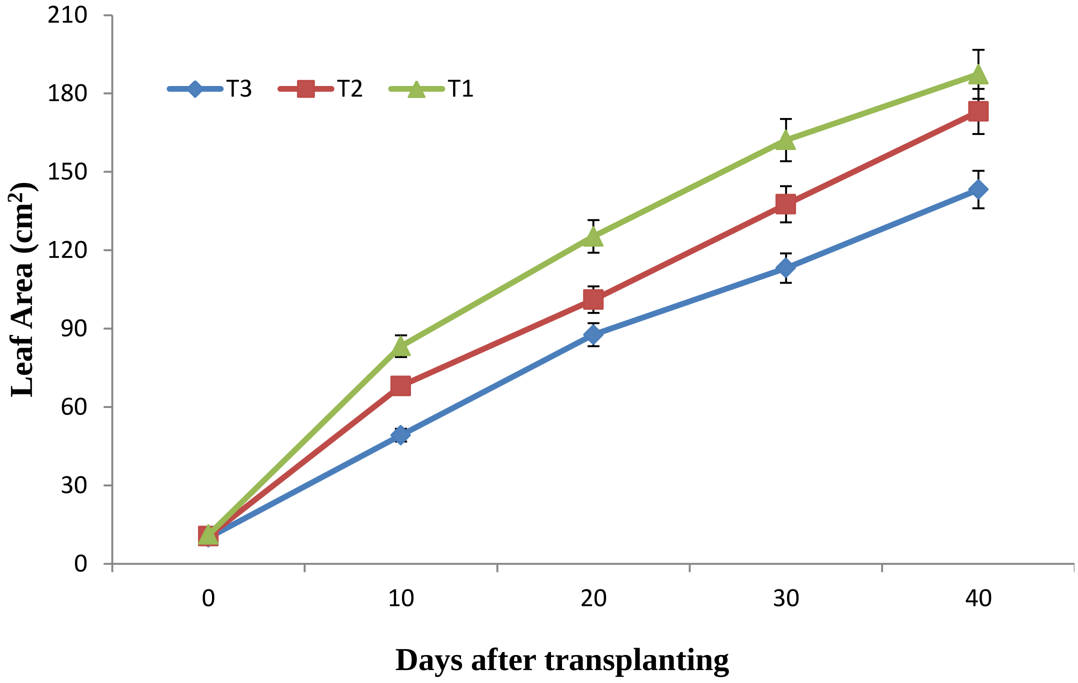

Figure 9.1. Effect of salt industries byproduct as an alternative liquid fertilizer on leaf area of lettuce at different DAT (days after transplanting);
T_1 : ½ Rahman and Inden (2012) + 0 ml of SIB; T_2 : ½ Rahman and Inden (2012) + 0.5 ml of SIB; T_3: ½ Rahman and Inden (2012) + 0.75 ml of SIB.
Vertical bars represents the error bars with percentage.

4.9.2 Leaf Mass Ratio (LMR)

Leaf mass ratio varied significantly by different nutrient solution (figure 9.2). Results revealed that LMR increased in T_1 (0.88) compared to T_2 (0.84) and T_3 (0.82). Higher LMR is one of the important criteria for producing higher metabolites. Prieto *et al.* (2007) reported that increased LMR gave the plants an increased ability to intercept light. Higher LMR was found due to application of T_3 that may have the ability to produce higher metabolites in lettuce.

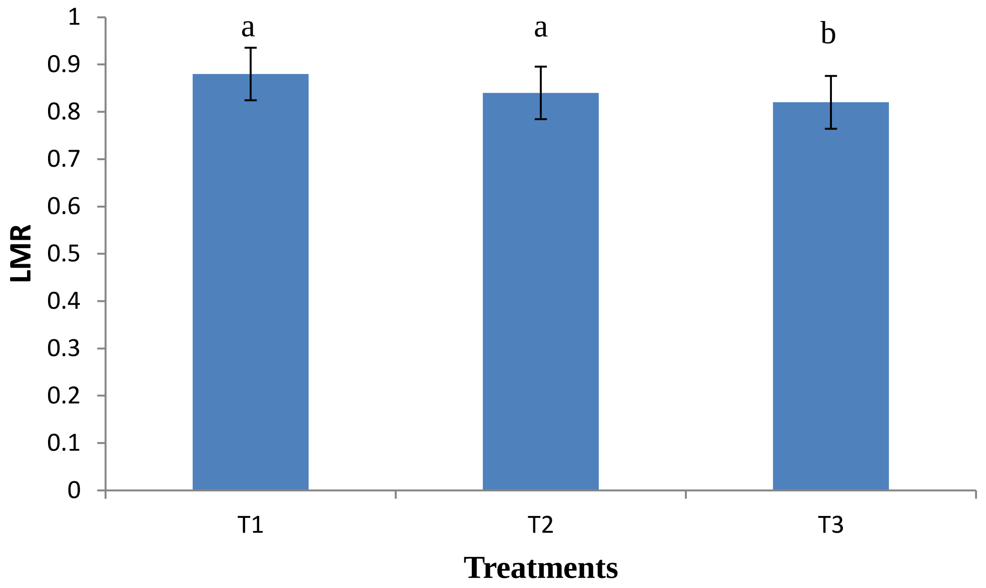

Figure 9.2 Effect of salt industries byproduct as a liquid fertilizer on LMR of lettuce at different treatments.

T_1 : ½ Rahman and Inden (2012) + 0 ml of SIB; T_2 : ½ Rahman and Inden (2012) + 0.5 ml of SIB; T_3: ½ Rahman and Inden (2012) + 0.75 ml of SIB.

Vertical bars represents the standard errors.

4.9.3 Leaf Area Ratio (LAR)

Leaf area ratio varied significantly by different nutrient solution (figure 9.3). Results revealed that LAR decreased in T_1 (71.27) compared to T_2 (99.48) and T_3 (98.75). Lower LAR is one of the important criteria for producing higher metabolites. Prieto *et al.* (2007) reported that increased LAR gave the plants an increased ability to intercept light. Lower LAR was found due to application of T_1 that may have the ability to produce higher metabolites in lettuce. Decreased LAR was found by Starck (1983) in tomato, which agreed with our findings due to application of nutrient solution in lettuce.

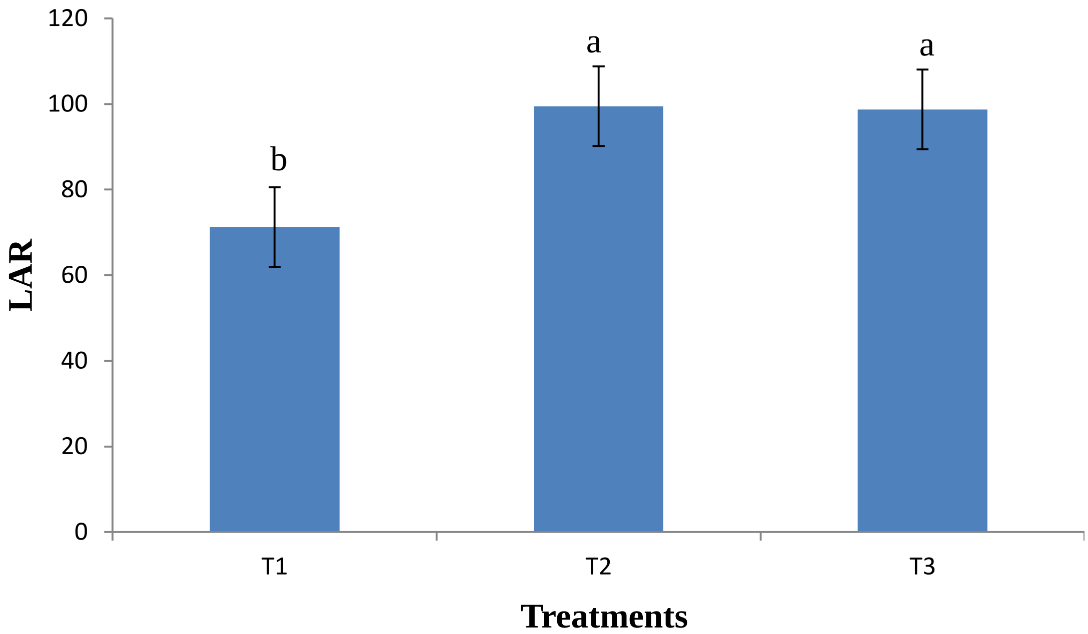

Figure 9.3 Effect of salt industries byproduct as a liquid fertilizer on LAR of lettuce at different treatments.

T_1 : ½ Rahman and Inden (2012) + 0 ml of SIB; T_2 : ½ Rahman and Inden (2012) + 0.5 ml of SIB; T_3: ½ Rahman and Inden (2012) + 0.75 ml of SIB.

Vertical bars represents the standard errors.

4.9.4 Root Weight Ratio (RWR)

Root weight varied significantly by different nutrient solution (figure 9.4). Results revealed that RWR decreased in T_1 (0.120) which was similar to T_2 (0.160) and the higher RWR was found in T_3 (0.180). Lower RWR is one of the important criteria for producing higher metabolites. Prieto *et al.* (2007) reported that increased RWR gave the plants an increased ability to intercept light. Lower RWR was recorded due to application of T_1 that may have the ability to produce higher metabolites in lettuce. Decreased RWR was found by Starck (1983) in tomato, which agreed with our findings due to application of nutrient solution in lettuce.

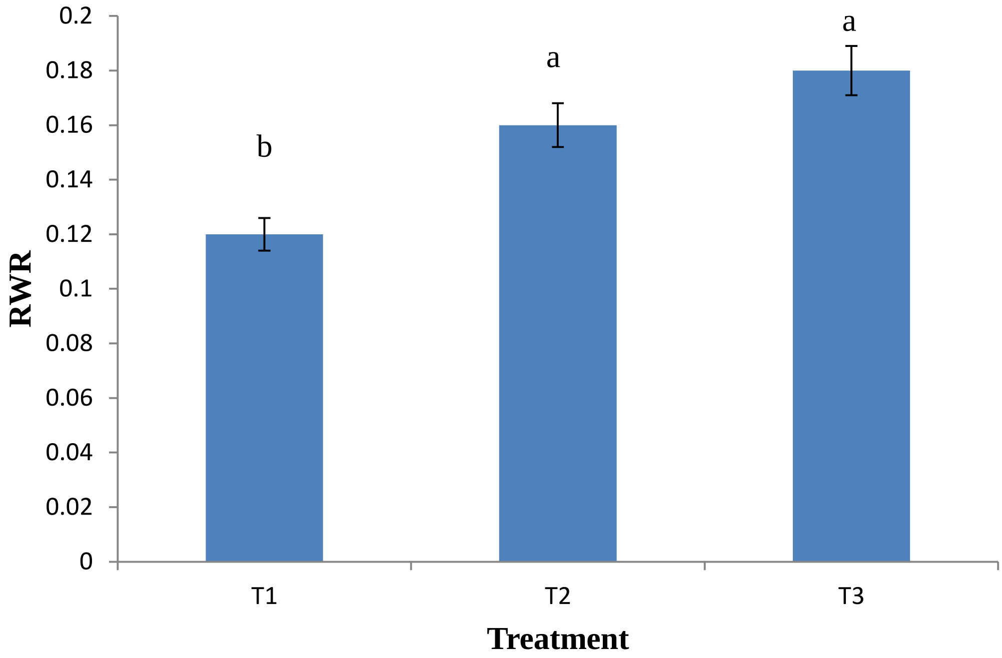

Figure 9.4 Effect of salt industries byproduct as a liquid fertilizer on RWR of lettuce at different treatments.

T_1 : ½ Rahman and Inden (2012) + 0 ml of SIB; T_2 : ½ Rahman and Inden (2012) + 0.5 ml of SIB; T_3: ½ Rahman and Inden (2012) + 0.75 ml of SIB. Vertical bars represents the standard errors.

4.9.5 Net Assimilation Rate (NAR)

Net assimilation rate varied significantly by different nutrient solution (figure 9.5).Results revealed that NAR increased in T_1 (0.00000799) compared to T_2 (0.00000513) and T_3 (0.00000435). Higher NAR is one of the important criteria for producing higher metabolites. Prieto *et al.* (2007) reported that increased NAR gave the plants an increased ability to intercept light. Higher NAR was found due to application of T_1 that may have the ability to produce higher metabolites in lettuce.

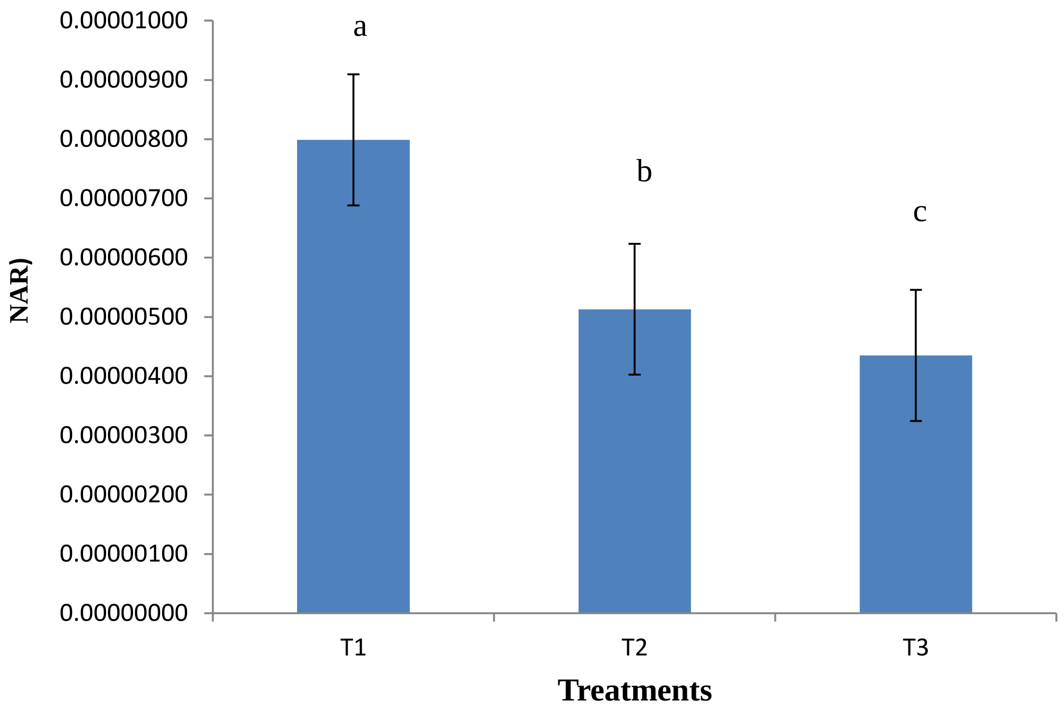

Figure 9.5 Effect of salt industries byproduct as a liquid fertilizer on NAR of lettuce at different treatments.

T_1 : ½ Rahman and Inden (2012) + 0 ml of SIB; T_2 : ½ Rahman and Inden (2012) + 0.5 ml of SIB; T_3: ½ Rahman and Inden (2012) + 0.75 ml of SIB. Vertical bars represents the standard errors.

4.9.6 Relative Growth Rate (RGR)

Relative growth rate varied significantly by different nutrient solution (figure 9.6).Results revealed that RGR increased in T_1 (0.00057) followed by T_2 (0.00051).Higher RGR is one of the important criteria for producing higher metabolites. Prieto *et al.* (2007) reported that increased RGR gave the plants an increased ability to intercept light. Higher RGR was found due to application of T_2 that may have the ability to produce higher metabolites in lettuce. The plant growth analyses data suggested that T_1 provided better nutrition to the plants which was statistically similar to T_2.This was most relevant in higher RGR and NAR due to application of T_1. However, plant growth parameters indicated that application of T_1 ½ Rahman and Inden (2012) + 0 ml of SIB supported a higher level of plant growth.

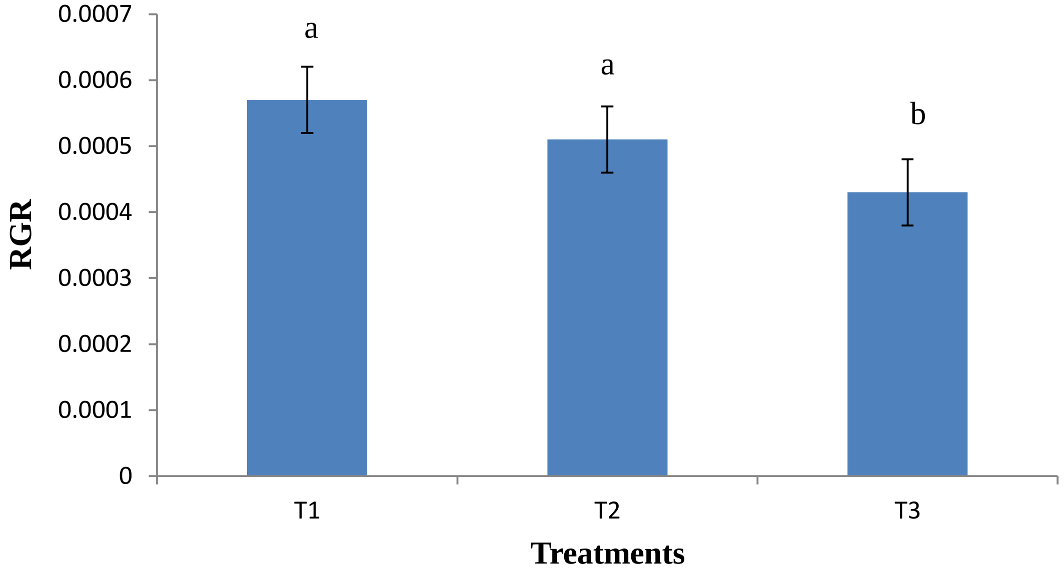

Figure 9.6 Effect of salt industries byproduct as a liquid fertilizer on RGR of lettuce at different treatments.

T_1 : ½ Rahman and Inden (2012) + 0 ml of SIB ; T_2 : ½ Rahman and Inden (2012) + 0.5 ml of SIB; T_3: ½ Rahman and Inden (2012) + 0.75 ml of SIB. Vertical bars represents the standard error.

CHAPTER V

SUMMARY AND CONCLUSION

Vegetables production in hydroponic system has been popular worldwide including Bangladesh. Although, hydroponic technique is new in Bangladesh, but some rooftop hydroponic vegetables production is practicing in many suburbs of large cities in Bangladesh as aesthetic purpose as well. In hydroponic production of leaf vegetables, growers tend to control the concentration of nutrient solution at rather high level. The results of the present experiment indicate that under these conditions the content of nitrate nitrogen is not rather high in ½ Rahman and Inden (2012) + 0.75 ml of salt industries byproduct, because ascorbic acid content is high in the same treatment. If the nitrate nitrogen is rather high in ½ Rahman and Inden (2012) + 0.75 ml of salt industries byproduct, ascorbic acid content becomes low. Further the present results show a possibility that lettuce with high contents of ascorbic acid can be harvested if T_3 nutrient solution is applied before harvest. Although the reasons for growth promotion in floating hydroponic system are still under investigation, one of the possibilities is the optimum supply of the required plant nutrient in the most available form for the plants as compared to open field condition. Another cause might be that plants do not suffer any type of stress either environmental or nutritional that might common in the open field condition. These seem to positively stimulate plant growth. The negative observation in this experiment was insufficient light management system in our laboratory. As a result, internodes elongation was found. In conclusion, growth, fresh marketable yield and ascorbic acid concentration were affected by different strength of nutrient solution. In case of plant height, the Tallest plant height (19.53 cm) was recorded from plant grown in T_1 which was similar to the T_2 while the lowest plant height (15.61 cm) was recorded from T_3, in case of number of leaves per plant, the maximum (10.65) number of leaves per plant was recorded from plant grown in T_1 and similar to T_2 while the minimum number of leaves/plant (8.80) was recorded plant grown in T_3, in case of leaf breadth, higher leaf breadth (11.36 cm) was recorded from plant grown in T_1

and similar to T_2 and lower leaf breadth (9.56 cm) recorded from plant grown in T_3, in case of leaf length, higher leaf length (17.61 cm) was recorded from the plant grown in T_1 and lower leaf length (13.9 cm) recorded from the plant grown in T_3, in case of fresh weight maximum fresh weight (48.81 g/plant) was recorded from the plant grown in T_1 and similar to T_2 (45.63 g/plant) and minimum fresh weight (27.94 g/plant) recorded from the plant grown in T_3. In case of ascorbic acid content, maximum ascorbic acid content (157.61 mg/100g fresh weight) was recorded from the plant grown in T_1 and lower ascorbic acid content (127.41 mg/100g fresh weight) recorded from the plant grown in T_3.In case of β-carotene content, maximum β-carotene content (3207 µg/100g fresh weight) was recorded from the plant grown in $T_{3,}$ on the other hand β-carotene content (3100 µg/100g fresh weight) was recorded from the plant grown in T_1 Different physiological analysis parameters: viz; in case of leaf mass ratio (LMR), higher leaf mass ratio (0.88) was recorded from the plant grown in T_1 and lower leaf mass ratio (0.82) was recorded from the plant grown in T_3; in case of leaf area ratio (LAR), best result found from the grow in T_2(99.48) followed by T_3(98.75) and T_1(71.27). Incase of root weight ratio (RWR), best result found from the grow in T_1 followed by T_2, in case of net assimilation ratio NAR, best result was found from $T_1$and relative growth rate(RGR), best result found from the grow in T_1 followed by T_2.

Vegetative growth, physiological parameters, ascorbic acid content and β-carotene content were remarkably changed by applying different concentrations of nutrient solution. The maximum number of leaf, highest plant height, higher plant fresh weight were found in T_1(½ Rahman and Inden (2012) + 0ml of SIB) which was followed by T_2 and maximum ascorbic acid content and β-carotene content was found in T_3(½ Rahman and Inden (2012) + 0.75 ml of SIB).Therefore, the present study showed lettuce can be grown in hydroponic system by using ½ Rahman and Inden (2012) + 0.5 ml of SIB with moderate yield as well as higher ascorbic acid and β-carotene content.

CHAPTER VI

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Appendix I. Analysis of variances of the data on plant height (cm) at different days after transplanting (DAT) of lettuce

Source of variation	Degrees of Freedom (df)	Mean square for plant height (cm)				
		00 DAT	10DAT	20DAT	30DAT	40DAT
Factor	2	0.270	2.163	4.973*	8.860*	11.785*
Error	6	0.030	0.034	0.048	0.059	0.941

*: Significant at 0.05 level of probability

Appendix II. Analysis of variances of the data on leaf no at different days after transplanting (DAT) of lettuce

Source of variation	Degrees of Freedom (df)	Mean square for leaf No.				
		00DAT	10DAT	20DAT	30DAT	40DAT
Treatment	2	0.030	0.494	1.146	2.131	2.567*
Error	6	0.016	0.023	0.026	0.043	0.048

*: Significant at 0.05 level of probability

Appendix III. Analysis of variances of the data on leaf breadth (cm) at different days after transplanting (DAT) of lettuce

Source of variation	Degrees of freedom(df)	Mean square for leaf Breadth (cm)				
		00DAT	10DAT	20DAT	30DAT	40DAT
Treatment	2	0.092	0.94	0.658	1.08	2.546*
Error	6	0.009	0.023	0.03	0.043	0.048

*: Significant at 0.05 level of probability

Appendix IV. Analysis of variances of the data on leaf Length (cm) at different days after transplanting (DAT) of lettuce

Source of variation	Degrees of Freedom (df)	Mean square for leaf Length (cm)				
		00DAT	10DAT	20DAT	30DAT	40DAT
Treatment	2	0.002	1.77	6.670*	7.601**	10.324**
Error	6	0.026	0.030	0.043	0.048	0.112

*: Significant at 0.05 level of probability
**: Significant at 0.01 level of probability

Appendix V. Analysis of variances of the data on leaf area (cm^2) at different days after transplanting (DAT) of lettuce

Source of variation	Degrees of freedom	Mean square for leaf area (cm^2)				
		00DAT	10DAT	20DAT	30DAT	40DAT
Treatment	2	0.91	875.53**	1089.48**	1800.76**	2451.31**
Error	6	0.043	1.613	4.813*	8.33**	22.141**

*: Significant at 0.05 level of probability
**: Significant at 0.01 level of probability

Appendix VI. Analysis of variances of the data on different attributes of lettuce

Source of variation	Degrees of freedom(df)	Mean square for different attributes of lettuce						
		LDW	RDW	LMR	RWR	LAR	RGR	NAR
Treatment	2	3.025	4.003*	2.203	3.003	346.707**	8.680**	28.262**
Error	6	0.006	0.043	0.0410	0.021	0.574	0.049	0.118

*: Significant at 0.05 level of probability
**: Significant at 0.01 level of probability