EFFECTS OF SODIUM AZIDE AND GRAFTING ON SOME QUALITY TRAITS IN TOMATO (*LYCOPERSICON LYCOPERSICUM*MILL.)

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EFFECTS OF SODIUM AZIDE AND GRAFTING ON SOME QUALITY TRAITS IN TOMATO *(LYCOPERSICON LYCOPERSICUM* MILL.)

BY

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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA. IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER OF EDUCATION DEGREE IN EDUCATIONAL BIOLOGY.

DEPARTMENT OF BIOLOGICAL SCIENCES,
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DECEMBER, 2015

DECLARATION

I declared that this Thesis entitled **EFFECTS OF SODIUM AZIDE AND GRAFTING ON SOME QUALITYTRAITS IN TOMATO *(LycopersiconlycopersicumMill)*** has been carried out by me in the Department of Biological Sciences, Ahmadu Bello University,Zaria. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution. All sources of references are duly acknowledged in the reference.

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Aminu YAHAYA	Signature	Date

CERTIFICATION

This Thesis entitled **EFFECTS OF SODIUM AZIDE AND GRAFTING ON SOME**QUALITY **TRAITS IN TOMATO*(LYCOPERSICON LYCOPERSICUM*Mill.*)*** by Aminu YAHAYA meets all the requirements governing the award of Master of Education degree in **EDUCATIONAL BIOLOGY** of the Department of Biological Sciences, Faculty of Science, AhmaduBello University Zaria. It was approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research work is dedicated to my beloved mother HajiyaHauwa Yusuf Fagge, my entire family,my late father MalamYahaya Hassan Fagge and my late 2nd Supervisor Dr. S. Mu'azu (May their souls rest in perfect peace) ameen.

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ABSTRACT

The effect of sodium azideinduced mutation and grafting methods on the growth and yield of three varieties of tomato was investigated with the aim of inducing variability that could be exploited in the improvement of some quality traits in Tomato plants. Three different treatments (chemical mutagenesis via sodium azide, grafting and a combination of grafting with sodium azide) were applied on to the three tomato varieties. The seeds of three varieties of tomato: *Roma, UC* and *Localvarieties*were treated at four different concentrations of sodium azide (0.1mM, 1.0 mM, 2.0 mM and 0.0 mM as control) after which some of the mutants were grafted using tongue grafting method at seedlings stage; while the other set of the seeds were not treated with the mutagen but were grafted at seedlings stage. The result obtained revealed highly significant difference ($P \leq 0.01$) in the effects of sodium azide on germination percents, plant heights, survival rates, leaf attributes, number of fruits, fruit weight, pericarp thickness, number of seeds and pH.Significant improvement ($P \leq 0.05$) was also recorded on fruit diameter. Similarly, highly significant differences ($P \leq 0.01$) were found between the treatments in all the selected traits except on the leaf area,number of fruits, fruit weight, pericarp thickness, number of seeds and shoot dry weight where no significant differences exist. Furthermore, significant difference exists in the varietal response to the treatments except in the percentage germination and shoot dry weight. More so, significant differenceswere found in the traits between the seasons except germination percent (1 WAP), leaf and fruit number, pericarp thickness and fruit diameter. The result showed that sodium azide and grafting improve important quality traits of tomato. It was deduced that variety variety UC responds significantly to sodium azide while variety Roma responds more to grafting treatment. It was also concluded that, the mutants and grafted tomato could be grown both during the rainy and dry seasons. It was concluded that 0.1 mM concentration of Sodium Azide and grafting improve some important quality traits of tomato that could be utilized for further improvement of tomato crop.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Tomato (*Lycopersiconlycopersicum* Mill.) is an annual plant which originated from the south America probably Peru (Purseglove, 1968), from there transported by Spanish explorers to Southern Europe where it was utilized most extensively before taking it to Northern Europe and later to the United States (Johnson, 2005) and other parts of the globe. It belongs to the small genus *Lycopersicon* consisting of nine species within the large family *Solanaceae* (Purseglove, 1968; Hille *et al*., 1989). It is nowadays one of the major vegetable crops cultivated throughout the world and is grown in a wide range of environments comprising natural and protected conditions (Dhaliwal *et al.,* 2002) of both the tropical, sub-tropical and temperate parts of the world.

The cultivated tomato (2n=24) is an annual herb with different growth habits comprising of erect, prostrate or climbing stems (Purseglove, 1968). The stem can be determinate or indeterminate with reddish to yellowish glandular hairs having monopodial branching system. The root is of tap-root system. The leaves are opposite and pinnately compound with lobed margins which are ovate to oblong and petiolated. The flowers form raceme inflorescence, perfect, actinomorphic and pentamerous with superior ovary. The fruit is a berry with smooth skin which is reddish to yellowish succulent at maturity and many seeded. The seeds are flat and kidney shaped (Johnson, 2005).

1.2 Economic Importance

Tomato *(L.lycopersicum*Mill.) is a plant with variety of uses. The importance of the plant is mostly centered upon its edible fruits (Purseglove, 1968; Mann *et al*., 2003). The fruit is rich

in alkaloid tomatine, lycopene, carotene, ascorbic acid and vitamins (Gill, 1992). The seeds, leaves and skin can provide oil on extraction that can be used as cooking oil. The fruit is used for making soup and sausage (Johnson, 2005).

Commercially, the sale of the fruits served as a source of income to peasant farmers and as a source of income to the governments. The 'kwanar Gafan' tomato market in Kano state serve as the centre for purchasing and supply of tomato to the nation; providing job opportunities to thousands of individuals in the area. The desirable characters usually sought in a tomato variety include total soluble solids (TSS), pH, fruit size, fruit shape, and color of the fruits. Some other characters such as fruit firmness, thick pericarp, optimum pH and high TSS are important characteristics from a processing point of view (Dhaliwal *et al*., 2002).

The plant is of high medicinal importance as the fruit is a good remedy for preventing or inhibiting various forms of venous and arterial thrombosis and fibrin clots formation in veins. It is a valuable food mineral and vitamins particularly vitamin A and C. Studies have shown that people who ate tomatoes or tomato products may be at lower risks of some kind of cancer, particularly cancer of the prostate gland, lungs and stomach (Anonymous, 2009). The fruits are recommended for patients suffering from obesity, hormone replacement therapy, anti phospho-lipid syndrome, cancer or patients suffering from genetic and plasmic risk factors as well as those that had recently undergone surgical operations (Anonymous, 2010).

1.3 Statement of the Research Problem

Although tomato was first cultivated by Indians in Mexico and later introduced into Europe as early as the 16th century, its value as a highly valuable and nutritious crop (Hille *et al*., 1989) become generally recognized in the second half of the 19th century. Since that time, it is one of the most important horticultural crops in the world, and since consumers demand more

varieties of higher quality, strategies focused on increasing fruit quality continue to be of great interest (Dorais *et al.,* 2001; Gruda, 2009). Fruit quality is defined as a combination of visual stimuli, like size, shape and color and sensory properties, like sweetness, acidity and aroma (Bai and Lindhout, 2007). Research on the genetic control of fruit quality traits has been dominated by studies of the ripening process, since this specific developmental process in fruit greatly affects the evolution of several quality parameters, like colour, aroma, Soluble Solute Contents (SSC) and Titratable Acidity (TA). High SSC and TA are highly desirable not only in processing tomato cultivars but also in fresh-market cultivars due to the important contribution of sugars and acids to the overall flavour and nutritional value of tomatoes(Foolad, 2007). Applying molecular marker-assisted breeding selection in order to obtain cultivars with high SSC and other quality parameters has proven difficult; yet positive results have been achieved (Lecomte *et al*., 2004). As a consequence of inbreeding during tomato domestication, the genetic diversity in cultivated tomato is very narrow (Cuartero and Fernandez-Munoz, 1999).

And despite all the tremendous importance of tomato, little importance have been put into the improvements of its genetic diversity to meet the demand of the local populace in Nigeria. There is lack of proper attention given to the improvement of this plant to prevent its seizure at some period of the year to reduce its risen cost by both the governments and the scientific community. The lack of diversity in the cultivated tomato can be visualized using DNA technologies. However, very few polymorphisms within the cultivated tomato gene pool have been identified, even using sensitive molecular markers (Van Der Beek *et al*., 1992; Villand *et al.,* 1998; Park *et al*., 2004; Garcia-Martinez *et al*., 2005; Tam *et al.,* 2005). Another strategy for improving tomato fruit consists of the development of new genotypes through introgression of genetic traits from wild relative species such as *Solanumpimpinellifolium*, *Solanumpennellii*,

Solanumcheesmaniae and *Solanumchmielewskii* (Eshed and Zamir, 1994; Chetelat *et al*., 1995; Goldman *et al*., 1995; Harada *et al.*, 1995; Fridman *et al*., 2000; Husain *et al*., 2001; Balibrea *et al*., 2006). Germplasm from wild-type tomato relatives is currently used to improve this quality parameter and other organoleptic and nutritional characteristics in tomato fruit by conventional marker-assisted and genetic transformation breeding strategies (Baxter *et al.*, 2005; Tieman *et al*., 2006). However, despite the high variability of the species within the genus *Lycopersicon* regarding SSC levels in fruit, breeders have had limited success in increasing SSC without losing other production traits.

The plant is threatened by neglect from the authorities concerned the consequent effect of which is it's seizure during some periods of the year; leading to high increase in price. Therefore, efforts need to be placed in order to improve the quality and quantity of this valuable plant to relieve the larger society from its incessant demand that projects prices above tolerable limits for the poor man. An understanding of the genetic architecture or characters of economic interest greatly helps in formulating breeding methodology for combining desirable characters dispersed in two or more genotypes, into one (Lambeth *et al.*, 1966) through grafting and/or mutation.

Grafting (an asexual method of propagating plants) is a method whereby tissues of one plant are encouraged to fuse with those of another (Anonymous, 2011). Grafting is frequently used to combine advantageous characteristics of scion and stock. For instance, branches or buds of trees known to produce good fruit are grafted to stronger trees that produce fruit of indifferent quality. Grafting is also used in propagating seedless fruits, such as seedless oranges and grapes (Anonymous, 2009). It is used in European green house and tunnel production and is gaining popularity in the United States (Anonymous, 2007). Mutation on the other hand, is one of the methods used in the improvement of economic crops. It facilitates the isolation, identification and

cloning of genes which would ultimately help in designing crops with improved yield, increased stress tolerance, and longer life span and reduced agronomic in-puts (Ahloowalia and Maluszynski, 2001). Thus, this study utilized grafting in combination with mutation on tomato with the view of improving its yields.

1.4 Justification of the Study

Tomato *(Lycopersicon lycopersicum*Mill.) is a crop of high importance in many countries (FAO, 1998). For instance, in Greece, 1.8 million MT were produced. In the Mediterranean area, where land use is very intensive and continuous cropping is in common practice, vegetable grafting is considered an innovative technique with an increasing demand by farmers. Viewing recent data concerning the Mediterranean area by Leonardi and Romano (2004) it was reported that Spain is the most important country for the spreading of vegetable grafting with mainly tomato and watermelon, with 40 and 52% of the total of 154 million plants in 2004, respectively. They also indicated that in Italy an increasing dissemination of the grafting technique increased the number of the vegetable grafted plants from 4 million in 1997 to 14 million in 2000. In Greece, grafting is becoming highly popular, especially in southern areas, where the ratio of the production area using grafted plants to the total production area, amounts to almost 90-100% for early cropping watermelons, 40-50% for melons under low tunnels, 5-10% for cucumbers and 2-3% for tomato and eggplant. In contrast, in northern Greece, the cultivation of grafted fruit-bearing vegetables is rare (Traka-Mavrona *etal*., 2000).

Although in the beginning, tomato grafting was adopted to limit the effects of Fusarium wilt (Lee, 1994), the reasons for grafting have increased dramatically over the years. For example, grafts have been used to induce resistance against low (Bulder *etal*., 1990) and high (Rivero *etal*., 2003) temperatures; to enhance nutrient uptake (Ruiz *etal*., 1997); to improve yield

when plants are cultivated in infected soils (Bersi, 2002; Kacjan-Marsic and Osvald, 2004); to increase the synthesis of endogenous hormones (Proebsting *etal*., 1992); to improve water use (Cohen and Naor, 2002); to increase flower and seed production (Lardizabal and Thompson, 1990); to enhance vegetable tolerance to drought, salinity and flooding (AVRDC, 2000; Estan *etal*., 2005). Moreover, many researchers reported that an interaction between rootstocks and scions exists resulting in high vigor of the root system and greater water and mineral uptake leading to increased yield and fruit enhancement (Lee, 1994; Oda, 1995; Bersi, 2002; Leoni *etal*., 1990; Ioannou, *etal*., 2002; Kacjan-Marsic and Osvald, 2004). On the contrary, Romano and Paratore (2001) stated that vegetable grafting does not improve the yield when the selection of the rootstock is not suitable, for example the self-grafted plant 'Rita x Rita' had a lower yield than the non-grafted plants. Also there are some contradictory results about the fruit quality traits and how grafting affects them. For example Traka-Mavrona *etal*. (2000) report that the solutes associated with fruit quality are translocated in the scion through the xylem, whereas Lee (1994) states that quality traits for instance fruit shape, skin color, skin or rind smoothness, flesh texture and color, soluble solids concentration are influenced by the rootstock. However, other researchers showed that grafting did not affect fruit quality (Leoni *etal*., 1990; Romano and Paratore, 2001). The primary advantage of grafting for tomato production is similar to that of the previously published works(to utilize root stocks that: reduce the likely hood of infection by a pathogen, tolerant of certain abiotic stress, or can add to plant vigor and ultimately fruit yields as well as resulting in better yield and economic stability throughout the year). Tongue grafting approach was used. This is due to the relative advantage of the method over others such as its being used on larger plants, three times faster than other techniques, high success rate and is easy to handle.

Mutation on the other hand, was applied to increase yield, stress tolerance and reduce agronomic in-puts (Ahloowalia and Maluszynski, 2001). This research explored grafting and induced mutation using sodium azide to improve the yield of cultivated tomato so as to make the plant available for local consumption throughout the year in the savanna ecological zone of Nigeria. Sodium Azide was found to be effective in the improvement of yield components of many plants such as maize (Asmahan, 1993).

Despite the significance of tomato to the world economy and health status of a modern man, proper attention in terms of its improvement among the authorities concerned in Nigeria is lacking. Tomato is faced with the problem of seizure within some period of the year; especially in the guinea and sudan savanna zones of Nigeria. It is a classic example of a crop plant in which, until mid-century, germ-plasm resources was inadequate for significant crop improvement or major advantage in basic genetic research. These can be attributed to the selection force with consequent reduction in genetic variability; leading to difficulties experienced by breeders in finding the genes essential for desired improvements. The possibility of applying grafting to improve fruit quality has been scarcely investigated.

Since tomato is one of the most important crops, special measures are therefore needed to increase the range of genetic variation (Rick, 1989). The lack of improved varieties that can withstand the environmental stress of the time with increased vigor posed a great challenge to tomato improvements in Nigeria. This research explored the use of grafting and mutation to improve the yield of cultivated tomato so as to make the plant available for local consumption throughout the year in the savanna ecological zone of Nigeria. The primary advantage of grafting for tomato production is to utilize root stocks that: reduce the likely hood of infection by a pathogen, are tolerant of certain abiotic stressors, or can add to plant vigor and ultimately fruit

yields as well as resulting in better yield and economic stability throughout the year (Garner, 1988).

1.5 Aim of the Research

The aim of this research was to assess the effects of mutation and grafting on some selected traits of tomato (*Lycopersicon lycopersicum* Mill.).

1.6 Objectives of the Research

The objectives of this research are:-

i. To determine the effects of grafting and sodium azide on some selected traitsof three tomato varieties.

ii. To determine the responses of the three tomato varieties to grafting and sodium azide.

iii. To determine the relationships between the growth components and yield parameters of grafted and mutated tomato.

1.7 Research Hypotheses

For the purpose of conducting this research, the following hypotheses were postulated:-

i. There is no significant difference in the effects of grafting and sodium azide on the selected traits of the three tomato varieties.

ii. There is no significant difference between the response of the three tomato cultivars to grafting and sodium azide.

iii. There is no significant relationship between the growth parameters and yield components of grafted and mutated tomatoes.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Grafting and Mutation

Tomato (*Lycopersiconlycopersicum* Mill.) being one of the most important vegetables grown in a wide range of environments comprising natural and protected conditions (Dhaliwal *etal*., 2002) is faced with the problem of seizure within some period of the year; especially in the guinea and sudan savanna zones of Nigeria. Several approaches were devised the world over in the improvements of economic plants among which are: Selection of desirable traits (Holm, 1988), hybridization (Dhaliwal *etal*., 2002) and artificial induction of mutation (Micke *etal*., 1987).

Grafting is one of the most important techniques used for the suitable cultivation of fruit bearing plants in areas where intensive and continuous cultivation is performed such as Japan, Korea and some other Asian and European countries (Yetisir and Sari, 2003). Grafting technique in vegetables was first performed in Korea and Japan in the late 1920s by grafting watermelon onto gourd rootstocks (Yamakawa, 1983; Kubota *et al*., 2008). And since after the first experiments, the area gained popularity for other vegetables (Yetisir and Sari, 2003). Grafting is therefore a method of asexual plant propagation widely used in agriculture and horticulture where the tissues of one plant are encouraged to fuse with those of another (Anonymous, 2011). It is used most extensively in vegetables for a variety of reasons. In fruit trees like apple, dwarfing rootstock are used to control the size and vigor of the tree. With field grown vegetables,

grafting is used to increase resistance to soil-borne diseases (McVoy, 2005). Grafting in horticultural plants is increasing as a means to improve plant growth, control disease, impart tolerance to temperature and salt stress, and increase nutrient uptake beside being an important component of low-input sustainable and organic horticulture due to increase in vigor and disease resistance (Anonymous, 2011).

Tomato is a crop of significant importance to human diet. For instance, in Greece, 1.8 million MT were produced. In the Mediterranean area, where land use is very intensive and continuous cropping is in common practice, vegetable grafting is considered an innovative technique with an increasing demand by farmers. Viewing recent data concerning the Mediterranean area by Leonardi and Romano (2004) it was reported that Spain is the most important country for the spreading of vegetable grafting with mainly tomato and watermelon, with 40 and 52% of the total of 154 million plants in 2004, respectively. They also indicated that in Italy an increasing dissemination of the grafting technique increased the number of the vegetable grafted plants from 4 million in 1997 to 14 million in 2000. In Greece, grafting is becoming highly popular, especially in southern areas, where the ratio of the production area using grafted plants to the total production area, amounts to almost 90-100% for early cropping watermelons, 40-50% for melons under low tunnels, 5-10% for cucumbers and 2-3% for tomato and eggplant. In contrast, in northern Greece, the cultivation of grafted fruit-bearing vegetables is rare (Traka-Mavrona *et al.*, 2000).

Although in the beginning, tomato grafting was adopted to limit the effects of Fusarium wilt (Lee, 1994), the reasons for grafting have increased dramatically over the years. For example, grafts have been used to induce resistance against low (Bulder *et al*., 1990) and high (Rivero *et al*., 2003) temperatures; to enhance nutrient uptake (Ruiz *et al.,* 1997); to improve

yield when plants are cultivated in infected soils (Bersi, 2002; Kacjan-Marsic and McVoy, 2005); to increase the synthesis of endogenous hormones (Proebsting *et al*. 1992); to improve water use (Cohen and Naor, 2002); to increase flower and seed production (Lardizabal and Thompson, 1990); to enhance vegetable tolerance to drought, salinity and flooding (AVRDC, 2000; Estan *et al*., 2005). Moreover, many researchers reported that an interaction between rootstocks and scions exists resulting in high vigor of the root system and greater water and mineral uptake leading to increased yield and fruit enhancement (Leoni *et al*., 1990; Lee, 1994; Oda, 1995; Bersi, 2002; Ioannou, *et al*., 2002; Kacjan-Marsic and Osvald, 2004). On the contrary, Romano and Paratore (2001) stated that vegetable grafting does not improve the yield when the selection of the rootstock is not suitable, for example the self-grafted plant 'Rita x Rita' had a lower yield than the non-grafted plants. Also there are some contradictory results about the fruit quality traits and how grafting affects them. For example Traka-Mavrona *et al*. (2000) reported that the solutes associated with fruit quality are translocated in the scion through the xylem, whereas Lee (1994) stated that quality traits such as fruit shape, skin color, skin or rind smoothness, flesh texture and color, soluble solids concentration and so forth, are influenced by the rootstock. However, other researchers showed that grafting did not affect fruit quality (Leoni *et al.*,1990; Romano and Paratore, 2001).

The prime strategy in mutation-based breeding on the other hand has been to upgrade the well-adapted plant varieties by altering one or two major traits. These include characters such as plant height, maturity, seed shattering, and disease resistance, which contribute to increased yield and quality traits, for instance, modified oil profile and content, malting quality, and size and quality of starch granules (Ahloowalia *et al*., 2003). However, in many cases, the changed traits had a synergistic effect on the cultivation of the crop, agronomic inputs, crop rotation and

utilization. For instance, the short height genotypes in rice, wheat, barley and maize have contributed significantly to increasing grain yield because of their resistance to lodging and high planting density. The short height trait also allowed the use of relatively high doses of nitrogen application. The early maturity of some mutants resulted in timely planting of the follow-up crop; for example early maturity of cotton in Pakistan allowed early planting of the wheat crop, resulting in higher wheat yield. The induction of thermo-sensitive genic male-sterile mutant in Japonica rice, which is controlled by a single recessive gene (Maruyama *et al*., 1991), contributed significantly to develop strategies for the production of hybrid rice varieties. Similar mutants were induced through gamma irradiations in rice (Shen *et al*., 1993). Such mutants allow production of hybrid seed based on only two lines, and show increased yield from heterosis.

2.2 Grafting Techniques

There are various approaches used in grafting vegetables, but in most cases, one plant is selected for its roots, and this is called the stock or rootstock. The other plant is selected for its stems, leaves, flowers or fruits and is called the scion. The scion contains the desired genes to be duplicated in future production by the stock/scion plant (Anonymous, 2011). It mostly involves grafting a shoot of a selected, desired plant cultivar onto the stock of another type. In another common form called budding, a dormant side bud is grafted on the stem of another stock plant and when it has fused successfully, it is encouraged to grow by cutting out the stem above the new bud (Anonymous, 2011). It is therefore a process whereby, a freshly cut section of stem with buds, called a scion, is joined to another plant called the stock. The upper stem of the stock is severed and the scion is joined to the lower stem. The scion is securely attached to the stock, and the tissues of the two plants grow into each other, forming a single plant. The scion produces

the stems, leaves, and flowers on the new plant and the stock provides the root system (Anonymous, 2009).

Grafts are usually unsuccessful unless plants of the same or closely related kind are used. A seedling or cutting, usually chosen for hardiness and resistance to pests and diseases, or for special characteristics such as dwarfing, is commonly used as the stock in grafting. When a seedling is used as a stock, it is first allowed to establish its root system; a graft is then inserted at the base of the stem. As soon as the union of scion and stock has become established, any remaining portions of the shoot of the stock are cut away; all substances absorbed by the root system are thereafter available to the scion for its development. When a cutting is used, the graft is made first, and then the cutting is rooted. Nursery stock for rubber plantations and for many fruit orchards is produced by the seedling type of grafting (Anonymous, 2009). The area surrounding the juncture of scion and stock is protected by paraffin or by grafting wax, which consists of a mixture of beeswax, beef tallow, and resin. Grafting tape is usually used to cover the waxed wound, so as to exclude moisture and prevent attack by diseases or pests.

2.3 Grafting Types

Several methods of grafting vegetable crops were identified as: Cleft grafting, Tongue Approach grafting, Tube grafting (McVoy, 2005) and Micro grafting (Anonymous, 2009).

2.3.1 Cleft Grafting

Cleft grafting is the most widely used method for grafting scions that produce high-quality fruit on mature tree (Anonymous, 2009). It was carried out when the plants were slightly larger. A V-shaped cut is made in the stem of the scion. The scion is then inserted into the rootstock, which has a vertical slice cut down the center of the stem. The rootstock and scion are then held together by a spring clip while the graft union forms (Oda, 1999). In this process,

branches of the stock can also be sawed straight across, and the stub of the branch is split to depth approximating the diameter of the stock. A temporary wedge, sufficient to open the slit, is inserted at the center of the split. Two scions, each having several buds, are inserted at the edges of the split, and are adjusted so that the lowest bud is close to the top of the stock and facing outward. The wedge is removed without displacing the scions, and the cut is covered with grafting wax and, if necessary bound with grafting tape. Sometimes, more than two scions are used, with all the scions but the strongest being removed in the following season (Anonymous, 2009). The diameter of the cut ends (of the shoot and the rootstock) must match up perfectly. If not, the graft might take longer time to heal and the rootstock will slowly starve to death (McVoy, 2005).

Other forms of cleft grafting are the Awl, Veneer, Splice, Saddle and Side grafting. In Awl grafting, a screw driver can be used to make a slit in the bark, not penetrating the cambium layer completely. The wedged scion is then inserted into the incision. While the Veneer (Inlay) grafting is used for stocks larger than three centimeters in diameter. Clefts of the same size are used as the scion is made on the side of the branch, not on top. The scion end is shaped as a wedge, inserted, and wrapped with tape to the scaffolding branches for more strength (Anonymous, 2011). In splice grafting, the scion and the rootstock are joined, covered with grafting wax or paraffin, and bound with grafting tape. Saddle grafting on the other hand is accomplished by cutting one stem, usually the stock, in the shape of a wedge, and cutting the other stem in the shape of a slot that will fit the wedge tightly. While, side grafting is useful for grafting new branches onto bare spaces of tree trunks. In this method, a longitudinal cut is made through the bark layer. The scion, with its base cut in a wedge shape, is inserted beneath the bark, tied, and then waxed (Anonymous, 2009).

2.3.2 Tongue Approach Grafting

This is otherwise known as Approach grafting. It is done by cutting opposing and complementary notches in the stem of the rootstock and scion. The complementary notches are fit together and held with a spring clip or some type of tape. Once the graft union heals the root system is cut from the scion plant and the shoot is removed from the rootstock plant. This method is used to join together plants that are otherwise difficult to join. The plants are grown close together, and then joined so that each plant has roots below and grown above the point of union (Anonymous, 2007). Both scion and stock retain their respective parents that may or may not be removed after joining. It can be successfully accomplished any time of the year (Garner, 1988). It is a technique that allows the scion donor-plant to remain on its own rootstock until the graft heals. The technique is mostly applicable on members of the Cucurbitaceae family such as Melons and Cucumbers (McVoy, 2005). This process allows the root portion of the scion plant remains in-tact until the graft union heals. Larger plants are therefore used (seedlings 14-21 days) to ensure sufficient stem diameter to perform the graft. The top of the rootstock is firstly removed so that the shoot cannot grow. The stem of both the scion and the rootstock are cut in such a way that they tongue into each other and the graft is secured with the larger clip. The root of the scion is left intact for three to four days while the graft union heals and then the stem of the scion donor is crushed between the fingers or partially cut below the graft. Finally, the stem is completely cut-off with a razor blade three or four days after being crushed (McVoy, 2005).

Another form of tongue grafting is the whip grafting. It is commonly used in top-dressing commercial fruit trees as it offers the most cambium contact between the two plants. It is used with stock of less than 1.3cm in diameter, with the ideal diameter of 0.95 cm and the scion should be of roughly the same diameter as the stock. The stock is cut through on one side only at

a shallow angle with a sharp knife. But if the stock is a branch and not the main trunk of the rootstock then the cut surface should face outward from the center of the tree. The scion is similarly sliced through at an equal angle starting just below a bud, so that the bud is at the top of the cut and on the other side than the cut face. A notch is cut downwards into the sliced face of the stock and a similar cut upwards into the face of the scion cut. This act as the tongues and it requires some skills to make the cuts so that the scion and the stock marry up neatly. The join is then taped around and treated with tree sealing compound or grafting wax (Anonymous, 2010).

Approach grafting therefore involves notching opposing sides of the stems of the rootstock and scion, and then using a clip to hold the stems together while they fuse. Once the graft has healed, the original scion is then cut off of the desired rootstock and the unused rootstock is detached from the scion (Lee, 2003).

2.3.3 Tube Grafting

Tube grafting is otherwise known as Japanese Top Grafting; a technique used on small seedlings (McVoy, 2005). It occurs when the scion and rootstock are severed as seedlings and reattached with a small, silicon tube or clip (Oda, 1995, Rivard and Louws, 2006). It is highly effective on very small plants (seedlings) eliminating the need for large healing chamber with typical success rates ranging from 85-90% (Oda, 1995). The advantage of this method lies on the fact that smaller plants are used which makes possible grafting plants two or three times faster than with conventional cleft grafting. Also the smaller plants take up less room during the healing and acclimation process (McVoy, 2005).

2.3.4 MicroGrafting

Micro grafting is a new technique that has been recently integrated into micro propagation of plants. It uses micro propagated scions shoots that grafted onto three week-old rootstock seedlings (Grigoriadis *et al*., 2005).

2.4 Functions of Grafting

Grafting is often done for non-woody and vegetable plants (Core, 2005). It combines desirable qualities from one species, such as disease resistance or the ability to grow in waterlogged soils, with desirable qualities of another, such as the ability to produce high quality fruit. Grafting is often used to make fruit trees more vigorous and productive. In nature, roots of oak trees of the same species commonly graft together, hastening the spread of diseases such as oak wilt, a fungal disease that kills a variety of oak trees (Anonymous, 2009). Grafting is also beneficial in plants that are difficult to propagate vegetatively by other means. It is used to speed up the maturity rate of hybrids in fruit tree breeding programs (Anonymous, 2010). The main advantage of grafting is for disease-resistant rootstocks. Researches (Onoda *et al*., 1992 and Kobayashi *et al*., 1999) have recently developed automated processes using grafting robots. Grafting in horticultural plants is increasing as a means to improve plant growth, control disease, impart temperature and salt tolerance, and increase nutrient uptake (Anonymous, 2010). Currently, 81% of Korean and 54% of Japanese vegetables cultivation uses grafting (Rivero *et al*., 2003). It is carried out for intensive cropping systems like greenhouse and tunnel production. It is popular especially for vegetable production with almost 540 million transplants in Korea and 750 million in Japan in 1998 (Lee *et al*., 1998). It is used as an integrated management strategy for managing soil borne diseases and crop productivity in Europe and Mediterranean region of the world (Besri, 2005). It induces precocity (the ability to induce fruitfulness without the need

for completing the juvenile phase), speed hybrids maturity and change cultivars into profitable types (Anonymous, 2010).

2.4.1 Grafting and Disease Resistance

Grafting techniques have been used to study pathological and physiological responses in fruit and annual crop plants (Vuong, 2002). For insect resistance, grafting was used to demonstrate that resistance factors from plant introductions were translocated to leaves throughout the plants of susceptible genotypes (Lambert and Kilen, 1984). Soil borne diseases mainly caused by *Fusariumoxysporum* common in various regions of the Mediterranean Basin, Far East and other European countries can be combated using cucurbits grafted onto various rootstocks (Kurata, 1994; Lee, 1994). Beside these, the transmission of plant viruses has been studied extensively using grafting. The virus indexing involves grafting a symptom-less plant that is suspected of carrying a virus onto an indicator plant that is very susceptible to the virus (Anonymous, 2010).

Resistance to brown stem rot was found among the reciprocal grafts between brown stem rot resistant soya bean plants with susceptible soya bean genotypes (Bachman and Nickell, 1999). Grafting resistant variety of soya bean on a susceptible type to *Sclerotiniasclerotiorum* (causing stem rot in soya bean (*Glycinemax*) has proved vital in controlling the infection (Vuong, 2002). Grafting commercial Dutch type cucumber hybrids onto various resistant Cucurbit rootstocks was used as a biological control of root and stem rot disease caused by *Fusariumoxysporum* (Pavlou, 2002). Enhanced resistance to pests such as *Phyrenochaetalycopersici* (Corky rot), *Verticilliumsp*., *F. oxysporum* races 1 and 2 and *F. oxysporum* fsp and *Radicislycopersici* (Crown rot) were found in grafts between two tomato cultivars Maxifort and Beaufort (McCoy, 2005).

Grafting is therefore an important part of crop plant production to avoid soil-borne diseases and/or chemical fumigation in areas where land rotation is not feasible. Current commercial grafting practices depend on maintaining at least one rootstock cotyledon during the healing period following grafting for high survival (Lee, 1994; Oda, 1995; Lee and Oda, 2003; Cushman, 2006). Rootstock re-growth originating from meristematic tissue next to the remaining cotyledon is one main contributing barrier preventing affordable costs which prevent its introduction into the United States agricultural system (Edelstein, 2004). With the phase-out of methyl bromide fumigant, new interests are being reviewed for potential alternatives (Cohen *et al*., 2007; Davis *et al*., 2008). For many years grafting in watermelons has been viewed as an option solely in areas where labor costs are minimal. This benefit has great potential to have a very positive effect for commercial production in the United States by improving the plants overall environmental efficiency and overcoming soil-borne pathogens. An alternative grafting method which eliminates potential re-growth is needed in order for grafting technology and benefits to progress into the United States. Removal of both cotyledons in a one-step fashion at time of grafting eliminates all potential re-growth and greatly reduces overall grafting costs. Observations indicated however that the rootstock hypocotyl begins to yellow and declines until death when grafted at the 1st leaf stage or younger which is customary for current commercial grafting techniques.

2.4.2Grafting and Physiological Traits

Grafting technique was found to be vital in the control of several physiological traits of plants. In vegetables, grafting was initiated to study the physiology of shoots and roots (Masuda and Gomi, 1984), graft compatibility (Zarrouk *etal*., 2010), plant virus relationships and crop improvement (Lee and Oda, 2003). It has been found to affect flowering in plants. Kiyosawa and

Kiyosawa (1962) used side grafting techniques in their study of genetic differences. Grafting was used as an effective tool in breeding, successfully inducing flowering of late-flowering cultivars of soya beans by grafting them on early maturing cultivars (Kiihi *et al*., 1977). Przepiorkowski and St. Martin (2003) grafted two genotypes of soya bean differing in time of flowering and discovered the translocation of flowering hormones. Grafting experiments have furthered the understanding of the control of flowering time in photoperiod-sensitive plants (Cober and Curtis, 2003). They have been instrumental in developing understanding of floral inhibitors and promoters through observation of rootstock effects on scions. Mango (*Mangiferaindica* L.) was stimulated to flower out of season with the addition of a leaf from a flowering mango plant (Kulkarni, 1986).

Short day or day neutral plants of *Nicotianatabacum* grafted onto the closely related long day species of *Nicotianasylvestris* hastened their flowering time (Lang *et al*., 1977). Carver *et al*. (1987) showed that flowering of a scion from an early maturing soybean plant was delayed when grafted to the rootstock of a late maturing line. But Beaver and Nelson (1981) found that scions from late-maturing plants when grafted to early maturing rootstock flowered earlier than un-grafted plants. Wild accession of soybean (*G. tomentella* Hayata PI393567) was induced to flower and set seeds when grafted to *G.max* rootstock (Newell and Hymowitz, 1979).

Grafting is also another way of reducing losses in production and for improving water use efficiency under drought conditions in high-yielding genotypes. This would be achieved by grafting them onto rootstocks capable of reducing the effect of water stress on the shoot as observed in tree crops (Garci´a-Sa´nchez *et al*., 2007; Satisha *et al*., 2007). In the past, grafting was used widely in vegetable crops to limit the effects of soil pathogens (Lee, 1994), but the reasons for grafting as well as the species of vegetables grafted have increased over the years.

Grafts have been used to induce resistance against low (Bulder *et al*., 1990) and high (Rivero *et al*., 2003) temperatures and against iron chlorosis in calcareous soils (Romera *et al*., 1991) and to enhance nutrient uptake and mineral nutrition (Pulgar *et al*., 2000; Ruiz *et al*., 1997), increase synthesis of endogenous hormones (Proebsting *et al*., 1992), reduce uptake of persistent organic pollutants from agricultural soils (Otani and Seike, 2006), raise salt and flooding tolerance (Estan´*et al*., 2005; Yetisir *et al*., 2006) and limit the negative effect of boron and copper toxicity (Edelstein *et al*., 2007; Rouphael *et al*., 2007). Nevertheless, no published data are available concerning the effects of water stress on agronomical and physiological responses of grafted mini-watermelon (*Citrulluslanatus* Thunb.).

2.4.3 Grafting and Morphological Traits

It is imperative that grafting, besides increasing disease and pest tolerance is also associated with yield increase (Lee and Oda, 2003) by enhancing water and nutrients up-take (Masuda *et al*.,1981; Oda, 1995). Grafting was used to study Nitrogen fixation in Soybean, and it was shown that soybean shoots regulated the rate of Nitrogen fixation in the nodules (Malik, 1983). Beside these, grafting could lead to the extension of growing season resulting in better yield and economic stability through the year (Rivero *et al*., 2003). Research has shown that, possible mechanisms for increased yield are likely due to increased water and nutrients uptake among vigorous rootstock genotypes (Fernandez-Garcia *et al*., 2002), as nutrient uptake for macronutrients such as Phosphorus and Nitrogen were enhanced by grafting (Ruiz and Romero, 1999; Leonardi and Giufrida, 2006).

Mng'omba *et al*. (2010) reported higher increase in height and diameter after thinning. A higher survival (> 75%) and reduced time to graft-take (19 days) were achieved with thicker rootstocks (0.7 cm) than thinner rootstocks (0.3 cm). The early emerging plants produced more

leaves than late emerging plants after grafted. Grafting is a common and preferred vegetative propagation method for mango trees (Bally, 2006). The graft success can be improved when rootstock selection is considered and based on desirable growth attributes of rootstocks (Simons, 1987). Rootstocks play an important role for tree survival and establishment in the field, tree productivity and dwarfing of grafted fruit trees (Mng'omba *et al*., 2008). Seedling rootstocks with desirable attributes such as rapid growth (in height and diameter) could reduce the 'waiting period' to grafting time. Furthermore, proper alignment of scion and rootstock cambium tissues could determine the graft success (Pina and Errea, 2005).

Grafting is now undergoing a transformation from a mere propagation to a crop improvement method. Though the concept is not new, world over now there is a new interest in this aspect of grafting, which is called graft hybridization. The origins of grafting can be traced back to ancient times. The practice of grafting was carried on by the Chinese thousands of years before the Christian era (Daniel, 1929; Hartmann and Kester 1975). Grafting was first initiated in fruit trees as a method of clonal propagation and slowly the practice was expanded to vegetables, flowers and other horticultural crops. Among vegetables, egg plants were the first to be grafted followed by cucumber and other solanaceous crops (Edelstein, 2004). The graft induced genetic changes were first known to the Chinese more than 1400 years ago (Liu, 2000). Although there were many records of graft induced genetic changes from time to time, this concept of graft hybridization was first put forth by Darwin (1883).

There are also further evidences of graft hybrids in several crops like eggplant (Stroun *et al*., 1963), tomato (Glavinic, 1955; Lee, 1994), petunia (Frankel, 1970) and blue fruits (Zu and Zhao, 1957). Though the graft hybrids were reported in many crops since the late nineteenth century, there has been a refusal to accept it, which have been regarded only as a type of chimera

(Liu, 2007). Heavy lignification of stem cells, as seen in trees, is one of the characteristics of capsicum, which resulted in successful graft hybrids for several traits (Ohta, 1991). The studies on graft hybridization for different traits by the same group of scientists in capsicum have given very fruitful results. Since it is an annual crop, the research on graft induced changes and analysis of the changes at genetic level was enormous than any other crop. Here an attempt has been made to study the graft induced variants, its analysis, mechanism and perspectives. Nature and pattern of variation observed in graft hybridization Studies on genetic changes induced by grafting in capsicum were first started by Russian and East European scientists. However, the lack of satisfactory Mendelian explanation and the failure of Western scientists to repeat their work lead to rejection of 'graft hybridization' as a genuine genetic exchange mechanism (Glavinic, 1955; Michie, 1958 and Pandey, 1975). However, in Japan, Kasahara and his co-workers obtained a higher rate of graft induced variants in capsicum by applying the mentor grafting method (Kasahara *et al*., 1973). The main feature of this technically simple method is the grafting of an immature scion such as a small seedling of 10-14 days after emergence on to a more mature stock. In order that the scion is nutritionally fully dependent on the stock, leaves of the scion except for 2 or 3 leaves at the top are removed twice a week during the entire growth period. According to Ohta (1977), this results in one way flow of nutritional and genetic material from stock to scion. When the scion is allowed to mature and set seeds, plants grown from these selfed seeds may show genetic characters of the stock. Thus individuals with variant characteristics were developed.

2.5 Functions of Mutation

Mutation is among the most useful techniques used in plant breeding to improve the quality and quantity of crop plants to meet the needs of the growing world population. A wide range of

mutation types occur but most are inherently unstable or deleterious at least under the conditions prevailing at the time. Those which survive a succession of critical stages at which rigorous elimination occurs and ultimately become established as successful new karyotypes represent only a small and highly selected sample of those first formed. This selected chromosome mutations are of particular evolutionary significance (Dyer, 1979). Therefore chromosome mutations arise repeatedly and presumably in all species, creating a potential for karyotype change to accompany or even direct the evolution of new species. The process of mutation is the source of new alleles. Each new allele leads to a change in the phenotype. A new phenotype results from a change in the functional activities of the cellular product controlled by the gene. However, it becomes clear that most of the changes were not in the basic units of heredity but in the structure and distribution of the chromosomes (Adamu, 1992), which may affect the protein that the gene produces and ultimately change an individual's traits (Anonymous, 2009).

2.5.1 Mutation and Disease Resistance

There is a very rapidly-growing interest in the effects of ionizing radiations upon plants and in the use of radiations to induce beneficial mutations in crop plants. A study (Anonymous, 2009) revealed a curious effect of X-rays on the resistance of tomato plants to the Fusarium wilt disease which is caused by the fungus, *Fusariumoxysporum*. When the plants were X-rayed with a dosage of 21,000 roentgens, 5 or 10 days before being inoculated with the disease-causing organism, they were more resistant to the disease than were non-irradiated plants. Plants inoculated and irradiated on the same day actually appeared to be more susceptible to the disease. In an attempt to determine whether the roots and shoots differed in these responses, shielding experiments were performed in which only roots or only stems were irradiated. It was discovered that the irradiated roots were entirely responsible for the increased resistance. Shoots

irradiated prior to root irradiation caused somewhat greater susceptibility. The suggestion is made that perhaps auxin, a plant growth hormone, may control resistance and that irradiation acts through its alteration of the auxin levels in the plant.

Mutation through radiation is credited with having produced a true-breeding mutation in wheat which is highly resistant to the stripe rust disease caused by the fungus, *Pucciniaglumarum*. Seeds of the Gabo variety of wheat were treated with X rays and thermal neutrons in 1953 and the plants were grown in Mexico. Third generation plants, grown in 1955, were subjected to a very severe infection and a number of plants were found to be very highly resistant to the disease. Plants from non-irradiated seed grown in an identical manner showed no variants that were resistant to the stripe rust, and it is concluded that the resistant plants were produced through mutation induced by the radiation treatment (Konzak, 1989).

Another example of an agriculturally beneficial mutation derived from irradiated seed was reported by Down and Andersen (1956). Seeds of a vine type of Navy bean were treated with X-rays. Among the progeny of these irradiated seed there appeared a non-vining or bush type that was smaller and ripened its fruit sooner than did the parent. This variant was tested for two years and found to breed true for the new characters. These new characters have since been used as the basis of a new variety which should be released to the public within a very few years. The new variety, named Sanilac, matures six days sooner, has a higher yield, is quite resistant to the white mold disease of beans, and is fully resistant to the bean anthracnose disease. Resistance to the last-mentioned disease was genetically transferred from other varieties and was not induced by the radiation. The upright growth habit of the bush type provides better protection for the pods against periods of wet and humid weather which often results in discolored beans in the vine types. This new variety will probably have the distinction of being the first variety induced

by radiation to be produced and released to the public in the United States. Increased resistance to infection as associated to polyploidy (Taylor *et al*., 2005) was also a manifestation of the effectiveness of mutation in the improvement of desirable qualities in economic plants.

2.5.2 Mutation and Physiological Traits

Mutation is one of the mechanisms controlling physiological traits of plants. Early maturing mutants were found in soya beans (Zacharias and Chrenberg, 1962) and in wheat (Kar *et al*., 1978). In rice, early ripening mutants sometimes are photoperiod insensitive and of semi-dwarf height. The early maturing medium grain Japonica cultivar has both semi-dwarf mutant and gamma ray induced early flowering (Rutger, 1982). Increased tolerance to harsh environmental conditions and increased water retention were enhanced through mutation as stressed by Uno *et al*. (2001). Higher doses of mutation treatment in soya beans resulted in an increased day required for maturity (Archana *et al*., 2004). Early maturing mutants were reported by Rubailhayo (1976) in soya bean.

2.5.3 Mutation and Morphological Traits

Several morphological traits of plants such as height, leaf size and number, fruits number, size and so forth were changed through mutations. A high frequency of mutations for semi-dwarfness was observed in many experiments leading to the development of short stature varieties in almost all cereals (Maluszynski *et al*., 2001). Anandakumar and Sree Rangasamy (1995) reported the occurrence of semi-dwarf rice progeny from a cross between gamma rays induced mutants in rice with a pure line selected parents. Leaf and plants structure modification were reported to be induced in garden pea (Micke and Donini, 1982). Leaf and plant structure modifications have also been induced in pea, and a small number of new *Pisumsativum* L. cultivars have been induced in pea (Micke and Donini, 1982). Increased in leaf area was reported by Pasztor *et al*. (1985) in crosses between gamma rays induced mutants in maize.

The mutation sd1 that determines short height in rice, similar to the spontaneous mutation sd1 (Deegeo-woo-gen in indica rice), was induced with gamma rays (Rutger, 1992). As a result of the introduction of semi-dwarf varieties, the average yield of rice in Egypt increased to 8.9 t/ha compared with 3.8 t/ha of the world. Of these, 'Giza 176' became one of the leading varieties, with a potential yield of 10 t/ha (Badawi, 2001). In Pakistan, the mutation induction in 'Basmati 370' resulted in the release in 1977 of a new variety 'Kashmir Basmati' which matures early and has cold tolerance, and yet retains the aroma and cooking quality of the parent. Conventional crosses derived from Basmati rice with non-aromatic varieties do not retain the aroma trait of the Basmati parent. Due to earliness and cold tolerance, Kashmir Basmati can grow at an altitude of 1000–1500 m, on areas not suitable for 'Basmati 370'. Hence, mutation induction has been a very specific method in the improvement of Basmati rice (Awan, 1991).

The Indian Agricultural Research Institute (IARI) has been a pioneer institution for research on induced mutations in the country since 1957, and has released many mutant varieties of crops and ornamentals. Several rice mutants induced with gamma radiation were released in India as high yielding varieties under the series 'PNR'; some of these were also early in maturity and had short height (Chakrabarti, 1995). According to a recent report of Science and Technology Agency, Japan, these varieties contributed US$ 937 million annually to the Japanese agriculture (Anonymous, 2000). In Thailand, the work on induced mutations on rice was initiated in 1965 and stimulated in cooperation with IAEA. Two aromatic indica type varieties of rice, 'RD6' and 'RD15', were produced by gamma irradiation of a popular rice variety 'Khao Dawk Mali 105' ('KDML 105'), an aromatic and non-glutinous variety.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Study Site

The research was conducted in the Green House of the Botanical Garden of the Department of Biological Sciences, Ahmadu Bello University Zaria (Lat 11^0 12^1N, Long 7^0,37^1E, Alt 550-700 m above sea level) (Anonymous, 2014).

3.2 Sources of the Seeds

Seeds of three varieties of cultivated tomato (*Roma*, *UC*82B and a *localvariety*) were collected from the Institute for Agricultural Research (I.A.R), Ahmadu Bello University Zaria, Nigeria.

3.3 Treatment and Experimental Design

The treatments used in the research are mutation using various concentrations of sodium azide, grafting and combination of grafting and sodium azide. Some seeds of the three tomato varieties were treated with four different concentrations of Sodium Azide (0.1mM, 1.0mM, 2.0mM and 0.0mM as control) respectively. The three varieties used were Roma, UC and one local variety. Roma was said to flourish successfully during the rainy season while UC flourishes and grows successfully during the dry season. Three different treatments were formed: Chemically treated with sodium azide, grafted and combination of grafting and sodium azide treated plants were grown during the 2013 rainy season and 2013/2014 dry season. The treated plants were grown in 45 polythene bags arranged in a Completely Randomized Design (CRD) with three repetitions in each season. Atotal of 370 plants were raised in each season after thinning. After two weeks of planting, the plants treated with the mutagen that germinated were grafted by transferring the scions of one variety to the stock of another variety. Similarly, the plants that are not treated with the mutagen were grafted. More so, the plants that are treated with the mutagen only were allowed to grow without grafting. The untreated plants were allowed to grow as control.

3.4 Grafting Method

The seeds used for rootstocks were planted 2 days prior to that of the shoots. After two weeks of planting, and a day prior to grafting, the plants used for grafting were watered fully to

make them turgid. One-fourth of the plants used for rootstock was cut at slant early in the morning. The shoot was also cut in the same way. The two cut ends were placed in direct contact and use a small clip to hold the cut surfaces together. This was repeated in the 3rd and 4th week of planting, while the remainder was left as control as described in McVoy (2005) protocol.

3.5 **Data Collection**

Data were obtained for: germination percents (1 and 2 WAP), seedlings height, height at maturity, survival rates, number of leaves, leaf area, number of fruits/plant, and diameter of the fruits, thickness of pericarp, number of seeds, fruit weight, pH values, roots and shoot dry weights.

3.5.0 Germination Percent (1 and 2 Weeks after Planting)

The percentage of plants that germinated per treatment per variety was recorded after first week of planting. This was repeated after two weeks of planting.

3.5.1Seedlings Height (cm)

The heights of the plants per treatment per variety were determined after eight weeks of planting by holding the highest leaf erect and the heights measured in centimeters

3.5.2Height at Maturity (cm)

The heights of the successful grafts were determined after the emergence of the first flower by holding the highest leaf erect and the heights measured in centimeters

3.5.3Survival Rate (%)

The number of grafts that survive during the emergence of first flower were determined and their percentages taken. Leafless grafts were regarded as dead.

3.5.4Number of Leaves/Plant

The number of leaves produced per plant was counted and recorded for each treatment after the emergence of the first flower.

3.5.5Leaf Area (cm^2)

The leaf area of each treatment was determined by measuring the leaf area in centimeters using the formula described by Pearce *et al.* (1979):

$$A = [(L)(W)(0.75)] \times 2$$

Where:

A=Leaf Area per plant

L=Length of Leaves

W=Width of leaves

3.5.6Number of Fruits/Plant

The number of fruits produced per plant was determined through counting per treatment per variety after twelve weeks of planting and recorded.

3.5.7 Thickness of Pericarp (mm)

The pericarps of the fruit of the different treatments were measured using screw gauge in millimeters and recorded.

3.5.8 Diameter of the Fruits (cm)

The diameter of the fruits per treatment was determined by screw gauge and recorded.

3.5.9Number of Seeds/Fruit

The number of seeds produced per fruits was determined by counting after the fruits were cut open by a razor blade.

3.6.0 pH-values of the Fruit Juice

The pH values of the fruit juices were determined by pH-meter and recorded. 6 fruits were randomly harvested from each replication and were used for pH determination.

3.6.1Dry Weights of the Fruits (g)

The weights of 100 fruits dried in the oven at 90 ^{0}C for 48 hours were determined in grams using a balance and recorded.

3.6.2Roots Dry Weights (g)

The weights of the roots per treatment were taken in grams using a balance and recorded.

3.6.3Shoot Dry Weights (g)

The dry weights of the plant shoots were taken after drying in the oven in grams and recorded.

3.7 Data Analysis

All the data obtained were analyzed using Analysis of Variance. The means were separated using Duncan's Multiple Range Test (Duncan, 1955). All tests of relationships were done using pearson's product moment correlation co-efficient.

CHAPTER FOUR

4.0RESULTS

4.1 Analysis of Variance for the Effects of Sodium Azide and Grafting on Tomato Traits

The resultsfor the analysis of variance (ANOVA)following the treatments of three varieties of tomato with sodium azide and grafting during the dry season (Table 4.1) revealed the presence of highly significant difference ($P \leq 0.01$) in the effects of different concentrations of sodium azide on almost all the selected traits except on the root dry weight; where the effect was significant ($P \leq 0.05$) and on fruit diameter and shoot dry weights where the effect of sodium azide is non-significant. More so, the result indicated highly significant difference ($P \leq 0.01$) among the varieties on almost all the selected traits except on pericarp thickness, fruits diametersand shoot dry weights; where no significant differenceexists among the varieties. Furthermore, highly significant difference ($P \leq 0.01$) was found on the effects of grafting and sodium azide singly and in combine dosage as treatments on germination percent (2 WAP), plant heights, and number of leaves, leaf area and pH. Significant difference ($P \leq 0.05$) was found on the effects of these treatments on the germination percent (1 WAP) and fruit diameter. However, no significant difference was found on the effects of the treatments on the survival rate, number of fruits, fruit weights and pericarp thickness, number of seeds, root and shoot dry weights.More so, no significant differences were found in the interactions except in the interaction of variety and treatments on the number of seeds produced per fruit where highly significant difference ($P \leq 0.01$) was found.

However, the result for the analysis of variance of the effects of sodium azide and grafting on three varieties of tomato during the wet season was presented in (Table 4.2) The result showed the presence of highly significant difference ($P \leq 0.01$) in the effects of different concentrations of sodium azide on almost all the selected traits except on the pericarp thickness, fruit diameter and root dry weight; where nosignificant difference was found among the effects of sodium azide concentrations.More so, the result indicated highly significant difference

(P≤0.01) among the varieties on the selected traits except in germination percent (1 WAP); where significant difference (P≤0.05) was found and in number of leaves, pericarp thickness, fruits diameters, rootand shoot dry weights; where no significant differenceexists among the varieties. Furthermore, highly significant difference (P≤0.01) was found on the effects of grafting and sodium azide singly and in combine dosage as treatments on germination percent (1 and 2 WAP), plant heights,numberof leaves/plant and root dry weight. Significant difference (P≤0.05) was found on the effects of these treatments on the survival rate, leaf area, and fruit weight and pericarp thickness.While, no significant difference was found on the effects of the treatments on the number of fruits, number of seeds, fruit diameter,and pHand shoot dry weights.More so, no significant differences were found in the interactions except in the interaction of concentrations and treatments on seedlings height and root dry weight where significant differences (P≤0.05) were found and in the interactions of variety and treatments on the number of leaves produced per plant and fruit weight where highly significant difference (P≤0.01) was found and on the plant heights; where significant difference (P≤0.05) was found.

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Table4.1: Mean Squares for the Effects of Grafting and Sodium Azide on Some Varieties of Tomato in Dry Season

Sources of Variation	DF	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits/plant	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
Replication	2	1711.23*	621.57^{ns}	172.19*	314.84^{ns}	333.70^{ns}	10.95^{ns}	165.08*	7.68^{ns}	70.26**	0.10^{ns}	147.81^{ns}	0.04^{ns}	0.001^{ns}	0.40^{ns}	82.78^{ns}
Concentration	3	10982.60**	9564.65**	378.12**	7119.60**	1257.63**	131.96**	1663.79**	90.14**	141.05**	0.58**	1569.06**	0.11^{ns}	0.01**	4.63*	53.93^{ns}
Variety	2	2079.65**	3868.67**	492.46**	5840.46**	1055.20**	355.34**	769.52**	99.70**	320.62**	0.12^{ns}	1474.04**	0.11^{ns}	0.53**	8.28**	95.78^{ns}
Treatments	2	1303.50*	2280.87**	222.69**	226.04^{ns}	1250.39**	32.95**	55.26**	9.79^{ns}	13.79^{ns}	0.12^{ns}	108.23^{ns}	0.34*	0.28**	0.53^{ns}	68.30^{ns}
Conc x Variety	6	187.37^{ns}	208.45^{ns}	16.21^{ns}	19.72^{ns}	7.70^{ns}	1.22^{ns}	49.92^{ns}	7.02^{ns}	8.58^{ns}	0.13^{ns}	19.02^{ns}	0.04^{ns}	0.60^{ns}	0.36^{ns}	76.46^{ns}
Conc x Treatment	6	39.55^{ns}	54.94^{ns}	19.44^{ns}	59.30^{ns}	41.53^{ns}	2.53^{ns}	13.96^{ns}	1.48^{ns}	4.01^{ns}	0.11^{ns}	49.40^{ns}	0.08^{ns}	0.01^{ns}	0.40^{ns}	83.69^{ns}
Variety x Treatment	4	535.87^{ns}	164.15^{ns}	33.35^{ns}	260.85^{ns}	86.25^{ns}	13.51^{ns}	75.66^{ns}	7.13^{ns}	2.56^{ns}	0.26^{ns}	827.16**	0.08^{ns}	0.04^{ns}	0.42^{ns}	73.00^{ns}
Conc x Variety x Treatment	12	121.13^{ns}	70.85^{ns}	7.78^{ns}	161.69^{ns}	20.48^{ns}	2.35^{ns}	16.54^{ns}	2.99^{ns}	1.77^{ns}	0.04^{ns}	10.63^{ns}	0.27^{ns}	0.24^{ns}	0.28^{ns}	81.42^{ns}
Error	142	217.81	221.30	21.45	126.32	75.96	2.90	18.57	2.60	3.82	0.05	62.77	0.04	0.03	0.80	80.01

Keys: ns= No significant difference * = Significant difference (P≤0.05) **= highly significant difference (P≤0.01)

Table 4.2: Mean Squares for the Effects of Grafting and Sodium Azide on Some Varieties of Tomato in Wet Season

Sources of Variation	DF	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits/plant	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
Replication	2	442.51^{ns}	219.42^{ns}	105.25*	881.07*	241.58*	53.86**	129.08^{ns}	4.39^{ns}	4.82^{ns}	0.05^{ns}	694.17*	0.36*	0.03*	5.39^{ns}	5.76**
Concentration	3	12191.08**	6386.37**	1226.32**	7181.49**	2581.62**	171.27**	1261.87**	99.38**	251.63**	0.08^{ns}	4384.26**	0.19^{ns}	0.40**	2.24^{ns}	15.12**
Variety	2	2248.15*	4525.46**	725.50**	2823.29**	239.66**	6.69^{ns}	720.76**	33.12**	255.85**	0.002^{ns}	1535.14**	0.08^{ns}	0.21**	0.93^{ns}	1.00^{ns}
Treatments	2	12824.68**	7275.75**	1068.59**	790.88*	467.62**	45.44**	118.76*	7.70^{ns}	52.45*	0.35*	395.34^{ns}	0.22^{ns}	0.02^{ns}	17.11**	1.21^{ns}
Conc x Variety	6	206.41^{ns}	122.25^{ns}	38.54^{ns}	34.16^{ns}	63.23^{ns}	1.71^{ns}	35.46^{ns}	6.06^{ns}	9.63^{ns}	0.03^{ns}	157.33^{ns}	0.04^{ns}	0.009^{ns}	0.49^{ns}	0.14^{ns}
Conc x Treatment	6	668.55^{ns}	185.93^{ns}	67.63*	88.22^{ns}	49.20^{ns}	4.53^{ns}	13.11^{ns}	3.83^{ns}	2.98^{ns}	0.02^{ns}	105.71^{ns}	0.06^{ns}	0.004^{ns}	6.61*	0.16^{ns}
Variety x Treatment	4	1917.81^{ns}	632.57^{ns}	59.81*	287.79^{ns}	150.55*	33.72**	92.06^{ns}	11.45^{ns}	122.51**	0.09^{ns}	151.95^{ns}	0.03^{ns}	0.01^{ns}	1.42^{ns}	2.57^{ns}
Conc x Variety x Treatment	12	169.41^{ns}	131.94^{ns}	8.86^{ns}	123.29^{ns}	42.54^{ns}	2.05^{ns}	7.99^{ns}	3.89^{ns}	3.67^{ns}	0.05^{ns}	50.51^{ns}	0.04^{ns}	0.002^{ns}	0.72^{ns}	0.16^{ns}
Error	142	395.64	196.89	13.17	143.01	24.18	3.58	27.27	3.05	10.92	0.07	140.81	0.07	0.008	1.39	0.69

Keys: ns= No significant difference * = Significant difference (P≤0.05) **= Highly significant difference (P≤0.01)

4.2 Results from Combined Analysis of Variance for the Effects of Sodium Azide and Grafting on Tomato Traits

The results from the combined analysis of variance on the effects of mutation and grafting on some selected traits of three tomato varieties are presented in (Table 4.3) The results showed highly significant difference ($P \leq 0.01$) in the effect of concentrations of sodium azide on the selected tomato traits except on fruit diameter; where the effect is significant ($P \leq 0.05$) and root and shoot dry weights; where no significant differences were found. Similarly, high significant difference ($P \leq 0.01$) was found among the varieties in terms of the selected traits except in height at maturity and fruit diameter, where significant difference exist ($P \leq 0.05$). But no significant difference was found among the varieties in terms of germination percents and shoot dry weight. More so, highly significant difference ($P \leq 0.01$) was found among the treatments (mutation, grafting and combination of mutation and grafting) on the selected traits of tomato except on survival rate where the effect is significant ($P \leq 0.05$). However, no significant difference was found in the effect of the treatments on leaf area, fruits number and weight, pericarp thickness, number of seeds and shoot dry weight.More so, highly significant difference ($P \leq 0.01$) was found among the seasons in terms of germination percent (2 WAP), seedlings height, fruit weight, seeds number, pH and root dry weight. Significant difference ($P \leq 0.05$) was found among the seasons on survival rate, height at maturity, leaf area and shoot dry weight. While no significant difference was found among the seasons in terms of germination percents (1 WAP), leaf number, fruits number, thickness of pericarp and fruit diameter.

However, no significant difference in the interactions of sodium azide with varieties and between sodium azide with the treatments on all the selected traits of the three tomato varieties. Similarly, no significant difference was found in the interactions of sodium azide with seasons in

almost all the selected traits except on seedlings height; where the effects of the interaction is highly significant (P≤0.01) and on seeds number; where significant difference (P≤0.05) was found.However, highly significant diference (P≤0.01) was found in the interaction of varieties with treatments on germination percents (1 WAP), leaf and fruit number, fruit weight and pH. Significant difference (P≤0.05) was found in the interaction on leaf area. While, no significant difference was found in the interaction of varieties with treatments on the other remaining selected traits. More so, highly significant difference (P≤0.01) was found in the interaction of varieties with seasons on the selected traits of tomato varieties except on leaf area and pH; where significant difference (P≤0.05) was found and on fruit weight, pericarp thickness, seeds number, fruit diameter, root and shoot dry weights where no significant difference was found.

Furthermore, highly significant difference (P≤0.01) was found in the interaction of the treatments with seasons on the selected traits of tomato varieties except on fruit number; where the interaction is significant (P≤0.05) and on germination percents (2 WAP), survival rates, seeds number, fruit diameter and shoot dry weight; where no significant difference was found in the interaction. However, no significant difference was found in the interaction of sodium azide concentrations with varieties and treatments and interaction of sodium azide with varieties and seasons on the selected traits of the tree tomato cultivars. More so, no significant difference was found in the interaction of varieties with treatments and seasons on the selected tomato traits except on fruit weight, seeds number and pH; where highly significant difference (P≤0.01) was found in the interaction and on leaves number where significant (P≤0.01) interaction was found. More so, no significant difference was found in the interaction of sodium azide concentrations with varieties, treatments and seasons on all the selected traits of the three tomato varieties.

4.3 Mean Effects of Sodium Azide Concentrations on some Selected Tomato Traits

The result of the mean effects of different concentrations of sodium azide on the selected traits of tomato is shown in (Table 4.4) The result showed that, 77.61% of the mutants treated with 0.1mM concentration germinated after one week of planting; and the germination rate decreases to 44.50% among those treated with 2.0 mM. Similarly, 80.27% of the mutants treated with 0.1mM germinated after two weeks of planting while 57% of those treated with 2.0mM germinated after two weeks of planting. More so, the mutants treated with 0.1mM concentrations attained the highest mean heights at both seedlings and maturity stage with 31.81 cm and 51.05 cm respectively. Similarly, 67.59% of the mutants treated with 1.0mM concentration survived to maturity stage while 42.13% of those treated with 2.0mM survived to maturity stage. Furthermore, the mutants treated with 0.1mM concentration produced the highest number of leaves (17 leaves/plant) that are larger in size (24.55 cm^2) and produced large number of fruits (6 fruits/plant) with a mean weight of 16.16g. More so, the pericarp thickness and the number of seeds produced by the mutants treated with 0.1mM (0.43 mm and 66 seeds/fruit) are higher than that of all other mutants. Similarly, the mutants treated with 0.1 mM concentration produced larger fruits that are 0.34 cm in diameter with a pH of 4.38 with higher root and shoot dry weights (2.50g and 11.26g respectively).

Table 4.3: Mean Squares for theCombined Effects of Grafting and Sodium Azide on Some Varieties of Tomato in Two Different Seasons

Sources of Variation	DF	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
Replication	2	483.69^{ns}	748.53^{ns}	269.79**	74.54^{ns}	88.41^{ns}	27.83**	60.4^{ns}	11.87*	55.92**	0.01^{ns}	476.72*	0.12^{ns}	0.01^{ns}	3.31^{ns}	24.51^{ns}
Concentration	3	23104.60**	15669**	1459.65**	14265**	3716**	300.33**	2898**	188.59**	383**	0.53**	5594**	0.28*	0.92**	3.42^{ns}	15.26^{ns}
Variety	2	739.93^{ns}	499.04^{ns}	599.37**	3803.53**	270.39*	226.86**	1376**	37.26**	564.34**	0.07^{ns}	2892**	0.20*	0.42**	7.38**	57.88^{ns}
Treatments	2	10960**	8840.43**	347.47**	878.43*	951.20**	55.06**	9.82^{ns}	5.26^{ns}	21.68^{ns}	0.16^{ns}	224.03^{ns}	0.53**	0.35**	5.85**	39.19^{ns}
Seasons	1	544.70^{ns}	13041**	418.11**	874.67*	258.50*	5.67^{ns}	126.19*	0.01^{ns}	189.84**	0.20^{ns}	6868.16**	0.08^{ns}	0.45**	10.98**	142.10*
Conc x Var	6	63.59^{ns}	47.41^{ns}	23.64^{ns}	44.73^{ns}	32.83^{ns}	1.38^{ns}	44.98^{ns}	3.19^{ns}	14.17^{ns}	0.05^{ns}	76.59^{ns}	0.07^{ns}	0.009^{ns}	0.61^{ns}	39.39^{ns}
Conc x Trt	6	418.12^{ns}	132.08^{ns}	14.03^{ns}	72.30^{ns}	81.57^{ns}	5.33^{ns}	8.83^{ns}	1.36^{ns}	6.23^{ns}	0.06^{ns}	69.06^{ns}	0.11^{ns}	0.02^{ns}	2.58^{ns}	40.75^{ns}
Conc x Seas	3	68.87^{ns}	281.29^{ns}	144.79**	35.35^{ns}	123.0^{ns}	2.89^{ns}	27.14^{ns}	0.91^{ns}	9.67^{ns}	0.12^{ns}	359.19*	0.01^{ns}	0.01^{ns}	3.44^{ns}	53.78^{ns}
Var x Trt	4	2212.68**	144.77^{ns}	41.85^{ns}	164.47^{ns}	150.1^{ns}	32.0**	114.06*	14.79**	70.64**	0.18^{ns}	279.45^{ns}	0.02^{ns}	0.12**	0.50^{ns}	32.32^{ns}
Var x Seas	2	3587.86**	7895.08**	618.58**	4860.2**	1024.46**	135.17**	113.42*	95.56**	12.12^{ns}	0.04^{ns}	117.05^{ns}	0.001^{ns}	0.07*	1.83^{ns}	38.89^{ns}
Trt x Sea	2	3167.65**	716.18^{ns}	943.80**	138.49^{ns}	766.80**	23.33**	164.19**	12.22*	44.54**	0.30**	279.45^{ns}	0.02^{ns}	0.26**	11.77**	30.31^{ns}
Conc x Var x Trt	12	58.12^{ns}	78.26^{ns}	9.77^{ns}	93.04^{ns}	26.29^{ns}	1.87^{ns}	15.17^{ns}	4.61^{ns}	3.37^{ns}	0.06^{ns}	28.65^{ns}	0.02^{ns}	0.01^{ns}	0.48^{ns}	40.78^{ns}
Conc x Var x Sea	6	330.19^{ns}	283.28^{ns}	31.10^{ns}	9.13^{ns}	38.10^{ns}	1.54^{ns}	40.40^{ns}	9.88^{ns}	4.03^{ns}	0.11^{ns}	99.76^{ns}	0.005^{ns}	0.01^{ns}	0.23^{ns}	37.19^{ns}
Var x Trt x Sea	4	240.98^{ns}	651.94^{ns}	50.30^{ns}	384.17^{ns}	86.68^{ns}	15.21*	56.65^{ns}	3.78^{ns}	54.43**	0.16^{ns}	699.65**	0.08^{ns}	0.13**	1.34^{ns}	43.25^{ns}
Conc x Var x Trt x Sea	18	251.59^{ns}	119.27^{ns}	28.92^{ns}	153.02^{ns}	27.53^{ns}	2.26^{ns}	12.32^{ns}	2.82^{ns}	1.63^{ns}	0.04^{ns}	50.34^{ns}	0.03^{ns}	0.01^{ns}	1.81^{ns}	41.55^{ns}
Error	142	325.97	207.41	17.17	148.56	56.22	3.21	25.89	2.78	7.53	0.05	105.50	0.06	0.01	1.11	40.68

Keys: ns= No significant difference * = Significant difference (P≤0.05) **= Highly significant difference (P≤0.01)

Table 4.4: Effects of Sodium Azide Concentrations on the Selected Traits of Three Tomato Varieties

Concentration (mM)	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
0.0	29.30^{d*1}	40.54^{d}	19.37^{d}	29.65^{d}	31.27^{d}	11.64^{d}	7.83^{d}	2.03^{d}	9.93^{d}	0.21^{c}	45.01^{d}	0.17^{c}	4.07^{d}	1.95^{b}	10.03^{a}
0.1	77.61^{a}	80.27^{a}	31.81^{a}	67.59^{a}	51.05^{a}	17.20^{a}	24.55^{a}	6.35^{a}	16.16^{a}	0.43^{a}	66.74^{a}	0.34^{a}	4.38^{a}	2.50^{a}	11.26^{a}
1.0	59.67^{b}	69.21^{b}	26.28^{b}	54.16^{b}	43.09^{b}	15.46^{b}	18.43^{b}	4.12^{b}	13.79^{b}	0.30^{b}	60.29^{b}	0.26^{ba}	4.23^{b}	2.27^{ba}	10.91^{a}
2.0	44.50^{c}	57.06^{c}	23.70^{c}	42.13^{c}	38.44^{c}	13.92^{c}	12.06^{c}	2.92^{c}	11.88^{c}	0.24^{b}	52.64^{c}	0.23^{b}	4.16^{c}	2.02^{a}	10.51^{a}
Mean	52.77	59.52	25,29	48.38	40.96	14.55	15.72	3.85	12.94	0.30	56.17	0.25	4.21	2.18	10.68

N.B:$*^{1}$Meanswithinthecolumnswiththesameletter(s)arenotsignificantlydifferent($P \leq 0.05$)

4.4 Mean Varietal Response to Grafting and Mutation Treatments in some Selected Tomato Traits

The result of the mean responses of the three varieties of tomato to the treatments is presented in (Table 4.5). The result showed that, higher germination rate was found among the local variety after one week of planting but at two weeks after planting, higher germination rate was found among variety Roma. However variety UC was found to be taller at both seedlings and maturity stages (27.72 cm and 43.13 cm respectively) with highest survival rate. Similarly, the response of variety UC to all the treatments was found to be better than that of the other varieties in terms of leaf number and size (17 leaves that are 20.70 cm^2 in cross sectional area). The variety UC also produced the highest number of fruits that are larger in size (0.31 cm in diameter) that weigh 16.11g containing 64 seeds/fruit. But in terms of pericarp thickness, the response of the local variety is the best. Furthermore, Variety UC showed the highest response in terms of pH, root and shoot dry weights.

4.5 Mean Effects of the Treatments on some Selected Tomato Traits

The result of the mean effects of the treatments on some selected tomato traits was shown in (Table 4.6). The result showed that, grafting is more efficient in terms of high germination rates, heights at seedlings and maturity stages as well as in leaf number and size. Similarly, grafting leads to the formation of tomato fruits that are higher in number (4 fruits/plant) weighing 13.48g with thicker pericarps (0.35mm) containing almost 55 seeds/fruit. More so, the grafted tomatoes were found to be larger in size (0.35 cm in diameter) with a shoot dry weight of 11.53g.

Table 4.5: Responses of the Three Tomato Varieties to Sodium azide and Grafting

Variety	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
Local	56.28^{a*1}	59.03^{b}	22.10^{c}	40.30^{b}	39.39^{b}	13.26^{b}	13.91^{b}	3.04^{b}	11.93^{b}	0.33^{a}	51.70^{c}	0.22^{b}	4.14^{c}	1.91^{b}	10.13^{a}
UC	52.05^{ba}	62.00^{ba}	27.72^{a}	54.39^{a}	43.13^{a}	16.58^{a}	20.70^{a}	4.38^{a}	16.11^{a}	0.28^{a}	63.66^{a}	0.31^{a}	4.29^{a}	2.50^{a}	11.71^{a}
Roma	49.99^{a}	64.28^{a}	26.05^{b}	50.47^{a}	40.38^{b}	13.83^{b}	12.54^{b}	4.15^{a}	10.79^{c}	0.28^{a}	55.05^{b}	0.22^{b}	4.21^{b}	2.11^{b}	10.19^{a}
Mean	52.77	61.77	25.29	48.38	40.97	14.55	15.72	3.86	12.94	0.27	56.80	0.25	4.21	2.17	10.67

N.B: $*^{1}$ Means within the columns with the same letter(s) are not significantly different ($P \leq 0.05$)

Table 4.6: Effects of the Treatments on some Selected Tomato Traits

Treatments	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
Grafting	66.91^{a*1}	69.94^{a}	27.75^{a}	44.47^{b}	44.80^{a}	14.73^{a}	15.59^{a}	4.16^{a}	13.48^{a}	0.35^{a}	54.68a	0.35^{a}	4.13^{b}	2.14^{b}	11.53^{a}
Grafting x Mutation	47.20^{b}	49.16^{b}	26.61^{b}	49.49^{a}	37.58^{c}	13.61^{b}	16.13^{a}	3.65^{a}	12.38^{b}	0.27^{b}	57.31^{a}	0.18^{b}	4.24^{a}	2.49^{a}	10.28^{a}
Mutation	44.20^{b}	66.20^{a}	23.51^{b}	51.91^{a}	40.51^{b}	15.33^{a}	15.43^{a}	3.76^{a}	12.96b^{a}	0.27^{b}	58.02^{a}	0.22^{b}	4.26^{a}	1.92^{b}	10.23^{a}
Mean	52.77	61.77	25.95	48.62	40.96	14.55	15.72	3.85	12.94	0.29	56.67	0.25	4.21	2.18	10.68

N.B: *[1] Means within the columns with the same letter(s) are not significantly different (P≤0.05)

However, mutation using sodium azide was found to be more efficient on germination percents (2 WAP), survival rates, leaf number and size, number of fruits and seeds produced and on shoot dry weights.

4.6 Mean Effects of Seasons on some Selected Tomato Traits

The result of the mean effects of the two seasons on the selected tomato traits was presented in (Table 4.7). The result indicated significant improvement in almost all the selected traits during rainy season compared to dry season except on survival rates and leaf area.

4.7 Mean Effects of the Interactions of Variety and Concentrations on some Selected Tomato Traits

The result of the mean effect of a combination of variety and sodium azide concentrations on some selected traits of tomato is presented in (Table 4.8). The result showed significant improvement in almost all the selected traits with decrease in the mutagen concentration for all the three varieties except in the pericarp thickness and fruit diameter.

4.8 Mean Effects of the Interactions of Concentrations and Treatments on some Selected Tomato Traits

The mean effect of a combination of concentrations of sodium azide and treatments was presented in (Table 4.9). The result indicated that, 0.1 mM concentration produced the highest effect in almost all the selected traits in terms of grafting and mutation except in pericarp thickness and fruit diameter under grafting and root dry weight under mutation. The effect increases with decrease in concentration. Similarly, the effect of a combination of the treatments and sodium azide concentrations also showed significant increase with decrease in concentration of the

Mutagen except in the pericarp thickness, fruit diameter and root dry weight.

Table 4.7: Effects of Seasons on some Selected Traits of Three Tomato Varieties

Seasons	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height(cm)	Survival Rate (%)	Height at Maturity(cm)	Number of Leaves	Leaf Area(cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
Dry Season	51.18^{a*1}	54.00^{b}	23.90^{b}	50.40^{a}	39.87^{b}	14.39^{a}	16.48+	3.87^{a}	12.00^{b}	0.33^{a}	51.07^{b}	0.23^{a}	4.17^{b}	1.96^{b}	11.49^{a}
Rainy Season	54.36^{a}	69.54^{a}	26.68^{a}	46.37^{b}	42.06^{a}	14.72^{a}	14.95^{b}	3.85^{a}	13.88^{a}	0.26^{a}	62.31^{a}	0.27^{a}	4.26^{a}	2.41^{a}	9.87^{a}
Mean	52.77	61.77	25.29	48.39	40.96	14.55	15.71	3.86	12.94	0.29	56.69	0.25	4.21	2.18	10.68

N.B: *[1] Means within the columns with the same letter(s) are not significantly different (P≤0.05)

Table 4.8: Effects of the Interaction of Variety and Sodium Azide Concentrations on some Selected Traits of Tomato

Variety	Concentration (mM)	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height(cm)	Survival Rate (%)	Height at Maturity(cm)	Number of [d]	Leaf Area(cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
Local	0.0	32.15[d*1]	38.66[d]	17.78[d]	23.66[d]	28.61[d]	10.05[d]	6.91[d]	1.66[d]	9.13[d]	0.50[d]	39.72[d]	0.34[d]	4.00[d]	2.00[d]	9.40[d]
	0.1	80.38[a]	79.29[a]	27.71[a]	59.96[a]	48.34[a]	16.27[a]	22.33[a]	4.88[a]	15.22[a]	0.20[c]	62.22[a]	0.17[b]	4.31[a]	2.20[a]	10.77[s]
	1.0	64.64[b]	65.51[b]	22.13[b]	44.36[b]	43.32[b]	14.27[b]	16.00[b]	3.33[b]	12.55[b]	0.23[b]	56.72[b]	0.17[b]	4.13[b]	1.96[b]	10.35[b]
	2.0	47.94[c]	52.64[c]	20.79[c]	33.22[c]	37.27[c]	12.44[c]	10.41[c]	2.27[c]	10.83[c]	0.40[a]	46.55[c]	0.29[a]	4.09[c]	1.48[c]	10.00[c]
Roma	0.0	28.35[d]	42.36[d]	19.19[d]	31.29[d]	30.94[d]	11.11[d]	5.91[d]	2.16[d]	8.72[d]	0.45[d]	42.88[d]	0.28[d]	4.00[d]	1.93[d]	9.53[d]
	0.1	74.87[a]	83.11[a]	33.71[a]	69.94[a]	51.87[a]	16.38[a]	20.08[a]	7.11[a]	13.00[a]	0.21[b]	69.33[a]	0.20[b]	4.36[a]	2.32[a]	10.91[Ss]
	1.0	57.20[b]	72.05[b]	27.28[b]	56.33[b]	41.52[b]	14.55[b]	14.66[b]	4.33[b]	11.38[b]	0.22[a]	58.83[b]	0.21[a]	4.24[b]	2.18[b]	10.41[b]
	2.0	39.55[c]	59.59[c]	24.01[c]	44.33[c]	37.17[c]	13.27[c]	9.50[c]	3.00[c]	10.05[c]	0.24[c]	49.16[c]	0.18[c]	4.18[c]	1.98[c]	9.92[c]
UC	0.0	27.42[d]	40.59[d]	21.13[d]	33.99[d]	34.27[d]	13.77[d]	10.66[d]	2.27[d]	11.94[d]	0.35[d]	52.44[d]	0.41[d]	4.10[d]	2.13[d]	9.86[d]
	0.1	77.57[a]	78.40[a]	34.02[a]	72.88[a]	52.92[a]	18.94[a]	31.25[a]	7.05[a]	20.27[a]	0.21[b]	74.66[a]	0.14[c]	4.47[a]	2.97[a]	11.06[a]
	1.0	57.18[b]	70.07[b]	29.43[b]	61.79[b]	44.42[b]	17.55[b]	24.63[b]	4.72[b]	17.44[b]	0.27[a]	65.33[b]	0.29[b]	4.33[b]	2.68[b]	10.77[b]
	2.0	46.01[c]	58.94[c]	26.30[c]	48.85[c]	40.89[c]	16.05[c]	16.27[c]	3.50[c]	14.77[c]	0.27[a]	62.22[c]	0.40[a]	4.21[c]	2.37[c]	10.16[c]
	Mean	52.77	61.77	31.31	48.38	40.96	14.55	15.71	3.85	12.94	0.29	56.67	0.25	4.20	2.18	10.26

N.B: *[1] Means within the columns with the same letter(s) are not significantly different ($P \leq 0.05$)

Table 4.9: Effects of the Interactions Sodium Azide Concentrations and Treatments on some Selected Tomato Traits

Treatment	Concentration (mM)	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
Grafting	0.0	40.44^{d*1}	47.98^{d}	22.08^{d}	12.27^{d}	37.39^{d}	12.27^{d}	7.83^{d}	2.22^{d}	11.05^{d}	0.56^{d}	42.61^{d}	0.53^{d}	3.94^{d}	0.76^{d}	14.71^{d}
	0.1	86.0^{a}	88.60^{a}	34.51^{a}	16.77^{a}	53.91^{a}	16.77^{a}	23.75^{a}	6.83^{a}	16.16^{a}	0.28^{b}	68.27^{a}	0.15^{c}	4.34^{a}	0.92^{a}	10.88^{a}
	1.0	78.50^{b}	75.72^{b}	28.01^{b}	15.61^{b}	45.88^{b}	15.61^{b}	18.33^{b}	4.38^{b}	14.05^{b}	0.25^{c}	59.88^{b}	0.30^{b}	4.18^{b}	2.41^{b}	10.83^{a}
	2.0	62.72^{c}	67.42^{c}	26.38^{c}	14.27^{c}	42.03^{c}	14.27^{c}	12.44^{c}	3.22^{c}	12.66^{c}	0.32^{a}	47.94^{c}	0.41^{a}	4.07^{c}	2.05^{c}	10.06^{b}
Mutation	0.0	22.73^{d}	42.42^{d}	17.15^{d}	11.66^{d}	30.72^{d}	11.67^{d}	6.99^{d}	2.00^{d}	9.19^{d}	0.34^{d}	45.33^{d}	0.30^{d}	4.13^{d}	0.87^{d}	9.37^{d}
	0.1	69.31^{a}	84.00^{a}	30.78^{a}	18.66^{a}	48.92^{a}	18.70^{a}	25.00^{a}	6.44^{a}	16.83^{a}	0.18^{c}	69.44^{a}	0.17^{c}	4.43^{a}	0.91^{c}	11.03^{a}
	1.0	49.77^{b}	75.61^{b}	25.22^{b}	16.33^{b}	42.78^{b}	16.00^{b}	17.66^{b}	3.72^{b}	14.22^{b}	0.20^{b}	61.55^{b}	0.19^{b}	4.26^{b}	2.03^{a}	10.55^{b}
	2.0	34.98^{c}	62.79^{c}	20.90^{c}	14.66^{c}	39.61^{c}	14.70^{c}	12.08^{c}	2.88^{c}	11.61^{c}	0.35a	55.57^{c}	0.22^{a}	4.22^{b}	1.78^{b}	9.96c
Grafting x Mutation	0.0	24.73^{d}	31.22^{d}	18.87^{d}	11.00^{d}	25.70^{d}	11.00^{d}	8.66^{d}	1.88^{d}	9.55^{d}	0.40^{d}	47.11^{d}	0.20^{d}	4.15^{d}	2.95^{d}	9.70^{d}
	0.1	77.51^{a}	68.14^{a}	30.14^{a}	16.16^{a}	50.31^{a}	16.16^{a}	24.99^{a}	5.77^{a}	15.50^{a}	0.17^{c}	68.50^{a}	0.18^{b}	4.37^{a}	0.80^{c}	10.83^{a}
	1.0	50.75^{b}	56.31^{b}	25.61^{b}	14.44^{b}	40.61^{b}	14.44^{b}	19.30^{b}	4.27^{b}	13.11^{b}	0.27^{a}	59.44^{b}	0.19^{a}	4.26^{b}	2.38^{a}	10.47^{b}
	2.0	35.81^{c}	40.96^{c}	23.82^{c}	12.83^{c}	33.70^{c}	12.83^{c}	11.66^{c}	2.66^{c}	11.38^{c}	0.24^{b}	54.22^{c}	0.17^{c}	4.19^{c}	2.00^{b}	10.07^{c}
	Mean	52.77	61.76	25.28	14.52	40.96	13.70	15.72	3.85	12.94	0.96	56.65	0.25	4.21	1.65	10.70

N.B: *[1] Means within the columns with the same letter(s) are not significantly different ($P \leq 0.05$)

4.9 Mean Effects ofthe Interactions of Variety and Treatments on some Selected Tomato Traits

The result obtained from the effect of a combination of variety and treatments (Table 10) showed that grafting has the highest effect in improving some selected traits of local variety of tomato such as germination rates, plant heights at both seedlings and maturity stages, leaf number, fruit diameter and shoot dry weight. However, mutation using sodium azide is has the highest effect on survival rates, leaf area and pericarp thickness in local variety of tomato. While a combination of grafting and mutation improves the number of fruits produced per plant, fruit weight, number of seeds per fruit, pH and root dry weight of local variety of tomato.

More so, the effect of grafting on the selected traits of Roma was found to be more effective on germination rates, plant heights, fruit weights, pericarp thickness and fruit diameter. However, mutation was found to be more effective on the traits of Roma in terms of germination rate (2 WAP), leaf number and size, number of fruits and seeds produced and pH. While a combination of grafting and mutation has the highest effect on survival rates, pH and dry weights of variety Roma.

Furthermore, in variety UC, grafting has the highest effect on germination percents (1 WAP), seedlings height, fruit weight, pericarp thickness and fruit diameter. Similarly, mutation has the highest effect on the traits of variety UC in terms of germination percents (2 WAP), survival rates, leaf number, pH and shoot dry weight. More so, a combination of grafting and mutation showed highest effect on height at maturity, leaf area, number of fruits, number of seeds and root dry weight.

Table 4.10: Effects of Variety and Treatments Interactions on some Selected Tomato Traits

Variety	Treatment	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
	Grafting	64.36^{a*1}	69.27^{a}	25.82^{a}	34.55^{c}	43.67^{a}	14.79^{a}	14.12^{b}	3.00^{b}	11.37^{b}	0.31^{c}	52.00^{b}	0.33^{a}	3.97^{c}	1.71^{b}	10.47^{a}
	Mutation	42.81^{c}	60.86^{b}	20.09^{c}	45.61^{a}	39.70^{b}	13.41^{b}	14.75^{a}	2.95^{c}	11.02^{c}	0.35^{a}	49.33^{c}	0.19^{b}	4.21^{b}	1.70^{b}	9.86^{c}
Local	Grafting x Mutation	61.66^{b}	46.95^{c}	20.40^{b}	40.74^{b}	34.78^{c}	11.58^{c}	12.87^{c}	3.16^{a}	13.41^{a}	0.34^{b}	52.58^{a}	0.14^{c}	4.23^{a}	2.32^{a}	10.06^{b}
	Grafting	66.47^{a}	71.37^{a}	28.31^{a}	46.30^{c}	46.47^{a}	13.12^{b}	11.75^{c}	5.41^{b}	11.25^{a}	0.36^{a}	50.25^{c}	0.28^{a}	4.18^{b}	2.07^{b}	10.04^{c}
	Mutation	49.12^{b}	71.37^{a}	24.93^{b}	51.19^{b}	37.40b	15.54^{a}	13.74^{a}	3.91^{a}	11.04^{b}	0.17^{c}	60.54^{a}	0.19^{b}	4.23^{a}	1.81^{c}	10.19^{b}
Roma	Grafting x Mutation	34.38^{c}	50.09^{b}	24.90^{b}	53.93^{a}	37.20^{c}	12.83^{c}	12.12^{b}	3.12^{c}	10.08^{c}	0.30^{b}	54.37^{b}	0.18^{c}	4.23^{a}	2.44^{a}	10.35^{a}
	Grafting	69.91^{a}	69.19^{b}	29.11^{a}	52.56^{c}	44.27^{c}	16.29^{c}	20.89^{b}	4.08^{c}	17.83^{a}	0.39^{a}	61.79^{c}	0.43^{a}	4.25^{c}	2.65^{b}	14.08^{c}
	Mutation	40.46^{c}	66.38^{a}	25.52^{c}	56.77^{a}	44.41^{b}	17.04^{a}	17.81^{c}	4.41^{b}	16.83^{b}	0.27^{b}	64.20^{b}	0.27^{b}	4.35^{a}	2.26^{c}	10.63^{s}
UC	Grafting x Mutation	45.56^{b}	50.42^{c}	28.54^{b}	53.80^{b}	40.70^{a}	16.41^{b}	23.41^{a}	4.66^{a}	13.66^{c}	0.17^{c}	65.00^{a}	0.23^{c}	4.27^{b}	2.70^{a}	10.45^{b}
	Mean	52.74	61.76	25.29	48.38	40.95	14.55	14.85	3.85	12.94	0.29	56.67	0.25	4.21	2.18	10.68

N.B: *[1] Means within the columns with the same letter(s) are not significantly different (P≤0.05)

4.9.1 Mean Effects of the Interactions of Variety and Seasons on some Selected Tomato Traits

The result of the mean effect of a combination of variety and seasons was presented in (Table 4.11). The result revealed that local variety of tomato flourished better during the dry season in terms of seedlings height, survival rate, leaf area, pericarp thickness and shoot dry weight. However, during the rainy season it flourished better in terms of all the remaining selected traits. On the other hand, variety Roma flourished better during the dry season in terms of leaf number, pericarp thickness and dry weights and flourished better during the rainy season in terms of all the remaining characters selected. However, variety UC flourished better during the dry season in almost all the selected traits except in fruit weight, seeds number, fruit diameter, pH and root dry weight (where it flourished better in the rainy season).

4.9.2 Mean Effects of Interactions of Concentrations and Seasons on some Selected Tomato Traits

The result of a combination of the effect of concentrations and seasons is presented in (Table 4.12). The result showed that, during the dry season, 0.1mM concentration has the highest effect in terms of almost all the selected traits except on pericarp thickness and fruit diameter. The effect of the mutagen concentration increases with decrease in concentration. Similarly during the rainy season, 0.1mM concentration has the highest effect in all the selected traits except on germination percent (2 WAP), pericarpthickness and fruit diameter

`Table 4.11: Effects of Variety and Seasons Interaction on some Selected Traits of Tomatoin Dry and Wet Seasons

Variety	Season	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
	Dry	51.68^{b*1}	47.90^{b}	22.29^{a}	41.49^{a}	37.87^{b}	12.22^{b}	16.00^{a}	2.50^{b}	10.52^{b}	0.39^{a}	46.72^{b}	0.20^{b}	4.06^{b}	1.55^{b}	10.53^{a}
Local	Rainy	60.87^{a}	70.15^{a}	21.91^{b}	39.11^{b}	40.90^{a}	14.30^{a}	11.83^{b}	3.58^{a}	13.34^{a}	0.27^{b}	55.88^{a}	0.24^{a}	4.21^{a}	2.27^{a}	9.73^{b}
Roma	Dry	43.35^{b}	48.12^{b}	21.27^{b}	22.96^{b}	35.74^{b}	12.97^{a}	12.12^{s}	3.38^{b}	10.05^{b}	0.30^{a}	48.00^{b}	0.19^{b}	4.20^{b}	1.84^{a}	10.57^{a}
	Rainy	56.63^{a}	80.43^{a}	30.82^{a}	56.24^{a}	45.01^{a}	14.69b	12.95^{a}	4.91^{s}	11.52^{a}	0.26^{b}	62.11^{a}	0.24^{a}	4.22^{a}	2.38^{b}	9.82^{b}
	Dry	58.52^{a}	65.97^{a}	28.13^{a}	64.99^{a}	46.00^{a}	18.00^{a}	21.33^{a}	5.72^{a}	15.44^{b}	0.29^{a}	58.38^{b}	0.30^{b}	4.23^{b}	2.49^{b}	13.37^{a}
UC	Rainy	45.57^{b}	58.03^{b}	27.31^{b}	43.77^{b}	40.25^{b}	15.16^{b}	20.08^{b}	3.05^{b}	16.77^{a}	0.26^{b}	68.94^{a}	0.33^{a}	4.35^{a}	2.58^{a}	12.15^{s}
	Mean	52.77	61.76	25.28	44.76	40.96	14.55	15.72	3.85	12.94	0.29	56.67	0.25	4.21	2.18	11.02

N.B: *[1] Means within the columns with the same letter(s) are not significantly different (P≤0.05)

Table 4.12: Effects of Sodium Azide Concentration and Season Interaction on some Selected Tomato Traits

Season	Concentration (mM)	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
	0.0	27.55^{d*1}	31.85^{d}	20.00^{d}	31.23^{d}	32.19^{d}	11.59^{d}	7.66^{d}	1.96^{d}	9.25^{d}	0.32^{d}	42.03^{d}	0.32^{d}	4.01^{d}	1.42^{d}	13.57^{c}
	0.1	74.49^{a}	20.86^{a}	28.98^{a}	68.82^{a}	48.40^{a}	16.88^{a}	25.50^{a}	6.22^{a}	14.66^{a}	0.20^{c}	59.81^{a}	0.18^{c}	4.30^{a}	2.35^{a}	11.13^{a}
Dry	1.0	59.04^{b}	17.95^{b}	23.67^{b}	57.24^{b}	41.38^{b}	15.07^{b}	19.98^{b}	4.22^{b}	12.77^{b}	0.25^{b}	54.00^{b}	0.20^{b}	4.10^{c}	2.20^{b}	10.83^{b}
	2.0	43.65^{c}	14.62^{c}	22.94^{c}	18.78^{c}	37.50^{c}	14.03^{c}	12.79^{c}	3.03^{c}	11.33^{c}	0.32^{a}	48.29^{c}	0.23^{s}	4.12^{b}	1.87^{c}	10.43^{bc}
	0.0	31.06^{d}	49.23^{d}	27.18^{d}	28.07^{d}	27.30^{d}	11.70^{d}	7.99^{d}	2.11^{d}	10.61^{d}	0.37^{d}	48.00^{d}	0.37^{d}	4.14^{d}	2.65^{d}	8.96^{c}
Rainy	0.1	80.72^{a}	23.49^{c}	34.64^{a}	62.37^{a}	53.62^{a}	17.51^{a}	23.61^{a}	6.48^{a}	17.66^{a}	0.22^{c}	77.66^{a}	0.16^{c}	4.40^{a}	2.64^{a}	10.70^{a}
	1.0	60.30^{b}	32.16^{a}	28.89^{b}	51.08^{b}	44.80^{b}	15.85^{b}	16.88^{b}	4.00^{b}	14.81^{b}	0.23^{b}	66.59^{b}	0.26^{b}	4.20^{c}	2.35^{b}	10.20a
	2.0	45.35^{c}	28.42^{b}	24.46^{c}	24.65^{c}	39.39^{c}	13.81^{c}	11.33^{c}	2.81^{c}	12.44^{c}	0.25^{a}	51.60^{c}	0.30^{a}	4.28^{b}	2.02^{c}	9.62b
	Mean	52.77	27.32	26.34	42.78	40.57	14.55	15.72	3.85	12.94	0.27	55.99	0.25	4.19	2.18	10.68

N.B: *[1] Means within the columns with the same letter(s) are not significantly different (P≤0.05)

4.9.3 Mean effects of the Interactions of Treatments and Seasons on some Selected Tomato Traits

The result of the mean effect of treatments and seasons interaction on some selected tomato traits was shown in (Table 4.13). It revealed that grafting is more efficient during the rainy season in terms of almost all the selected characters except in terms of survival rate, height at maturity, leaf area, number of fruits and shoot dry weight; where it is efficient in dry season. However, mutation was found to be more efficient during the dry season in terms of germination percents (1 WAP), seedlings height, survival rate, leaf number and size as well as in dry weights. More so, mutation is more efficient during the rainy season germination percents (2 WAP), height at maturity, fruit number, fruit weight, pericarp thickness, number of seeds, fruit diameter and pH (Table 13). Furthermore, a combination of mutation and grafting is more efficient during the rainy season in terms of seedlings height, survival rate, leaf number, fruit number, pericarp thickness and shoot dry weight but more efficient on other selected traits during the dry season.

4.9.4 Mean Effects of the Interactions of Treatments, Variety and Concentrations on some Selected Tomato Traits

The result obtained from the effect of a combination of treatments, variety and concentrations of sodium azide on the selected tomato trait was presented in (Table 4.14). The result showed that, in the local variety of tomato, grafting has the highest effect on germination rate (2 WAP), survival rate, plant heights, and leaf and fruit number, fruit diameter and shoot dry weight. While, highest effect of mutation was found on leaf area and pericarp thickness. But a combination of mutation and grafting showed highest effect on germination percent (1 WAP), fruit weight, seeds number, pH and root dry weight of local variety of tomato. However, in variety Roma, grafting is more

Table 4.13: Effects of Treatments and Seasons Interaction on some Selected Tomato Traits

Treatment	Season	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
Grafting	Dry	58.09^{b*1}	59.52^{b}	22.66^{b}	47.51^{a}	46.64^{a}	13.91^{b}	15.76^{a}	4.33^{a}	11.69^{b}	0.34^{b}	50.69^{b}	0.34^{b}	4.02^{b}	2.01^{b}	13.08^{a}
	Rainy	95.74^{a}	80.37^{a}	32.83^{a}	41.43^{b}	42.97^{b}	15.55^{a}	15.41^{b}	4.00^{b}	15.27^{a}	0.36^{a}	58.66^{a}	0.36^{a}	4.25^{a}	2.27^{a}	9.98^{b}
Mutation	Dry	48.40^{a}	57.60^{b}	22.27^{a}	51.62^{a}	35.90^{b}	15.50^{a}	17.91^{a}	3.30^{b}	12.72^{b}	0.26^{b}	52.91^{b}	0.21^{b}	4.25^{b}	2.05^{a}	10.80^{a}
	Rainy	39.99^{b}	74.81^{a}	24.75^{b}	50.75^{b}	45.12^{a}	15.16^{b}	12.95^{b}	4.22^{a}	13.20^{a}	0.27^{a}	63.13^{a}	0.23^{a}	4.28^{a}	1.80^{b}	9.66^{b}
Grafting x Mutation	Dry	47.06^{b}	44.87^{b}	26.76^{a}	52.05^{a}	37.07^{b}	13.77^{a}	15.77^{b}	3.97^{a}	11.61^{b}	0.37^{a}	49.50^{b}	0.14^{b}	4.24^{b}	1.82^{b}	10.60^{a}
	Rainy	47.35^{a}	53.44^{a}	22.46^{b}	46.93^{b}	38.08^{a}	13.44^{b}	16.50^{a}	3.33^{b}	13.16^{a}	0.16^{b}	60.13^{a}	0.22^{a}	4.25^{a}	3.16^{a}	9.96^{b}
	Mean	56.10	61.77	25.28	48.38	40.96	14,55	15.71	3.85	12.94	0.29	55.83	0.25	4.21	2.18	10.68

N.B: $*^{1}$ Means within the columns with the same letter(s) are not significantly different ($P \leq 0.05$)

Table 4.14: Effects for the Interaction of Treatments, Variety and Sodium Azide Concentration on some Selected Tomato Traits

Concentration (mM)	Variety	Treatment	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
0.0	Local	Grafting	35.77^{b*1}	52.55^{a}	21.90^{a}	24.66^{a}	34.66^{a}	11.83^{a}	7.25^{b}	1.83^{a}	8.66^{b}	0.50^{b}	42.33^{b}	0.57^{a}	3.7^{c}	1.1^{c}	9.60^{a}
0.0	Local	Mutation	21.77^{c}	35.99^{b}	17.20^{c}	24.55^{b}	29.65^{b}	9.33^{b}	8.00^{a}	1.50^{c}	7.58^{c}	0.58^{a}	33.66^{c}	0.35^{b}	4.1^{c}	1.3^{b}	9.18^{s}
0.0	Local	Grafting x Mutation	38.88^{a}	27.44^{c}	18.25^{b}	21.77^{c}	21.51^{c}	9.00^{c}	5.50^{c}	1.66^{b}	11.1^{a}	0.43^{c}	43.16^{a}	0.12^{c}	4.1^{a}	3.5^{a}	9.43^{b}
0.0	Roma	Grafting	41.27^{a}	46.94^{a}	21.00^{a}	30.44^{a}	40.21^{a}	11.00^{b}	6.50^{a}	2.66^{a}	9.00^{b}	0.60^{a}	35.33^{c}	0.37^{a}	4.0^{c}	1.3^{c}	9.51^{b}
0.0	Roma	Mutation	27.55^{b}	47.05^{b}	15.36^{c}	30.33^{b}	27.06^{b}	11.66^{a}	5.48^{c}	1.83^{c}	8.83^{c}	0.20^{c}	49.16^{a}	0.21^{c}	4.1_{b}	1.5^{b}	9.23^{c}
0.0	Roma	Grafting x Mutation	16.22_{c}	33.11^{c}	16.10^{b}	33.11^{a}	25.55^{c}	10.66^{c}	5.75^{b}	2.00^{b}	9.33^{a}	0.53^{b}	44.16^{b}	0.25^{b}	4.11	2.9^{a}	9.85^{a}
0.0	UC	Grafting	44.27^{a}	44.44^{a}	22.23^{b}	30.22^{c}	37.30^{a}	14.00^{a}	9.75^{b}	2.16^{c}	15.50^{a}	0.58^{a}	50.16^{c}	0.66^{a}	4.08	2.0^{b}	25.0^{a}
0.0	UC	Mutation	18.88^{c}	44.22^{b}	18.90^{c}	38.88a	35.44^{b}	14.00^{a}	7.50^{c}	2.66^{a}	11.16^{b}	0.25^{b}	53.16^{b}	0.33^{b}	4.2^{a}	1.9^{c}	9.71^{b}
0.0	UC	Grafting x Mutation	19.11^{b}	7.07^{c}	22.28^{a}	32.88^{b}	30.05^{c}	13.33^{b}	14.75^{a}	2.00^{c}	9.16^{c}	0.22^{c}	54.00^{a}	0.23^{c}	4.1^{b}	2.43^{a}	9.83^{c}

N.B: *[1] Means within the columns with the same letter(s) are not significantly different ($P \leq 0.05$).

Table 4.14: Effects for the Interaction of Treatments, Variety and Concentration (Cont'd)

Concentration (mM)	Variety	Treatment	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height	Survival Rate	Height at Maturity	Number of Leavebs	Leaf Area	Number of Fruits	Fruit Weight	Pericarp Thickness	Number of Seeds/Fuit	Fruit Diameter	pH	Root DW	Shoot DW
0.1	Local	Grafting	83.16^{b*1}	88.66^{a}	31.06^{a}	47.22^{b}	43.95^{c}	17.00^{s}	21.00^{c}	4.66^{b}	14.33^{c}	0.28^{a}	62.16^{b}	0.15^{b}	4.25^{c}	2.23^{b}	11.11^{a}
0.1	Local	Mutation	69.16^{c}	83.00^{b}	26.08^{c}	66.33^{a}	52.55^{a}	17.50^{a}	23.50^{a}	5.00^{a}	15.16^{b}	0.16^{c}	62.00^{c}	0.18^{a}	4.36^{a}	2.13^{c}	10.55^{c}
0.1	Local	Grafting x Mutation	88.83^{a}	66.22^{c}	25.98^{b}	66.33^{a}	48.53^{b}	14.33^{c}	22.50^{b}	5.00^{a}	16.16^{a}	0.17^{b}	62.50^{a}	0.18^{a}	4.33^{b}	2.25^{a}	10.66^{b}
0.1	Roma	Grafting	88.83^{a}	88.66^{a}	36.05^{a}	63.33^{c}	55.83^{a}	15.33^{b}	18.25^{c}	9.83^{a}	13.33^{a}	0.28^{a}	68.00^{c}	0.19^{b}	4.31^{c}	2.46^{b}	10.68^{b}
0.1	Roma	Mutation	72.22b	88.66^{a}	35.03^{b}	71.83^{b}	49.40^{c}	18.83^{a}	21.25^{a}	7.16^{b}	3.66^{c}	0.19^{b}	71.66^{a}	0.21^{a}	4.38^{b}	2.00^{c}	11.15^{c}
0.1	Roma	Grafting x Mutation	63.55^{c}	72.00^{b}	30.05^{c}	74.66^{a}	50.40^{b}	15.00^{c}	20.75^{b}	4.33^{c}	12.00^{b}	0.16^{c}	68.33^{b}	0.18^{c}	4.40^{a}	2.51a	10.90^{a}
0.1	UC	Grafting	86.00^{a}	88.66^{a}	36.43^{a}	74.83^{a}	53.36^{b}	18.00^{c}	32.00^{a}	6.00^{c}	20.83^{b}	0.27^{a}	74.66^{a}	0.12^{c}	4.46^{b}	3.11a	10.83^{b}
0.1	UC	Mutation	66.55^{c}	80.33^{b}	31.25^{c}	72.00^{b}	53.41^{a}	19.66^{a}	30.25^{c}	7.16^{b}	21.66^{a}	0.21^{b}	74.66^{a}	0.14^{b}	4.56^{a}	2.70^{c}	11.40ss^{c}
0.1	UC	Grafting x Mutation	80.16^{b}	66.22^{c}	34.40^{b}	71.83^{c}	52.00^{c}	19.16^{b}	31.50^{b}	8.00^{a}	18.33^{c}	0.17^{c}	74.66^{a}	0.17^{a}	4.40^{c}	3.10^{b}	10.95^{a}

N.B: *[1] Means within the columns with the same letter(s) are not significantly different (P≤0.05)

Table 4.14: Effects for the Interaction of Treatments, Variety and Concentration (Cont'd)

Concentration (mM)	Variety	Treatment	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
1.0	Local	Grafting	77.66[a*1]	72.16[a]	24.24[a]	38.77[c]	47.16[a]	15.66[a]	15.75[b]	3.16[b]	12.00[b]	0.16[b]	58.50[a]	0.25[a]	3.96[c]	1.96[a]	10.73[s]
1.0	Local	Mutation	47.11[c]	69.00[b]	21.25[b]	52.66[a]	43.25[b]	15.00[b]	17.00[a]	3.00[c]	11.66[c]	0.13[c]	55.16[c]	0.12[c]	4.21[b]	1.80[b]	10.05[c]
1.0	Local	Grafting x Mutation	69.16[b]	55.38[c]	20.90[c]	41.66[b]	39.56[c]	12.16[c]	15.25[c]	3.83[a]	14.00[a]	0.40[a]	56.50[b]	0.15[b]	4.23[a]	2.11[a]	10.28[b]
1.0	Roma	Grafting	77.50[a]	80.33[a]	29.36[a]	52.66[c]	46.66[a]	13.83[a]	13.75[c]	5.66[a]	12.00[a]	0.23[b]	56.83[b]	0.28[a]	4.25[a]	2.33[a]	10.26[c]
1.0	Roma	Mutation	58.11[b]	50.16[c]	26.01[c]	55.50[b]	39.66[b]	16.16[c]	15.75[a]	3.66[a]	11.66[b]	0.17[c]	64.16[a]	0.19[b]	4.23[b]	1.93[c]	10.46[b]
1.0	Roma	Grafting x Mutation	35.99[c]	77.33[b]	26.46[b]	60.33[a]	38.35[c]	13.66[b]	14.50[b]	3.66[a]	10.50c	0.26[a]	55.50[c]	0.16[c]	4.25[b]	2.30[b]	10.51[a]
1.0	UC	Grafting	80.33[a]	77.33[b]	30.43[a]	60.88[b]	43.83[c]	17.33[c]	25.50[b]	4.33[c]	18.16[a]	0.36[a]	64.33[a]	0.36[a]	4.35[a]	2.93[a]	10.43[a]
1.0	UC	Mutation	44.11[c]	77.50[a]	28.40[b]	63.66[a]	45.53[a]	17.83[a]	20.25[c]	4.50[b]	9.33[c]	0.29[b]	65.33[a]	0.25[c]	4.35[a]	2.36[c]	11.15[b]
1.0	UC	Grafting x Mutation	47.11[b]	55.38[c]	26.08[c]	60.83[c]	43.91[b]	17.50[b]	28.16[a]	5.33[a]	14.83[b]	0.15[c]	66.33[a]	0.27[b]	4.30[b]	2.75[b]	10.75[c]

N.B: *[1] Means within the columns with the same letter(s) are not significantly different ($P \leq 0.05$)

Table 4.14: Effects for the Interaction of Treatments, Variety and Concentration (Cont'd)

Concentration (mM)	Variety	Treatment	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter c(m)	pH	Root DW (g)	Shoot DW (g)
2.0	Local	Grafting	60.836^{a*1}	63.72^{a}	26.08^{a}	27.53^{c}	40.33^{b}	14.66^{a}	12.50^{a}	2.33^{a}	10.50^{b}	0.28^{s}	45.00^{c}	0.37^{s}	3.91^{c}	1.56^{a}	10.45^{a}
2.0	Local	Mutation	33.22^{c}	55.44^{b}	17.68^{c}	38.88^{s}	41.98^{a}	11.83^{b}	10.50^{b}	2.33^{a}	9.66c	0.55^{a}	46.50^{b}	0.12^{c}	4.16^{b}	1.51^{b}	9.68^{c}
2.0	Local	Grafting x Mutation	49.77^{b}	38.77^{c}	18.61^{b}	33.22^{b}	29.51^{c}	10.83^{c}	8.25^{c}	2.16^{b}	12.33^{a}	0.36^{b}	48.16^{a}	0.13^{b}	4.20^{a}	1.45^{c}	9.86^{b}
2.0	Roma	Grafting	58.27^{a}	72.22^{a}	25.71^{a}	38.77^{s}	43.16^{a}	12.33^{b}	8.50^{b}	3.50^{a}	10.66^{a}	0.34^{a}	40.83^{c}	0.27^{a}	4.18^{b}	2.11^{a}	9.71^{c}
2.0	Roma	Mutation	38.61^{b}	69.44^{b}	21.50^{c}	47.11^{a}	33.60^{c}	15.50^{a}	12.50^{a}	3.00^{b}	10.00^{b}	0.14^{c}	57.16^{b}	0.15^{b}	4.21^{a}	1.81^{c}	9.91^{b}
2.0	Roma	Grafting x Mutation	21.77^{c}	37.11^{c}	24.83^{b}	47.11^{a}	34.73^{b}	12.00^{c}	7.50^{c}	2.50^{c}	9.50^{c}	0.24^{b}	49.50^{a}	0.13^{c}	4.16^{c}	2.03^{b}	10.15^{a}
2.0	UC	Grafting	69.05^{a}	66.33^{b}	27.35^{b}	44.33^{c}	42.5^{8}	15.83^{b}	16.32^{a}	3.83^{a}	16.83^{a}	0.33^{b}	58.00^{c}	0.58^{a}	4.11^{c}	2.55^{a}	10.01^{c}
2.0	UC	Mutation	33.11^{c}	65.50^{a}	23.53^{c}	52.55^{a}	43.25^{a}	16.66^{a}	13.25^{b}	3.33^{b}	15.16^{b}	0.35^{a}	63.66^{b}	0.38^{b}	4.30^{a}	2.03^{b}	10.28^{a}
2.0	UC	Grafting x Mutation	35.88^{b}	46.99^{c}	28.03^{a}	49.66^{b}	36.85^{c}	15.66^{b}	2,25^{c}	3.33^{b}	12.33^{c}	0.13^{c}	65.00^{a}	0.24^{c}	4.21b	2.53^{b}	10.20^{b}

N.B: *[1] Means within the columns with the same letter(s) are not significantly different (P≤0.05)

efficient in improving the selected traits except in the number of leaves and number of seeds produced per fruit where mutation is more effective and in fruit weight, pH, and plant dry weights where the combination of the two treatments is more effective. Similarly, in variety UC, grafting is more efficient on the selected traits except on survival rate, number of fruits and pH where mutation is more effective and on seedlings height, leaf area, number of seeds per fruit and root dry weight where a combination of the treatments is more efficient.

More so, in 0.1 mM treated mutants of local variety, combined treatments with variety and concentration showed that, grafting is more efficient on the selected traits except on survival rate, height at maturity, leaf number and size, number of fruits fruit diameter and pH where mutation is more effective and on germination percent (1 WAP), survival rate, number of fruit, fruit weight, number of seeds, fruit diameter and root dry weight. But in variety Roma, grafting is more efficient on germination percent (2 WAP), leaf number and size, number of seeds and fruit diameter where mutation is effective and on survival rate, pH dry weights where treatments combination is more effective. Similarly, in variety UC, grafting is more effective except on height at maturity, number of leaves, fruit weight, number of seeds and pH where mutation is more effective and on number of fruits, number of seeds, fruit diameter and shoot dry weight where treatments combination is more efficient (Table 4.14).

Furthermore, in 1.0mM treated mutants, grafting is more efficient on the selected traits of local variety except on survival rates and dry weights where mutation is more effective and on number of fruits, pericarp thickness, pH and root dry weight where treatments combination is more effective. Similarly in variety Roma, grafting is more effective except on leaf area, number of fruitsandnumberof seeds where mutation is effective and on survival rate, number of fruits, thickness of pericarp and shoot dry weight where treatments combination is more effective

(Table 4.14). More so, in variety UC, the effect of grafting was found to be more effective on the selected traits except on germination percent (2 WAP), survival rate, height at maturity, number of leaves, number of seeds and pH on which mutation is more effective and on number of fruits, leaf area and number of seeds where the treatments combination is more effective (Table 4.14).

Similarly, the mean effect of the combination of treatments, variety and concentration on 2.0mM treated mutants revealed that, grafting is more effective on the selected traits of local variety except on survival rate, height at maturity, number of fruits and pericarp thickness where mutation is more effective and on fruit weight, number of seeds and pH where treatments combination is more effective. However, on variety Roma, grafting is more effective on the selected traits except on survival rate, leaf number and size and pH where mutation is more effective and on number of seeds and shoot dry weight where treatments combination is more effective (Table 14). More so, the effect of the combination of treatments with variety and concentrations on 2.0 mM treated mutants of variety UC (Table 4.14) showed that, grafting is more effective on the selected traits except on survival rate, height at maturity, leaf number, thickness of pericarp, pH and shoot dry weight where mutation is more effective and on seedlings height and number of seeds where treatments combination is more effective.

4.9.5 Mean Effects of the Interactions of Variety, Treatments and Seasons on some Selected Tomato Traits

The result of the mean effect of the interactions of the variety, treatments and seasons on the selected traits of tomato was presented in (Table 4.15). The result showed that grafted local variety of tomato was highly improved during the rainy season except in terms of leaf area, number of seeds and shoot dry weight where the improvement was highly found during the dry season. Similarly, mutation has highest effect on the traits of local variety during the rainy season except in terms of percentage germination (1 WAP), leaf area, pericarp thickness and dry weights. More so, treatments combination has highest effects on the selected traits of local variety of tomato during the rainy season except on seedlings height, survival rate, leaf area, pericarp thickness, pH and shoot dry weight where the effect was higher in the dry season.

However, grafting highly improved almost all the selected traits of variety Roma during the rainy season except in terms of shoot dry weight where it is higher during the dry season. Almost similar result was found among the mutants of variety Roma as they were highly improved during the rainy season except in terms of leaf area, fruit weight, pericarp thickness, fruit diameter and dry weights. More so, treatments combination highly improved the traits of variety Roma during the rainy season with exception of survival rate, height at maturity, pericarp thickness, pH and shoot dry weight (Table 4.15).

Furthermore, grafted variety UC was highly improved during the dry season in terms of some selected traits except on germination percent (1 WAP), seedlings height, leaf area, fruit weight, number of seeds pH and root dry weight where the improvement is well manifested in the rainy season. Similarly, the mutants of variety UC were highly improved during the dry season except in the height at maturity, fruit weight, and pericarp thickness, number of seeds,

fruit diameter and pH where the variety flourished more in the rainy season. More so, treatments combination exerts highest effect on the selected traits during the dry season except on fruit weight, number of seeds, fruit diameter, pH and root dry weight (Table 4.15).

4.9.6 Mean Effects of the Interactions of Concentration, Variety and Seasons on some Selected Tomato Traits

The result of the mean effect of the interaction of concentration with variety and season is presented in (Table 4.16). The result indicated that, the interactions makes all the three varieties of tomato to respond more to the mutagenic treatments during the rainy season than the dry season. The interaction showed that, seedlings height, height at maturity and pericarp thickness of the controls have the highest response during the dry season. However, all the mutants treated with 0.1mM concentration showed highest response in all the selected traits during rainy season except fruit diameter. Similarly, all the 1.0mM treated mutants showed highest response during rainy season except in leaf area where highest response was found in dry season. Similar result was found in 2.0 mM treated mutants.

4.9.7 Mean Effects of the Interactions of Concentration, Variety, Treatments and Seasons on some Selected Tomato Traits

The result of the interactions of concentrations with variety, treatments and seasons on some selected traits of tomato was presented in (Table 17). The result showed that, the interactions on the controls of local variety are higher during the rainy season for most of the selected traits except in grafting where the interaction is higher during the dry season. Similar result was found

in the controls of variety Roma. However, in the controls of variety UC, the interactions are higher during the dry season in term of mutation and treatments combination.

Similarly, the interaction among the mutants of local variety treated with 0.1mM concentration was higher during the rainy season for most of the selected traits. Similar result was found among the mutants of variety Roma treated with 0.1 mM concentration of sodium azide. However, the interaction on variety UC was higher during the dry season in most of the traits (Table 4.17).

Furthermore, the interactions of the concentrations with variety, treatments and seasons on the selected traits of 1.0 mM treated mutants of local variety indicated highest effect during the rainy season. Similar result was found on the traits of variety Roma. However, the effect of the interaction on the traits of variety UC was more pronounced during the dry season (Table 17). More so, the effects of the interactions was found to be higher on the selected traits of 2.0 mM treated mutants of local variety and variety Roma during the rainy season but higher in variety UC during the dry season (Table 4.17).

4.9.8 Relationships between Growth and Yield of Tomato

The result of the correlations between the growth and yield parameters of the three varieties of tomato was presented in (Table 4.18). The result revealed significant positive correlations between the seedlings height and number of seeds, fruit weight and number of seeds and between seedlings height and number of fruits.

Table 4.15: Effect for the Interaction of Variety, Treatments and Seasons on some Selected Tomato Traits

Variety	Treatment	Season	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
Local	Grafting	Dry Season	54.02^{b*1}	51.22^{b}	22.40 ^{b}	37.44^{b}	43.83^{a}	12.25^{b}	16.37^{a}	2.58^{b}	10.41^{b}	0.27^{b}	55.16^{a}	0.30^{b}	3.73^{b}	1.69^{b}	10.54^{a}
	Grafting	Rainy Season	74.69^{a}	87.33^{a}	29.41^{a}	31.66^{a}	43.52^{b}	17.33^{a}	11.87^{b}	3.41^{a}	12.33^{a}	0.35^{a}	48.83^{b}	0.37^{a}	4.20^{a}	1.73^{a}	10.40^{b}
Local	Mutation	Dry Season	45.58^{a}	53.88^{b}	18.92^{b}	41.44^{b}	35.42^{b}	13.08^{b}	17.50^{a}	2.41^{b}	10.83^{b}	0.40^{a}	38.91^{b}	0.19^{b}	4.22^{a}	1.71^{a}	10.54^{a}
	Mutation	Rainy Season	40.05^{b}	67.83^{a}	21.26^{a}	49.77^{a}	43.99^{a}	13.75^{a}	12.00^{b}	3.50^{a}	11.20^{a}	0.31^{b}	59.75^{a}	0.20^{a}	4.20^{b}	1.68^{b}	9.19^{b}
Local	Grafting x Mutation	Dry Season	55.44^{b}	38.61^{b}	25.54^{a}	45.61^{a}	34.35^{b}	11.33^{b}	14.12^{a}	2.50^{b}	10.33^{b}	0.52^{a}	46.08^{b}	0.14^{b}	4.25^{a}	1.25^{b}	10.51^{a}
	Grafting x Mutation	RainySeason	67.88^{s}	55.30^{a}	15.25^{b}	35.88^{b}	35.20^{a}	11.83^{a}	11.62^{b}	3.83^{a}	16.50^{a}	0.1^{b}	59.08^{a}	0.15^{a}	4.21^{b}	3.40^{a}	9.66^{b}

N.B: *[1] Means within the columns with the same letter(s) are not significantly different (P≤0.05)

Table 4.15: Effect for the Interaction of Variety, Treatments and Seasons on some Selected Tomato Traits (Cont'd)

Variety	Treatment	Season	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter(cm)	pH	Root DW (g)	Shoot DW (g)
Roma	Grafting	Dry Season	51.13^{b*1}	51.16^{b}	20.34^{b}	38.66^{b}	45.58^{b}	11.58^{b}	11.75^{b}	4.75^{b}	9.25^{b}	0.29^{b}	41.91^{b}	0.21^{b}	4.17^{b}	1.68^{b}	10.45^{a}
	Grafting	Rainy Season	81.80^{a}	91.58^{a}	36.29^{a}	53.94^{a}	47.36^{a}	14.66^{a}	15.25^{a}	6.08^{a}	13.25^{a}	0.43^{a}	58.58^{a}	0.35^{a}	4.20^{a}	2.45^{a}	9.64^{b}
	Mutation	Dry Season	45.78^{b}	52.49^{b}	20.28^{b}	45.66^{b}	30.42^{b}	15.33^{b}	15.25^{a}	2.50^{b}	11.08^{a}	0.19^{a}	57.66^{b}	0.22^{a}	4.21^{b}	1.94^{a}	10.79^{a}
	Mutation	Rainy Season	52.49^{a}	90.25^{a}	29.59^{a}	56.72^{a}	44.39^{a}	15.75^{a}	12.24^{b}	5.33^{a}	11.00^{b}	0.15^{b}	63.91^{a}	0.16^{b}	4.25^{a}	1.69^{b}	9.59^{b}
	Grafting x Mutation	Dry Season	33.16^{b}	40.72^{b}	23.20^{b}	58.05^{a}	43.29^{a}	12.00^{b}	9.37^{b}	2.91^{b}	9.83^{b}	0.42^{a}	44.91^{b}	0.15^{b}	4.23^{a}	1.90^{b}	10.47^{a}
	Grafting x Mutation	Rainy Season	35.61^{a}	59.47^{a}	26.59^{a}	49.80^{b}	31.22^{b}	13.66^{a}	14.87^{a}	3.33^{a}	10.33^{a}	0.19^{b}	63.83^{a}	0.21^{a}	4.23^{a}	2.99^{a}	10.23^{b}

N.B: *[1] Means within the columns with the same letter(s) are not significantly different ($P \leq 0.05$)

Table 4.15: Effect for the Interaction of Variety, Treatments and Seasons on some Selected Tomato Traits(Cont'd)

Variety	Treatment	Season	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
UC	Grafting	Dry	69.11^{b*1}	76.19^{a}	25.22^{b}	66.44^{a}	50.51^{a}	17.91^{a}	19.16b	5.66^{a}	15.41^{b}	0.46^{a}	55.00b	0.50^{a}	4.15^{b}	2.65^{a}	18.25^{a}
UC	Grafting	Rainy	70.72^{a}	62.19^{b}	33.00^{a}	38.69^{b}	38.02^{b}	14.66^{b}	22.62$^{=}$	2.50^{b}	20.25^{b}	0.31^{b}	68.58a	0.36^{b}	4.35^{a}	2.64^{a}	9.91^{b}
UC	Mutation	Dry	53.88=	66.41b^{a}	27.62^{a}	67.77^{a}	41.85^{b}	18.08^{a}	21.00$^{=}$	5.00^{a}	16.25^{b}	0.20^{b}	62.66b	0.24^{b}	4.30^{b}	2.50^{a}	11.07^{a}
UC	Mutation	Rainy	27.44^{b}	66.36^{b}	23.41^{b}	45.77^{b}	46.98^{a}	16.00^{b}	14.62$^{=}$	3.88^{b}	17.41^{a}	0.35^{a}	65.75^{a}	0.31^{a}	4.40^{a}	2.03^{b}	10.20^{b}
UC	Grafting x Mutation	Dry	52.58^{a}	55.30^{a}	31.55^{a}	60.75^{a}	45.54^{a}	18.00^{a}	23.83^{a}	6.50^{a}	3.42$^{=}$	0.19^{a}	57.50^{b}	0.15^{b}	4.24^{b}	2.31^{b}	10.80^{a}
UC	Grafting x Mutation	Rainy	38.55^{b}	45.55^{b}	25.54^{b}	46.86^{b}	35.76^{b}	14.83^{b}	23.60^{b}	2.83^{b}	12.66^{b}	0.14^{b}	72.50^{a}	0.31^{a}	4.30^{a}	3.09^{a}	10.05^{b}

N.B: *[1] Means within the columns with the same letter(s) are not significantly different (P≤0.05)

Table 4.16: Effects for Interaction of Concentration, Variety and Seasons on some Selected Tomato Traits

Concentration (mM)	Variety	Season	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
0.0	Local	Dry	31.25^{b*1}	29.33^{b}	19.51^{a}	23.70^{a}	29.65^{a}	9.00^{b}	7.00^{a}	1.33^{b}	8.55^{b}	0.60^{a}	38.55^{b}	0.32^{b}	3.90^{b}	1.15^{b}	10.14^{a}
	Local	Rainy	33.03^{a}	47.99^{a}	16.06^{b}	23.62^{a}	27.52^{b}	11.11^{a}	6.83^{b}	2.00^{a}	9.72^{a}	0.41^{b}	40.88^{a}	0.37^{a}	4.12^{a}	2.84^{a}	8.66^{b}
	Roma	Dry	23.85^{b}	25.70^{b}	17.67^{b}	25.70^{b}	29.18^{b}	10.66^{b}	6.16^{a}	1.77^{b}	8.00^{b}	0.60^{a}	39.22^{b}	0.25^{b}	4.04^{a}	1.44^{b}	10.06^{a}
	Roma	Rainy	32.85^{a}	59.03^{a}	20.71^{a}	36.88^{a}	32.70^{a}	11.55^{a}	5.65^{b}	2.55^{a}	9.44^{a}	0.29^{b}	46.55^{a}	0.31^{a}	4.10^{a}	2.43^{a}	9.00^{b}
	UC	Dry	27.55^{a}	40.51^{a}	22.83^{a}	44.29^{a}	37.73^{a}	15.11^{a}	9.83^{a}	2.77^{a}	11.22^{a}	0.40^{a}	48.33^{a}	0.39^{a}	4.08^{a}	1.66^{a}	20.50^{a}
	UC	Rainy	27.29^{a}	40.66^{a}	19.44^{a}	23.70^{a}	30.81^{a}	12.44^{a}	11.50^{a}	1.77^{a}	12.66^{a}	0.30^{a}	56.55^{a}	0.42^{a}	4.21^{a}	2.60^{a}	9.22^{a}
0.1	Local	Dry	72.00^{b}	69.92^{b}	28.21^{a}	60.81^{a}	46.15^{b}	15.11^{b}	26.50^{a}	4.00^{b}	12.55^{b}	0.15^{b}	53.66^{b}	0.17^{a}	4.30^{b}	1.88^{b}	11.01^{a}
	Local	Rainy	88.77^{a}	88.66^{a}	27.21^{b}	59.11^{b}	50.53^{a}	17.44^{a}	18.16^{b}	5.77^{a}	17.88^{a}	0.26^{a}	70.77^{a}	0.17^{a}	4.33^{a}	2.52^{a}	10.54^{b}
	Roma	Dry	64.70^{a}	73.77^{b}	25.67_{b}	62.55^{b}	43.56^{b}	15.22^{b}	18.16^{b}	5.33^{b}	12.11^{b}	0.17^{b}	56.77^{b}	0.21^{a}	4.33^{b}	2.14^{b}	11.12^{a}
	Roma	Rainy	85.02^{b}	92.44^{a}	41.74^{a}	77.33^{a}	60.18^{a}	17.55^{a}	22.00^{a}	8.88^{a}	13.88^{a}	0.25^{a}	81.88^{a}	0.18^{b}	4.40^{a}	2.51^{a}	10.70^{b}
	UC	Dry	86.77^{a}	83.11^{a}	33.07^{b}	83.11^{a}	55.50^{a}	20.33^{a}	31.83^{a}	9.33^{a}	19.33^{b}	0.28^{b}	69.00^{b}	0.15^{a}	4.41^{b}	3.04^{a}	11.27^{a}
	UC	Rainy	68.37^{b}	73.70^{b}	34.97^{a}	62.66^{b}	50.35^{b}	17.55^{b}	30.66^{b}	4.77^{b}	22.21^{a}	0.50^{a}	80.33^{a}	0.14^{b}	4.54^{a}	2.90^{b}	10.85^{b}
1.0	Local	Dry	59.11^{b}	51.70^{b}	20.07^{b}	46.29^{a}	40.35^{b}	12.77^{b}	19.33^{a}	2.55^{b}	11.11^{b}	0.28^{a}	49.55^{b}	0.13^{b}	4.05^{b}	1.88^{b}	10.60^{a}
	Local	Rainy	70.18^{a}	79.33^{a}	24.18^{a}	42.44^{b}	46.30^{a}	15.77^{a}	12.66^{b}	4.11^{a}	14.00^{a}	0.19^{b}	63.88^{a}	0.22^{a}	4.22^{a}	2.03^{a}	10.11^{b}
	Roma	Dry	49.81^{b}	57.11^{b}	21.86^{b}	51.72^{b}	36.50^{b}	13.66^{b}	14.66^{a}	4.00^{b}	10.66^{b}	0.22^{a}	51.88^{b}	0.17^{b}	4.25^{a}	1.93^{b}	10.80^{a}
	Roma	Rainy	64.59^{a}	87.00^{a}	32.70^{a}	60.88^{a}	46.55^{a}	15.44^{a}	14.66^{s}	4.66^{a}	12.11^{a}	0.22^{a}	65.77^{a}	0.25^{a}	4.23^{b}	2.44^{a}	10.03^{b}
	UC	Dry	68.22^{a}	75.77^{a}	29.07^{b}	73.66^{a}	47.31^{a}	18.77^{a}	25.94^{a}	6.22^{a}	16.55^{b}	0.25^{b}	60.55^{b}	0.28^{b}	4.27^{b}	2.77^{a}	11.10^{a}
	UC	Rainy	46.14^{b}	64.37^{b}	29.78^{a}	49.92^{b}	41.54^{b}	16.33^{b}	23.33^{b}	3.22^{b}	18.33^{a}	0.28^{a}	70.11^{a}	0.30^{a}	4.38^{a}	2.58^{b}	10.45^{b}
2.0	Local	Dry	44.36^{b}	40.66^{b}	21.40^{a}	35.18^{a}	35.32^{b}	12.06^{b}	11.16^{a}	2.11^{b}	9.88^{b}	0.55^{a}	45.11^{b}	0.20^{b}	4.02^{b}	1.28^{b}	10.37^{a}
	Local	Rainy	51.51^{a}	64.62^{a}	20.18^{b}	31.25^{b}	39.23^{a}	12.88^{a}	9.66^{b}	2.44^{a}	11.77^{a}	0.24^{b}	48.00^{a}	0.21^{a}	4.16^{a}	1.68^{a}	9.62^{b}
	Roma	Dry	35.05^{b}	35.92^{b}	19.88^{b}	38.81^{b}	33.72^{b}	12.33^{b}	9.50^{a}	2.44^{b}	9.44^{b}	0.20^{b}	44.11^{b}	0.13^{b}	4.20^{a}	1.84^{b}	10.30^{a}
	Roma	Rainy	44.07^{a}	83.25^{a}	28.14^{a}	49.85^{a}	40.62^{a}	14.22^{a}	9.50^{a}	3.55^{a}	10.66^{a}	0.28^{a}	54.22^{a}	0.23^{a}	4.17^{b}	2.13^{a}	9.55^{b}
	UC	Dry	51.55^{a}	64.48^{a}	27.54^{a}	58.88^{a}	43.46^{a}	17.77^{a}	17.72^{a}	4.55^{a}	14.66^{b}	0.21^{b}	55.66^{b}	0.36^{b}	4.16^{b}	2.47^{a}	10.63^{a}
	UC	Rainy	40.48^{b}	53.40^{b}	25.66^{b}	38.81^{b}	38.32^{b}	14.33^{b}	14.83^{b}	2.44^{b}	14.88^{a}	0.32^{a}	68.77^{a}	0.45^{a}	4.25^{a}	2.26^{b}	9.70^{b}

N.B: *[1] Means within the columns with the same letter(s) are not significantly different ($P \leq 0.05$)

Table 4.17: Effects for the Interaction of Concentration, Variety, Treatments and Seasons on some Selected Tomato Traits

Conc (mM)	Variety	Treatment		Seasons	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	Ph	Root DW (g)	Shoot DW (g)
0.0	Local	Mutation		Dry	33.11^{b*1}	33.11^{b}	20.23^{b}	27.55^{a}	35.00^{a}	9.00^{b}	7.00^{b}	1.66^{b}	8.00^{b}	0.47^{b}	45.33^{a}	0.53^{b}	3.40^{b}	1.16^{a}	10.20^{a}
	Local	Mutation		Rainy	38.44^{a}	72.00^{a}	23.56^{a}	21.77^{b}	10.00^{b}	14.66^{a}	7.50^{a}	2.00^{a}	9.33^{a}	0.53^{a}	39.66^{b}	0.60^{a}	4.10^{a}	1.13^{b}	9.00^{b}
	Local	Grafting		Dry	21.77^{a}	33.11^{b}	16.60^{a}	21.77^{a}	10.00^{b}	8.66^{b}	9.00^{a}	1.00^{a}	8.66^{a}	0.60^{a}	30.66^{b}	0.34^{b}	4.13^{a}	1.63^{a}	10.03^{a}
	Local	Grafting		Rainy	21.77^{a}	38.88^{a}	14.13^{b}	27.33^{b}	29.36^{a}	10.00^{a}	7.00^{b}	2.00^{a}	6.50^{b}	0.56^{b}	36.66^{a}	0.37^{a}	4.10^{b}	1.06^{b}	8.33^{b}
	Local	Grafting Mutation	x	Dry	38.88^{a}	21.77^{b}	21.70^{a}	21.77^{a}	24.03^{a}	9.33^{a}	5.00^{b}	1.33^{b}	9.00^{b}	0.73^{a}	39.66^{b}	0.10^{b}	4.16^{a}	0.66^{b}	10.20^{a}
	Local	Grafting Mutation	x	Rainy	38.88^{a}	33.11^{a}	17.43^{b}	21.77^{a}	19.00^{b}	8.66^{b}	6.00^{a}	2.00^{a}	13.33^{a}	0.13^{b}	46.66^{a}	0.13^{a}	4.16^{a}	6.33^{a}	8.66^{b}
	Roma	Mutation		Dry	21.77^{b}	27.55^{b}	26.83^{a}	16.44^{b}	40.00^{b}	9.33^{b}	6.00^{b}	2.00^{a}	7.33^{b}	0.80^{a}	30.66^{b}	0.34^{b}	3.90^{b}	1.16^{b}	10.03^{a}
	Roma	Mutation		Rainy	60.77^{a}	66.33^{a}	17.80^{b}	44.44^{a}	40.43^{a}	12.66^{a}	7.00^{a}	3.33^{a}	10.66^{a}	0.40^{b}	40.00^{a}	0.41^{a}	4.10^{a}	1.56^{a}	9.00^{b}
	Roma	Grafting		Dry	33.33^{a}	33.11^{b}	16.60^{b}	27.55^{b}	26.43^{b}	12.66^{a}	7.50^{a}	1.66^{b}	8.66^{b}	0.28^{a}	51.33^{a}	0.29^{a}	4.10^{a}	1.46^{b}	10.13^{a}
	Roma	Grafting		Rainy	21.77^{b}	61.00^{a}	17.80^{a}	33.11^{a}	27.70^{a}	10.66^{b}	3.46^{b}	2.00^{a}	9.00^{a}	0.12^{b}	47.00^{b}	0.13^{b}	4.10^{a}	1.56^{a}	8.33^{b}
	Roma	Grafting Mutation	x	Dry	16.44^{a}	16.44^{b}	18.70^{b}	33.11^{a}	21.13^{b}	10.00^{b}	5.00^{b}	1.66^{b}	8.00^{b}	0.73^{a}	35.66^{b}	0.12^{b}	4.13^{a}	1.70^{b}	10.03^{a}
	Roma	Grafting Mutation	x	Rainy	16.00^{b}	49.77^{a}	18.76^{a}	33.11^{b}	29.96^{a}	11.33^{a}	6.50^{a}	2.33^{b}	8.66^{a}	0.37^{b}	52.66^{a}	0.39^{a}	4.10^{b}	4.16^{a}	9.66^{b}
	UC	Mutation		Dry	44.44^{a}	44.44^{a}	25.70^{a}	44.44^{a}	46.60^{a}	16.00^{a}	6.00^{b}	2.66^{a}	12.66^{b}	0.76^{a}	44.00^{b}	0.73^{a}	3.96^{b}	1.86^{b}	41.06^{a}
	UC	Mutation		Rainy	44.11^{b}	44.44^{a}	24.20^{b}	16.00^{b}	28.00^{b}	12.00^{b}	13.50^{a}	1.66^{b}	18.33^{a}	0.40^{b}	56.33^{a}	0.60^{b}	4.20^{a}	2.13^{a}	9.00^{b}
	UC	Grafting		Dry	21.77^{a}	44.00^{b}	13.66^{b}	44.44^{a}	30.16^{b}	14.66^{a}	7.50^{a}	3.00^{a}	10.00^{b}	0.11^{b}	53.00^{b}	0.33^{a}	4.16^{b}	2.30^{a}	10.10^{a}
	UC	Grafting		Rainy	16.00^{b}	44.44^{a}	25.53^{a}	33.33^{b}	40.76^{a}	13.33^{b}	7.50^{a}	2.33^{b}	12.33^{a}	0.40^{a}	53.33^{a}	0.33^{a}	4.23^{a}	1.63^{b}	9.33^{b}
	UC	Grafting Mutation	x	Dry	16.44^{b}	33.11^{a}	19.03^{a}	44.00^{a}	36.43^{a}	14.66^{a}	16.00^{a}	2.66^{a}	11.00^{a}	0.33^{a}	48.00^{b}	0.12^{b}	4.1^{3b}	0.83^{b}	10.33^{a}
	UC	Grafting Mutation	x	Rainy	21.77^{a}	33.11^{a}	12.15^{b}	21.77^{b}	23.66^{b}	12.00^{b}	13.50^{b}	1.33^{b}	7.33^{b}	0.11^{b}	60.00^{a}	0.34^{a}	4.20^{a}	4.03^{a}	9.33^{b}

N.B: *[1] Means within the columns with the same letter(s) are not significantly different ($P \leq 0.05$)

Table 4.17: Effects for the Interaction of Concentration, Variety, Treatments and Seasons on some Selected Tomato Traits(Cont'd)

Conc (mM)	Variety	Treatment	Seasons	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Number of Seeds/Fruit	Fruit Diameter (cm)	Ph	Root DW (g)	Shoot DW (g)
0.1	Local	Mutation	Dry	72.00^{b*1}	77.33^{b}	28.13^{b}	44.44^{b}	53.66	15.33^{b}	25.50^{a}	3.66^{b}	12.33^{b}	0.17^{b}	64.00^{a}	0.18^{a}	4.16^{b}	2.16^{b}	11.00^{b}
	Local	Mutation	Rainy	94.33^{a}	100.00^{a}	34.00^{a}	50.00^{a}	51.43	18.66^{a}	16.50^{b}	5.66^{a}	16.33^{a}	0.40^{a}	60.33^{b}	0.13^{b}	4.33^{a}	2.30^{a}	11.23^{a}
	Local	Grafting	Dry	66.33^{b}	77.33^{b}	23.03^{b}	60.66^{b}	38.43	17.33^{b}	28.50^{a}	4.00^{b}	13.33^{b}	0.14^{b}	42.66^{b}	0.15^{b}	4.36^{a}	1.66^{b}	11.06^{a}
	Local	Grafting	Rainy	72.00^{a}	88.66^{a}	29.13^{a}	72.00^{a}	49.46	17.66^{a}	18.50^{b}	6.00^{a}	17.00^{a}	0.17^{a}	81.33^{a}	0.20^{a}	4.36^{a}	2.60^{a}	10.03^{b}
	Local	Grafting Mutation	x Dry	77.66^{b}	55.11^{b}	33.46^{a}	77.33^{a}	46.36	12.66^{b}	25.50^{a}	4.33^{b}	12.00^{b}	0.14^{b}	54.33^{a}	0.18^{a}	4.36^{a}	1.83^{b}	10.96^{b}
	Local	Grafting Mutation	x Rainy	100.00^{a}	77.33^{a}	18.50^{b}	55.33^{b}	50.70	16.00^{a}	19.50	5.66^{a}	20.33^{a}	0.20^{a}	70.66^{a}	0.18^{a}	4.30^{b}	2.66^{a}	10.36^{a}
	Roma	Mutation	Dry	77.66^{b}	77.33^{b}	24.46^{b}	60.66^{a}	53.33	14.00^{b}	17.00^{b}	8.66^{b}	10.66^{b}	0.15^{b}	52.33^{b}	0.22^{a}	4.30^{b}	1.96^{b}	11.00^{a}
	Roma	Mutation	Rainy	100.00^{a}	100.00^{a}	47.63^{a}	66.00^{b}	58.33	16.66^{a}	19.50^{a}	11.00^{a}	16.00^{a}	0.41a	83.66^{a}	0.16^{b}	4.33^{a}	2.96^{a}	10.36^{b}
	Roma	Grafting	Dry	66.66^{b}	77.33^{b}	23.86^{b}	60.66^{b}	36.00	17.66^{b}	22.50^{a}	3.00^{b}	14.00^{a}	0.19^{a}	61.66^{b}	0.22^{a}	4.33^{b}	2.20^{a}	11.40^{b}
	Roma	Grafting	Rainy	77.77^{a}	100.00^{a}	46.20^{a}	83.00^{a}	62.80	20.00^{a}	20.00^{b}	11.33^{a}	13.33^{b}	0.19_{a}	81.66^{a}	0.20^{b}	4.43^{a}	1.80^{b}	10.90^{a}
	Roma	Grafting Mutation	x Dry	49.77^{b}	66.66^{b}	28.70^{b}	66.33^{b}	41.36	14.00^{b}	15.00^{b}	4.33^{a}	11.66^{b}	0.18^{a}	56.33^{b}	0.19^{a}	4.36^{b}	2.26^{b}	10.96^{a}
	Roma	Grafting Mutation	x Rainy	77.33^{a}	77.33^{a}	31.40^{a}	83.00^{a}	59.43	16.00^{a}	26.50^{a}	4.33^{a}	12.33^{a}	0.15^{b}	80.33^{a}	0.18^{b}	4.43^{a}	2.76^{a}	10.83^{b}
	UC	Mutation	Dry	88.66^{a}	94.33^{a}	30.16^{b}	88.66^{a}	58.73	19.33^{a}	31.00^{b}	8.66^{a}	18.33^{b}	0.40^{a}	68.66^{b}	0.11^{b}	4.36^{b}	3.13^{a}	10.90^{a}
	UC	Mutation	Rainy	83.33^{b}	83.00^{b}	42.70^{a}	61.00^{b}	48.00	16.66^{b}	33.00^{a}	3.33^{b}	23.33^{a}	0.14^{b}	80.66^{a}	0.13^{a}	4.56^{a}	3.10^{b}	10.80^{b}
	UC	Grafting	Dry	88.66^{a}	77.66^{b}	29.70^{b}	88.66^{a}	51.10	21.00^{a}	34.50^{a}	8.33^{a}	21.00^{b}	0.28^{a}	71.00^{b}	0.13^{b}	4.53^{b}	2.86^{a}	11.76^{a}
	UC	Grafting	Rainy	44.44^{b}	83.00^{a}	32.80^{a}	55.33^{b}	55.73	18.33^{b}	26.00^{b}	6.00^{b}	22.33^{a}	0.14^{b}	78.33^{a}	0.15^{a}	4.60^{a}	2.53^{b}	11.03^{b}
	UC	Grafting Mutation	x Dry	83.00^{a}	77.33^{a}	39.36^{a}	72.00^{a}	56.66	20.66^{a}	30.00^{a}	11.00^{a}	18.66^{a}	0.17^{a}	67.33^{b}	0.21^{a}	4.33^{b}	3.13^{a}	11.16^{a}
	UC	Grafting Mutation	x Rainy	77.33^{b}	55.11^{b}	29.43^{b}	71.66^{b}	47.33	17.66^{b}	33.00^{a}	5.00^{b}	18.50^{b}	0.16^{b}	82.00^{a}	0.14^{b}	4.46^{a}	3.06^{b}	10.73^{b}

N.B: *[1] Means within the columns with the same letter(s) are not significantly different (P≤0.05)

Table 4.17: Effects for the Interaction of Concentration, Variety, Treatments and Seasons on some Selected Tomato Traits (Cont'd)

Conc (mM)	Variety	Treatment	Seasons	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height	Survival Rate	Height at Maturity	Number of Leaves	Leaf Area	Number of Fruits	Fruit Weight	Pericarp Thickness	Number of Seeds/Fuit	Fruit Diameter	pH	Root DW	Shoot DW
1.0	Local	Mutation	Dry	61.00^{b*1}	50.00^{b}	17.09^{b}	44.44^{a}	46.66^{b}	12.00^{b}	18.50^{a}	2.66^{b}	11.33^{b}	0.80^{a}	58.00^{b}	0.12^{b}	3.70^{a}	2.10^{a}	10.86^{a}
	Local	Mutation	Rainy	94.33^{a}	94.33^{a}	31.40^{a}	33.11^{b}	47.66^{a}	19.33^{a}	13.00^{b}	3.66^{a}	12.66^{a}	0.25^{b}	59.00^{a}	0.38^{a}	4.23^{b}	1.83^{b}	10.70^{b}
	Local	Grafting	Dry	55.33^{a}	60.66^{b}	19.20^{b}	50.00^{b}	37.40^{b}	14.66^{b}	22.00^{a}	2.66^{b}	11.66^{a}	0.12^{b}	41.00^{b}	0.12^{b}	4.23^{a}	1.80^{a}	9.40^{b}
	Local	Grafting	Rainy	38.88^{b}	77.33^{a}	23.30^{a}	55.33^{a}	49.10^{a}	15.33^{a}	12.00^{b}	3.33^{a}	11.66^{a}	0.14^{a}	69.33^{a}	0.13^{a}	4.20^{b}	1.80^{a}	10.50^{a}
	Local	Grafting Mutation	x Dry	61.00^{b}	44.44^{b}	23.93^{a}	44.44^{a}	37.00^{b}	11.66^{b}	17.50^{a}	2.33^{b}	10.33^{b}	0.63^{a}	49.66^{b}	0.15^{b}	4.23^{a}	1.76^{b}	10.06^{b}
	Local	Grafting Mutation	x Rainy	77.33^{a}	66.33^{a}	17.8^{6}	38.88^{b}	42.13^{a}	12.66^{a}	13.00^{b}	5.33^{a}	17.66^{a}	0.18^{b}	63.33^{a}	0.16^{a}	4.23^{a}	2.46^{a}	10.66^{a}
	Roma	Mutation	Dry	60.66^{b}	55.33^{b}	20.90^{b}	50.00^{b}	46.00^{b}	12.33^{b}	14.50^{a}	5.33^{b}	9.66^{b}	0.11^{b}	47.66^{b}	0.15^{b}	4.26^{a}	1.83^{b}	9.86^{b}
	Roma	Mutation	Rainy	94.33^{a}	100.0^{0}	37.83^{a}	55.33^{a}	47.33^{a}	15.33^{a}	13.00^{b}	6.00^{a}	14.33^{a}	0.34^{a}	66.00^{a}	0.42^{a}	4.26^{a}	1.86^{a}	11.13^{a}
	Roma	Grafting	Dry	49.88^{b}	60.66^{b}	20.26^{b}	50.00^{b}	30.46^{b}	16.00^{b}	17.50^{a}	3.00^{b}	11.66^{a}	0.16^{b}	59.66^{b}	0.21^{a}	4.23^{b}	2.73^{b}	9.80^{b}
	Roma	Grafting	Rainy	66.33^{a}	100.00^{a}	31.76^{a}	61.00^{a}	48.66^{a}	16.33^{a}	14.00^{b}	4.33^{a}	11.66^{a}	0.18^{a}	68.66^{a}	0.17^{b}	4.30^{a}	3.06^{a}	10.60^{a}
	Roma	Grafting Mutation	x Dry	38.88^{a}	55.33^{b}	24.43^{b}	55.33^{b}	33.03^{b}	12.66^{b}	12.00^{b}	3.66^{a}	10.66^{a}	0.40^{a}	48.33^{b}	0.17^{a}	4.40^{a}	2.80^{a}	10.43^{b}
	Roma	Grafting Mutation	x Rainy	33.11^{b}	61.00^{a}	28.50^{a}	66.23^{a}	43.66^{a}	14.66^{a}	17.00^{a}	3.66^{a}	10.33^{b}	0.13^{b}	62.66^{a}	0.15^{b}	4.26^{b}	2.46^{b}	10.66^{a}
	UC	Mutation	Dry	77.33^{b}	88.66^{a}	26.86^{b}	77.33^{a}	48.33^{a}	18.66^{a}	26.00^{a}	6.00^{a}	16.00^{b}	0.37^{a}	57.66^{b}	0.60^{a}	4.43^{a}	2.80^{a}	10.20^{b}
	UC	Mutation	Rainy	83.33^{a}	66.00^{b}	34.00^{a}	44.44^{b}	39.33^{b}	16.00^{b}	25.00^{b}	2.66^{b}	20.33^{a}	0.35^{b}	71.00^{a}	0.12^{b}	4.26^{b}	2.46^{b}	11.63^{a}
	UC	Grafting	Dry	60.66^{a}	77.66^{a}	28.96^{a}	77.33^{a}	45.15^{a}	18.66^{a}	24.00^{a}	5.00^{a}	18.66^{b}	0.24^{b}	65.33^{a}	0.11^{b}	4.33^{a}	2.26^{b}	10.66^{b}
	UC	Grafting	Rainy	27.55^{b}	77.33^{b}	27.83^{b}	50.00^{b}	45.93^{b}	17.00^{b}	16.50^{b}	4.00^{b}	20.00^{a}	0.35^{a}	65.33^{a}	0.39^{a}	4.26^{b}	2.80^{a}	11.00^{a}
	UC	Grafting Mutation	x Dry	66.66^{a}	61.00^{a}	31.40^{a}	66.33^{a}	48.46^{a}	19.00^{a}	27.83^{b}	7.66^{a}	15.00^{a}	0.15^{a}	58.66^{b}	0.15^{b}	4.33^{a}	2.70^{b}	11.50^{a}
	UC	Grafting Mutation	x Rainy	27.55^{b}	49.77^{b}	27.53^{b}	55.33^{b}	39.36^{b}	16.00^{b}	28.50^{a}	3.00^{b}	14.66^{b}	0.15^{a}	74.00^{a}	0.39^{a}	4.30^{b}	2.80^{a}	10.50^{b}

N.B: *[1] Means within the columns with the same letter(s) are not significantly different (P≤0.05)

Table 4.17: Effects for the Interaction of Concentration, Variety, Treatments and Seasons on some Selected Tomato Traits(Cont'd)

Conc (mM)	Variety	Treatment		Seasons	Germination % (1 WAP)	Germination % (2 WAP)	Seedlings Height	Survival Rate	Height at Maturity	Number of Leaves	Leaf Area	Number of Fruits	Fruit Weight	Pericarp Thickness	Number of Seeds/Fuit	Fruit Diameter	pH	Root DW	Shoot DW
2.0	Local	Mutation		Dry	50.00^{b*1}	44.44^{b}	24.26^{b}	33.33^{a}	39.36^{b}	12.66^{b}	14.50^{a}	2.33^{a}	10.00^{b}	0.35^{a}	53.33^{a}	0.38^{a}	3.66^{b}	1.33^{b}	10.36^{b}
	Local	Mutation		Rainy	71.66^{a}	83.00^{a}	27.90^{a}	21.77^{b}	40.66^{a}	16.66^{a}	10.50^{b}	2.33^{a}	11.00^{a}	0.21^{b}	36.66^{b}	0.37^{b}	4.16^{a}	1.66^{a}	10.53^{a}
	Local	Grafting		Dry	38.88^{a}	44.44^{b}	16.86^{a}	33.33^{b}	35.93^{b}	11.66^{b}	10.50^{a}	2.00^{b}	9.66^{a}	0.73^{a}	41.33^{b}	0.11^{b}	4.16^{a}	1.76^{a}	10.36^{a}
	Local	Grafting		Rainy	27.55^{b}	66.44^{a}	18.50^{b}	44.44^{a}	48.03^{a}	12.00^{a}	10.50^{a}	2.66^{a}	9.66^{a}	0.37^{b}	51.66^{a}	0.12^{a}	4.16^{a}	1.66^{b}	9.00^{b}
	Local	Grafting Mutation	x	Dry	44.22^{b}	33.11^{b}	23.06^{a}	38.88^{a}	30.03^{a}	11.66^{a}	8.50^{a}	2.00^{b}	10.00^{b}	0.57^{a}	40.66^{b}	0.12^{b}	4.16^{a}	1.76^{b}	10.40^{a}
	Local	Grafting Mutation	x	Rainy	55.33^{a}	44.44^{a}	14.16^{b}	27.55^{b}	29.00^{b}	10.00^{b}	8.00^{b}	2.33^{a}	14.66^{a}	0.15^{b}	55.66^{a}	0.14^{a}	4.16^{a}	1.26^{a}	9.33^{b}
	Roma	Mutation		Dry	44.44^{b}	44.44^{b}	18.56^{b}	27.55^{b}	43.00^{b}	10.66^{b}	9.50^{a}	3.00^{b}	9.33^{b}	0.11^{b}	37.00^{b}	0.13^{b}	4.23^{a}	0.76^{b}	10.10^{a}
	Roma	Mutation		Rainy	72.11^{a}	100.00^{a}	32.86^{a}	50.00^{a}	43.36^{a}	14.00^{a}	7.50^{b}	4.00^{a}	12.00^{a}	0.57^{a}	44.66^{a}	0.41^{a}	4.16^{b}	2.13^{a}	9.33^{b}
	Roma	Grafting		Dry	33.11^{b}	38.88^{b}	19.20^{b}	44.44^{b}	28.80^{b}	15.00^{b}	13.50^{a}	2.33^{b}	10.00^{a}	0.14^{a}	56.00^{b}	0.16^{a}	4.23^{a}	1.76^{b}	10.50^{a}
	Roma	Grafting		Rainy	44.11^{a}	100.00^{a}	23.80^{a}	49.97^{a}	38.40^{a}	16.00^{a}	11.50^{b}	3.66^{a}	10.00^{a}	0.14^{a}	58.33^{a}	0.15^{b}	4.13^{b}	2.46^{a}	9.33^{b}
	Roma	Grafting Mutation	x	Dry	27.55^{b}	24.44^{b}	21.90^{b}	44.44^{b}	29.36^{b}	11.33^{b}	5.50^{b}	2.00^{b}	9.00^{b}	0.35^{a}	39.33^{b}	0.12^{b}	4.20^{b}	2.00^{a}	10.30^{a}
	Roma	Grafting Mutation	x	Rainy	16.00^{a}	49.77^{a}	27.76^{a}	49.77^{a}	40.10^{a}	12.66^{a}	9.50^{a}	3.00^{a}	10.00^{a}	0.12^{b}	59.66^{a}	0.14^{a}	4.23^{a}	1.63^{b}	10.00^{b}
	UC	Mutation		Dry	66.00^{b}	77.33^{a}	25.10^{b}	55.33^{a}	48.40^{a}	17.66^{a}	13.66^{b}	5.33^{a}	14.66^{b}	0.33^{b}	49.66^{b}	0.56^{b}	4.16^{a}	1.76^{b}	10.36^{a}
	UC	Mutation		Rainy	72.11^{a}	55.33^{b}	29.60^{a}	33.33^{b}	36.76^{b}	14.00^{b}	19.00^{a}	2.33^{b}	19.00^{a}	0.34^{a}	66.33^{a}	0.61^{a}	4.16^{a}	2.30^{a}	9.66^{b}
	UC	Grafting		Dry	44.44^{a}	66.33^{b}	27.63^{a}	60.60^{s}	41.00^{b}	18.00^{a}	18.00^{a}	3.66^{a}	15.33^{a}	0.19^{b}	61.33^{b}	0.38^{b}	4.00^{b}	2.56^{a}	10.80^{a}
	UC	Grafting		Rainy	21.77^{b}	60.66^{a}	19.43^{b}	44.44^{b}	45.50^{a}	15.33^{b}	8.50^{b}	3.00^{b}	15.00^{b}	0.51^{a}	66.00^{a}	0.39^{a}	4.23^{a}	2.53^{b}	9.76^{b}
	UC	Grafting Mutation	x	Dry	44.22^{a}	49.72^{a}	29.90^{a}	60.66^{a}	41.00^{a}	17.66^{a}	21.50^{b}	4.66^{a}	14.00^{a}	0.12^{b}	56.00^{b}	0.14^{b}	4.26^{a}	2.36^{b}	10.73^{a}
	UC	Grafting Mutation	x	Rainy	27.55^{b}	44.22^{b}	26.16^{b}	38.66^{b}	32.70^{b}	13.66^{b}	17.00^{b}	2.00^{b}	10.66^{b}	0.13^{a}	74.00^{a}	0.35^{a}	4.20^{b}	2.56^{a}	9.66^{b}

N.B: *[1] Means within the columns with the same letter(s) are not significantly different

Table 4.18: Correlation Co-efficient between Growth and Yield Components of Tomato

	Germ % (1 WAP)	Germ % (2 WAP)	Survival Rate (%)	Height at Maturity (cm)	No of Leaves	Leaf Area (cm^2)	No of Fruits	Fruit Weight (g)	Pericarp Thickness (mm)	Seedlings Height (cm)	No of Seeds/Fruit	Fruit Diameter (cm)	pH	Root DW (g)	Shoot DW (g)
Germ % (1 WAP)	1.00														
Germ % (2 WAP)	0.58*	1.00													
Survival Rate	0.37^{ns}	0.43^{ns}	1.00												
Height at Maturity	0.47*	0.52*	0.51*	1.00											
No of Leaves	0.40^{ns}	0.61*	0.57*	0.55*	1.00										
Leaf Area	0.47*	0.35^{ns}	0.62*	0.44^{ns}	0.52*	1.00									
No of Fruits	0.54*	0.49*	0.53*	0.55*	0.47*	0.41^{ns}	1.00								
Fruit Weight	0.41^{ns}	0.43^{ns}	0.37^{ns}	0.37^{ns}	0.53*	0.53*	0.32^{ns}	1.00							
Pericarp Thickness	-0.17^{ns}	-0.19^{ns}	-0.19^{ns}	-0.13^{ns}	-0.18^{ns}	-0.27^{ns}	-0.20^{ns}	-0.09^{ns}	1.00						
Seedlings Height	0.46*	0.50*	0.48*	0.49*	0.50*	0.50*	0.47*	0.44^{ns}	-0.11^{ns}	1.00					
No of Seeds/Fruit	0.32^{ns}	0.41^{ns}	0.47*	0.40^{ns}	0.46*	0.48*	0.34^{ns}	0.49*	-0.27^{ns}	0.49*	1.00				
Fruit Diameter	-0.07^{ns}	-0.002^{ns}	-0.18^{ns}	-0.10^{ns}	-0.04^{ns}	-0.17^{ns}	-0.12^{ns}	-0.06^{ns}	0.11^{ns}	-0.06^{ns}	-0.01^{ns}	1.00			
pH	0.29^{ns}	0.34^{ns}	0.40^{ns}	0.27^{ns}	0.45*	0.47*	0.29^{ns}	0.41^{ns}	-0.18^{ns}	0.39^{ns}	0.37^{ns}	0.37^{ns}	1.00		
Root DW	0.15^{ns}	0.14^{ns}	0.18^{ns}	0.10^{ns}	0.18^{ns}	0.14^{ns}	0.06^{ns}	0.29^{ns}	-0.14^{ns}	0.12^{ns}	0.28^{ns}	0.07^{ns}	0.14^{ns}	1.00	
Shoot DW	0.03^{ns}	-0.04^{ns}	0.01^{ns}	0.16^{ns}	0.12^{ns}	-0.01^{ns}	0.01^{ns}	-0.03^{ns}	0.11^{ns}	-0.03^{ns}	-0.08^{ns}	0.11^{ns}	-0.001^{ns}	-0.06^{ns}	1.00

Keys: ns= No significant difference * = Significant difference (P≤0.05) **= Highly significant difference (P≤0.01)

CHAPTER FIVE

DISCUSSION

5.1Quantitative and Qualitative Traits Improvement among Sodium Azide Induced Mutantsof Tomato

The distinct differences observed in most of the quantitative and qualitative traits among the sodium azide induced mutants of tomato evaluated showed significant improvements in the selected traits. Although there were few traits with no significant differences in responses to the applied treatments; the ability of the mutants to germinate faster after one and two weeks of planting in respect to the controls showed that the mutagenic treatments induced increase enzymatic activities, which could be responsible for the early germination. This finding is in agreement with the findings of Mensah *et al*. (2007) who reported decreased in germination with increase in the dose of chemical mutagens. In the present investigation, germination, survival percentage, plant heights and leaf number and area decreased with increasing concentration of sodium azide. This finding conformed to the earlier report by Ahloowalia and Maluszynski (2001) that, the viable mutants observed are mainly dependable measure of genetic effect in mutagen. The increased in the number of leaves, plant heights and number of fruits per plant due to sodium azide treatments is also in conformity with the work of Adamu and Aliyu (2007) who reported increased in growth and yield parameters of tomato due to sodium azide treatments.There were reductions in the germination and survival percentages with increasing concentrations for both chemicals in the C_1 generation. Reductions in germination and survival percentages due to the effects of mutagens on various crop plants have earlier been documented by Mensah and Akomeah (1997)and Mensah *et al*. (2005).

Similarly, it has been reported by Kumar *etal*. (2009) that chemical mutagens induce physiological damages (injury), gene mutations and chromosomal mutations in the organisms in

M_1 generation (which can be measured by seed germination, survival reduction [lethality], plant height reduction (due to injury), fertility reduction or sterility (reduction in pod and seed formation). This also agrees with the findings of Deepalakshmi (2000) and ThangaHamavathy (2002) who independently reported similar effects of mutagens in black gram and Kumar *etal*. (2009) in cowpea. The increased in the number of leaves and leaf area among the mutants signifies the ability of the mutagen (sodium azide) to initiate more foliar buds. This finding agrees with the work ofMaluszynski *et al.* (2001) and Pasztor *et al.* (1985) who independently reported an increase in leaf number and leaf area among *Zeamays* mutants.

More so, the improvement in the growth and yield components of tomato due to sodium azide treatmentsstressed the effect of mutation on the growth and yield of plants. This is in conformity to the work of Adamu *et al*. (2002) when groundnut was treated with gamma rays and Sheeba *et al*. (2005) when gamma rays and EMS were used to treat *Sesanumindicum* L. where seed germination, seedling survival, plant height and pollen fertility were reduced significantly with an increase in dosage levels of both mutagens. However,in contrast, Sasi *et al*. (2005) showed that all plant mutant types registered lower yields compared to their parents in the study of the effects of diethylsulphate and EMS on Okra (*Abelmoschusesculentum* (L.) var. MDU-1).

The increased in fruit quality (such as pericarp thickness, juice pH and fruit weight) and number due to induced mutagenesis by sodium azide signifies the vital role played by the mutagen in improving the quality traits of tomato. The increased in dry weights of the tomatovarieties due to sodium azide treatments is in contrast to the findings of Ikhajiagbe*etal*. (2012).

5.2 Effects of Grafting on some Quality Traits of Tomato

The distinct differences observed in most of the quantitative and qualitative traits among the mutants and grafted tomato plants evaluated showed, though there were few characteristics with no significant differences in responses to the applied treatments. The increased survival rates of the grafted tomato recorded showed excellent percentage of grafting success after 12 days in the incubation. This is similar to the earlier report by Anonymous (2011) that the percentage of survival ratios of all types of grafting was 97, 98 and 99% for splicing, top and tongue respectively.The survival rate of grafted plants depends on compatibility between scion and rootstock, quality and age of seedlings, quality of the joined section, and post-grafting management. Different grafting techniques are adapted for different scions and rootstocks depending on grafting objectives, farmer's experience, and post-grafting management conditions as described by Hang *et al*. (2005).

The increased in plant height induced by grafting is in agreement with the findings of Lee (1994) and Ioannou *et al*. (2002) who found that grafted plants were taller and more vigorous than self-rooted ones and had a larger central stem diameter but is in contrast to the work of Khah *et al*. (2006). The increased dry weights of the grafted tomato with respect to the controls agrees with the work of Romano and Paratore (2001) who reported increased dry weight of the aerial organs of grafted tomato plants. Large leaf area measurements due to grafting is in line with the findings of Pulgar *et al*. (1998) who observed increased production of leaves in grafted plants as a result of an increased uptake of water and nutrients.

Higher fruit yield parameters found in this study could be due to the fact that grafting combines novel traits of the two grafted plants after grafting operation. This has also been reported by Tsouvaltzis *et al*. (2004). The increased pH of the juice in grafted plants is in contrast to the findings of Leoni *et al*. (1990) and Romano and Paratore (2001) who found that fruit descriptive and qualitative characteristics were not affected by grafting. But Lee (1994) found an increase in yield which was attributed to the vigour of the rootstock and the higher uptake of water and nutrients. Passam *et al*. (2005) found that eggplants grafted on to two tomato rootstocks gave a higher yield and bigger fruit size than those grafted on to two eggplant rootstocks, but the mineral composition of fruits from grafted plants did not differ from that of non-grafted plants.

The fruit characteristics of grafted plants were compared with those of non-grafted plants. The results showed that the fruit index (diameter/length, number of fruits and fruit weight) were significantly influenced by grafting. The results agree with those reported by Lee (1994) who concluded that fruit shapes are influenced by rootstocks. Pogonyi *et al*. (2005) reported that when Lemance F_1 was grafted onto Beaufort rootstock, increased yield was caused mainly by higher average fruit weight. Ibrahim *et al*. (2014) also found that the total number of fruits per truss in non-grafted plants was statistically different from the total for grafted plants. In a similar study by Khah *et al*. (2006) fruit weight of grafted plants was found to be higher than in non-grafted plants and plants grafted onto Heman and Primavera produced more fruit than the non-grafted, both in the greenhouse and in the open field. In the present study, the number of fruits and fruit weights of non-grafted plants were significantly lower than the corresponding values for plants grafted onto both rootstock cultivars.

The results of the study showed that tomato grafting on suitable rootstocks had positive effects on the yield. In grafted combinations, the total fruit yield per plant increased significantly in comparison with that of the control plants. Ibrahim *et al*. (2001) observed similar results in grafted and non-grafted tomato plants. These investigators suggested that the higher yield of fruit from grafted tomato plants was most likely an effect of the vigorous root system of the rootstock. According to Lee (1994), the increased yield of grafted plants is also believed to be due to enhanced water and mineral uptake. Similarly, Osvald (2004) reported that tomato grafting on suitable rootstocks has positive effects on cultivation performance, especially under greenhouse conditions.

The pH value also plays an important role in determining fruit quality characteristics. Many studies focused on pH as a key element in tomato selection as stressed by Hong Tsou (1998). The analyzed results showed that the pH values of tomato fruit increased among the grafted plants. This is in conformity to the findings of Kuzucu *et al*. (2004) who also reported that Koral, Mobil and H-2274 (fresh tomato) have a pH value of 4.31, 4.33 and 4.33, respectively; but is contrary to the work of Khah *et al*. (2006) who found that fruit pH values were not affected by grafting.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 SUMMARY

The research was conducted to ascertain the effects of grafting and mutation via sodium azide on three varieties of tomato. Induced mutation using various concentrations of sodium azide and grafting technique were employed singly and in combination on the three varieties of tomato with the aim of improving the growth and yield parameters of the plants in both the wet and dry seasons. Significant improvements were found among the grafted and mutant tomatoes in both the dry and wet seasons.

6.2 CONCLUSION

It was concluded that:

i. There is significant difference in theeffect of sodium azide and grafting on the growth and yield components of the three tomato varieties under study. It was found that 0.1mM concentration of sodium azide has the highest effect.

ii. Significant difference was found in the response of the three tomato varieties to the treatments with variety UC respondingmore significantly to sodium azide treatment while variety Roma responds more to grafting treatment.

iii. Significant positive correlations were found to exist between the growth parameters withthe yield components of the three tomato varieties.

It was generally concluded that, 0.1mM concentration of sodium azide (NaN_3) and grafting are significant in inducing variability that could be exploited in the improvement of highly economic crops like tomato. It was also concluded that, the mutants and grafted tomato can be grown all the year round (both during the rainy and dry seasons).

6.3 RECOMMENDATIONS

This research recommends the following:

i. Lower concentrations of sodium azide in the form of 0.1mM should be used for inducing favorable mutations in tomato.

ii. Tongue grafting should be employed in the improvement of tomato cultivars.

iii. Further cytological and molecular researches should be taken on the improved tomato cultivars to further clarify the genetic bases of these beneficial methods of improvement.

iv. Further researches should be embark upon the mutants and grafted tomato to test for disease and stress tolerance.

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