**Snake tomato (*Tricosanthes cucumerina* L.) Leaf area and fruit mineral contents as affected by fertilizer, salinity and bicarbonate treatments.**

**ABSTRACT**

**Aims:** To evaluate growth in leaf area and some fruit mineral content of snake tomato, affected by fertilizer, salinity and bicarbonates.

**Study design:** Complete randomized block design (CRBD).

**Place and Duration of Study:** Place of study was Department of Botany, Nnamdi Azikiwe University, Awka, botanical garden located on (Latitude 6.25/Longitude7.11) , plants were raised under screen house between August to November, 2024. Methodology: Viable seeds of snake tomato obtained from NRCRI Umudike, was sown into pots, later thinned to one plant per pot, with 3 replicates. Treatments were fifteen comprising of fertilizer (inorganic single, organic single and 1:1 combination, while irrigation water was prepared at 2mM of NaCl, NaHCO3 and KHCO3, given at 7 days interval. Growth was observed and recorded as leaf area (cm2), some fruit minerals composition were determined using (AAS). The 15 treatments are represented with T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, T13, T14, T15, and Control

**Results:** Results were analyzed with ANOVA using SPSS version 26, and means were separated using Duncan’s multiple range test, confidence level was P = .05. Results showed that leaf area increased progressively generally from seedling stage. T1,T2 showed lager leaf area followed by T14 and T15 at week 1, while at week 6, T2 had the largest followed by T14 and at week 11 T12 had the largest followed by T11, while T6 has shown considerable increase in leaf size. For fruit magnesium T12 was highest followed by T14, for Calcium T12 was highest while the least was control also, Phosphorus composition was lowest in T1 and highest in T12 followed by T13. Zinc and Iron were highest in T12 and lowest in T2, for ripe fruits while in unripe fruits similar pattern was observed.

**Conclusion:** Plant leaf area was influenced by treatments, however fruit mineral composition was significantly affected by the treatments, implying that yield of minerals in fruits like snake tomato can be improved using fertilizer treatments and bicarbonates.

*Keywords: snake tomato, bicarbonates, mineral nutrients*, mobilization

**1. INTRODUCTION**

Food is one necessary need of humans and more especially when the population of nations are increasing without commensurate production in quantity and quality of food to be consumed. A major concern is that rice one of the major staple food in Nigeria is consumed without necessarily considering the quality, in terms of mineral composition. Plants grow well and function properly when the nutrient elements are in optimum supply making physiological functions to progress with ease. Some plant nutrient management methods does not hold for achieving this. Yield of plant should be looed not only in vegetative sense but also in nutrient mineral yield in desired organ of the plant.

Poverty is very much high among Nigerians, statistics (NBS, November 17, 2022 report on Channelstv.com). Very many households are malnourished, due to poor nutrition. The demand for tomato is high that it is not affordable to make stew. Thereby, resulting n the search affordable options. Alternatives, and inventions are the ways day ways of survival of the poor group. The need for food availability among poor sub-Saharan Africans is prompting the research into providing alternative sources especially when their economic status could not sustain importation of canned tomato paste for the poor populace. The closest alternative obvious is snake tomato (*T. cucumerina* L.). The plant yielded pastes used in preparing recipes for eating rice especially among households. The fruits of snake tomato has the size, production not cost intensive, and possesses nutritional and medicinal properties of importance.

Reports available shows that about 10 % of all the processed tomato need of Nigeria can be provided, giving a deficit in supply of more than 80 %, making the entire population in starvation sense for the needed tomato pastes, (Tomato News, Daily Trust, Jan. 27 2024). Many families and people are finding it hard to meet with the adequate quantity and quality of tomato to satisfy their need for culinary purposes as well as dietary needs. Seeking for alternative due to high demands with very poor purchasing power of the population, led to the inventions of different sorts of food types hoping to get a good option. Out of all the tried options included bell pepper, carrot and beets, palm fruit extract 'ofe-akwu' and so on. Of all these options none have actually satisfied the demand for known traditional tomato. There is still serious search of alternatives more so now that most countries are returning to improving each countries domestic production for their population and raising their gross domestic product, (Farming Farmers Farm, 2023).

The closest to the search of replacement to the conventional tomato is the Snake tomato, *Tricosanthes cucumerina* L. also known as snake guard by different groups of human population. It has short growth period of less than six months, it’s a monoecious plant, tropical and subtropical in spread, and possesses good nutritional qualities, (Abukusa-Onyago, 2003; Idowu, 2019). The status of the plant in Nigeria is that it is an underutilized plant with ethno-medicinal and culinary properties. Few farmers who participate in growing the plant are facing the challenge of spoilage when plants reach maturity, due to lack of processing facility for the harvested fruit, making the amount of lost product amounting to about 50 % is lost to spoilage. The wastage associated with the fruit is thus enormous and farmers are no longer, interested on cultivating the crop, the agronomic advantages not withstanding (Onyeka, 2002). The usefulness of the plant, snake tomato, includes that it is highly nutritious, a good source of vitamins, and gives several medicinal values which include treatment of fever, cough, dysentery, headache, skin rashes and loss of hair or baldness, (Idowu et al. 2019). Snake tomato has shown to contain vitamins, proteins, soluble carbohydrates, lipids, as well as fibre. Organically made mineral nutrients as it has mineral elements such as, Mg, Cu, K, Zn, Ca, Na, N, P, Pb, Ag, Fe, Se, Cd, Pb, Cr, Co, Ni and Hg. Other nutritionally bio active compounds found present are the phenolic antioxidants, tannins, saponins, and some anti-nutritionals. (Izundu et al., 2011, Liyanage et al., 2016, Okonwu, 2019).

Sodium bicarbonate is a pH buffer, promotes nutrient uptake and enhances how plants cope with abiotic stress and oxidative damage. It is known to add more carbon to the roots of plants thus increases photosynthetic activity of plant cells, increases expression of enzyme of Calvin cycle which helps in CO2 assimilation thereby generating glyceraldehyde-3-phosphate (G-3-P) as well as other precursors to sugar synthesis ( Liang *et al*., 2023, Reinoso *et al*., 2024).

Potassium bicarbonate improves the activation of most enzymes that catalyze the pathway of carbohydrate synthesis, especially sucrose-6-phosphate synthase (SPS) as well sucrose-6- phosphate phosphatase, Fructokinase, and Glucokinase as enzymes contributing to the synthesis of sucrose as well as conversion into other forms of sugars. (Xu *et al*., 2020, Luo *et al*., 2022)

Inorganic fertilizers are good for rapid growth of plants because the nutrients are already water soluble. Therefore, the effect is usually immediately and fast, contains all necessary nutrients that are ready to use. Inorganic fertilizers are quite high in nutrient content and only relatively small amounts are required for productivity. Correct amount applications of inorganic fertilizer can increase soil organic matter through higher levels of root mass and crop residues (Roba, 2018).

However, many health problems and unrecoverable environmental pollutions are caused by the intensive use of inorganic fertilizer in agriculture for ensuring the world’s food security. Comparatively, inorganic fertilizers are costly and have numerous undesirable ecological effects if coped poorly (Hijbeek, 2018).

Inorganic fertilizers are used to provide immediate nutrients to the plant when they need it unlike organic fertilizers that only have a slow release capability. Inorganic fertilizer works more rapidly and it may be utilized in balance of the farms need. They are less expensive than commercial organic fertilizers as well as may be used in large amounts (Ibrahim *et al*., 2014). The inorganic fertilizers are required for promoting plant growth and production. They enhance the chemical soil properties, such as increasing the supply of macro and micro essential nutrients to meet the crop needs (Ilahi *et al*., 2020).). Chemical fertilizers perform valuable contribution to get high crop productivity. Despite the fact that chemical fertilizer increases the plant growth rate and strength, hence meets the food safety of the world, but the plants grown in this way does not develop good plant character such as, good root structure, shoot structure, nutritional properties and will not get proper time to grow and ripe correctly (Kumar et al., 2019). In continuous cropping system, the use of excessive nutrients (N or NP alone) through inorganic fertilizers cannot maintain the desired level of crop production hence deteriorate the normal functioning of agriculture crops in a long sense (Ilahi *et al*., 2020). In addition, high use of chemical fertilizer, especially N, can cause to crop tips browning, lesser leaf yellowing, bendy and crop lodging. When scorches roots, the root may blacken and go shuffle. All these symptoms occur due to increase amount of salt in soil which would cause reduction in water absorption by plants (Ilahi *et al*., 2020). Researches, suggests that excessive use of chemical fertilizers to plants may affect the leaves by turning into yellow or brown, destructing the plant and reducing crop yield.

On the other hand, continuous use of chemical fertilizer may result in a toxic storage of heavy metal such as arsenic, cadmium and uranium in the soil. The effects of chemical fertilizers on soil are very adverse and irretrievable (Gupta et al., 2014). The major inconvenience of inorganic fertilizers is that they have huge contents of acids including hydrochloric acid and sulfuric acid which leads to increase concentration of soil acidity that could in turn have a toxic effect on nitrogen fixing bacteria. These microorganisms play a key role in the supply of nitrogen needed by growing plants. The sole use of inorganic fertilizers is dangerous and its long term use can pollute the soil (Ilahi *et al*., 2020).

In another light, a major concern is the increase in soil pH as a result of increased use of bicarbonates can present with its challenges of affecting nutrient mobilization from soils into the plant. This could be possible when some useful elements form insoluble salts of Phosphorus, Iron, Calcium, Zinc, Manganese, and even Potassium with the bicarbonates, (Ding *et al*., 2020).

The aim of this study is to determine how fertilizers, salinity and bicarbonate affects snake tomato leaf area and fruit mineral contents.

**2. MATERIALS AND METHODS**

**2.1 Pot set up and seed planting:**

Viable seeds of snake tomato (*T. cucumerina L*.) obtained from NRCRI Umudike were planted in 30 litres plastic buckets filled with sandy loam soil, mixed with respective fertilizer. Following germination the plants were treated with 2mM of salinity, and or bicarbonate as may be required from 21 days after germination. The saline and bicarbonate treatments were supplied in irrigation water using standard methods of Ogbonna *et al*., (2016). Pots were of fifteen treatments and a control with five replicates, out of which 3 pots were used for making growth observation and the other two were used for random selection of fruits for analysis. The treatments were as follows;

T1. Control

T2. Inorganic +NaCl

T3. Inorganic+NaHCO3

T4. Inorganic+KHCO3

T5. Inorganic+NaCl+NaHCO3

T6. Inorganic+NaCl+KHCO3

T7. Organic+NaCl

T8. Organic+NaHCO3

T9. Organic+KHCO3

T10. Organic+NaCl+NaHCO3

T11. Organic+NaCl+KHCO3

T12. Combined+NaCl

T13. Combined+NaHCO3

T14. Combined+KHCO3

T16. Combined+NaCl+NaHCO3

T16. Combined+NaCl+KHCO3

**2.2 Growth parameter (leaf area):**

This was observed and recorded by randomly selecting and measuring the fourth fully open leaf from the shoot apex, and readings of vertical – (leaf apex to leaf base) and horizontal (largest width), then multiplied by leaf correction factor of 0.68 for palmately lobed leaves (Julia et al., 2021).

**2.2 Fruit Mineral content:**

The following minerals, Magnesium (Mg), Calcium (Ca), Phosphorus (P), Zinc (Z) and Iron (Fe) were analyzed, using standard procedures of AOAC (2002) modified by Ogbonna et al., 2016 using AAS. The ash residues of the fruit mesocarp samples of ripe and unripe was digested using 5 cm3 of concentrated Nitric acid and then filtered using a filter paper in to 100 cm3 volumetric flask and was diluted to the mark with distilled water. It was then transferred in to sampling bottle, ready for analysis. The procedure was repeated for all other samples.

Data were analyzed using SPSS version 26 for ANOVA and means were separated using Duncan Multiple Range Test (Duncan, 1955).

**3. RESULTS AND DISCUSSION**

**3.1 Leaf area**

The figure showed the leaf area of snake tomato measured in centimeters (cm2) as influenced by fertilizer, salinity and bicarbonate treatments. The figure explains steady progression of increase in leaf area size for all the treatments including the control. In the first week of observation from 21 days after germination (21DAG), treatments T1, T2, and T3 had larger leaf area compared to T12, T13, and T14 up to week 6. By week 10, the set of compared treatments has nearly levelled out in the leaf area measured, while at week 11, T12, and T13 had increased in leaf area surpassing the first set of treatments with fast increase in leaf area. Furthermore, T14, T15 and T16 were not increasing as T12 and T13 t. On the other hand, treatments T7, T8 were steadily increasing in leaf area but did not reach that of T1, T2, and T3 irrigation water NaCl, NaHCO3 and KHCO3 respectively. Statistical analysis using ANOVA showed that the treatment effect on leaf area was significant *P = .05*, Figure 1.

Figure 1. Mean leaf area as influenced by treatments at one (1) week interval

Progressive increase in size of the leaf marks proper mobilization and transport of mineral elements from the soil into the plant organs for growth and development.

Inorganic fertilizer gave a rapid increase in leaf area, followed by the combined fertilizer type. Over the several weeks of observation, there were not significant differences, but in the interaction between the fertilizer types, it was significant. These differences could be attributed to the additional amounts of sodium and potassium added to the soil via irrigation water treatments. Sodium is important for the osmotic water potential balance of the plants. Also, where the extra sodium through irrigation reaches the root of plants, uptake is rapid, and there is also a contribution to the availability and uptake of other mineral nutrients because sodium plays its part in active transport that will enhance the transport of other elements in the soil. Inorganic fertilizers have been shown to constitute more of the required mineral nutrients than the organic fertilizers. This was in agreement with the findings of Ogundijo *et al*. (2015) as they compared the mineral nutrient composition of inorganic fertilizer with poultry manure. It is important to note that the combined fertilizer gave the highest values of leaf area, while the organic fertilizer were gradually increasing.

The leaf is the largest plant organ and one of the most vital for several crucial physiological processes and has maximum environmental interaction. Interestingly, leaf area directly correlates with the photosynthetic capacity of the plant, transpiration rate, and stomatal conductance. Plant growth and biomass accumulation can be predicted using leaf area data. This relationship has applications in estimating crop yield and carbon sequestration. Leaf area data is used to measure abiotic and biotic stress and plant response to climate change since it is sensitive to the environment. The leaf traits usually used are leaf area, longevity, chemical composition, and carbon allocation. Among these, leaf area is one of the most common plant traits measured, as it provides information on several processes and is relatively easy to estimate, Vijayalaxmi Kinhal, (2023).

Bicarbonates are providers of CO2 to the roots of plants, in the work of Burbulis *et al*., (2017), on the effects of potassium bicarbonate on photosynthetic parameters of *Setaria viridis* L. Beauv., when treated with water only and potassium bicarbonate before subjecting them to moderate and severe drought. The findings showed that plants treated with different concentrations of KHCO₃ had improved yields compared to those treated with water only. They reported that this was as a result of the protection of photosystem II components of the plants. However, in this study, KHCO₃ irrigation water had reduced effect than that of NaHCO₃.

**3.2 Some Fruit Mineral content**

The result of the influence of fertilizer, salinity and bicarbonate treatments on ripe fruit mineral content, revealed that the treatments were significantly different at P = .05 of data analyzed using ANOVA in SPSS. While in comparing the means of the treatments the result showed that T1 is statistically different from T6, T7, T10, T11, T12, T13, T14 and T15, while Control is not statistically different from T1 and T2 each other. Also, T3, T12, Table 1.

Table 1: Effect of treatment on ripe fruit magnesium content (mg/100 g)

|  |  |
| --- | --- |
| Treatment | Mg  (M±SD) Ripe |
| Control | 78.04± 0.51a |
| T1 | 78.11 ± 0.04ab |
| T2 | 78.21 ± 0.51abc |
| T3 | 78.49 ± 0.13bc |
| T4 | 78.58 ± 0.04cde |
| T5 | 78.69 ± 0.04de |
| T6 | 78.94 ± 0.15e |
| T7 | 79.43±0.21f |
| T8 | 79.71±0.23fg |
| T9 | 80.09±0.12gh |
| T10 | 80.25±0.2h |
| T11 | 81.63±0.14i |
| T12 | 82.69±0.16j |
| T13 | 94.47±0.28k |
| T14 | 109.66±0.04l |
| T15 | 112.12±0.02m |

Key \* M±SD

Mean values not sharing same superscript are significantly different at *P = .05*

Results of ripe fruit calcium content affected by treatments showed that the treatments had significant effect at P = .05. T1 had the lowest amount compared to the highest given by T14. In comparing the treatment effect, Control was different from T2, T3, T4, T5, T7, T9, T10, T12, T13, T14 and T15 while T3, T8, and T11 do not have significant difference in their effect, Table 2

Table 2: Effect of treatments on ripe fruit calcium content (mg/100 g)

|  |  |
| --- | --- |
| Treatment | Ca |
| Control | 60.12±1.45ab |
| T1 | 59.76±0.02a |
| T2 | 61.11±0.32def |
| T3 | 60.77±0.03bcde |
| T4 | 60.92±0.03cde |
| T5 | 60.59±0.13bcd |
| T6 | 60.16±0.05abc |
| T7 | 61.40±0.02ef |
| T8 | 60.77±0.06bcde |
| T9 | 60.91±0.04cde |
| T10 | 61.03±0.23de |
| T11 | 60.83±0.08bcde |
| T12 | 63.22±0.06h |
| T13 | 61.81±0.19fg |
| T14 | 62.34±0.47g |
| T15 | 61.39±0.24ef |

Key \*M±SD

Values not sharing same superscript are significantly different at *P = .05*

Results of ripe fruit phosphorus content revealed that the treatment effect was significant at *P = .05.* The means showed that the highest phosphorus was obtained in T12 and the lowest was T1. T8 and T9 did not show statistical significant difference. Other treatments control was different from T1, and the rest of the treatments, Table 3.

Table 3: Effect of treatments on ripe fruit phosphorus content (mg/100 g)

|  |  |
| --- | --- |
| Treatment | P |
| Control | 187.18±0.28b |
| T1 | 185.59±0.3a |
| T2 | 187.84±0.03cde |
| T3 | 187.49±0.06bc |
| T4 | 187.71±0.01cd |
| T5 | 187.45±0.03bc |
| T6 | 188.16±0.03ef |
| T7 | 189.12±0.05g |
| T8 | 188.07±0.01de |
| T9 | 187.99±0.44de |
| T10 | 188.52±0.03f |
| T11 | 187.7±0.04cd |
| T12 | 192.19±0.74i |
| T13 | 188.27±0.04ef |
| T14 | 190.34±0.14h |
| T15 | 189.07±0.1g |

Key \* M±SD

Values not sharing same superscript are significantly different at *P =.05*

Result of the ripe fruit zinc composition showed that the treatment effect was significant at *P = .05*. In comparing the treatment means, the highest yield in zinc was obtained in T12, and the lowest is in T1. However, T2, T7 and T11 were not different, same as between T9 and T10, Table 4

Table 4: Effect of treatment on ripe fruit Zinc content (mg/100 mg)

|  |  |
| --- | --- |
| Treatment | Zn |
| Control | 0.84±0.02abc |
| T1 | 0.82±0.01a |
| T2 | 0.85±0.01abcde |
| T3 | 0.87±0def |
| T4 | 0.87±0cde |
| T5 | 0.85±0.02abcd |
| T6 | 0.83±0.01ab |
| T7 | 0.85±0.02abcde |
| T8 | 0.84±0.01ab |
| T9 | 0.86±0.02bcde |
| T10 | 0.86±0.02bcde |
| T11 | 0.85±0.01abcde |
| T12 | 1.05±0.02i |
| T13 | 0.90±0.02g |
| T14 | 0.96±0.01h |
| T15 | 0.88±0.03ef |

Key \* M±SD

Values not sharing same superscript are significantly different at *P = .05*

Result of ripe fruit iron content showed that T12 yielded the highest iron, followed by T14, 1nd T13. Also, T2, T4, T10 and T11 are having similar treatment effect, also Control and T15 are also showed simmilar effect, Table 5.

Table 5: Effect of treatments on ripe fruit Iron content (mg/100 mg)

|  |  |
| --- | --- |
| Treatment | Fe |
| Control | 11.88±0.03cde |
| T1 | 10.76±0.03a |
| T2 | 11.83±0.05bcde |
| T3 | 11.7±0.025bc |
| T4 | 11.79±0.12bcde |
| T5 | 11.74±0.06bcd |
| T6 | 11.67±0.05bc |
| T7 | 11.75±0.15bcd |
| T8 | 11.96±0.13de |
| T9 | 11.63±0.08b |
| T10 | 11.79±0.26bcde |
| T11 | 11.85±0.03bcde |
| T12 | 13.2±0.03g |
| T13 | 12±0.04e |
| T14 | 12.83±0.13f |
| T15 | 11.9±0.01cde |

Key \* M±SD

Values not sharing same superscript are significantly different at *P = .05*

This study has established the presence of minerals in *T. cucumerina* fruits (ripe and unripe) in quantities like the reports of other studies (Ugbaja *et al*., 2017). Although this study focused on the effect of salinity, bicarbonate, and fertilizer treatments on the mineral composition, the values of the minerals reported were comparatively higher than those reported in *Solanum lycopersicum* (L.) cultivars in Nigeria (Ugbaja *et al*., 2017). In this study, it was observed that the mineral content of *T. cucumerina*, unripe and ripe fruit, in decreasing order is phosphorus, magnesium, calcium, iron, and zinc. The quantities recorded for phosphorus, iron, and zinc were more in ripe fruits, while magnesium and calcium were more in unripe fruits of *T. cucumerina*.

The treatment of *T. cucumerina* grown on different types of fertilizer with salt and bicarbonate had a significant effect on all the minerals evaluated except calcium in either ripe or unripe fruit. The lack of a significant effect on the quantity of calcium present may be attributable to several factors. The addition of salt and bicarbonate makes calcium less sensitive to pH changes due to calcium's relatively high pH buffering capacity. Calcium is an essential nutrient for plant growth, and plants have mechanisms to regulate calcium uptake and distribution (Thor, 2019). This regulation might reduce the impact of external factors like fertilizer type and salt/bicarbonate treatment on calcium levels in the fruit (Hocking et al., 2016). Tonetto de Freitas *et al*. (2014) showed that calcium accumulation in tomato fruit was significantly dependent on rates of xylem sap flow, influenced by transpiration and growth rates. Hence the quantity of calcium in fruit is more dependent on physiological than treatment factors.

It is important to note that all the mineral elements evaluated in this study have been reported to play important roles in health and disease states of humans. For example, Gemede *et al*. (2016) reported that a high amount of potassium in the body increases iron utilization. Calcium- and phosphorus-containing substances are required by children and pregnant and lactating women for bones and teeth development (Farias et al., 2020). Zinc is required for building the immune system, regulating cellular growth, and acting as a coenzyme for carbohydrates, protein, and nucleic acids metabolism; regulating blood sugar levels; and producing energy (Wessels et al., 2017). The mineral contents of *T. cucumerina* in this study are high enough and compare favorably with the composition of those reported in S. lycopersicum cultivars. Therefore *T. cucumerina* can be considered as an alternative mineral source for households, food industries, and pharmaceutical industries due to its high mineral composition and its potential roles in Medicare

**4. CONCLUSION**

The use of fertilizers for growing snake tomato has shown that better yield in terms of growth and important antioxidants content in the fruit in the form of lycopene and carotene is achievable by using a combination of inorganic and organic fertilizer with bicarbonates especially that of sodium.

**REFERENCES**

1. Abukusa-Onyango M.A. (2003). The role of African indigenous vegetables in poverty alleviation in Kenya. Proceedings of the first International Workshop, 23rd – 25th, September, 2002. Nairobi Kenya, 269 – 270
2. AOAC, Association of Official and Analytical Chemistry (2000). Official methods of analysis, (Dr. William Horwith) 17th Ed, Gaithersburg, MD., USA
3. Bilalis D., Krokida M., Roussis I., Papastylianou P., Travlos I., Nikolina N., and Dede A., (2018). Effects of organic and inorganic fertilization on yield and quality of processing tomato (Lycopersicon esculentum Mill.), Folia Horticulture. 30(2): 321-332
4. Burbulis N., Vainorienė R., Blinstrubienė A., Jonytienė V., and Liakas V. (2017). Effect of potassium bicarbonate on photosynthetic parameters of Setaria viridis under drought conditions. Zemdirbyste-Agriculture, 104 (1): 79–84
5. Daily Trust Online News Paper (30/01/2020). https://www.tomatonews.com/en/nigeria-tomato-jos-targets-10-paste-domestic-needs\_2\_926.html Accessed, November 10, 2024. 4.45am
6. Ding, W., Clode, P. L., and Lambers, H. (2020). Effects of pH and bicarbonate on the nutrient status and growth of three Lupinus species. *Plant and Soil*, *447*, 9-28
7. Duncan, D.B. (1955) Multiple Range and Multiple F-Tests. Biometrics, 11, 1-42.
8. Farming Farmers Farm (2023). https://farmingfarmersfarms.com/2023/07/amid-rising-prices-5-cheap-substitutes-for-tomatoes/ Accessed, November 9, 2024. 4.15am
9. Hijbeek, R., Ten Berge, H. F. M., Whitmore, A. P., Barkusky, D., Schroder, J. J., and Van Ittersum, M. K. (2018). Nitrogen fertilizer replacement values for organic amendments appear to increase with N application rates Nutr. Cycling Agroecosyst. 110(1): 105-115
10. Ibrahim, M., Tasi’u, Y. R., Umma, M., and Dangora, II. (2014).The effects of inorganic fertilizer on soil characteristics and production of Egg Plant (Solanum melongena L.) in Warawa area of Kano State Standard Research Journal of Agricultural Science 2(8): 129-135
11. Ilahi, H., Hidayat, K., Adnan, M., Rehman, F. U., Tahir, R., Saeed, M. S., and Toor, M. D. (2020). Accentuating the impact of inorganic and organic fertilizers on agriculture crop production: A review. *Indian Journal of Pure Applied. Bioscience*, *9*(1), 36-45.
12. Idowu O.O., Fashina A. B., Kolapo O. E., and Awulosi O. M. (2019). Snake Gueard (Tricosanthes cucumerina L.) An Underutilized Crop with Great Potentials. International Journal of Current Microbiology and Applied Sciences, 8(9): 1711 – 1717
13. Izundu A.I, Lips S. H. and Nwana I. E. (2011). Effect of salinity and bicarbonate fertilization on tomato fruit yield and quality. International Journal of Biological Sciences, 3(3): 134 – 143
14. Kumar, R., Kumar, R., and Prakash, O. (2019). Chapter-5 the impact of chemical fertilizers on our environment and ecosystem. *Chief Ed*, *35*(69): 1173-1189.
15. Kumari, R., Kaur, I., & Bhatnagar, A. K. (2011). Effect of aqueous extract of Sargassum johnstonii Setchell & Gardner on growth, yield and quality of Lycopersicon esculentum Mill. Journal of Applied Phycology, 23, 623-633.
16. Liang F., Shi Z., Wei S., Wu L., and Yan S., (2023). What is the appropriate content of HCO3 irrigated into tomato cultivation soil for enhancing its carbon fixation? Environmental Technology & Innovation, 32: 103332
17. Liyanage, R., Nadeeshani, H., Jayathilake, C., Visvanathan, R., and Wimalasiri, S. (2016). Comparative analysis of nutritional and bioactive properties of aerial parts of snake gourd (*Trichosanthes cucumerina* Linn.). International journal of food science, 2016(1), 8501637
18. Lu Y and Fricke W. (2023). Salt Stress-Regulation of Root Water Uptake in a Whole-Plant and Diurnal Context. International Journal of Molecular Science, 24(9):8070
19. Luo, A., Zhang X., Wang C., and Zhou C. (2022). Effects of Different Water and Potassium Supply on Glucose, Fructose, and Sucrose Carbon Allocation in Tomato Fruit, Journal of Plant Growth Regulation, 47: 684 – 700
20. Mirela C. and Orsolya B. (2021). Salt and Water Stress Responses in Plants, In: Plant Stress Physiology – Perspective in Agriculture, Intech Open
21. Ogbonna O. J., Udia P.M., Abe P.N., Omoregha C.U. and Anele E.I. (2016). Phytochemical and proximate analysis, mineral and vitamin composition of Allium cepa bulb extract, Advances in Biomedicine and Pharmacy, 3(4): 181 – 186
22. Ogundijo D., Adetunji, M., Azeez, J., Toyin A., Olla N. and Adekunle, A.. (2015). Influence of Organic and Inorganic Fertilizers on Soil Chemical Properties and Nutrient Changes in an Alfisol of South Western Nigeria. *International Journal of Plant & Soil Science*. 7: 329-337
23. Okonwu, K., & Muonekwu, J. E. (2019). Potentials of underexploited seed of *Trichosanthes cucumerina* Linn. Journal of Applied Sciences and Environmental Management, 23(5), 791-797.
24. Olaniyi J.O and Ajibola A.T. (2008). Effects of inorganic and organic fertilizers application on the growth, fruit yield and quality of tomato (Lycopersicon lycopersicum). Journal of Applied Biosciences 8 (1): 236 – 242
25. Reinoso L. G., Majláth I., Dernovics M., Fábián A., Jose J., Jampoh E. A., Hamow K. Á., Soós V., Sági L. and Éva C.(2024). Root-based inorganic carbon uptake increases the growth of Arabidopsis thaliana and changes transporter expression and nitrogen and sulfur metabolism, Frontiers in Plant Sciences, 15: 1 – 22
26. Roba, T. B. (2018). Review on: The effect of mixing organic and inorganic fertilizer on productivity and soil fertility. *Open Access Library Journal*, *5*(06): 1
27. Serri, F., Souri, M. K., and Rezapanah, M. (2021). Growth, biochemical quality and antioxidant capacity of coriander leaves under organic and inorganic fertilization programs. Chemical and Biological Technologies in Agriculture, 8, 1-8
28. Vijayalaxmi Kinhal (2023). Crucial applications of leaf area data for plant research. *CID Bio-Science Weekly Article Series*, <https://cid-inc.com/blog/seven-crucial-applications-of-leaf-area-data/>, Accessed 11/17/2024 4.04 am.
29. Wondim G.B., Daba A.W., and Qureshi A.S. (2020). Effects of salinity on producers’ livelihoods and socio-economic conditions; the case of Afar region, Northeastern Ethiopia. J Sustainable Agricultural Science 46(3): 35-46
30. Xu X., Du X., Wang F., Sha J., Chen Q., Tian G., Zhu Z., Ge S. and Jiang Y. (2020). Effects of Potassium Levels on Plant Growth, Accumulation and Distribution of Carbon, and Nitrate Metabolism in Apple Dwarf Rootstock Seedlings, Frontiers in Plant Science, 11:904

DEFINITIONS, ACRONYMS, ABBREVIATIONS

CO2: carbon (iv) oxide

NaCl: sodium chloride

NaHCO3: sodium bicarbonate

KHCO3: potassium bicarbonate

ANOVA: Analysis of Varians