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Impact of Sodium Azide on the Growth and Development of Tomato (*Lycopersicum esculentum Mill.*) in Gombe, Nigeria

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Abstract
Induced mutagenesis is one of the most effective strategies for particular enhancement without altering the well-optimized inheritable background of the factory cultivars. This research project therefore investigates the impacts of Sodium Azide Induced Mutation on three varieties of tomatoes for inducing variability. Different concentrations of Sodium Azide such as 0.01, 0.02, 0.03 and 0.04 g were applied to induce variability and the result showed that the tomato species responded differently to the increase in Sodium Azide concentrations. Overall, the concentrations 0.02 and 0.03g Sodium Azide concentration were found to be effective for inducing vegetative leaves, and fruiting, in Rio Grande, followed by 0.04 and 0.01g in Tandilo and UC 82. In terms of plant dry matter production, Sodium Azide concentration of 0.04g was found to be effective in Tandilo (3.83), followed by Rio grande (3.56) and least which is UC 82 (3.53) respectively. For a study on the number of seed production, 0.02g was found to produce the highest number of seeds (84) while the least was 0.04g with 71 seeds. pH values of the different varieties of tomatoes do not show much difference across different concentrations of Sodium Azide. The result of this study has demonstrated that the employment of Sodium Azide could be beneficial for the enhancement of tomato quality and yield for improving large-scale sustainable tomato production across the globe.

Keywords: Mutation, Effect, Concentration, Inducement, Varieties

Introduction

Tomato (*Solanum esculentum*) (Alternative names: *Lycopersicon pimpinelli folium; Lycopersicon esculentum* and *Solanum lycopersicon*). The cultivated tomato (Lycopersicon esculentum Mill.) which belongs to the family Solanaceae is considered as the alternate most important vegetable crop in the world after potato (Bhatia et al,2004). According to EL-Kaaby et al. (2012), tomatoes occasionally is referred to as poor man's orange. Foolad, (2004), ranks tomato third among vegetable crops with a periodic product of 283 million metric tons in the year 2009. Tomato has a nutritive and medicinal value content from vitamins A and C. (Ajenifujah-Solebo et al., 2013). besides carotenoid colours which doubles as an antioxidant guarding the mortal body from free revolutionaries' damages and reduces the threat of getting cancer and also cholesterol accumulation Chaudhry et al. (2004). The global demand for tomato increased extensively in recent times due to its different mileage in raw, cooked, and reused food as well as its nutritive value. Due to its importance as a vegetable and medicinal value, many laboratories have undertaken numerous researches on tomato and other different economic crops to improve their production under abiotic stresses by using chemical or physical mutagens incorporated with in-vitro technique (Al-Qurainy & Khan.2009). Since several researches proved that Sodium azide (NaN_3) was very effective in inducing mutation with respect to tomatoes, (Adamu & Aliyu, 2007).

Tomato continues to be the most important vegetable in the world due to its increasing commercial and dietary value, widespread production as well as a model plant for research Kimura et al. (2008). Tomato is utilized as a fresh crop or processed into various forms such as paste, puree and juices. Tomato is a rich source of vitamins (A and C), minerals (iron, phosphorus), lycopene, Beta-carotene, high amounts of water and low calories (Wilcox et al.,2003). This view can be justified by the continuing increase in the demand for fresh and processed tomatoes in Gombe State, Tomato is nowadays considered one of the major vegetable crops cultivated throughout the world

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and is grown in a wide range of environments comprising natural and protected conditions (Dhaliwal et al., 2002) of both the tropical, subtropical and temperate parts of the world.
Tomato (*Lycopersicon esculentum* Mill.) being one of the most important vegetables grown in a wide range of environments comprising natural and protected conditions (Dhaliwal et al., 2002) is faced with the problem of seizure within some periods 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 the selection of desirable traits (Holm, 1988), hybridization (Dhaliwal et al., 2002) and artificial induction of mutation (Micke et al., 1987).

The prime strategy in mutation-based breeding 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., 2001). 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 the timely planting of the follow-up crop; for example, the 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 developing strategies for the production of hybrid rice varieties. Similar mutants were induced through gamma irradiations in rice (Shen et al., 1993). Such mutants allow the production of hybrid seed based on only two lines and show increased yield from heterosis.

Mutation can be defined as a sudden heritable alteration in the structure or sequence of DNA of an organism which is not caused as a result of segregation and recombination of genes Mutation in plants is any heritable change in the idiotypic constitution of sporophytic or gametophytic plant tissue, not caused by normal genetic recombination or segregation (Harten, 1998). These changes in our target plant can be passed on to progeny and used for human benefit through breeding. While recombination of alleles gives rise to a certain degree of variation which already present in the genome, it is not capable of creating novel traits. Mutations therefore create genetic variability in a closed population. Variation is the source from which plant breeders are able to produce new and important cultivars. Alleles of varying forms at given loci in a population can be selected and fixed within a new individual or line. We depend on recombination and an independent assortment of favourable alleles to produce new and unique individuals from which to select and produce the lines that will serve as our cultivars. While recombination of alleles provides offspring with presumably selectable variation for the spectrum of traits exhibited, it is only capable of creating new combinations of traits already existing. Recombination does not of itself produce novel traits. Exploiting natural or induced genetic diversity is a proven strategy in the improvement of all major food crops, and the use of mutagenesis to create novel variation is particularly valuable in those crops with restricted genetic variability (Martin et al., 2009). Through breeding and selection, species can have improved yield, quality, taste, size and resistance to disease and plants adapt to diverse climates and conditions (William, 2007). Mutations can occur spontaneously in nature or are induced by man.

Sodium Azide is a rapidly acting, potentially deadly chemical that exists as an odourless white solid. It is a well-known respiratory, catalase and peroxidase inhibitor and it is a potent chemical mutagen in both higher and lower organisms (Nilan et al., 1973). It is a common bactericide, pesticide and industrial nitrogen gas generator which is known to be highly mutagenic in several organisms (Grant et al., 1994; Rines, 1985). The mutagenicity created by sodium azide is mediated through the production of an organic metabolite of azide compound, presumably azidoalanine. The production of this metabolite was found to be dependent on the enzyme O-acetylserine sulfhydrylase (Khan et al., 2005). Sodium azide is a mutagenic mechanism used for the improvement of economic characteristics in rice, wheat, barley and sorghum (Maluszynski et al., 2009). Secondary metabolite synthesis was increased compared to the untreated seeds of P. odontadenius with a more important synthesis in phenolic compounds (Nakweti et al., 2015). The high inhibitory effects of secondary metabolite against the growth of medically important parasites suggest that sodium azide in plant breeding increases the production of secondary metabolite for medical and pharmaceutically importance. In another work, sodium azide also has been reported to reduce the germination percentage, root length and shoot length; however, at low concentrations, it was not different from the control (Srivastava & Singh, 2011). The magnitude of genotypic and phenotypic variability, heritability and genetic gain for various polygenic traits were also decreased with the increases in concentration of sodium azide. However, yield attributing characters showed both positive and negative shifts in mean than those of control. Similarly, an increase in the seedling height, number of leaves, high frequency of paracytic

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stomata, higher stomatal index and density on the abaxial leaf surface and large stomata in seedlings induced with sodium azide in Jatropha (AbdulRahaman et al., 2013).

Statement of the problem

Despite the importance of this crop, the production and productivity are constraint by different biophysical and socio-economic reasons, such as lack of adopted and improved tomato technology, inadequate knowledge in production and poor extension services (Mersha, 2008). However, research developed in the past and current times mainly focused on varietal development, fertilizer trials and agronomic practices in different centres. As a result, the quality of fruit is reduced and a considerable amount is wasted. Weight loss, decay and rapid deterioration are often major factors that determine the marketability duration of fruits and vegetables. Therefore, it is evident from different scholars that, even though these harvest practices are compulsory for their quality, they must be coupled with the postharvest experiment period. Tomato is faced with the problem of seizure within some periods 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, germplasm resources were inadequate for significant crop improvement or major advantage in basic genetic research. This 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 mutation to improve fruit quality has been scarcely investigated. The lack of improved varieties that can withstand the environmental stress of the time with increased vigour posed a great challenge to tomato improvements in Nigeria. This research will explore induced mutation using Sodium Azide to improve the yield of tomatoes to make them available for consumption throughout the year in Nigeria.

Objectives:

i. Identify variety or varieties that respond positively to Sodium Azide (NaN_3) treatment.
ii. To measure the effects of Sodium Azide (NaN_3) on the growth and yield of tomato
iii. To determine the effects of Sodium Azide (NaN_3) on fruit characteristics of tomato

Hypotheses

i. Sodium azide does not have any significant effects on the agronomic traits of Tomato.
ii. Agronomic traits of tomato treated with Sodium Azide are not significantly heritable.
iii. Sodium Azide is not significantly efficient and effective in inducing mutation in Tomato.

Materials and Methods

The apparatus used include beakers, glass funnels, measuring cylinders, stirrers, conical flasks, meter rule, micrometre screw gauge, broom, polythene bag, masking tape, and electronic weighing machine. Chemical Mutagen: The chemical Mutagen used in the study was sodium azide (NAN_3) by Central Arog House (p) Ltd, New Delhi, India. The research was conducted in the botanical garden of the Department of Biological Sciences, Gombe State University, Gombe (Lat 10° 17ᴵ N; Long 11°N 10ᴵ Altitude 456m above sea level). Gombe lies in the Sudan savanna zone of Nigeria with a mean annual rainfall of about 097mm/35.7 inch. The average annual temperature is 25.4ºC/77.8ºF**.** The research was conducted from August 2022 to January 2023.

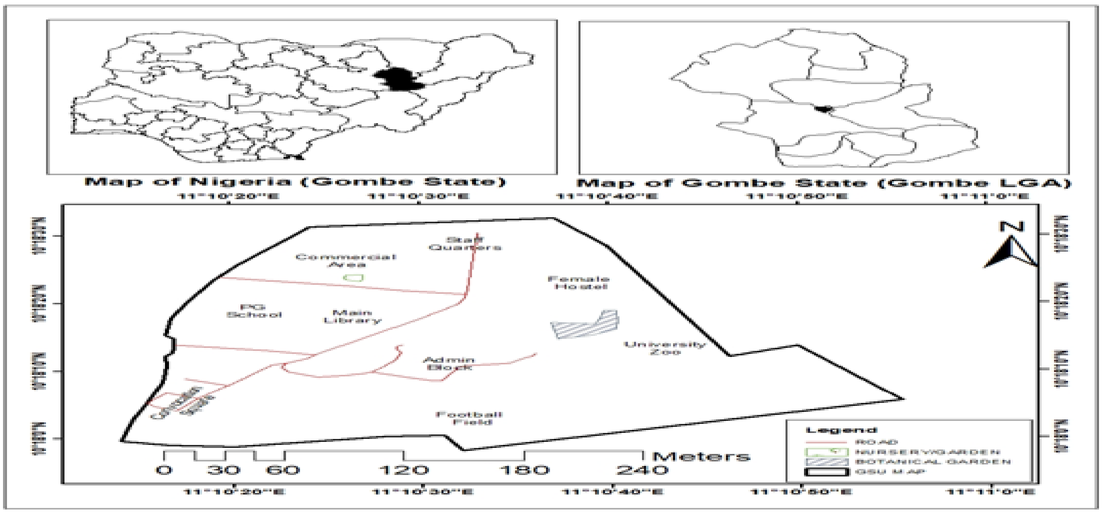

Figure 1: Map of the Study area Showing Nigeria, Gombe State, Gombe State University and Botanical Garden.

Dry seeds (with a moisture content of 10-12%) of three Tomato seeds (Rio-Grande, Tandilo and UC 82) were obtained from the Botany Department of Gombe State University and from Local sellers in the Gombe main market. The treatment used in the study involves mutation using various concentrations of sodium azide, Seeds of the three tomato varieties were treated with four different concentrations of Sodium Azide (0.00g (Control), 0.01g, 0.02g, 0.03g and 0.04g) respectively. The varieties used were Rio-grande, Tandilo and UC 82. The seeds went through surface sterilization thereby establishing aseptic seedlings from treated seeds. Seeds of three tomato cultivars (*UC 82, Tandilo* and *Rio Grande*) were soaked for 4 hours with sodium azide (NaN_3) as a chemical mutagen to increase the genetic variation at concentrations 0.00g (control), 0.01g, 0.02g, 0.03g and 0.04g respectively. The treated seeds were washed several times to remove excess NaN_3 with distilled water. Subsequently, treated and untreated seeds were surface disinfected with ethanol at concentration 70 % for 2 min, followed by sodium hypochlorite at concentrations (6 %) for 20 min and rinsed for 15 min with distilled water 3 times for 5 min each respectively in order to remove the residual effects of mutagen. The treated seeds were grown in Two Hundred Twenty-Five (225) polythene bags (10 seeds per pot) that were arranged in a Completely Randomized Block Design (CRBD).

Data were obtained for germination percentage, seedlings height, height at maturity, survival rates, number of leaves, leaf area, number of fruits/plants, diameter of the fruits, thickness of pericarp, number of seeds, fruit weight, pH values, and plant dry matter respectively. The percentage of plants that germinated per treatment per variety was recorded after the first week of planting. This was repeated after two weeks of planting. The heights of the plants in each individual treatment per variety were determined from 21 days up to maturity level after germination by holding the highest leaf erect and the heights measured in centimetres. The number of plants that survive during the emergence of the first flower was determined and their percentages were taken. The number of leaves produced per plant was counted and recorded for each treatment after the emergence of the first flower. The leaf area of each treatment was determined by measuring the leaf area in centimetres using the formula below:

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

Where:
A=Leaf Area per plant
L=Length of Leaves
W=Width of leaves

The number of fruits produced per plant was determined by counting per treatment per variety and then recorded. The pericarps of the fruit of the different treatments were measured using a micrometre screw gauge in millimetres and recorded. The diameter of the fruits per treatment was determined by a micrometre screw gauge and recorded. The number of seeds produced per fruit was determined by counting after the fruits were cut open by a blade and chopping board. The pH values of the fruit juices were determined by a pH meter and recorded. The dry weights of the plants per treatment were taken in grams using a beam balance and recorded. The data generated were subjected to statistical analysis using Analysis of variance (ANOVA) to test for significant differences and Duncan's multiple range test (DMRT) was used to separate the means where there were differences. All data analyses were carried out using the Statistical Package for Social Science version 20 at 5% level of significance

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Results

Table 1: Effects of Sodium Azide on Seedling Length

Treatment	Varieties														
	21days			35days			49days			63days			77days		
	Rio Grande	Tandilo	UC882	Rio Grande	Tandilo	UC 82	Rio Grande	Tandilo	UC 82	Rio Grande	Tandilo	UC 82	Rio Grande	Tandilo	UC 82
Control	14.50 ± 0.50	16.80 ± 0.26	16.66 ± 0.57	22.66 ± 0.57	31.66 ± 1.15	30.66 ± 1.15	40.33 ± 0.57	44.63 ± 0.23	44.10 ± 3.08	53.33 ± 0.57	62.76 ± 0.92	48.33 ± 0.57	69.33 ± 1.15	67.56 ± 0.55	67.33 ± 1.15
0.01	11.60 ± 0.36	17.16 ± 0.23	16.33 ± 0.57	18.60 ± 0.36	25.00 ± 1.00	20.96 ± 0.57	32.16 ± 1.25	38.26 ± 0.23	38.25 ± 5.31	45.83 ± 0.28	46.00 ± 0.00	42.66 ± 2.51	55.55 ± 1.15	65.00 ± 8.66	56.00 ± 0.00
0.02	11.70 ± 0.26	16.83 ± 0.11	17.03 ± 0.15	16.10 ± 0.10	28.53 ± 0.50	21.93 ± 0.11	27.66 ± 0.57	26.66 ± 1.15	31.00 ± 5.80	39.16 ± 1.44	40.66 ± 0.57	39.26 ± 0.46	71.66 ± 1.15	73.66 ± 2.08	46.66 ± 1.15
0.03	11.53 ± 0.20	16.30 ± 0.20	17.26 ± 0.25	23.80 ± 1.04	32.00 ± 1.73	18.46 ± 0.40	27.33 ± 0.57	35.66 ± 1.15	30.66 ± 3.87	42.33 ± 1.15	40.66 ± 0.28	39.33 ± 0.57	71.33 ± 0.57	71.00 ± 5.19	50.66 ± 0.57
0.04	11.50 ± 0.43	16.20 ± 0.17	16.81 ± 0.46	16.70 ± 0.20	17.60 ± 0.51	18.20 ± 0.36	27.66 ± 0.57	31.83 ± 0.28	31.27 ± 2.99	41.30 ± 0.51	42.66 ± 0.57	27.00 ± 1.73	68.83 ± 1.60	60.00 ± 0.00	37.33 ± 1.15
Mean	12.16	16.66	16.81	19.77	26.96	22.04	31.03	35.41	38.73	44.39	46.55	43.42	67.36	67.44	51.60
Stand Dev.	1.24	0.41	0.46	3.48	5.58	4.72	5.19	6.28	6.88	5.19	8.64	7.67	6.24	6.27	10.33
Variety	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Treatment	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Var*Treat	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Keys: 0.01, 0.02, 0.03 and 0.04 g = treatment concentrations

Effects of Sodium Azide on Number of leaves of tomato

The results of this study revealed that there is a significant effect of Sodium Azide treatments on number of seeds of tomato (Table 2). At 21 days after germination, the number of leaves of all the tomato varieties are the same, (Rio Grande, Tandilo and UC 82) all have 18 number of leaves.

Table 2: Effects of Sodium azide on Number of Leaves

Treatment	Varieties														
	21days			35days			49days			63days			77days		
	Rio Grande	Tandilo	UC82	Rio Grande	Tandilo	UC 82	Rio Grande	Tandilo	UC 82	Rio Grande	Tandilo	UC 82	Rio Grande	Tandilo	UC 82
Control	18.00 ± 0.00	18.00 ± 0.00	18.00 ± 0.00	21.00 ± 0.00	30.00 ± 0.00	23.00 ± 0.57	40.66 ± 0.57	69.66 ± 0.57	54.33 ± 0.57	60.00 ± 0.00	77.00 ± 1.73	63.33 ± 2.88	126.00 ± 1.73	128.33 ± 2.88	125.00 ± 4.58
0.01	18.00 ± 0.00	18.00 ± 0.00	18.00 ± 0.00	18.00 ± 0.00	25.66 ± 2.08	20.33 ± 0.57	37.00 ± 1.15	63.66 ± 0.57	50.00 ± 0.00	65.33 ± 0.57	64 ± 1.73	70.66 ± 1.15	104.33 ± 1.15	92,33 ± 1.15	100.00 ± 2.00
0.02	18.00 ± 0.00	18.00 ± 0.00	18.00 ± 0.00	18.00 ± 0.00	24.00 ± 0.00	24.00 ± 0.00	39.00 ± 0.00	59.00 ± 0.00	47.00 ± 1.73	63.00 ± 0.00	55.00 ± 0.00	37.33 ± 1.15	105.66 ± 0.57	107.00 ± 1.73	63.00 ± 2.64
0.03	18.00 ± 0.00	18.00 ± 0.00	18.00 ± 0.00	27.33 ± 1.57	24.00 ± 0.00	24.00 ± 0.00	38.00 ± 0.00	60.33 ± 0.57	39.00 ± 0.00	40.00 ± 0.00	75.33 ± 1.15	62.00 ± 2.00	70.33 ± 2.30	70.00 ± 0.00	69.66 ± 9.07
0.04	18.00 ± 0.00	18.00 ± 0.00	18.00 ± 0.00	21.33 ± 1.53	24.00 ± 0.00	24.00	36.00 ± 0.57	37.00 ± 0.00	23.00 ± 0.00	45.00 ± 0.00	43.66 ± 1.15	39.00 ± 0.00	95.46 ± 1.00	70.66 ± 1.15	50.00 ± 0.00
Mean	18.00	18.00	18.00	21.13	25.53	22.93	38.33	57.93	42.66	54.66	63.00	54.46	95.46	93.66	81.53
Stand Dev.	0.00	0.00	0.00	3.60	2.53	1.53	1.54	11.49	11.44	10.56	13.03	14.19	22.45	23.05	28.48
Variety	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Treatment	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Var*Treat	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	`0.000	0.000	0.000	0.000

Key: 0.01, 0.02, 0.03 and 0.04g = treatment concentration

Effects of Sodium Azide on Leaf Area of Tomato: The results of this study indicated significant effects of Sodium Azide on Leaf Area of Tomato (Table 3).

Table 3: Effects of Sodium Azide on Leaf Area (cm^2)

Treatment	Varieties														
	21days			35days			49days			63days			77days		
	Rio Grande	Tandilo	UC82	Rio Grande	Tandilo	UC82	Rio Grande	Tandilo	UC82	Rio Grande	Tandilo	UC 82	Rio Grande	Tandilo	UC 82
Control	2.46 ± 0.57	2.86 ± 0.15	3.13 ± 0.57	1.36 ± 0.11	2.63 ± 0.57	3.00 ± 0.00	2.26 ± 0.57	2.43 ± 0.11	2.60 ± 0.00	4.46 ± 0.57	4.63 ± 0.11	4.63 ± 0.11	3.43 ± 0.57	3.43 ± 0.57	6.70 ± 0.17
0.01	1.46 ± 0.57	2.83 ± 0.11	3.00 ± 0.00	0.90 ± 0.00	2.50 ±0.00	2.63 ±0.15	2.33 ± 0.11	2.26 ± 0.11	2.30 ± 0.00	2.43 ± 0.57	3.76 ± 0.11	4.20 ± 0.43	3.50 ± 0.00	3.50 ± 0.00	3.76 ± 0.11
0.02	1.43 ± 0.57	2.70 ± 0.20	3.13 ± 0.57	2.30 ± 0.00	2.40 ± 0.20	2.50 ± 0.17	2.30 ± 0.00	2.50 ± 0.00	2.10 ± 0.00	3.00 ± 0.10	2.50 ± 0.00	4.76 ± 0.11	3.26 ± 0.57	2.90 ± 0.00	2.23 ± 0.11
0.03	1.43 ± 0.11	3.36 ± 0.57	2.93 ± 0.11	2.30 ± 0.20	2.76 ± 0.57	2.66 ± 0.23	2.30 ± 0.00	2.40 ± 0.57	2.50 ± 0.00	2.16 ± 0.28	2.40 ± 0.00	2.66 ± 0.25	2.10 ± 0.00	3.10 ± 0.00	3.36 ± 0.23
0.04	1.30 ± 0.10	3.06 ±0.57	3.16 ± 0.11	1.06 ± 0.57	2.46 ± 0.57	1.83 ±0.11	2.16 ± 0.57	2.50 ± 0.00	2.30 ± 0.00	2.10 ± 0.00	2.50 ± 0.00	1.96 ± 0.57	2.30 ± 0.00	3.13 ± 0.57	2.30 ± 0.00
Mean	1.62	2.96	3.07	1.59	2.55	2.52	2.27	2.42	2.36	2.83	3.64	3.21	2.92	3.21	3.67
Stand Dev.	0.45	0.26	0.11	0.63	0.15	0.41	0.07	0.10	0.18	0.94	1.18	1.05	0.61	0.23	1.68
Variety	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Treatment	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Var*Treat	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Key: 0.01, 0.02, 0.03 and 0.04 g = treatment concentration

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Effects of sodium azide on fruit and yield characteristics of tomato: The results showed significant differences between treatments and across all the varieties on yield characteristics of tomato.

Effects of Sodium Azide on Number of Fruits: The result of this study indicated significant effects of Sodium Azide on a number of fruits of tomato (Table 4). The result showed significant effects (P<0.0001) of the treatment on the Rio-Grande variety where the control had the highest number of fruits (4.33). This is followed by 0.02g (4.00) , while the least is 0.01g with the 3.33 number of fruits. On the other hand, 0.02g produced the highest number of fruits in Tandilo (4.66), followed by 0.03g with 4.00, while 0.01g had the least (3.00). Meanwhile, 0.04g had the highest number of fruits in UC 82. This is followed by 0.02g (4.33) number of fruits, while control had the least number of fruits (3.66).

Effects of Sodium Azide on Fruit Weight: The result of this study indicated significant effects of Sodium Azide on the weight of fruits of tomato (Table 4). The result showed a significant effect (p<0.0001) of the treatment on the Rio-Grande variety where the control had the highest weight of fruits (84.00), followed by 0.03g (83.00), while 0.04g had the least fruit weight (71.00). So also, 0.02g had the highest fruit weight in Tandilo (74.00). This is followed by 0.04g (68.33), while the control had the least weight of fruits (64.00). Furthermore, 0.01g had the highest fruit weight in UC 82 (78.33), followed by 0.02g with 77.33, while the least is 0.04g (64.66).

Table 4: Effects of Sodium Azide on Number of Fruits/Weight of Fruit (g) /Diameter of Fruits (cm) (Post harvest)

Treatment		Number of fruits			Weight of fruits			Diameter of fruits	
	Rio Grande	Tandilo	UC 82	Rio Grande	Tandilo	UC 82	Rio Grande	Tandilo	UC 82
Control	4.33 ± 0.57	3.66 ± 1.52	3.66 ± 0.57	72.00 ± 7.00	64.00 ± 3.60	70.66 ± 8.14	16.33 ± 1.52	17.26 ± 0.25	18.23 ± 0.30
0.01	3.33 ± 0.57	3.00 ± 1.00	4.33 ± 0.57	77.66 ± 2.51	65.00 ± 13.07	78.33 ± 1.15	17.33 ± 1.15	17.86 ± 0.32	16.16 ± 0.40
0.02	4.00 ± 1.00	4.66 ± 0.47	4.33 ± 0.57	84.00 ± 3.60	74.00 ± 4.58	77.33 ± 4.92	16.70 ± 1.90	16.60 ± 0.36	17.03 ± 0.30
0.03	3.66 ± 1.52	4.00 ± 1.00	4.00 ± 0.00	83.00 ± 7.00	67.66 ± 3.05	74.33 ± 8.14	17.66 ± 1.52	18.70 ± 0.36	17.70 ± 1.40
0.04	3.33 ± 1.52	4.00 ± 0.00	4.66 ± 1.52	71.00 ± 1.73	68.33 ± 2.88	64.66 ± 7.23	18.13 ± 0.32	17.73 ± 0.25	18.56 ± 0.58
Mean	3.73	3.86	4.20	77.53	67.80	73.06	17.23	17.63	17.54
Stand Dev.	1.03	0.99	0.77	6.94	6.69	7.52	1.35	0.76	1.08
Variety	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Treatment	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Var*Treat	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Key: 0.01, 0.02, 0.03 and 0.04g = treatment concentration

Effects of Sodium Azide on the Thickness of Pericarp (mm) and Number of seeds: The result of this study indicated significant effects of Sodium Azide on the thickness of the Pericarp of Tomato (Table 5). The results showed the significant effects (p<0.0001) of the treatment on the Rio-Grande variety where treatment 0.03g had the highest thickness of pericarp (6.76mm). This is followed by 0.04g (6.70mm), while 0.02g had the least thickness of pericarp (5.53mm). Also, 0.03g had the highest thickness of pericarp (6.90mm) in Tandilo. This is followed by 0.04g (6.42mm), while 0.02g had the least thickness of pericarp (6.42mm). In addition, 0.04g had the highest thickness of pericarp (7.50mm) in UC 82, followed by 0.03g (7.23mm), while 0.01g had the least with 6.70mm.

Table 5: Effects of Sodium Azide on Thickness of Pericarp/Number of Seeds (Postharvest)

Treatment		Thickness of pericarp			Number of seeds	
	Rio-Grande	Tandilo	UC 82	Rio-Grande	Tandilo	UC 82
Control	6.53 ± 0.20	6.00 ± 0.36	6.73 ± 0.25	72.00 ± 7.00	64.00 ± 3.60	70.66 ± 8.14
0.01	6.66 ± 0.15	6.00 ± 0.20	6.70 ± 0.17	77.66 ± 2.51	65.00 ± 13.07	78.33 ± 1.15
0.02	5.53 ± 0.40	6.23 ± 0.32	6.53 ± 0.25	84.00 ± 3.60	74.00 ± 4.58	77.33 ± 4.93
0.03	6.70 ± 0.43	6.90 ± 0.30	7.23 ± 0.20	83.00 ± 7.00	67.66 ± 3.05	74.33 ± 8.14
0.04	6.70 ± 0.20	6.42 ± 0.56	7.50 ± 0.20	71.00 ± 1.73	68.33 ± 2.88	64.66 ± 7.23
Mean	6.42	6.42	6.94	185.33	214.06	250.86
Stand Dev.	0.53	0.54	0.42	7.00	38.30	51.79
Variety	0.000	0.000	0.000	0.000	0.000	0.000
Treatment	0.000	0.000	0.000	0.000	0.000	0.000
Var*Treat	0.000	0.000	0.000	0.000	0.000	0.000

Key: 0.01, 0.02, 0.03 and 0.04g = treatment concentration

Effects of Sodium Azide on pH values of Tomato Juice

The result of this study further indicated significant effects of Sodium Azide on the pH values of Tomato Juice **(**Table 6). The result showed a significant effect (p<0.0001) of the treatment on the Rio Grande variety where 0.04g has the highest pH value (4.33). This is followed by 0.02g (4.23), while 0.03g had the least values (4.10). Furthermore, the control has the highest pH values in Tandilo ((4.36). This is followed by 0.01g (4.26), while 0.03g showed the least value of pH (4.03). In addition, the control has the highest pH values on UC 82 (4.36), followed by 0.01g (4.26), while 0.03g has the lowest pH value (4.03).

Table 6: Effects of Sodium Azide on pH Values of Tomato Juice

Treatment	Rio Grande	Tandilo	UC 82
Control	4.13 ± 0.15	4.36 ± 0.25	4.36 ± 0.25
0.01	4.16 ± 0.15	4.26 ± 0.25	4.26 ± 0.25
0.02	4.23 ± 0.15	4.13 ± 0.15	4.13 ± 0.15
0.03	4.10 ± 01.0	4.03 ± 0.11	4.03 ± 0.11
0.04	4.33 ± 0.25	4.20 ± 0.20	4.20 ± 0.20
Mean	4.19	4.20	4.20
Standard deviation	0.16	0.20	0.20
Variety	0.000	0.000	0.000
Treatment	0.000	0.000	0.000
Var*trt	0.000	0.000	0.000

Effects of Sodium Azide on Plant Dry matter (g)

The result of this study indicated significant effects of Sodium Azide on Plant dry matter of Tomatoes (Table 7). The result showed the significant effects ($p<0.0001$) of the treatment on the Rio Grande variety where 0.03g has the highest plant dry weight (3.60g). This is followed by 0.04g (3.56g), while 0.01g has the least dry matter (2.46g). On the other hand, 0.02g has the highest plant dry matter (3.93g) in Tandilo. This is followed by 0.04g (3.83g), while the control has the least dry matter (3.13g). In addition, 0.01g has the highest plant dry weight in UC 82 (3.96g), this is followed by 0.02g (3.60g), while 0.03g has the least plant dry matter (2.96g).

Table 7: Plant Dry Weight (g)

Treatment		**Variety**	
	Rio-grande	**Tandilo**	**Uc 82**
Control	3.03 ± 0.14	3.13 ± 0.66	3.00 ± 1.34
0.01	2.46 ± 0.86	3.56 ± 0.64	3.96 ± 0.65
0.02	3.50 ± 0.65	3.93 ± 0.15	3.60 ± 0.81
0.03	3.60 ± 0.36	3.46 ± 0.55	2.96 ± 1.35
0.04	3.56 ± 0.20	3.83 ± 0.34	3.53 ± 0.47
Mean	3.23	3.41	3.41
Standard deviation	0.64	0.92	0.71
Variety	0.000	0.000	0.000
Treatment	0.000	0.000	0.000
Var*trt	0.000	0.000	0.000

Discussion

Sodium azide treatment in the recent study was noticed to have vegetative affected the number of leaves for all the three tomato Cultivars. It has been used in a wide range of applications to improve crops' ability to perform well than their counterparts which were not treated with such mutagen. The 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 increased 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 a decrease in germination with an increase in the dose of chemical mutagens. In this research, germination percentage, survival percentage, plant height leaf number and area are affected by increasing concentration of sodium azide. This finding conformed to the earlier report by Aminu et al. (2017) that, the viable mutants observed are mainly dependable measures of genetic effect in mutagen. The increase 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 an increase in growth and yield parameters of tomatoes due to sodium azide treatments.

So also, it has been reported by Kumar et al. (2009) that chemical mutagens induce physiological damages (injury), gene mutations and chromosomal mutations in the organisms in the M1 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 Aminu et al. (2017) who independently reported similar effects of mutagens Tomato and Kumar et al. (2009) in cowpeas. The increase 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 of Maluszynski et al. (2001) who independently reported an increase in leaf number and leaf area among Zeamays mutants. Mutagenic treatments at all concentrations affected germination percentage, seedling height, height at maturity, survival rates, number of leaves, leaf area, number of fruits, thickness of pericarp, number of seeds, fruit weight, pH values and plant biomass respectively. This is in concordance with the result obtained by Adamu et al. (2002). The increase 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 an increased in growth and yield parameters of tomatoes due to sodium azide treatments. There were reductions in the germination and survival percentages with increasing concentrations of Sodium azide.

Vegetative leaves and fruiting traits were observed to be produced more in the Rio Grande variety than other two cultivars. The effect was more pronounced in concentrations 0.02 g and 0.03 g. Previous studies have also reported such concentrations to inhibit a number of leaves and fruits for different crops, (Dhanavel et al., 2008). Noteworthy, Sodium Azide was very effective in inducing mutation concerning the parameters observed. The most effective concentration is 0.03g. Sodium Azide therefore could be used to increase variability in tomatoes and eventually increase the possibility of isolating beneficial mutants for improvement of tomato production. This is similar to the work done by Aminu et al. (2017) who found out that Sodium Azide concentration affects the growth and development of Tomato. The increase 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 tomatoes. The increase in dry weights of the tomato varieties due to sodium azide treatments is in contrast to the findings of Mensah et al. (2007).

Conclusion

This study was conducted to ascertain the effects of sodium azide at various levels of treatments on the morphological traits of Tomato (*Solanum lycopersicum).* This mutagen showed significant effects on the traits evaluated as great variation was observed as a result of the treatments. Induced mutation using various concentrations of sodium azide was 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 mutant tomatoes The application of sodium azide on Tomato is easy and inexpensive for improvement of agronomic traits. The mutagenic effects of sodium azide appear soon after sowing the seeds and can be observed by the naked eye. However, sodium azide has been used in various crops to improve their yield and quality traits and create resistance to their biotic and abiotic stresses. Rio Grande variety was observed to be responsive in all measured traits to sodium azide treatment at 0.02 and 0.03 g concentration respectively. It was generally concluded that the concentration of sodium azide positively affected growth and yield by inducing variability that could be exploited in the improvement of highly economic crops like tomatoes.

Recommendations

The overall results showed that sodium azide created high variability in agronomic traits hence the following recommendations:

- Further studies should be conducted to determine the heterotic value of crossing some of these mutants.
- Further trials for disease resistance, water tolerance, and drought tolerance, could be undertaken in subsequent generations to determine mutants that can adapt and produce maximally under such conditions.
- Further research could be carried out to determine the biochemical and molecular effects of these mutagens on Tomatoes.

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