KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI, GHANA

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF AGRICULTURE

DEPARTMENT OF HORTICULTURE

EFFECT OF DIFFERENT CONCENTRATIONS OF BIOZYME ON THE PHYSICO-CHEMICAL PROPERTIES OF F1 CASTLE BAR HYBRID TOMATO (*Solanum lycopersicon*)

BY

DANIEL KWASI ATTIVOR

JANUARY, 2016

EFFECT OF DIFFERENT CONCENTRATIONS OF BIOZYME ON THE PHYSICO-CHEMICAL PROPERTIES OF F1 CASTLE BAR HYBRID TOMATO (*Solanum lycopersicon*)

BY

DANIEL KWASI ATTIVOR

A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY (M. Phil. POSTHARVEST TECHNOLOGY) DEGREE

SEPTEMBER, 2015

DECLARATION

I hereby declare that the work herein presented is the result of my own investigations, and that, except for specific references which have been duly acknowledged, this project has not been submitted either in part or whole for any other degree elsewhere.

Signature..... …….....

DANIEL KWASI ATTIVOR Date

(Student)

Signature…… ……

MR. PATRICK KUMAH Date

(Main Supervisor)

Signature…… ……

DR. ENOCK OSEKERE Date

(Co-supervisor)

Signature…… ……

Dr. FRANCIS APPIAH Date

(Head of Department)

DEDICATIONS

This work is dedicated to God Almighty, my Children who in diverse ways have been a great source of inspiration during difficult times.

ACKNOWLEDGEMENT

My special gratitude goes to God Almighty for His sustenance throughout the course.

I humbly wish to express my deepest appreciation to my supervisor Mr. Patrick Kumah of the Department of Horticulture and my Co. Supervisor Dr. Enock Osekere of the Crop and Soil Science Department, both from the Faculty of Agriculture of the Kwame Nkrumah University of Science and Technology for their excellent guidance throughout the conduct of this research for which I remain indebted.

My warmest appreciation goes to all others whose support and encouragement made the completion of this work possible. Special thanks also go to my wife Vicentia and Children; Esinam, Edem, Elorm, Nununbueke, Seyram, Makafui and Akorfa.

I also thank Mr. Emmanuel Ewe, Madam Fortune Petrina Adzakpa and Madam Mabel Meteku whose support was a great value to the work.

All these people take credit in any merit that results from this work. They are however absolved from its short falls to which I alone remain accountable.

ABSTRACT

The tomato sector in Ghana has failed to realize its full potential, in terms of attaining yields comparable to other countries, chemical and nutritional compositions, prolonged shelf life and marketability in improving livelihoods of those households involved in tomato production. The need therefore arose to investigate the use of Biozymes to enhance production and significantly assess its effects on the nutritional, chemical and the postharvest shelf life of tomatoes. Hence, field and laboratory investigations were conducted in the year 2014-2015 to study the effect of different concentrations of Biozyme on the physico-chemical properties, growth, yield, quality and shelf life of F1 Castle Bar tomato. The treatments consisted of Biozyme rates as follows; (i) 0.00 lha^{-1} biozyme (control) (ii) 0.75 lha^{-1} biozyme (iii) 1.00 lha^{-1} biozyme (iv)1.25 lha^{-1} biozyme. Recommended rates of NPK (15-15-15) for tomato were applied to all the plants. Application of biozyme at 0.75 lha^{-1} resulted in the tallest plants (119.42 cm), biggest stems (1.99 mm), largest plant canopy (97.5 cm^2) as well as producing the highest (17.77) number of fruits. Application of 0.75 lha^{-1} biozyme also resulted in big fruit diameter which was similar to the diameters of fruits from the other biozyme treatments. In addition, fruits from the 0.75 lha^{-1} biozyme treatment were more firm than those of the control but similar to the firmness of fruits from the other biozyme rates. Fruits from the 1.0 lha^{-1} biozyme treatment had the thickest mesocarp, yet similar to the mesocarp from the 0.75 lha^{-1} biozyme treatment. No significant differences were however observed between the biozyme treatments for fruit pH (P=0.089), total soluble solids (P=0.755) and total titrable acidity (P=0.156). Fruits from the 0.75 lha^{-1} and 1.25 lha^{-1} biozyme treatments had significantly lower vitamin C content than the control which contained the highest. Biozyme positively affected fruit shelf life such that on

the average, biozyme treatment extended the fruit shelf life by 7 days in comparison with the control. The study concluded that application of Biozyme to tomato positively affected its vegetative growth, fruit yield and postharvest quality characteristics. The application of 0.75 lha^{-1} concentration of Biozymes performed best in plant girth, plant canopy, leaf diameter and plant chlorophyll.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0 INTRODUCTION

Tomato (*Solanum lycopersicon*) is one of the ingredients widely used for food preparation within the vegetable groups, (Ellis *et al*., 1998). The production of tomato serves as one of the sources of income for smallholder farmers in the country. However, as a result of the peasant nature of the cultivation of tomato by farmers, Ghana has been noted to be a net importer of fresh tomatoes from Burkina Faso every year, (Horna *et al*., 2006). Currently, the tomato sub- sector has been thwarted to be a low-productivity high-cost sector, (Robinson and Kolavalli, 2007).

Statistics from MOFA, (2009) indicated that the annual estimated yield for that year was 15 (fifteen) metric tons but realised only (7.5) metric tons. The remaining gap of about 50 (fifty) percent could have probably been bridged with the application of required amount of fertilizer and implementation of improved agronomical practices. Again, bio-regulators could be used to increase the physiological functioning of plants to which fertilizers have been applied.

Kumar *et al*. (2010) describe Biozyme as an environmentally friendly growth stimulant which at low concentrations enhances plant's physiological system by improving yield. Biozyme is a storehouse of naturally occurring nutrients. It increases plant nutrient uptake leading to an enhanced fruit set, numbers, quality and general crop performance. They emphasized that Biozymes also enhance fruit quality parameters such as total soluble solid content, carbohydrate content, sugar and flavor, antioxidant and vitamins levels in vegetables and other fruit crops.

Senn *et al*. (2010) added that high levels of natural plant hormones in seaweed including Cytokinins, stimulated plants could also provide growth in plants. Although it has been found very useful in the production of vegetable crops in several Latin American countries, its usage is not common in Ghana.

It was against this back drop that the objective of the research was set up to investigate the effect of different concentration in Biozyme (a new biostimulant) on the physico-chemical characteristics of Castle Bar tomatoes in Ghana.

Specific objectives were to determine the effect of different:

1. Biozyme concentrations on growth and yield of Castle Bar tomato;
2. Concentrations of Biozyme on the physico-chemical qualities; and
3. Concentrations of Biozyme on the shelf life of the tomato fruits.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 PLANT BIOSTIMULANTS

According to Kumar *et al* (2012), plant biostimulants contained substances and microorganisms whenever applied to plants would improve nutrient uptake, tolerance of abiotic stress and crop quality. They however indicated that biostimulants would usually not control pests and cannot be classified under the pesticide control regulation framework.

Senn *et al* (2013) supported the argument that biostimulants often applied to soil and plants to ensure plant development in North America. They also emphasized that biostimulants promoted seed germination and plant maturity by facilitating nutrient assimilation.

According to Bashan *et al* (1998) Biozymes typically could be classified as bio fertilizers because they contained biological products of living microorganism whenever applied to plants promote growth through several mechanisms as well as nutrient uptake capacity of the plants, Khalid *et al*., 2004; Berg, 2009 cited by Vessey, (2003).

2.2 CATEGORIES OF PLANT BIOSTIMULANTS.

According to Du Jardin, (2012) stated that major categories were widely identified many by scientists, regulators and stakeholders covering both substances and microorganisms. They explained further that microorganisms and beneficial bacteria include Plant Growth Promoter, Regulators (PGPR) and beneficial fungi.

2.2.1 Hulmic and Folic Acids.

Rose *et al*. (2014) stated that hulmic substances (HS) composed of natural organic matter as such variable effects of hulmic substances (HS) could be attributed to the source, environmental conditions, the dose and manner of hulmic substances applied.

Du Jardin (2012), noted regarding the sources of HS could be gathered from naturally humified organic matter, compost, vermicomposts and mineral deposits. Furthermore, Eyheraguibel *et al*. (2008) stated that agricultural by-products often decomposed in the soil instead of relying on oxidation a chemical process which humic substances could be identified.

Schiavon *et al*. (2010) noted that biostimulants loosens cell walls; provide organ enlargement and growth in general. Jindo *et al*. (2012) added that Hulmic substances are often realised as essential suppliers of soil fertility. Additionally, Du Jardin, (2012) also stated that hormonal effects could be considered as a containing functional group identified by the receptive plant known as the hormonal pathways.

2.2.2 Protein Hydrolysates and other Nitrogen Containing Compounds.

Vranova *et al* (2011) stated that nitrogenous molecules including butanes usually diversify and higher in plant characteristics with regards to their ecology and physiology. They also supported the description of Glycogen as a special amino acid derived from a well-established, anti-stressed properties.

Citing Du Jardin (2012), Halpern *et al*. (2014) noted that Amino-acids and peptides mixtures were collected from agro-industrial by-products obtained from both animal and plant wastes.

2.2.3 Seaweed Extracts and Botanicals

According to Khan *et al*. (2009) quoted by Craigie (2011) the use of organic matter being made from fresh seaweeds and fertilizer dated back to ancient agriculture but the effects of biostimulants have been noticed in recent year.

Wally *et al*., (2013a: 2013b) also explained Ascophyllum nodosum as the down and up regulation of the hormonal contents of seaweed products. Calvo *et al*. (2014) concluded by indicating that anti-stress effects reportedly could protect compounds in the seaweed extracts and regulators of endogenous genes. Again, the knowledge on seaweeds they stated that was not known regarding their biostimulants rather there were so many studies on their pesticide properties.

Ziosi *et al.*, 2012 and Ertani *et al*. (2013) noted that opportunities existed regarding the use of biostimulants. They further, explained that plant interactions in the ecosystems could interfere by plant active compounds known as allelochemicals which had received recognition for sustainable management of crops. In conclusion, they emphasized that since farming practices such as crop rotation and mulching were used to exploit chemical interactions between plants, in the same vain recognition should be given to biostimulants development and usage.

2.2.4 Chitosan and other Biopolymers

According to Povero *et al*. (2011) cited by Ferri *et al*. (2014), confirmed the assumption with regards to analysis of proteome of plant tissues treated with chitosan. They explained that chitosan application has been developed only with the focus on protection of plants against fungal pathogens. Iriti, (2009) stressed on the use of abiotic quality traits relating to metabolisms.

Gozzo and Faoro (2013) concluded by indicating that even though a difference could be drawn between bio-control and bio -stimulation which could be interconnected to effects resulting from the applications of inducers.

2.2.5 Inorganic Compounds

According to Pilon-Smits *et al* (2009) noted that beneficial elements should not be limited to their chemical components only but also effects on plant growth. They emphasized on how the quality of plant products could tolerate abiotic stress. In conclusion, they concluded that rigid cell walls reduced transpiration by depositing crystal and enzyme in plant nutrition through interactions with other elements.

Deliopoulos *et al*. (2010) also stressed the view that the benefits of inorganic salts have been used as fungicides though the modes of action not established. They concluded by explaining their distinct fungicidal functions from their fertilizer function as sources of nutrients.

2.2.6 Beneficial Fungi

Behie and Bidochka (2014) described fungi interactions with roots of plants in different ways such as living in mutual symbioses with organisms in direct contact with each other.

According to Gianinazzi *et al*. (2010) there was an interest for the use of mycorrhiza to promote agricultural sustainability as a result of the wide acceptance of benefits derived from the symbioses. Recent knowledge according to Johnson and Gilbert, (2015) also

supported the argument on the significant implications of fungi on the ecology and agriculture.

Dalpé and Monreal (2004) outlined numerous limitations of the use of biostimulants as being the difficulty involved in propagating AMF on a large scale as a result of their biotrophic character. However, fungal endophytes, like *Trichoderma* spp) and *Sebacinales* spp. differ from the mycorrhizal species to enable transfer of nutrients.

2.2.7 Beneficial Bacteria

Ahmad *et al*. (2008) define bacteria interaction with plants in all possible ways regarding agricultural uses. Vacheron *et al*. (2013) said the world market of bacterial biostimulants is growing and PGPR inoculants are now regarded as some kind of plant 'probiotics', i.e. efficient contributors to plant nutrition and immunity.

2.3 COMMON FEATURES OF BIOSTIMULANTS

2.3.1. The Diverse Nature of Biostimulants.

Przybysz *et al*. (2014) considered biostimulants as single compound substances or groups of compounds of single natural origin of which the composition and bioactive components are not fully characterized. Microbial inoculants may contain single strains or mixtures of microorganisms showing additive or synergistic effect.

2.3.2 The Diverse Physiological Functions.

Shabala *et al*. (2012) defined physiological functions as the protection of photosynthetic machinery against photo-damage or the initiation of lateral roots. They explained functions as supported by cellular mechanisms like reactive oxygen scavenging by antioxidants or increased synthesis of auxin transporters to carry on with the functions.

Finally, the modes of actions explained the agricultural functions of biostimulants, e.g. increased tolerance to abiotic stress (causing oxidative stress) or increased N use efficiency which depends on the capacity of roots and lateral root density. Agricultural functions may finally translate into economic and environmental benefits: higher crop yield, savings of fertilizers increased quality and profitability of crop products and enhanced ecosystem services. Shabala *et al*., (2012) cited the effects of biostimulants on crop productions from their cellular targets in plants to whole-plant physiological, horticultural as well as economic and environmental functions.

2.3.3. Agricultural Functions.

Biostimulants contain nutrition efficiency abiotic stress tolerant of crop quality traits. Quality traits composed of nutritional value, grain protein content, shelf life, etc. These converging actions should be the basis of any definition of biostimulants. Stimulation of pathogen response by elicitors and plant gene regulators is achieved by many of the described biostimulants as well as chitosan and laminarin. There is however a growing consensus among regulators and stakeholders to keep

biostimulation and biocontrol separate from regulation.

8

2.4 THE EFFECTS OF BIOZYMES ON PLANT GROWTH AND YIELD

According to Wu *et al.* (2008) enhanced plant yield and growth by Biozyme could be attributable to nutrient absorption as well as improved status of nutrients in plants. For instance, the inoculation of maize (*Zea mays*) with strains of *Bacillus megaterium* and *Bacillus muciaraglaginous* was associated with improved nutritional assimilation of NP K.

Saubidet *et al*. (2000) argued that nitrogen fixation alone would not contribute to the promotion of growth observed with the use of *Azospirillum* species; but that some microorganisms often increased the availability of selected soil nutrients.

Malik *et al*. (2002) cited from De Salamone *et al*, (1996) noted that significant increases in nitrogen content by inoculation with *Azospirillum* spp. were recorded in many crops including cotton, wheat, sugarcane and maize. They stated for instance that *Azospirillum brasilense* and *Azospirillum lipoferum ranged* between 7–12 percent to the total nitrogen content of wheat whereas sugarcane (*Saccharum officinarum*) ranged between 60–80percent of total plant nitrogen was from nitrogen fixation by *Azospirillum diazotrophicus*.

Egamberdiyeva and Höflich (2004) observed that with the application of plant growth stimulants resulted in a significant increase in N, P and K absorption as well as root and shoot dry weight in cotton (*Gossypium hirsutum*) and wheat (*Triticum aestivum*).

Hartmann and Bashan (2009) also added that bacteria with the capacity to fix atmospheric nitrogen (N_2) symbiotically belonged to many different genera, including *Azoarcus* spp, Beijerinckia spp, including *Azospirillum* spp. could be found in plant

roots and root tissues. According to them the ability of *Azospirillum* spp. to fix atmospheric nitrogen was widely identified in many crops.

Adesemoye *et al.* (2010) also noted that a three-strain mixture of *Bacillus* spp. promoted the growth of tomato and increased plant absorption of N-depleted fertilizer.

Several mechanisms were identified by various authorities regarding how specific Biozyme stimulated plant growth and absorption of nutrients, including;

- Solubilization of nutrients by De Freitas *et al* (1997),
- A symbiotic nitrogen fixation by Boddey and Dobereiner (1995)
- Sequestering of iron by production of siderophores, production of volatile organic compounds (VOCs).

2.5 EFFECTS OF BIOZYMES ON FRUIT YIELD AND QUALITY.

Kumar *et al*. (2010) biozymes could provide better and more uniform fruit development under high crop demanding situations. Biozymes ensures fruit quality parameters in vegetables and fruit crops. The balanced composition of Biozymes gives it unique and innovative properties that propel and stimulate plant growth, nutrition uptake, fruit development and consequently better yield performance.

Saimbhi *et al*. (2012) also stated that the application provides rapid plant nutrients uptake that optimize fruit setting and activates the development of bigger and better quality fruits.

According to Sharma *et al*. (2009), plants treated with Biozymes resulted in higher fruit set, yield, fruit weight and volume, total soluble solids, total sugars and longer shelf life. Again, biozymes are believed to be applied as a foliar application to soybean

enhanced zinc uptake at a faster rate than typical mineral zinc application even in soils with acceptable levels of available zinc in Brazil.

Washington Navel and Thomson increased fruit set and percentage of final fruits retained per plant. Biozymes also complemented the mineral fertilization in lettuce production resulting in increased commercial yields (Garcia *et al.* 2010).

Similarly, the application of Biozymes to pepper plants (*Capsicum annum*) increased plant nitrate assimilation and increased fruit yield per plant, (Edwards *et al*. 2010).

According to Singh (2008) and Hoang (2003) indicated that the fruit size, weight and volume of pomegranate was also increased with the application of either NAA alone or NAA in combination with Carbaryl.

2.6 EFFECTS OF BIOZYMES ON FRUIT SHELF LIFE

Sharma *et al.,* (2009) supported the argument that biozyme enhances fruit quality parameters in vegetables and fruit crops such as total soluble solid content (Brix level), carbohydrate content, sugar, flavour, and antioxidant vitamins levels and fruit shelf life.

Looney (1993) observed that biostimulants improved fruit size, appearance, quality, fruit growth. According to Casanovas *et al.* (2002) Gibberellic acid was used extensively in various horticultural crops for improving fruit.

Abubakar *et al.* (2012) agreed with the assertion that biozyme could be termed as commercial formulation of seaweed extract (*Ascophyllum nodosum*), including enzymes, hydrolyzed proteins whereas Spic Cytozyme contained gibberellic acid, auxins, cytokinins, seaweed extract (*Ascophyllum nodosum*), hydrolysed proteins and

trace elements. Additionally, spraying of Gibberellic acid has been evaluated to reduce the risk of crop loss by making fruit more resistant to diseases.

2.7. EFFECT OF BIOZYME ON FRUIT COLOUR

Roper et al. (1987) explained that an increase in fruit colour as well as anthocyanin content would accumulate a greater amount of carbohydrates under the influence of bio regulators.

Chandel and Jindal (1991) noted that triacontanol helped in increasing anthocyanin content in deepening colour and even ripening of fruits after applying Mixtalol to grapes berries. Fornes et al. (1995) also supported the assertion after they observed accelerated colour break and pigmentation in citrus after applying triacontanol.

2.8. EFFECT OF BIOZYME ON FRUIT DISEASE

According to Taiz and Zeiger, (2006) reduction in fruit disease was due to after the application of Biozyme. They added that all biostimulants significantly reduce fruit disease. In conclusion, application of GA_3 reduced disease in cherry reported that Gibberellic acid reduced disease in cherry. Gibberellic acid also used extensively in various horticultural crops for improving fruit set and also to Control disease of tomato fruit and litchi and to inhibit flowering of *Prunus* species.

CHAPTER THREE

3.0 METHODS AND MATERIALS

3.1 STUDY SITE

The method was conducted under greenhouse conditions in Kumasi from November 2014 to 27th March 2015.

3.2 SCOPE OF STUDY

Two experimental studies were conducted over the study period including a greenhouse agronomic experiment and a laboratory postharvest fruit quality assessment.

3.3 GREENHOUSE EXPERIMENT

3.3.1 Experimental Design and Treatments

A Completely Randomized Design (CRD) was applied in four replications in the experiment under a greenhouse. The treatments consisted of Biozyme rates in combination with a standard rate of NPK (15-15-15) fertilizer. The treatments were tested on a tomato var. F1 Castle Bar Hybrid. The treatments were as follows: (i) 0.00 Lha^{-1} biozyme (control) (ii) 0.75 Lha^{-1} biozyme (iii) 1.00 Lha^{-1} biozyme (iv) 1.25 Lhapeat media at the rate of 5 kg per bucket. The buckets were spaced 90cm x 30cm and water was provided manually by hand irrigation. Sixteen (16) plants were selected as data plants for each treatment.

NPK 15.15.15 at the rate of 5 gm per plant was applied as basal fertilizer to all treatments, seven days after transplanting. The first Biozyme application was done 7 days after transplanting and repeated every 14 days after the last application. The solutions of Biozyme at the defined rate were prepared by diluting with water and were applied late in the afternoon to avoid scorching. Each rate of concentration was sprayed

---

[1] biozyme.

3.3.2 Experimental and Crop Management Procedure

Seeds of the tomato variety, Castle Bar seeds were obtained from Monarch Seed Company Ltd, Kumasi Ghana. The seedlings were raised in trays. The seeds were sown one per tray hole in cocoa peat media. Twenty-one days after seed sowing, uniform seedlings with high vigour were transplanted into buckets filled with coco

on the leaves using a hand sprayer in the mornings. Weeds were handpicked as and when necessary.

Plants were staked with nylon straps at 50 percent flowering stage in all the buckets to minimize lodging and fruit infection by contact with the soil. Viper (Endozacarb and Acetamiprid), a dual systemic and contact pesticide, was applied every two weeks after transplanting to control white flies, which was the major pest observed.

The application was done at the rate of 70 mls per 15 litres of water using knap-sack prayer. All the plants were uniformly treated with the pesticide to avoid variation between treatments.

3.3.3 Data Collection

Data collection started seven days after transplanting of seedlings for a period of 12 weeks.

3.3.3.1 Plant height (cm)

The plant height was measured by a tape measure from the soil surface to the tip of the main stem for each treatment and the mean recorded.

3.3.3.2 Leaf Count

The number of leaves per treatment was counted for each plant and their mean computed which was used to represent the number of leaves per plant.

3.3.3.3 Plant girth (cm)

The girth of plants was measured at 7.5cm above soil level using veneer calipers and the mean calculated. This was repeated every two weeks up to the twelfth week.

3.3.3.4 Canopy size (cm)

The plant canopy spread was determined every two weeks by measuring the widest length and breadth angles of the canopy and the mean calculated.

3.3.3.5 Leaf size (cm)

Leaf size was measured at the widest point and across the leaf to determine the area using three leaves per treatment. This was done by measuring with a caliper and the product determined. The mean was calculated to represent the size for each treatment in centimeters (cm).

3.3.3.6 Leaf diameter (cm)

Leaf diameter was measured at the widest point of the leaf shoulder using three leaves per treatment Ngouajio *et al*. (2007). This was done by measuring the widest points with a caliper. The mean was calculated to represent the diameter for each treatment in centimeters (cm)

3.3.3.7 Leaf Chlorophyll (cci)

Leaf chlorophyll content was determined with the chlorophyll meter by randomly picking three (3) tomato leaves from the base, middle and the top portions of the plant and was repeated every three (3) weeks. The mean was calculated to represent the leaf chlorophyll content for each treatment in chlorophyll content index (CCI).

3.3.3.8 Number of flowers

The number of flowers was counted for each plant and was recorded every day from the day of flower set. The total number of flowers was recorded for each treatment.

3.3.3.9 Total number of fruits

The number of fruits of good quality without defect from each plant was counted to determine number of marketable fruits per treatment

Number of marketable fruits =

Total number of fruits – Number of unmarketable fruits

3.3.3.10 Number of marketable fruits

The number of fruits of good quality from each plant was washed in cold water to clean and also remove field heat. It was air dried and counted to determine the number of marketable fruits per treatment.

3.3.3.11 Percentage of shriveled fruits

At harvest, and after shelf life study, fruits were sorted into shriveled and the results expressed in percentages using the formula:

Shriveled = Number of Shriveled fruits/ Total number of harvested fruits X 100

3.4 LABORATORY EXPERIMENT ON POSTHARVEST FRUIT QUALITY

3.4.1 Experimental Procedure and Design

The harvested fruits were sorted and immersed in cold water to remove field heat. Twenty fruits (20) were then selected from each treatment; ten (10) fruits for destructive analysis and the other ten (10) for non-destructive analysis. Ten (10) fruits from each treatment were arranged in a completely randomized design with five replications and stored at a temperature of 26.9°C and relative humidity of 85.8 percent for shelf life studies **3.4.2 Data Collection**

3.4.2.1 Fruit diameter

Fruit diameter was measured at the widest point of the fruit shoulder using two fruits per treatment Ngouajio *et al*. (2007). This was done by dissecting the selected fruits into two parts from the equatorial region and measuring the widest points with a caliper.

The mean was calculated to represent the diameter for each treatment in millimeters (mm).

3.4.2.2 Fruit mesocarp

A digital caliper was used to measure the thickness of mesocarp at three randomly chosen locations around the fruit circumference for each of the two cut fruits per treatment. The mean was calculated to represent the fruit thickness for each treatment in millimeters (mm).

3.4.2.3 Fruit firmness

The firmness of the fruit was determined using the fruit tester (Effegi type Bishop FT 237). A circular portion of the peel of diameter of about 2 cm from each of the three fruits from each plant were removed before applying the plunger of the firmness tester in order to avoid the effect due to the peel. Firmness was expressed in Newton (N) Batu, (1998).

3.4.2.4 Fruit moisture content

Moisture content of the fruits was determined by desiccation of three (3) discs of 10 mm in diameter at the equatorial region of two fruits at 105ºC for 24 hours. The difference between the fresh weight and dry weight was expressed as a percentage of the initial fresh weight of the three (3) discs at the equatorial region of the two fruits (AOAC, 1990).

3.4.2.5 Total Soluble Solids (TSS)

Total soluble solid was determined in the same two fruits tested for fruit firmness, by squeezing out juice from fruits on Abbe's hand held refractometer and reflections measured in degree Brix.

3.4.2.6 Total Titrable Acid (TTA)

A quantity of 10 ml of fruit juice was diluted with 50 mls of distilled water and titrated against 0.1M NaOH. This was repeated three times for each replication and its titre values recorded. The average titre value was calculated for each replication. Total titrable acidity was calculated using the formula:

$$\text{Grams/litre acid} = \frac{\text{Normality of titrant x titre x Equivalent weight of predominant acid}}{\text{Volume of sample} \times 10}$$

3.4.2.7 Vitamin C determination

This was determined by using the 2, 6-Dichloroindophenol Titrimetric method and the results reported as mg/100g of tomato fruit (AOAC, 2006). Ascorbic acid reduced oxidation-reduction indicator dye, 2, 6-dichloroindophenol to a colourless solution. At end point, excess unreduced dye was rose pink in acid solution. Vitamin was extracted and titration performed in presence of HPO_3-CH_3CHOOH solution to maintain proper acidity for reaction and to avoid autoxidation of ascorbic acid at high pH.

3.4.2.8 Shelf life

The shelf life was observed from the start of harvesting up to the stage when fruits remained still acceptable for marketing yet approaching rotting, Mondal (2000). Fruit colour deterioration, disease incidence and fruit shriveling were determined by visual observation. The colour was determined using the colour chart and each colour stage was rated from 1-6.

Stage	Color	Description
1	Green	 The surface is completely green in color. The shade of green may vary from light to dark.
2	Breakers	 There is a definite "break" in color from green to tarnish-yellow, pink or red on less than 10% of the surface.
3	Turning	 10% to 30% of the surface shows a change in color from green to tarnish-yellow, pink, red or a combination thereof.
4	Pink	 30% to 60% of the surface shows pink or red in color.
5	Light Red	 60% to 90% of the surface shows pinkish-red or red.
6	Red	 More than 90% of the surface is red.

Chart 1 .0. Colour chart for tomato at different ripening stages.

Development of spots on the fruits skin, softening and rotting of the fruits were rated according to the magnitude of the spots. Shriveled fruits were expressed as a percentage of the total initial fruit number stored**.**

3.5 DATA ANALYSIS

An analysis of variance (ANOVA) using Statistix (version 9) statistical software was performed on the data collected. Means separation of the treatments was performed by the Honest Significant Difference (HSD) test at P=0.05 for the field experiment and P=0.01 for the laboratory experiment.

CHAPTER FOUR

4.0 RESULTS

4.1 THE EFFECTS OF BIOZYME ON GROWTH AND YIELD OF TOMATO

4.1.1 Effects of Biozyme on F1Castle Bar Tomato Plant Height

Plant height of tomato varied significantly (P=0.001) among the various Biozyme treatments (Figure 4.1). Application of 0.75 Lha^{-1} resulted in the tallest plants (119.42 cm), significantly different from those of the control and 1.0 Lha^{-1} but similar to that of 1.25 Lha^{-1} application. Plants from 1.0 Lha^{-1} were also significantly taller than those from the control which produced the shortest plants (104.29 cm) (Figure 4.1).

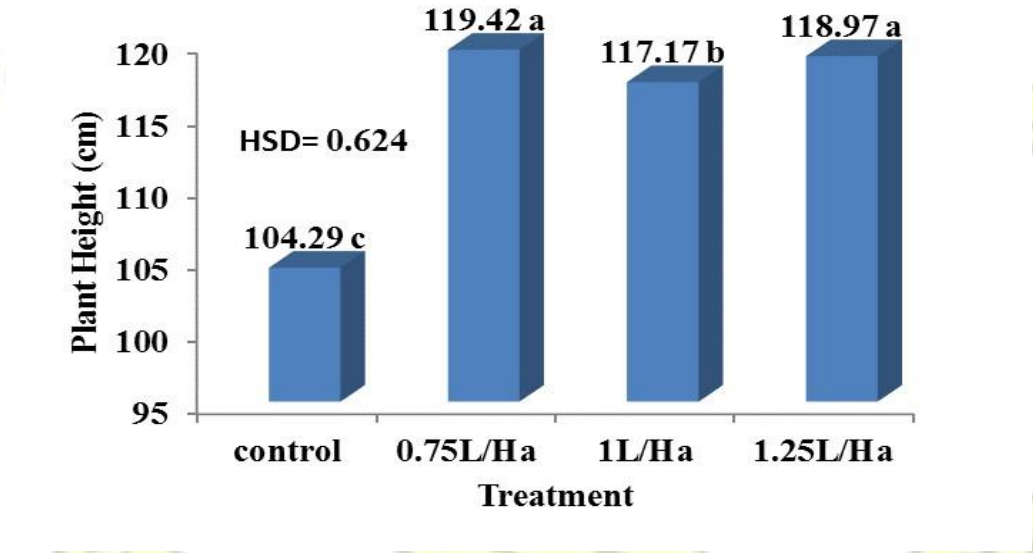

Figure 4.1: Plant height of tomato as affected by application of different rates of Biozyme .

4.1.2 Effects of Biozyme on Castle Bar Tomato Stem Girth

There were also significant (P=0.021) differences among treatments for tomato stem girth. 0.75 Lha^{-1} application resulted in the biggest stems (1.99 mm), significantly

different from stems of the other rates and the control which produced similar girths Figure 4.2.

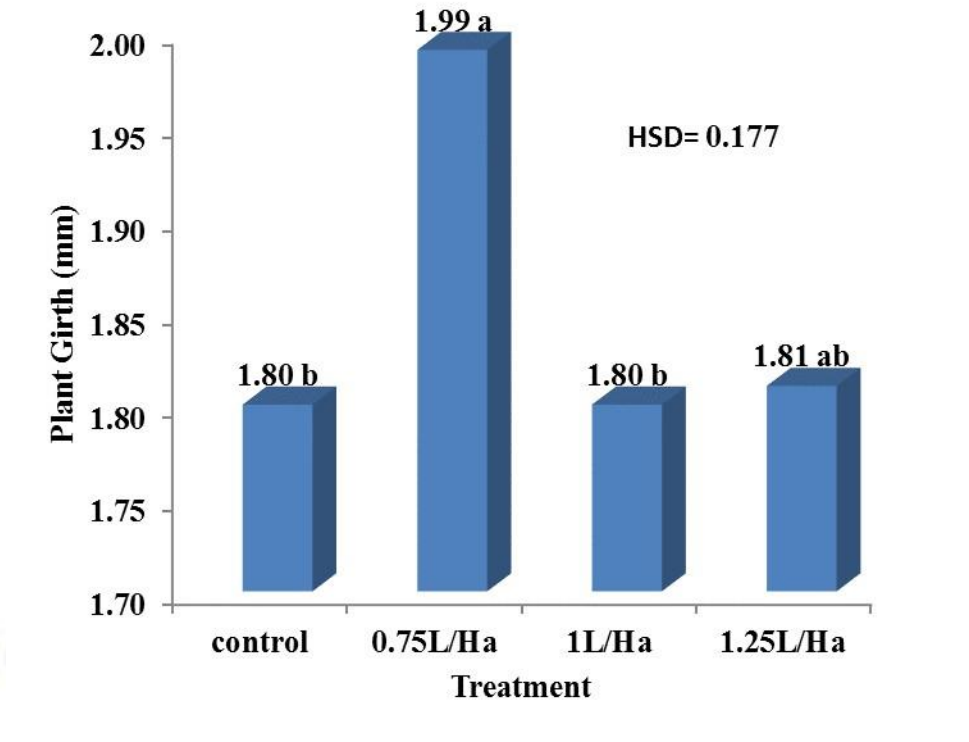

Figure 4.2: F1 Castle Bar Tomato stem girth as affected by Biozyme application rates.

4.1.3 Effects of Biozyme on Castle Bar Tomato Plant Canopy

There were significant (P=0.001) differences in plant canopy among the treatments. The 1.25 Lha^{-1} application resulted in the largest plant canopy (97.97 cm^2) though similar to that from the 0.75 Lha^{-1} application (Figure 4.4). The least plant canopy (94.94 cm^2) was recorded for control plants but not different from that of the 1.0 Lha^{-1} application.

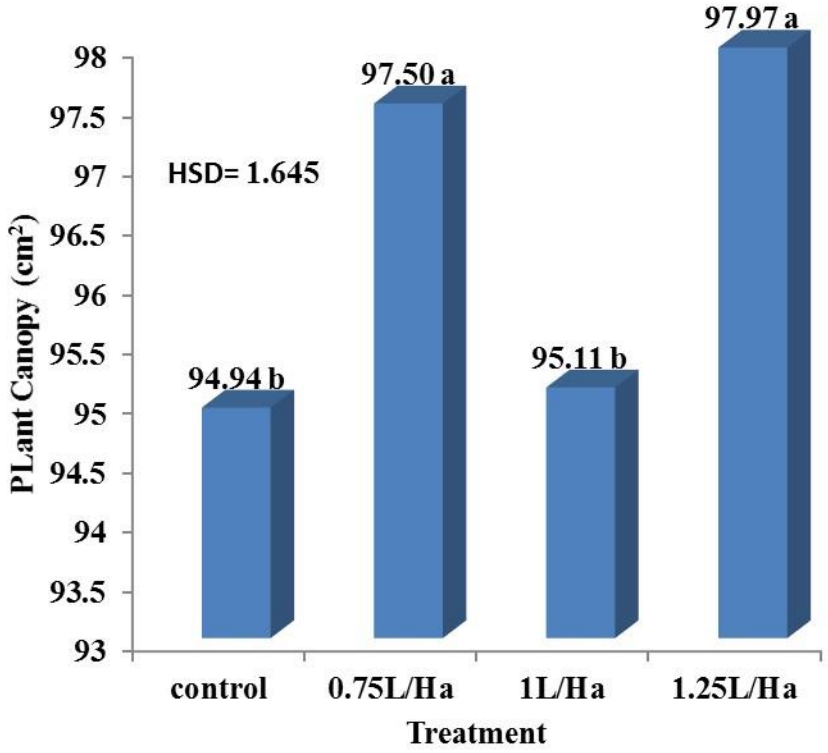

Figure 4.3: F1 Castle Bar Tomato plant canopy as affected by biozyme application rates.

4.1.4 Effects of Biozyme on F1 Castle Bar Tomato Leaf Count.

There were significant (P=0.001) differences among the biozyme treatments for tomato leaf count (Figure 4.4). Application of 1.0 Lha^{-1} resulted in the highest leaf count (6.74) though not different from that of the 1.25 Lha^{-1}. The control recorded the lowest fruit numbers (6.27) which was significantly different from 0.75 Lha^{-1} application Figure 4.4.

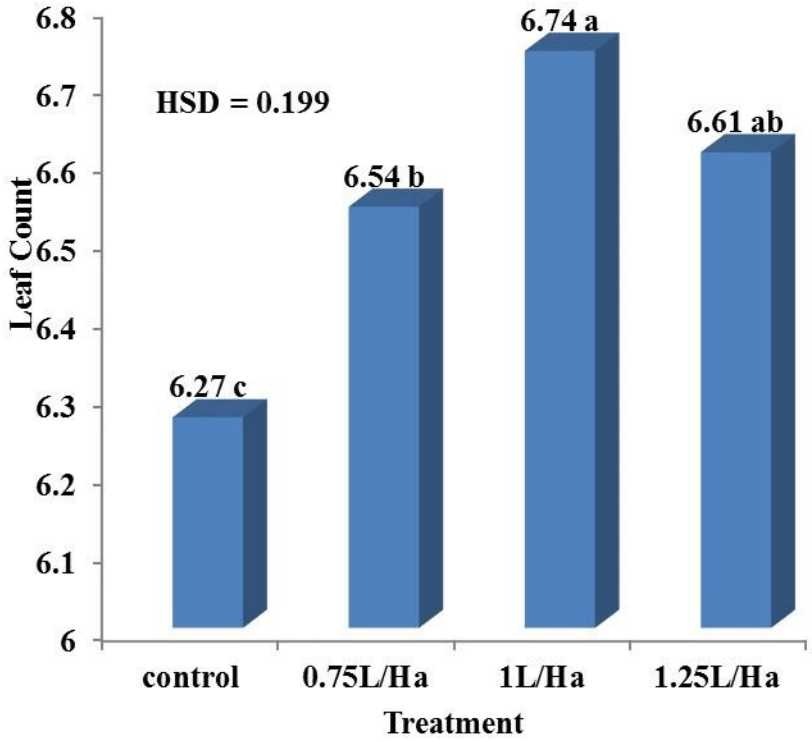

Figure 4.4: Leaf count of F1 Castle Bar tomato as affected by Biozyme application rates.

4.1. Biozyme 5 Effects of on F1 Castle Bar Tomato Leaf Diameter.

Figure 4.5 shows that there were significant (P=0.001) differences among the treatments for tomato leaf diameter. The 0.75 Lha^{-1} application resulted in the highest leaf diameter (14.16 mm) though similar to that from the control application. The least diameter (12.26 mm) was recorded by the 1.25 Lha^{-1} but not significantly different from that of the 1.0 Lha^{-1} application.

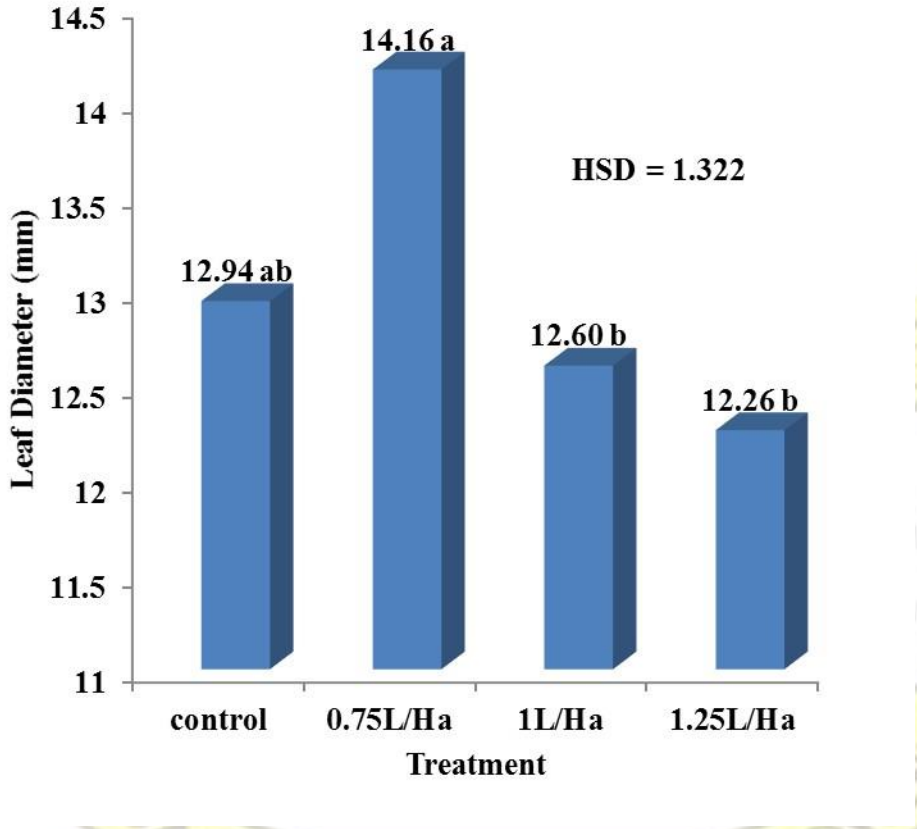

Figure 4.5: Leaf diameter of tomato as affected by Biozyme application rates.

4.1. Biozyme
6 Effects of on F1 Castle Bar Tomato Leaf Size

The leaf size of tomato varied significantly (P=0.001) among the various biozyme treatments (Figure 4.6). Control biozyme recorded the largest leaf size (31.54 mm), which was significantly greater than those from the other treatments. The least tomato leaf size was produced by plants treated with 1.25 Lha^{-1} biozyme Figure 4.6.

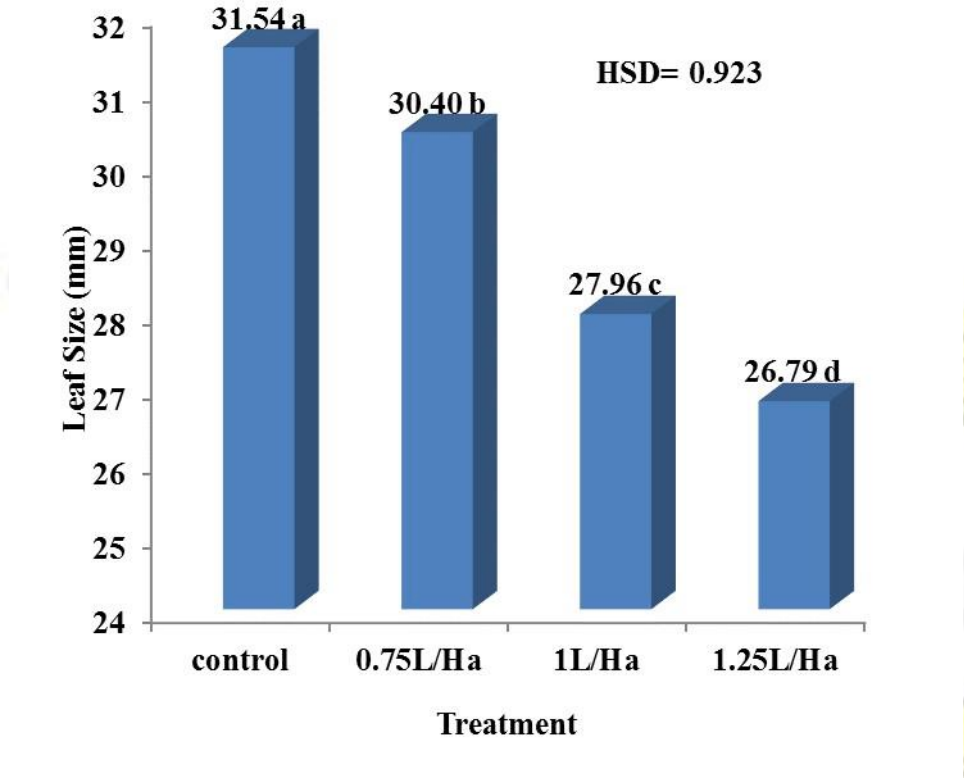

Figure 4.6: Leaf size of F1Castle Bar tomato as affected by biozyme application rates.

7 Effects of on the Chlorophyll Content of F1 Castle Bar Tomato Leaves.

4.1. Biozyme

Significant (P=0.001) differences were observed among the biozyme treatments for chlorophyll content of the tomato leaves (Figure 4.7). The 0.75 Lha^{-1} application resulted in the highest leaf chlorophyll content (36.73 cci) though similar to that from the 1.0 Lha^{-1} application. The least (31.45 cci) leaf chlorophyll content was recorded by the control plants.

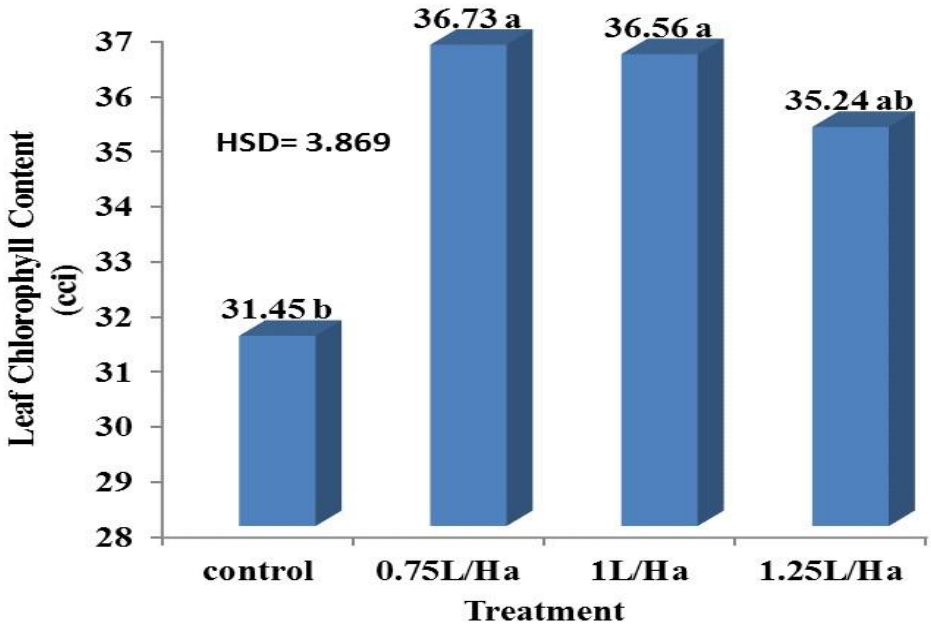

Figure 4.7: Leaf chlorophyll content of F1 Castle Bar tomato as affected by Biozyme

8 Effects of on F1 Castle Bar Tomato Flower Count.

The number of flowers varied significantly (P=0.001) among the various Biozyme treatments (Figure 4.8). The 1.25 Lha^{-1} Biozyme treated plants recorded the highest flower count (32.34), significantly greater than those from the other treatments and the control. The least number of flowers (5.30) was produced by plants treated with 0.75 Lha^{-1} Biozyme which was not different from the control.

4.1. Biozyme

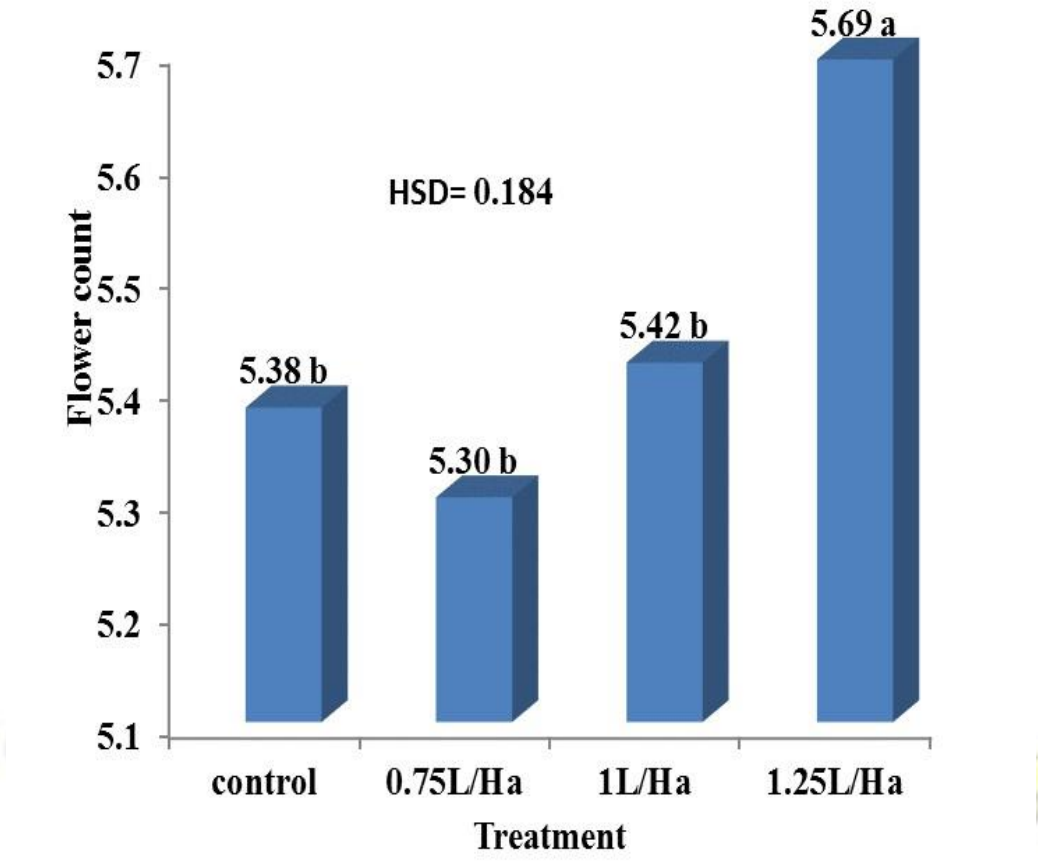

Figure 4.8: Number of F1 Castle Bar tomato flowers as affected by biozyme application rates.

4.1.

9 Effects of Biozyme on the Number of F1 Castle Bar Tomato Fruits. There were significant (P=0.001) differences among the biozyme treatments for the number of tomato fruits (Figure 4.9). Application of 0.75 Lha^{-1} resulted in the highest fruit number (17.77) though not different from that of the 1.00 Lha^{-1}. The control plant had the lowest fruit numbers (13.56) which were similar to that of plants treated with1.25 Lha^{-1} applications.

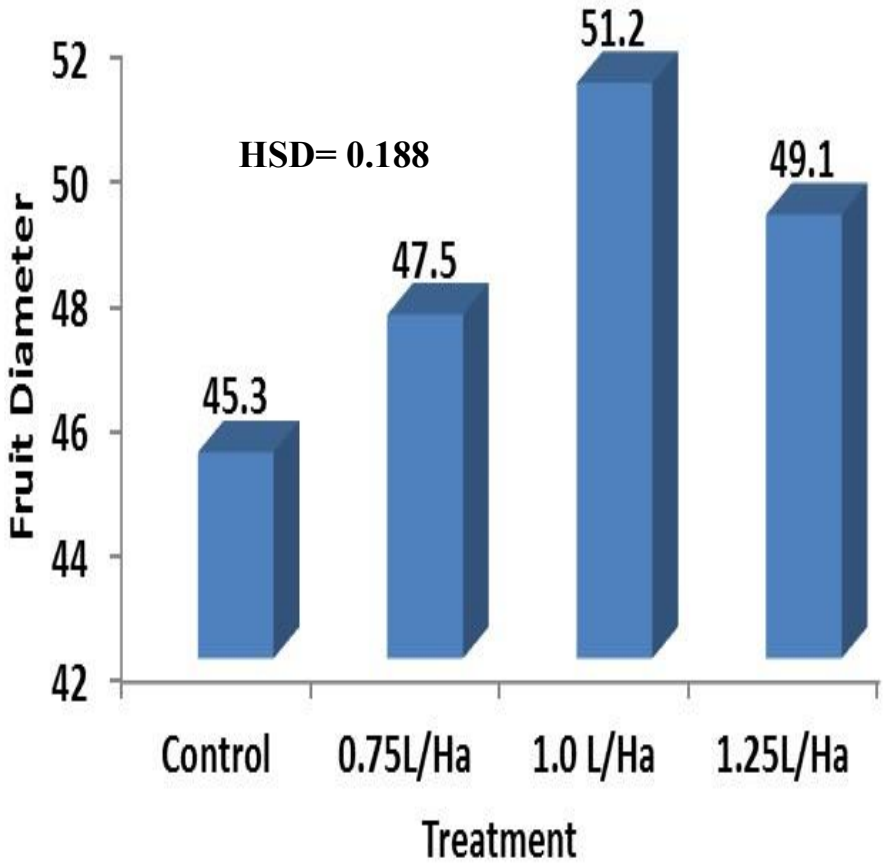

Figure 4.9: Number of F1 Castle Bar tomato fruits as affected by biozyme application rates.

4.1.10 Effects of Biozyme on F1 Castle Bar Tomato Fruit Weight

There were no significant (P=0.655) differences among the biozyme treatments for tomato fruit weight. The fruit weight ranged from 51.9 g to 60.8 g figure 4.10.

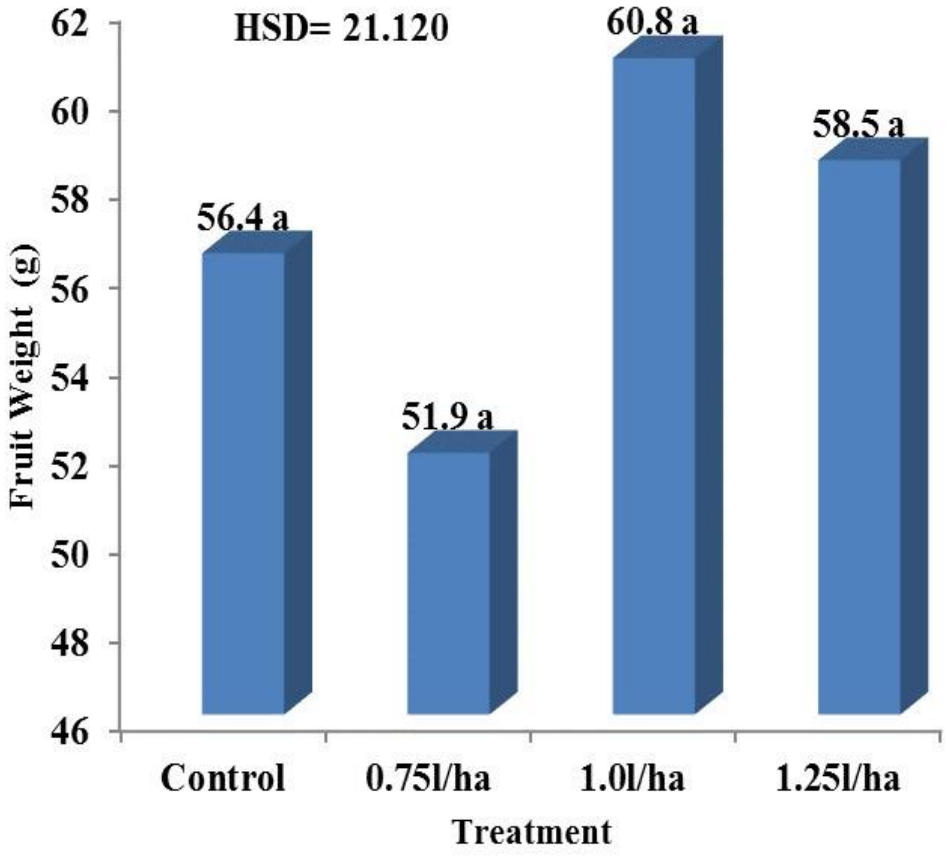

Figure 4.10: Fruit weight of F1 Castle Bar tomato as affected by biozyme application rates.

4.2 POSTHARVEST QUALITY CHARACTERISTICS OF F1 CASTLE BAR TOMATO FRUIT AS AFFECTED BY BIOZYME RATES.

4.2.1 Effects of Biozyme on Mean F1 Castle Bar Tomato Fruit Diameter across Ripening Stages.

There were significant (P=0.005) differences between the various biozyme rates for fruit diameter. Fruits from the 1.00 Lha^{-1} biozyme treatment were bigger in diameter than those of the control but similar to the diameters of fruits from the other biozyme rates figure 4.11.

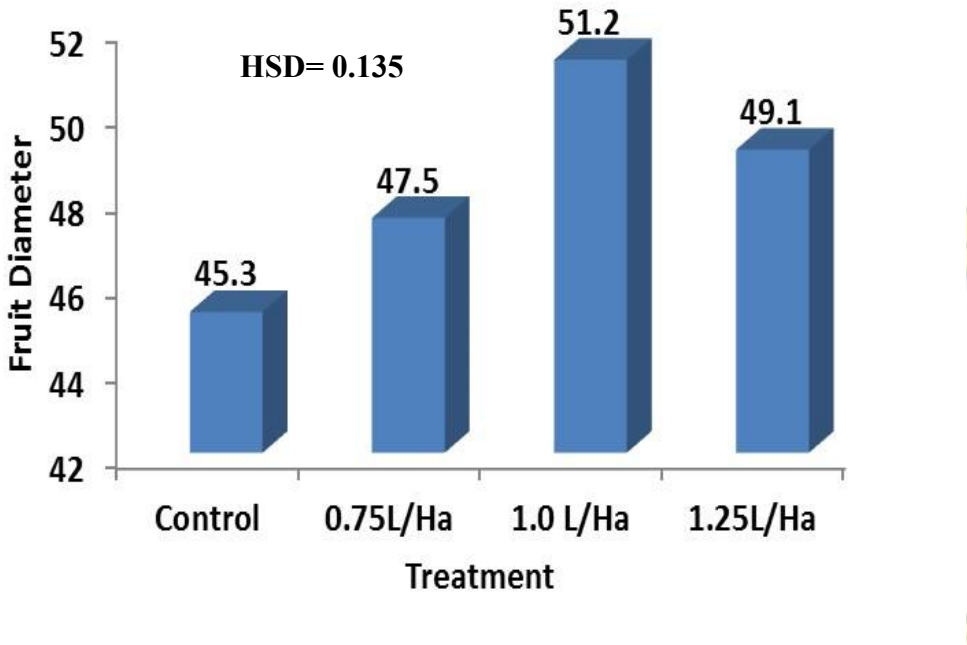

Figure 4.11: Fruit diameter of F1 Castle Bar tomato as affected by biozyme application rates.

4.2.2 Effects of Biozyme on Mean F1 Castle Bar Fruit Firmness of Tomato across Ripening Stages.

There were significant (P=0.005) differences between the biozyme rates for fruit firmness. Fruits from the 0.75 Lha^{-1} biozyme treatment were more firm than those of the control but similar to the firmness of fruits from the other biozyme rates figure 4.12.

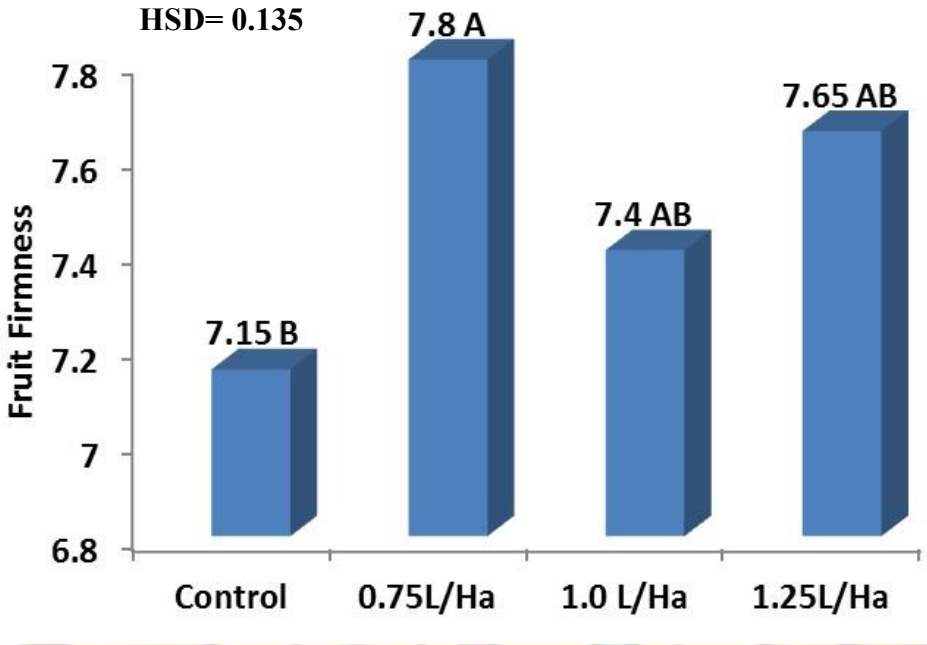

Figure 4.12: Fruit firmness of F1 Castle Bar tomato as affected by biozyme application rates.

4.2.3 Effects of Biozyme on Mean Mesocarp Thickness of Tomato Fruit across Ripening Stages.

There were significant (P=0.004) differences in mesocarp thickness were observed for fruits treated with the different rates of biozyme for fruit mesocarp thickness. Fruits from the 1.0 Lha^{-1} biozyme treatment had the thickest mesocarp, significantly greater than those of the control and 1.25 Lha^{-1} biozyme treatment but similar to the mesocarp from the 0.75 Lha^{-1} biozyme treatment figure 4.13

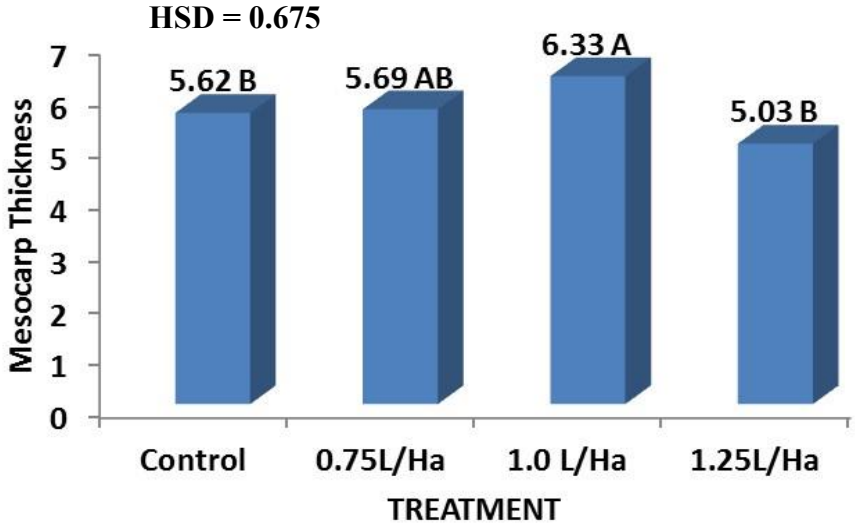

Figure 4.13: Fruit mesocarp thickness of F1 Castle Bar tomato as affected by biozyme application rates.

4.2.4 Effects of Biozyme on Fruit pH, Fruit Total Soluble Solids and Fruit Total Titrable Acidity across Ripening Stages.

There were no significant differences between the biozyme treatments for fruit pH (P=0.089), total soluble solids (P=0.755) and total titrable acidity (P=0.156) he pH ranged between 4.17 and 4.23; the total soluble solids ranged between 2.17 brix and 2.45 brix; the total titrable acidity ranged between 0.21 and 0.27 table 4.1

Table 4.1. Effects of different biozyme rates on fruit pH, total soluble solids and total titrable acidity.

Biozyme rates (l/ha)	Fruit pH	Fruit Total Soluble Solids (Brix)	Fruit Total Titrable Acidity
0	4.17 a	2.45 a	0.2[2] a

[2] .2.5 Effects of Biozyme on Mean Fruit Vitamin C across Ripening Stage

0.75	4.27 a	2.37 a	0.21 a
1.00	4.23 a	2.17 a	0.27 a
1.25	4.23 a	2.24 a	0.26 a
HSD [3] %	0.138	0.419	0.052

There were significant (P=0.001) differences between the various biozyme rates for fruit vitamin C content. Fruits from the 0 Lha^{-1} biozyme treatment contained the highest vitamin C content, significantly greater than the fruits from 0.75 Lha^{-1} and

[3] .25 Lha^{-1} biozyme but similar to the fruits from 1.0 lha^{-1} biozyme (Figure. 4.14).

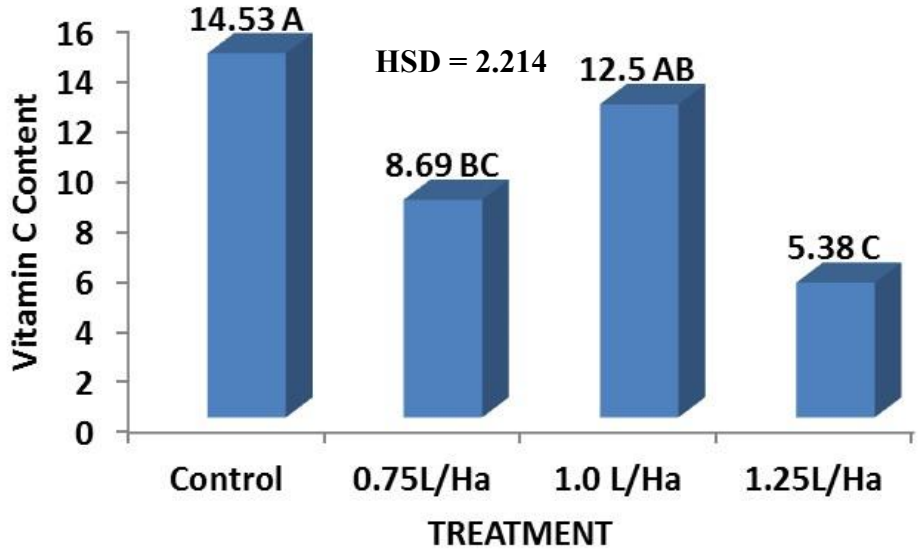

Figure 4.14: Vitamin C content of F1 Castle Bar tomato as affected by biozyme application rates.

4.3 THE EFFECTS OF BIOZYME ON THE SHELF LIFE OF TOMATO FRUITS.

4.3.1 Effects of Biozyme on Shelf Life of Tomato

The biozyme treatment of 1.25 Lha-1 resulted in the longest fruit shelf life of 45 days, significantly (P=0.001) better than the control treatment which recorded the shortest fruit shelf life of 35 days (Figure 4.15). On the average, biozyme treatment extended the fruit shelf life by 7 days in comparism with the control.

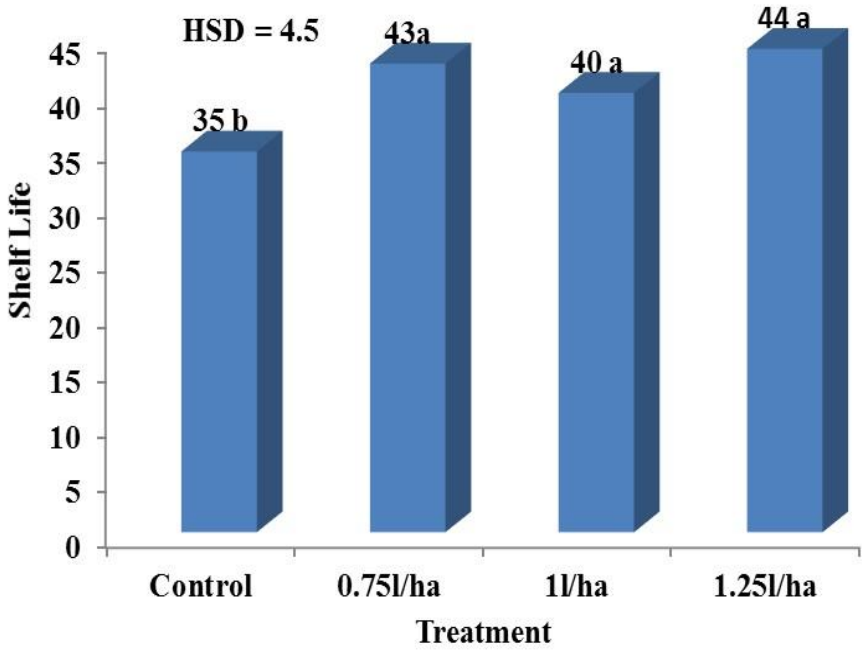

Fig. 4.15: Tomato shelf life as affected by biozyme application rates.

4.3.2 Effects of Biozyme on Percent Shriveled Tomato Fruits.

There were no significant (P=0.084) differences among the treatments for the percentage shriveled tomato. The percentage shriveled ranged from 8.02% to 9.38% figure 1.16

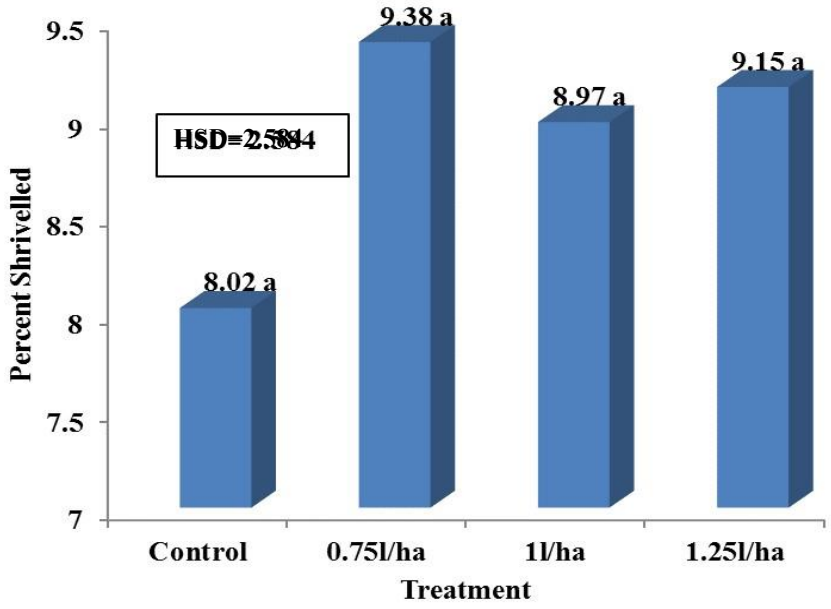

Figure. 4 16. Effect of biozyme rates on the shriveled percentage of tomato fruits.

4.3.3 Effects of Biozyme on Percent Diseased Tomato Fruits

Fruits from the control biozyme treatment contained the highest vitamin C content, significantly greater than the fruits from 0.75 Lha^{-1} and 1.25 Lha^{-1} biozyme but similar to the fruits from 1.0 Lha^{-1} biozyme. The percentage diseased fruits ranged from 2.28% to 3.60% (Figure 4.17).

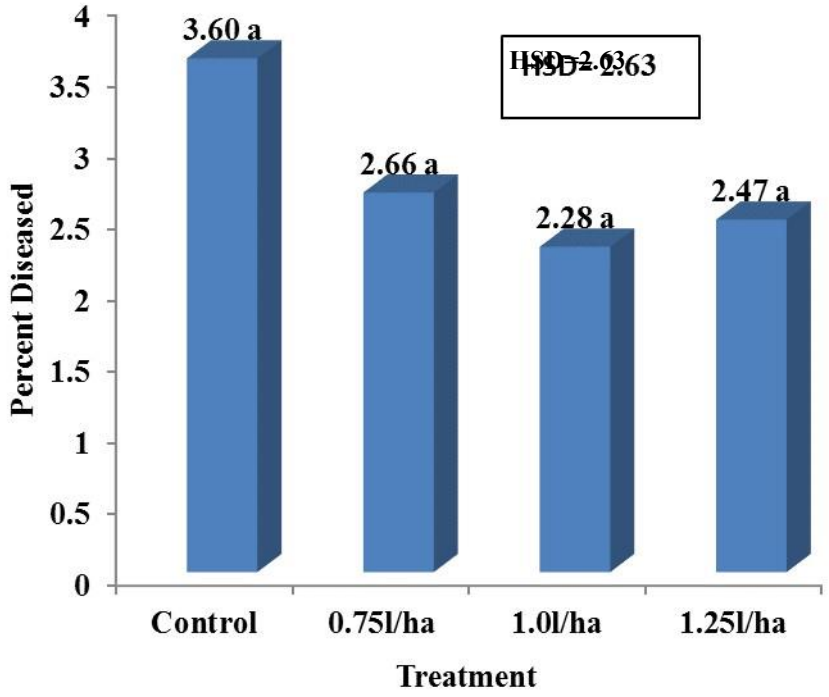

Figure 4.17: Effect of biozyme rates on the diseased percentage of tomato fruits.

CHAPTER FIVE

5.0 DISCUSSION

5.1 THE EFFECT OF BIOZYME ON GROWTH OF TOMATO

All the Biozyme treated plants produced taller plants than the control. This could be attributed to the presence of cytokinin and auxin precursors in the Biozyme which caused an increase in the growth of the tomato plants due to the better utilization of NPK fertilizer resulting in an enhanced cell division and cell enlargement, (Reeta *et al*., 2010). Plant girth as an index of growth enables the plant to stand erect to absorb sunlight for photosynthetic activities. The biggest plant girth was produced by the

application of 0.75 Lha^{-1}. Similarly, application of 0.75 Lha^{-1} also resulted in the highest leaf chlorophyll content, implying that the tomato plants with bigger stems were able to absorb more sunlight and subsequently produce more chlorophyll for increased photosynthesis. The same trend was observed with the canopy of the tomato plant which was bigger with the application of 0.75 Lha^{-1} although not different from the tomato canopy size with the application of 1.25 lha^{-1}. The present study has corroborated the findings of Gore *et al*. (2007) who observed that foliar application of Biozymes was effective in enhancing growth of tomato plants. The control plants which were the poorest in most of the indicators of vegetative growth were only treated with NPK fertilizer, thus suggesting that chemical fertilizer alone is not enough to cause massive growth in tomato but requires a booster in the form of a stimulant to realize enhanced growth.

5.2 THE EFFECT OF BIOZYME ON FLOWERING AND YIELD OF TOMATO.

Although tomato plants applied with 1.25 Lha^{-1} of Biozyme produced the highest number of flowers, it also resulted in a lower fruit set leading to significantly lower fruit numbers as compared to the other Biozyme rates. This phenomenon could be explained by the energy budget contained in the tomato plant thus up to about 300 energy source. Bos *et al*. (2007) reported that, more fruits set at a time could place greater demands on the energy budget of the tomato plant, disrupting its metabolism.

Consequently, the situation is saved by the greater rates of fruit abortion observed with a resultant decrease in fruit numbers (Brown and McNeil, 2006). In this vein therefore, application of 0.75 Lha^{-1} could be considered as the most appropriate Biozyme rate to

ensure production of high fruit numbers. Quintalan and Rojas, (1990) reported that biozymes increased yield and fruit weight of tomato through the formation of more epidermis cells, allowing the fruits to increase in size and commercial grade consistency. The present study supports the findings of OfosuAnim *et al.* (2007) that application of Biozyme increased the number of fruits per plant in tomato by ensuring rapid plant nutrients uptake that optimized fruit setting and activated the development of bigger and more quality fruits (Saimbhi *et al*., 2012).

The increase in fruit size, weight and volume with the application of Biozyme could be due to the presence of auxins (NAA) which stimulates cell division and cell enlargement and cause an increase in the sink strength of the fruits (Taiz and Zeiger, 2006). The weight and volume of pomegranate was also increased with the application of either NAA alone, Singh, (2008); Hoang, (2003) or NAA in combination with Carbaryl, Zhang and Whiting, (2011) by increasing the cell wall and hydrolysis of starch into sugars which reduced the cell water potential, resulting in the entry of water into the cell and causing elongation, Richard, (2006). Consequently, sprays of GA_3 have been widely adopted in commercial cherry

orchards to ensure increase in fruit size and firmness (Choi *et al*., 2002).

5.3 THE EFFECT OF BIOZYME ON POSTHARVEST FRUIT QUALITY OF TOMATO.

5.3.1 Effects on Fruit Diameter of Tomato across Ripening Stages

In the present study the higher number of fruits was observed to be inversely related to the fruit size such that the 1.25 l Lha^{-1} application rate resulted in the attainment of the biggest fruits in terms of diameter. This could be due to the fact that at the same level of

photosynthetic activity of the tomato plants, more assimilates were channeled into the fewer fruits than the many fruits resulting in the fewer fruits showing bigger sizes than the many fruits. The present results are in agreement with the observation by Gore *et al*. (2007) that foliar application of Biozyme enhanced fruit size of tomato. Richard (2006) also observed that fruit diameter was significantly increased with the increased application of seaweed extract in tomato.

In pomegranate, the fruit size and volume were also increased with the application of either NAA alone (Singh, 2008; Hoang, 2003) or NAA in combination with Carbaryl .

5.3.2 Effects on Fruit Firmness and Mesocarp Thickness of Tomato across Ripening Stages.

The highest fruit firmness was observed with the application of 0.75 Lha^{-1} and 1.0 $lLha^{-1}$ Biozyme. This could be due to the fact that these doses of Biozyme enhanced more nutrient absorption by the plant which influenced fruit development and thus increased the firmness of the tomato. Eris (1995) observed that fruit firmness significantly increased with the application of seaweed extract on tomato.

A similar trend was observed with the mesocarp thickness of the fruit and this is confirmed by Gore *et al.* (2007) who stated that foliar application of Biozyme also enhanced the mesocarp of tomato fruits. This observation is not surprising because firmness is related to the thickness of the pulp and therefore fruits with high firmness are expected to have thicker mesocarp than those with less firm firmness. Choi *et al*. (2002) reported sprays of GA_3 are widely adopted in commercial cherry orchards to ensure increase in fruit size and firmness.

5.3.3 Effects on Proximate Parameters of Fruit across Ripening Stages Biozyme applications have been reported to affect more of yield and physical postharvest qualities of vegetables than proximate qualities. This is because biostimulants positively affects the establishment and proliferation of roots resulting in increased nutrient uptake even from distant and deeper horizons (Zodape et al., 2008).

Furthermore, the biostimulants regulated bio-physical activities results in the maintenance of enhanced photosynthetic activities leading to increased yields, (Singh and Chandel, 2005). Contrarily, Sharma *et al*. (2009) stated that plants treated with Biozymes resulted in higher total soluble solids, total sugars and longer shelf life. As regards vitamin C, application of Biozyme in the present study had a significant effect on fruits such that at the red ripe stage, the content of vitamin C was lower in the fruits of the Biozyme treated plants than the control. Such effect is positive for the processing industry since less sugar would be added to puree prepared from such fruits. Also fresh consumption of such fruits would be enhanced because of the low sourness of the fruits.

5.3.4 Effects of Biozymes on Fruit Shelf Life

This corroborates the finding of the present study, which indicated that all the biozyme treatments led to increased shelf life of tomato fruits as compared with the control where no biozyme was applied.

Sharma *et al.* (2009) also reported that biostimulants enhance fruit quality parameters such as carbohydrate content, sugar, flavour, antioxidant levels, and vitamins levels and fruit shelf life. Casanovas *et al.* (2002) also indicated that GA_3 sprays improved fruit quality of sweet cherries including giving the fruits longer shelf life.

5.3.5. Effect of Biozyme on Fruit Disease

In the present study, there was a percentage reduction in tomato fruit disease although not significantly different from the control. Taiz and Zeiger (2006) stated that the reduction in fruit disease from application of biostimulants.

Usenik *et al*. (2005) also observed that GA_3 influenced cell wall strength or elasticity resulting in a reduction in disease infection. In cherry, application of GA_3 was found to reduce disease infection. Cline and Trought (2007) also indicated that in pomegranate application of GA_3 40 ppm in reduced fruit disease (Lal *et al*., 2012).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The following conclusions were drawn from the experiments undertaken in the study. The results of the study revealed that, after the application of Biozyme the vegetative growth and fruit yield of tomato were improved. Biozyme treated plants were taller with bigger canopies and had more leaf chlorophyll content than the controlled where there was no Biozyme application. Significantly more flower and subsequently more fruits were also produced by the Biozyme treated plants.

The most appropriate Biozyme rate to be applied for good vegetative growth, yield of tomato was found to be 0.75 l/ha**.** Biozyme also positively affected the postharvest physical quality characteristics of the fruit such as fruit diameter, fruit firmness and fruit mesocarp thickness. The Vitamin C content of the fruit was positively affected by the

lowering of its content at the red ripe stage. Biozyme also positively affected fruit shelf life by extending the tomato fruit shelf life by seven (7) days. The study has demonstrated that with the application of Biozyme to tomato has a positive effect on its vegetative growth, fruit yield and characteristics of postharvest quality.

6.2 RECOMMENDATIONS.

It is recommended that;

1. Further investigations should be carried out on other vegetable crops to provide more information that would ensure large scale usage of Biozyme by farmers to improve production in Ghana.

2. Future studies should be undertaken in an open field to ascertain the impact of the external environment on the performance of Biozyme on plants.

REFERENCES

A.O.A.C., (2006): Official Methods of Analysis, Association of Official Chemistry, 14th ed. Association of Official Analytical Chemists, Arlington, VA.

A.O.A.C.,)1990). Official methods of analysis. Association of official analytical chemists. 18th edition, Washington D. C.

Abubakar A.R., Ashraf N and Ashraf M. (2012) Effect of plant biostimulants on flowering, fruit drop, yield and return bloom of pomegranate. *The Asian Journal of Horticulture*. 473-477

Adesemoye, A.O, Torbert, H.A. and Kloepper, J.W. (2008). Enhanced plant nutrient use efficiency with PGPR and AMF in an integrated nutrient management system. *Canadian Journal of Microbiology* 54:876–886

Adesemoye, A.O, Torbert, H.A. and Kloepper, J.W. (2010). Increased plant uptake of nitrogen from 15N-depleted fertilizer using plant growth-promoting rhizobacteria. Appl Soil Ecol 46:54–58 against abiotic stress: mechanisms and biotechnological application Plant Cell Environment 34 (2011), pp. 1–20

Ahmad, I., Pichtel, J., Hayat, S., (2008). Plant-Bacteria Interactions. Strategies andTechniques to Promote Plant Growth. WILEY-VCH Verlag GmbH and Co., KGaA,Weinheim.

Anand, M., Kahlon PS, Mahajan BVC (2003). Effect of exogenous application of growth regulators on fruit drop, cracking and quality of litchi (Litchi chinensis Sonn.) cv. Dehradun. Agricultural Science. Digest, 23(3):191-194.

Bashan, Y., & De-Bashan, L. E. (2010). Chapter two-how the plant growthpromoting bacterium Azospirillum promotes plant growth a critical assessment. Advances in Agronomy, 108, 77-136.

Bashan, Y., Holguin, G. (1998) Proposal for the division of plant growth-promoting Rhizobacteria into two classifications: biocontrol-PGPB (plant growthpromoting bacteria) and PGPB. Soil Biol Biochem 30: 1225-1228

Bashan, Y., Holguin, G., & De-Bashan, L. E. (2004). Azospirillum-plant relationships: physiological, molecular, agricultural, and environmental advances (1997-2003). *Canadian Journal of Microbiology,* 50(8), 521-577.

Batu, V., (1998). A COMPREHENSIVE GUIDE TO HYDROGEOLOGIC DATA ANALYSIS by. John Wiley and Sons, Inc., New York. 727p.

Behie, S.W., Bidochka, M.J., (2014). Nutrient transfer in plant-fungal symbioses.Trends Plant Sci. 19, 734–740.

Berg, G (2009) Plant–microbe interactions promoting plant growth and health: perspectives for controlled use of microorganisms in agriculture. Applied Microbiol Biotechnol 84:11–18. doi:10. 1007/s00253-009-20 92–7

Boddey, R. M., & Dobereiner, J. (1995). Nitrogen fixation associated with grasses and cereals: recent progress and perspectives for the future. Fertilizer Research, 42(1-3), 241-250.

Boddey, R. M., Polidoro, J. C., Resende, A. S., Alves, B. J., & Urquiaga, S. (2001). Use of the15N natural abundance technique for the quantification of the contribution of N2 fixation to sugar cane and other grasses. Functional Plant Biology, 28(9), 889-895.

Boddey, R. M., Urquiaga, S., Reis, V., & Döbereiner, J. (1991). Biological nitrogen fixation associated with sugar cane. In Nitrogen Fixation (pp. 105-111). Springer Netherlands.

Bos, M.M., Steffan-Dewenter, I., and Tscharntke, T. (2007) Shade tree management affects fruit abortion, insect pests and pathogens of cacao. Agriculture, Ecosystems and Environment, 120:201–205

Brown, A.O., McNeil, J.N., (2006). Fruit production in Cranberry (Ericacae: Vaccinium macrocarpon): a bet-hedging strategy to optimize reproductive effort. Am. J. Bot. 93, 910–916

Byers, RE, Carbaugh DH, Presley CN (1990). „Stayman" fruit cracking as affected by surfactants, plant growth regulators and other chemicals. J. Am. Soc. Hort. Sci. 115(3):405-411.

Calvo, P., Nelson, L., Kloepper, J.W., 2014. Agricultural uses of plant biostimulants. Plant Soil 383, 3–41

Casanovas, E.M., Barassi CA, Sueldo RJ (2002) Azospirillum inoculation mitigates water stress effects in maize seedlings. Cerea Res Commun 30:343–350

Chandel, J. S., & Jindal, K. K. (1991). Effect of triacontanol (TRIA) and paclobutrazol (P. 333) on fruit set, yield and quality of Japanese plum (Prunus salicinLindl). Hort. J, 4(1), 21-25.

Chen, T.H.H. and Murata, N. (2011) Chen, N. Murata Glycinebetaine protects plants

(2010) High molecular size humic substances enhance phenylpropanoi

Choi, C., Wiersma, P.A., Toivonen, P., Kappel, F. (2002). Fruit growth, firmness and cell wall hydrolytic enzyme activity during development of sweet cherry fruit treated with gibberellic acid (GA3). J. Hortic. Sci. Biotechnol. 77: 615–621.

Christobel, G. J. (2008). Effect of seaweed (Sargassum wightii L.) on the germination and growth of Matured Green gram (Phaseolus aureus L.). *Journal of Basic Applied Biology* 2: 105-08

Cline, J.A, Trought M (2007). Effect of gibberellic acid on fruit cracking and quality of bing and sam sweet cherries. Can. J. Plant Sci. 87(3):545-550.

combination with foliar sprays of plant growth promoting bacteria and humic

Craigie, J.S. (2011). Seaweed extract stimuli in plant science and agriculture. J Appl Phycol. 23:371–393. doi: 10.1007/s10811-010-9560-4

Dalmastri, C., Chiarini L, Cantale C, Bevinino A, Tabacchioni S (1999) Soil type and maize cultivar affect the genetic diversity of maize root-associated Burkholderia cepacia populations. Microb Ecol 38:273–284

Dalpé, Y., Monreal, M., (2004). Arbuscular mycorrhiza inoculum to supportsustainable cropping systems. Online. Symposium Proceeding. CropManagement network, http://dx.doi.org/10.1094/CM-2004-0301-09-RV.

De Freitas, J. R., Banerjee, M. R., & Germida, J. J. (1997). Phosphate-solubilizing rhizobacteria enhance the growth and yield but not phosphorus uptake of canola (Brassica napus L.). Biology and Fertility of Soils, 24(4), 358-364.

De Salamone, I. G., Döbereiner, J., Urquiaga, S., & Boddey, R. M. (1996). Biological nitrogen fixation in Azospirillum strain-maize genotype associations as evaluated by the 15N isotope dilution technique. Biology and Fertility of Soils, 23(3), 249-256.

Deliopoulos, T., Kettlewell, P.S., Hare, M.C., (2010). Fungal disease suppression byinorganic salts: a review. Crop Prot. 29, 1059–1075.

Döbereiner, J. (1997). Biological nitrogen fixation in the tropics: social and economic contributions. Soil Biology and Biochemistry, 29(5), 771-774.

Dodd, I.C, Ruiz-Lozano JM (2012) Microbial enhancement of crop resource use efficiency Curr Opin Biotechnol 23:236–242. doi:10.1016/j.copbio.2011.09.005

Du Jardin, P., 2012. The Science of Plant Biostimulants—A bibliographic analysis. Ad hoc Study Report to the European Commission DG ENTR. 2012; http://ec. europa.eu/enterprise/sectors/chemicals/files/fertilizers/final report bio 2012

EBIC, (2012a). EBIC and biostimulants in brief. http://www.biostimulants.eu/

EBIC, (2012b). What are biostimulants? http://www.biostimulants.eu/about/whatarebiostimulants/

EBIC, 2013). Economic overview of the biostimulants sector in Europe, 17 April 2013.

Edwards, C.A., Askar, A., Vasko-Bennett, M., Arancon, N. 2010. The Use and Effects of Aqueous Extracts from Vermicomposts or Teas on Plant Growth and Yields. In: Edwards, C.A., Arancon, N.Q.,

Egamberdiyeva, D., & Höflich, G. (2004). Effect of plant growth-promoting bacteria on growth and nutrient uptake of cotton and pea in a semi-arid region of Uzbekistan. Journal of Arid Environments, 56(2), 293-301.

Ellis, W. O., Agbematle, R., Oldham, J. H. and Nsiah, K. (1998). Tomato paste production in the rural scale level. In: proceedings of a workshop to evaluated outputs and identity further vegetables research priorities in the Brong Ahatfo Regions of Ghana. 10-11 September 1998, Sunyani. 56-71.

Eris, A., Sivritepe, H. 0. and Sivritepe, N. (1995). Effect of seaweed (Ascophyllum nodosum) extract on yield and quality criteria in peppers. Int. Symp. on Solanacea for Fresh Market. Acta Hort., pp. 412.

Ertani, A., Schiavon, M., Muscolo, A., Nardi, S., (2013). Alfalfa plant-derivedbiostimulant stimulate short-term growth of salt stressed Zea mays L. plants.Plant Soil 364, 145–158.

European Biostimulants Industry Council (2012a) EBIC and biostimulants in brief. http://www.biostimulants.eu/

European Biostimulants Industry Council (2012b) What are biostimulants? Accessed on 5th May, 2016

European Biostimulants Industry Council (2013) Economic overview of the biostimulants sector in Europe, 17 April. http://www.biostimulants.eu/wpcontent/uploads/2013/0 Biostimulant_economics_17April2013.pdf

Eyheraguibel, B., Silvestre, J., Morard, P., 2008. Effects of humic substances derived from organic waste enhancement on the growth and mineral nutrition of maize. Biores. Technol. 99, 4206–4212.

Fayez, M., & Daw, Z. Y. (1987). Effect of inoculation with different strains of Azospirillum brasilense on cotton (Gossipium barbadense). Biology and fertility of soils, 4(1-2), 91-95.

Ferri, M., Franceschetti, M., Naldrett, M.J., Saalbach, G., Tassoni, A., (2014). Effects ofchitosan on the protein profile of grape cell culture subcellular fractions.Electrophoresis 35, 1685–1692.

Fornes F, Sanchez PM, Guardiola JL (1995). Effect of a seaweed extract on citrus fruit maturation. Acta Horticulturae 379:75-82.

García, L.F., Andreu G.G., Blasco I.J., Aleixos B.M.N., Valiente G.J.M. (2010). Automatic detection of skin defects in citrus fruits using a multivariate image analysis approach. Computers and Electronics in Agriculture. 71(2):189- 197. doi:10.1016/j.compag.2010.02.001.

Gianinazzi, S., Gollotte, A., Binet, M.-N., van Tuinen, D., Redecker, D., Wipf, D., (2010). Agroecology: the key role of arbuscular mycorrhizas in ecosystem services.Mycorrhiza 20, 519–530.

Gore, A. K., Jadhav, S. B., Gore, A. K. and Ghuge, T. D. (2007). Effect of different bioenzymes on growth, flowering and yield of Matured Green chilli (Capsicum annuum L.) variety "Pusa Jwala".J. Soils and Crops. 17: 105-09

Gozzo, F., Faoro, F., (2013). Systemic acquired resistance (50 Years after discovery) moving from the lab to the field. J. Agric. Food Chem. 61, 12473–12491. growth promotion by humic acids from composted and non-composted urban organic wastes Plant Soil, 353 (2012), pp. 209–220.

Gupta, O.P, Siddiqui S, Lal S (1987). Effect of various chemical formulations on the storage behavior of grapes. In: Crop productivity. Srivastava HC, Bhaskaran S, Menon KKG (Eds.). Oxford and IBH Publishing Co. New Delhi, pp. 197-201.

Halpern, M., Bar-Tal, A., Ofek, M., Minz, D., Muller, T., Yermiyahu, U., (2014). The use of biostimulants for enhancing nutrient uptake. In: Sparks, D.L. (Ed.), Advances in Agronomy, Vol. 129, pp. 141–174.

Hartmann, A., & Bashan, Y. (2009). Ecology and application of Azospirillum and other plant growth-promoting bacteria (PGPB)–Special Issue. European Journal of Soil Biology, 45(1), 1-2.

Hayat, R., Ali S, Amara U, Khalid R, Ahmed I (2010) Soil beneficial bacteria and their role in plant growth promotion: a review. Ann Microbiol 60:579–598

Hoang, N.H. (2003). Effect of plant growth regulators and other chemicals on fruit

thinning, fruit drop, yield and quality in pomegranate (Punica granatum L.) cv. G-137. Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan HP, India, M.Sc. Thesis

Horna, D.P., Zabel and Lindout, P. 2006. Assessing the potential economic impact of genetically modified crops in Ghana: Tomato, garden egg, cabbage and cassava. Program for Biosafety Systems report, October. http://www.biostimulants.eu/wp-content/uploads/2013/04/

Iriti, M., Picchi, V., Rossoni, M., Gomarasca, S., Ludwig, N., Gargano, M., Faoro, F., (2009). Chitosan antitranspirant activity is due to abscisic aciddependentstomatal closure. Environ. Exp. Bot. 66, 493–500.

Jindo, K., Jindo, S.A., Martim, E.C., Navarro, N.O., Aguiar, L.P., Canellas.(2012) Root 183 (2015), pp. 100–110

Johnson, D., Gilbert, L., (2015). Interplant signalling through hyphal networks. NewPhytol. 205, 1448–1453.

Khalid, A., Arshad M, Kahir ZA (2004) Screening plant growth promoting rhizobacteria for improving growth and yield of wheat. Appl Soil Ecol 96:473–480

Khan, W., Rayirath, U.P., Subramanian, S., Jithesh, M.N., Rayorath, P., Hodges, D.M., Critchley, A.T, Craigie, J.S., Norrie, J., Prithiviraj, B., (2009). Seaweed extracts as biostimulants of plant growth and development. J Plant Growth Regulators. 28:386–399. doi: 10.1007/s00344-009-9103.

Kloepper, J.W, Lifshitz R, Zablotowicz RM (1989) Free living bacterial inocula for enhancing crop productivity. Trends Biotechnol 7:39–44

Koo, RCJ, Mayo S (1995). Effects of seaweed sprays on citrus fruit production. Proceedings of Florida State Horticultural Society 107: 82-85.

Kumar, P., Dube, S. D. and Chauhan, V. S. (2000). Photosynthetic response of bell pepper to in relation to fruit yield. Veg. Sci., 27: 54-56.

Lal, S., Ahmed N, Mir JI (2012). Effect of different chemicals on fruit cracking in pomegranate under karewa condition of Kashmir Valley. Indian J. Plant Physiol. 16 (3&4):326-330.

Latimer, L.G. 1992. Drought, paclobutrazol, abscisic acid, and gibberellic acid as alternative to daminozide in tomato transplant production.J. American. Soc. Hort. Sci., 117: 243-47.

Looney N.E (1993). Improving fruit size, appearance and other aspects of fruit crop quality with plant bioregulating chemicals. Acta Horticulturae 329:120-127.

Malik, K. A., Mirza, M. S., Hassan, U., Mehnaz, S., Rasul, G., Haurat, J., ... & Normand, P. (2002). The role of plant-associated beneficial bacteria in ricewheat cropping system. Biofertilisers in action. Rural industries research and development Corporation, Canberra, 73-83.

metabolism in maize (*Zea mays* L.) J. Chem. Ecol., 36 (2010), pp. 662–669

Mondal, M.F. (2000). Production and storage of fruits (in Bangla). BAU Campus, Mymensingh-2202.

Mrkovacki, N., & Milic, V. (2001). Use of Azotobacter chroococcum as potentially useful in agricultural application. Annals of Microbiology, 51(2), 145-158.

Ngouajio, M., Goldy, R., Zandstra, B., Warncke, D. (2003) Plasticulture for

Michigan Vegetable Production. Extension Bulletin E-2980 January 2007. Michigan State University, East Lansing, p 20

Ofosu-Anim, J., Blay, E.T. and Bening, L. (2007). Effect of Biozyme T.F. on yield and quality of tomato (Lycopersicon esculentum). *Ghana Journal of Agricultural Science* 40: 113-17.

Olivares F.L., N.O. Aguiar, R.C.C. Rosa, L.P. Canella Substrate biofortification in

Pilon-Smits, E.A.H., Quinn, C.F., Tapken, W., Malagoli, M., Schiavon, M., (2009). Physiological functions of beneficial elements. Curr. Opin. Plant Biol. 12,267–274.

Pimentel, J. P., Olivares, F., Pitard, R. M., Urquiaga, S., Akiba, F., & Döbereiner, J. (1991). Dinitrogen fixation and infection of grass leaves by Pseudomonas rubrisubalbicans and Herbaspirillum seropedicae. Plant and Soil, 137(1), 61-65.

Povero, G., Loreti, E., Pucciariello, C., Santaniello, A., Di Tommaso, D., Di Tommaso, G., Kapetis, D., Zolezzi, F., Piaggesi, A., Perata, P., (2011). Transcript profiling ofchitosan-treated Arabidopsis seedlings. J. Plant Res. 124, 619–629.

Przybysz, A., Gawronska, H., Gajc-wolska, J., (2014). Biological mode of action of anitrophenolates-based biostimulant: case study. Front. Plant Sci. 5, 1–15 Article 713.

Reeta, K., Inderdeep, K. and Bhatnagar, A. K. (2010) .Effect of seaweed liquid fertilizer on growth and yield of Lycopersicon esculentum. XX Int. Seaweed Symp. Ensenada Baja California, Mexico. pp. 92.

Remans, S., Blair MW, Manrique G, (2008) Physiological and genetic analysis of root responsiveness to auxin-producing plant growth-promoting bacteria in common bean (Phaseolus vulgaris L.). Plant Soil 302:149–161

Richard, M. (2006). How to grow big peaches. Department of Horticulture, Virginia Tech. Blacksburg, VA 24061. Internet, www. Rce.rutgers.edu. 8 pages, August

Riggs, P. J., Chelius, M. K., Iniguez, A. L., Kaeppler, S. M., & Triplett, E. W. (2001). Enhanced maize productivity by inoculation with diazotrophic bacteria.Functional Plant Biology, 28(9), 829-836.

Robinson, E. J., & Kolavalli, S. L. (2010). The case of tomato in Ghana: Processing (No. 21). International Food Policy Research Institute (IFPRI).

Roper, TR, Loescher WH, Keller J, Rom CR (1987). Sources of photosynthate for fruit growth in „Bing" sweet cherry. J. Am. Soc. Hortic. Sci. 112: 808-812.

Rose, M.T., Patti, A.F., Little, K.R., Brown, A.L., Jackson, W.R., Cavagnaro, T.R., 2014. A meta-analysis and review of plant-growth response to humic substances: practical implications for agriculture. In: Sparks, D.S. (Ed.), Advances in Agronomy, Vol. 124, pp. 37–89

Saimbhi, M. S., Padda, D. S. and Singh, G. (2012). Ascorbic acid content of chilli varieties as affected by fruit maturity. J. Res., 9: 248-50.

Saubidet, M.I., Fatta N, Barneix AJ (2000) The effects of inoculation with Azospirillum brasilense on growth and nitrogen utilization by wheat plants. Plant Soil 245:215–222

Schiavon M., D. Pizzeghello, A. Muscolo, S. Vaccaro, O. Francioso, S. Nardi

Sekse, L, Bjerke KL, Vangdal E (2005). Fruit cracking in sweet cherries – An integrated approach. Acta Hortic. 667:471-474.

Senn, A.P., and Goldsmith, M.H. (2010). Regulation of electrogenic protonpumping by auxin and fusicoccin as related to the growth of Avena coleoptiles. Plant Physiol. 88, 131–138.

Shabala, L., Mackay, A., Jacobsen, S.-, erik, Z., hou, D., Shabala, S., (2012). Oxidativestress protection and stomatal patterning as components of salinity tolerancemechanism in quinoa (Chenopodium quinoa). Physiol. Plantarum. 146, 26–38.

Shaharoona, B., Naveed, M., Arshad, M. and Zahir, Z. (2008) Fertilizer dependent efficiency of Pseudomonads for improving growth, yield, and nutrient use efficiency of wheat (Triticum aestivum L.). Appl Microbiol Biotechnol 79:147–155.

Sharma, G., Sharma, O.C. and Thakur.B.S.2009.Systematics of fruit crops, New India Publishing Agency, New Delhi, 123-256.

Singh, G (2008). Effect of irrigation, foliar fertilization and plant bioregulators on growth, yield and quality of pomegranate cv. G-137. Dr Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan, H.P., India, Ph.D. Thesis soil and ecosystem interactions Plant Soil, 342 (2011), pp. 31–48

substances boosts production of organic tomatoes. Science of Horticulture.,

Taiz L, Zeiger E (2006). Plant Physiology. (2nd ed.), Sinauer Associates Publishers, Sunderland, pp. 617-634.

Usenik V, Kastelec D, Stampar F (2005). Physicochemical changes of sweet cherry fruits related to application of gibberellic acid. Food Chem. 90:663-671.

Vacheron, J., Desbrosse, G., Bouffaud, M.-L., Touraine, B., Moënne-Loccoz, Y.,Muller, D., Legendre, L., Wisniewski-Dye, P., rigent-combaret, C., (2013). Plantgrowth-promoting rhizobacteria and root system functioning. Front. Plant Sci.4, 1–19, Article 356.

Vessey, J.K. (2003) Plant growth promoting rhizobacteria as biofertilizers. Plant Soil 255:571–586. doi:10.1023/ a:1026037216893

Vranova, V., K. Rejsek, K.R. Skene, P. Formanek Non-protein amino acids: plant,

Wally, O.S.D., Critchley, A.T., Hiltz, D., Craigie, J.S., Han, X., Zaharia, L.I., Abrams, S.R., Prithiviraj, B., (2013a). Regulation of phytohormone biosynthesis and accumulation in Arabidopsis Following treatment with commercial extract from the marine macroalga ascophyllum nodosum. J. Plant Growth Regul. 32, 324–339.

Wally, O.S.D., Critchley, A.T., Hiltz, D., Craigie, J.S., Han, X., Zaharia, L.I., Abrams, S.R., Prithiviraj, B., (2013b). Erratum to: regulation of phytohormone biosynthesis and accumulation in arabidopsis following treatment with commercial extract from the marine macroalga ascophyllum nodosum. J. Plant Growth Regul. 32, 340–341.

Wu, H.J., Wang, S., Qiao, J.Q., Liu, J., Zhan, J., Gao, X.W. (2008) Expression of HpaGXooC protein in Bacillus subtilis and its biological functions. J Microbiol Biotechnol 19:194-203

Zhang, C., Whiting, M.D. (2011). Improving 'Bing' sweet cherry fruit quality with

plant growth regulators. Sci. Hortic. 127:341-346.

Ziosi, V., Zandoli, R., Di Nardo, A., Biondi, S., Antognoni, F., Calandriello, F., (2012). Biological activity of different botanical extracts as evaluated by means of anarray of in vitro and in vivo bioassays. Acta Hortic. 1009, 61–66.

Zodape, S.T., Kawarkhe, V.J. Patolia, J.S. and Warade, A.D. (2008). Effect of liquid seaweed fertilizer on yield and quality of okra (Abelmoschus esculentus L.). J Sci Ind Res 67:1115 1117.

APPENDICES

APPENDIX A: ANALYSIS OF VARIANCE (ANOVA) TABLES

Appendix A1: Analysis of Variance Table for Plant height

Source	DF	SS	MS	F	P
trt	3	463.731	154.577	2715.45	0.0000
Error	8	0.455	0.057		
Total	11	464.187			

Grand Mean 114.96 CV 0.21

Appendix A2: Analysis of Variance Table for stem girth

Source	DF	SS	MS	F	P
trt	3	0.07989	0.02663	5.82	0.0207
Error	8	0.03660	0.00458		
Total	11	0.11649			

Grand Mean 1.8492 CV 3.66

Appendix A3: Analysis of Variance Table for Leaf chlorophyll

Source	DF	SS	MS	F	P
trt	3	54.1491	18.0497	15.53	0.0011
Error	8	9.2984	1.1623		
Total	11	63.4475			

Grand Mean 34.994 CV 3.08

Appendix A4: Analysis of Variance Table for plant canopy

Source	DF	SS	MS	F	P
trt	3	22.4040	7.46801	18.85	0.0006
Error	8	3.1693	0.39617		
Total	11	25.5734			

Grand Mean 96.382 CV 0.65

Appendix A5: Analysis of Variance Table for flower count

Source	DF	SS	MS	F	P
trt	3	30.5330	10.1777	18.22	0.0006
Error	8	4.4695	0.5587		
Total	11	35.0025			

Grand Mean 29.686 CV 2.52

Appendix A6: Analysis of Variance Table for number of fruits

Source	DF	SS	MS	F	P
trt	3	43.7827	14.5942	50.20	0.0000
Error	8	2.3257	0.2907		

Total	11	46.1084

Grand Mean 15.712 CV 3.43

Appendix A7: Analysis of Variance Table for fruit diameter at green stage

Source	**DF**	**SS**	**MS**	**F**	**P**
trt	3	52.5015	17.5005	9.67	0.0049
Error	8	14.4742	1.8093		
Total	11	66.9757			

Grand Mean 41.079 CV 3.27

Appendix A8: Analysis of Variance Table for fruit firmness at green stage

Source	**DF**	**SS**	**MS**	**F**	**P**
trt	3	8.1167	2.70556	9.61	0.0050
Error	8	2.2533	0.28167		
Total	11	10.3700			

Grand Mean 11.750 CV 4.52

Appendix A9: Analysis of Variance Table for fruit mesocarp thickness at green stage

Source	DF	SS	MS	F	P
trt	3	8.5097	2.83656	10.13	0.0042
Error	8	2.2408	0.28010		
Total	11	10.7505			

Grand Mean 4.7467 CV 11.15

Appendix A11: Analysis of Variance Table for fruit moisture content at green stage

Source	DF	SS	MS	F	P
trt	3	1.22362	0.40787	0.44	0.7326
Error	8	7.46527	0.93316		
Total	11	8.68889			

Grand Mean 93.966 CV 1.03

Appendix A12: Analysis of Variance Table for fruit moisture content at breaker stage

Source	DF	SS	MS	F	P
trt	3	10.9744	3.65814	2.32	0.1514
Error	8	12.5943	1.57428		
Total	11	23.5687			

Grand Mean 93.675 CV 1.34

Appendix A13: Analysis of Variance Table for fruit moisture content at light red stage

Source	DF	SS	MS	F	P
trt	3	2.4470	0.81566	0.77	0.5418
Error	8	8.4608	1.05760		
Total	11	10.9078			

Grand Mean 94.008 CV 1.09

Appendix A14: Analysis of Variance Table for fruit TSS at green stage

Source	DF	SS	MS	F	P
trt	3	1.34250	0.44750	3.95	0.0534
Error	8	0.90667	0.11333		
Total	11	2.24917			

Grand Mean 2.1417 CV 15.72

Appendix A15: Analysis of Variance Table for fruit TSS at breaker stage

Source	DF	SS	MS	F	P
trt	3	1.52250	0.50750	4.83	0.0332
Error	8	0.84000	0.10500		
Total	11	2.36250			

Grand Mean 2.1750 CV 14.90

Appendix A16: Analysis of Variance Table for fruit TSS at light red stage

Source	DF	SS	MS	F	P
trt	3	0.86250	0.28750	2.28	0.1558
Error	8	1.00667	0.12583		
Total	11	1.86917			

Grand Mean 2.3583 CV 15.04

Appendix A17: Analysis of Variance Table for fruit TTA at pink stage

Source	DF	SS	MS	F	P
trt	3	0.01059	0.00353	0.40	0.7552
Error	8	0.07016	0.00877		
Total	11	0.08075			

Grand Mean 0.2964 CV 31.60

Appendix A18: Analysis of Variance Table for Vitamin C at green stage

Source	DF	SS	MS	F	P
trt	3	2.17816	0.72605	33.55	0.0001
Error	8	0.17313	0.02164		
Total	11	2.35129			

Grand Mean 1.1658 CV 12.62

Appendix A19: Analysis of Variance Table for Vitamin C at breaker stage

Source	DF	SS	MS	F	P
trt	3	600.073	200.024	1274.92	0.0000
Error	8	1.255	0.157		
Total	11	601.328			

Grand Mean 13.727 CV 2.89

Appendix A20: Analysis of Variance Table for Vitamin C at pink stage

Source	DF	SS	MS	F	P
trt	3	330.934	110.311	238.86	0.0000
Error	8	3.695	0.462		
Total	11	334.629			

Grand Mean 13.353 CV 5.09

Appendix A21: Analysis of Variance Table for Vitamin C at red ripe stage

Source	DF	SS	MS	F	P
trt	3	82.0489	27.3496	289.95	0.0000
Error	8	0.7546	0.0943		
Total	11	82.8035			

Grand Mean 12.859 CV 2.39