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Foliar Application of Calcium silicate Alleviate the Deleterious Effect of African Armyworm on Maize Plants

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ABSTRACT

Maize is one of the key determinants of food security around the world. In Africa, the productivity of maize is not yet satisfactory, as its yield, quantity and quality of the maize plant is degraded by African armyworm infestation. Widespread indiscriminate use of chemical pesticides undermines the pest control, and therefore the use of biodegradable botanical substances such as Calcium silicate is of utmost importance. Two varieties of maize (TZm-223 and TZm-224) were subjected to different concentration of Calcium silicate at 0, 100 150 and 200 mM. Thereafter, the Calcium silicate was further used to enhanced the growth traits, plant biomass, photosynthetic pigments, antioxidants contents and enzyme activities of maize under African armyworm infestation. The results revealed that different concentrations of Calcium silicate improve the growth traits such as plant heights, leaf area, leaf area ratio, net assimilation rate and plant biomass of the two maize varieties. Chlorophylls and carotenoid accumulation, antioxidant contents and enzyme activities were significa ntly ($p \leq 0.05$) influenced by Calcium silicate. Application of different concentration of Calcium silicate significantly enhanced the leaf area, net assimilation, leaf area ratio, chlorophyll b, total chlorophyll, carotenoid, TSS, SOD and APX of the two varieties of maize under African armyworm infestation. The two varieties of maize responded differently to different concentrations under the infestation. Calcium silicate can therefore stand to be effective measures for improving the yield and productivity of maize and, managing and controlling African armyworm infestation.

Keywords: Armyworm, Enzyme, Growth, Insect, Pigment.

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1. Introduction

African armyworm (*Spodoptera exempta* W.) is a voracious insect pest of maize belonging to the Noctuidae family. Presently, it is subsequently spread across all Africa countries and Australia and Asia [13]. The pest has been identified on more than 350 host plants [29, 31], but its major hosts are grain crops, including rice, wheat, and sorghum [22]. The major features of African armyworm that has contributed to its rapid spread across Africa is the remarkable outbreaks occurring during the rainy season after periods of prolonged drought, high fecundity rate, ability to lay up to 1500 eggs at their adult lifespan approximately three weeks under optimal conditions. African armyworm can rapidly colonize maize fields over a large area immediately after seedlings emergence and can then quickly build up populations if not checked. The growing points of African armyworm on maize plant is the leaves, cobs, and seeds. Its preference to maize to other crops might be because maize plants are vulnerable to pest attack, easy access and burrow into the seeds and cobs, and majorly the nutrients derived from the crop [2].

In Africa, the productivity of maize under African armyworm infestation is not satisfactory, as the insect has the potential to degrade yield, quantity, and quality of the maize plant. Presently, there was a paucity of knowledge on the management and control of African armyworm. Governments from various clans released millions of dollars as emergency funds to procure and distribute insecticides for its control. Many of these insecticides contained highly hazardous substances [5] and, were found to be ineffective [17]. The use of synthetic chemical pesticides was found to be significantly risky and were associated with harming the health of both human and animals besides the damage to the environments [30]. Widespread indiscriminate use of chemical pesticides also undermines the pest control services provided by natural enemies [10, 38]. Cultural control methods such as the use of organic amendments, crop rotation and biological control have been introduced and tried to manage the insect pest. However, this method was also found to be less effective as it requires skills and expertise. Therefore, there is urgent need for more suitable and cost-effective measures especially easily locally adaptable, accessible, and acceptable control measures for smallholder farmers in African countries where the infestation is at its peak [16]. Effective biodegradable botanical substances such as silicon derived compounds are more recommendable than the use of hazardous synthetic chemicals [1].

In most agricultural soil, silicon is known to exists as sodium and Calcium silicate ($NaSiO_2$ and $CaSiO_4$). Meanwhile, Calcium silicate is involved in inducing biochemical defense to insect pest attack by enhancing production of defensive enzymes and phenolic compounds. Also, Calcium silicate can induce defense mechanisms by causing decreased in digestibility capacity of insect pest, increased abrasiveness of plant tissues, and enhanced production and accumulation of peroxidases, chitinases, lignin and phenolics. Furthermore, Calcium silicate when accumulated in the epidermal tissue, can act as a mechanical barrier in leaf epidermis cells, increasing hardness that causes wear to insect mandibles and reducing digestibility [25, 40]. To date, numerous studies have documented the ability of Calcium silicate to improve resistance of plants to insect attack and reduce insect growth and reproduction in several plant crops [26]. Therefore, this study aims at understanding the effects of the application of Calcium silicate on maize and the application of different dose of the substance to ameliorate the infestation of fall armyworm and contributes to the higher productivity of maize. This will further provide agricultural importance of Calcium silicate in plants, and to underline it usefulness in controlling insect pests.

2. Materials and Methods

2.1. Experimental Organism and Raising of Seedlings

The experiment was conducted in the screenhouse of Department of Plant Biology, Osun State University, Osogbo, Nigeria. Seeds of two accessions of maize (TZm 223 and TZm 224) utilized in the experiment were obtained from International Institute of Tropical Agriculture, Ibadan, Oyo State, Nigeria. The seeds were sown in the nursery and nineth day after sowing, the seedlings were transplanted at the rate of two per pot into sixty-four plastic pots each containing 10kg of soil.

2.2. Foliar Application of Calcium silicate

Seven days after transplanting of seedlings into the sixty-four pots, foliar application of Calcium silicate was done at different level of concentrations (0mM, 100mM, 150mM and 200mM).

2.3. Infestation of the Maize Seedlings with African Armyworm

Plants in the sixty-four pots were divided into two groups of thirty-two pots each. The first thirty-two pots were placed in a mini screen house while the other thirty-two pots were arranged in the main screen house. African armyworm was introduced into the plants in the mini screen house seven days after foliar application of Calcium silicate while those in the main screen house were left undisturbed. Plants in each pot were supplied with 250 mL of water in the morning and evening throughout the experimental period.

2.4. Measurement of Morphological and Growth Indices

The following morphological parameters were taken at weekly intervals and for a period of eight weeks: Plant height, number of leaves and leaf area. Growth indices like Leaf Weight Ratio (LWR) and Root shoot Ratio (RSR) were determined using the method of [36] as follows:

LWR= LDW/TDW

RSR= RDW/SDW

Where: LWR-Leaf weight Ratio; LDW= Leaf Dry Weight; TDW= Total Dry Weight.

RSR= Root Shoot Ratio; RDW= Root Dry Weight; SDW= Shoot Dry Weight.

2.5. Estimation of Photosynthetic Pigment

2 g of leaves was harvested from each treatment regimes. The leaves were placed in a mortal and 20 ml of 80% of acetone was added. It was blended with a pestle and mortal. The homogenate was then sieved through a Whatman's No1 filter paper and the filtrate was collected. The absorbance of the filtrates was read on a digital spectrophotometer at wavelengths of 470 nm, 646 nm, and 663 nm. The analysis was carried out in three replicates. The concentrations of chlorophyll a, b, total chlorophyll, and carotenoid were estimated using Beer-Lambert expression [36].

Chlorophyll a (µg/ml) = $12.21A_{663}$- $2.81A_{646}$

Chlorophyll b (µg/ml) = $20.13A_{646}$- $5.03A_{663}$

Total Chlorophyll (µM) = $7.93A_{663}$- $19.53A_{646}$

Carotenoids (µg/ml) = $(1000A_{470}$- 3.27[Chl a] – 104[Chl b])/227*

In the carotenoid equation, '[chl a]' and '[chl b]' refer to the calculated concentration of chl 'a' and chl 'b' from the previous equations.

2.6. Estimation of Enzyme and Non-enzyme Antioxidants

2.6.1. Determination of Polyphenol Oxidase

The activity of PPO was performed according to [41] by adding 1.3 mL of sodium phosphate buffer (0.2 M) at 6.0 pH, mixed with 1.5 mL of catechol (Sigma-Aldrich, EUA) (0.2 M) as a substrate; the reaction mixture was incubated at 30ºC until the temperature stabilized. 30 µL of enzymatic extract was added, and the absorbance at 425 nm was measured every 30s for 2 min. PPO activity was calculated based on the molar extinction coefficient of 3400 mM^{-1} cm^{-1} for catechol. One enzymatic unit (EU) of PPO was refined as the amount of extract that could increase the absorbance by 0.001 absorbance unit in 1 minute. As a blank, the enzymatic extract was used which was boiled for 10 min.

2.6.2. Determination of Peroxidase (POD)

The POD assay was performed according to [41], by adding different volumes of extract; namely 50 µL of the extract to the reaction medium containing 1750 µL of phosphate buffer (0.2 M, pH 6.0), 100 µL guaiacol (5 g L–1), and 100 µL hydrogen peroxide (0.8 g L–1). Readings were taken using a spectrophotometer (Libra S8, Biochrom, Cambridge, UK) at 470 nm at 30°C every 1, 2 and 3 minutes. POD activity was calculated based on the molar extinction coefficient of 26.6 mM^{-1} cm^{-1} for guaiacol and expressed in µmol min–1 g FM–1. For the control, guaiacol was replaced with the reaction buffer.

2.6.3. Determination of Superoxide Dismutase (SOD)

Superoxide Dismutase activity was determined by its ability to inhibit the auto-oxidation of epinephrine determined by the increase in absorbance at 480nm as described by [42]. The reaction mixture (3 mL) contained 2.95mL 0.05M sodium carbonate buffer pH 10.2, 0.02 ml of liver homogenate and 0.03 mL of epinephrine in 0.05 N HCL was used to initiate the reaction. The reference cuvette contained 2.95ml buffer, 0.03mL of substrate (epinephrine) and 0.02mL of water. Enzyme activity was calculated by measuring the change in absorbance at 480nm for 5 min. $\sum$= $4020M^{-1}$ cm^{-1}

2.6.4. Determination of Ascorbic Peroxidase (APX)

The measure of APX activity using spectrophotometer was determined as described by [34]. The assay mixture

consisted of 100µg of the enzyme extract added to assay solution (50 mM K-phosphate buffer (pH 6.6) with 2.5mM ascorbate) and the reaction was initiated by the addition of 10 mM H_2O_2. The decrease in the absorbance of ascorbate was recorded at 290 nm for 3 min against assay solution ($\varepsilon = 2.8\ mM^{-1}\ cm^{-1}$).

2.6.5. Determination of phenylalanine (PAL)

PAL activity was assayed by measuring the L- phenylalanine formation at 290 nm using a UV-1800 UV–vis spectrophotometer (Genesys 5, ThermoSpectronic, Rochester, NY, USA), and calculated using a standard L-phenylalanine curve. The enzyme reaction mixture contained 100mM Tris HCl, 40mM trans-cinnamic acid, and an aliquot of the enzyme in a total volume of 1ml. PAL activity was expressed in U g^{1} FW according to [32].

2.6.6. Determination of Total soluble sugar (TSS)

Total soluble sugars were determined based on the phenol-sulphuric acid method [14]. 0.1 g of dry leaves was homogenized with deionized water, filtered and the extract was treated with 2% (w/v) phenol and 98% sulphuric acid. The mixture was incubated at room temperature for 1 hour and then absorbance at 490 nm was read on a spectrophotometer. Contents of soluble sugar were determined by using glucose as a standard and expressed as mg/g. A statistical analysis was performed using SAS version 9.1 quantitative analytical software package and post hoc testing was carried out using Duncan multiple range test to separate the means at 0.05 probability level.

2.6.7. Determination of Malondialdehyde (MDA)

Malondialdehyde (MDA) an index of lipid peroxidation was determined using the method of 1.0 ml of the supernatant was added to 2 ml of (1:1:1 ratio) TCA-TBA-HCl reagent (thiobarbituric acid 0.37%, 0.24N HCl and 15% TCA) tricarboxylic acid- thiobarbituric acid-hydrochloric acid reagent boiled at 100^{o}C for 15 minutes and allowed to cool. Flocculent materials were removed by centrifuging at 3000 rpm for 10 min. The supernatant was removed, and the absorbance read at 532 nm against a blank. MDA was calculated using the molar extinction coefficient for MDATBA- complex of $1.56 \times 10^{5}\ M^{-1}CM^{-1}$.

2.6.8. Determination of Proline

Proline accumulation in the fresh leaves was determined according to the method of [4]. Free proline was extracted from the plant leaves using aqueous sulfosalicylic acid. The filtrate (1mL) was mixed with equal volumes of glacial acetic acid and ninhydrin reagent (1.25 g ninhydrin, 30 mL of glacial acetic acid, 20 mL of H_3PO_4) and incubated for1 hour at 100°C. The reaction was stopped by placing the test tubes in cold water. The reaction mixtures were rigorously mixed with 3 mL toluene. The absorbance of toluene phase was estimated at 520 nm using a spectrophotometer. The proline concentration was determined using a standard curve. Free proline content was expressed as µmol/L of plant parts.

2.6.9. Estimation of Total Phenols

The Follins method was used to determine the phenol content. ImL of the extract was placed in a test tube, 2.5ml of 10% Folin-Ciocalteu's reagent dissolved in water and 2.5 ml of 7.5% of NaHCO3 aqueous solution were added. The samples were thereafter incubated in a thermostat at 45°C for 45 min. The absorbance was determined using spectrophotometer at wavelength = 765 nm. The samples were prepared in triplicate for each analysis and the mean value of absorbance was obtained.

3. RESULTS

3.1. Effect of Calcium silicate on growth parameters of maize (TZm-223) grown under African Armyworm infestation

The growth attributes such as plant heights, leaf area, leaf area ratio and net assimilation rates of the two varieties of maize appreciably increased under different concentrations of Calcium silicate. Although there was no significant difference was observed in the plant heights among the treated plants in the two varieties, but the plants treated with 100 mM of Calcium silicate had the highest shoot heights in TZm-223 variety, while those treated with 0mM of Calcium silicate had the highest shoot heights in TZm-224 variety. Meanwhile, a significant difference was observed in the leaf area, leaf area ratio and net assimilation rates among the treated plants in the two varieties (Table 1).

The application of Calcium silicate further influences the growth attributes of the two varieties of maize significantly under African armyworm infestation. Meanwhile, plant heights, leaf area, leaf area ratio and net assimilation rates increased over time for all treatments. Maximum plant heights, leaf area and leaf area ratio were obtained in the two varieties of maize treated with 100 mM of Calcium silicate. Highest net assimilation rate was obtained those treated 150 mM of Calcium silicate in TZm-223, and in those treated with0 mM of Calcium silicate in TZm-224 (Table 1).

Table 1: Effect of Calcium silicate on Growth Parameters of Maize (TZm-223 and TZm-224) Grown under African Armyworm Infestation

Growth Attributes								
Treatments	PH (cm)		LA (cm^2)		LAR (cm2/g)		NAR	
Without armyworm infestation								
	TZm 223	Var.2	TZm 223	TZm 224	TZm 223	TZm 224	TZm 223	TZm 224
Ca1W1	46.55a	56.03a	107.73b	93.58b	98.39a	67.47c	1.52b	2.58b
Ca2W1	54.24a	49.46a	89.46c	102.02a	58.19c	63.76d	3.39a	3.33a
Ca3W1	54.39a	49.78a	122.33a	87.66d	73.69b	80.02b	3.33a	1.58c
Ca4W1	54.49a	50.04a	89.45d	89.22c	63.05bc	85.09a	2.69ab	1.41d
LSD		7.65	0.94	1.08	14.06	1.08	1.22	0.02
With armyworm infestation								
Ca1W2	53.16a	51.30a	83.83b	104.79a	69.06bc	59.51c	2.01c	3.95a
Ca2W2	51.68a	54.58a	93.82a	91.33d	66.96c	69.51bc	2.63a	2.32bc
Ca3W2	47.69b	55.67a	93.88a	98.42c	105.72a	83.85a	0.92d	1.86c
Ca4W2	52.98a	55.95a	93.48a	100.47b	71.198b	73.57ab	2.32b	2.44b
LSD	3.52	10.33	0.77	0.91	3.69	10.83	0.23	0.57

Means with the same subscripts within the same column are not significantly different at $p \leq 0.05$. TZm 223-TZm-223, VAr.2-TZm-224. Ca1W1- Without African Armyworm at 0mM of Calcium silicate, Ca2W1- Without African Armyworm at 100mM of Calcium silicate, Ca3W1- Without African Armyworm at 150mM of Calcium silicate, Ca4W1- Without African Armyworm at 200 mM of Calcium silicate. Ca1W2- With African Armyworm at 0mM of Calcium silicate, Ca2W2- With African Armyworm at 100 mM of Calcium silicate, Ca3W2- With African Armyworm at 150 mM of Calcium silicate, Ca4W2- With African Armyworm at 200 mM of Calcium silicate.

3.2. Effect of Calcium silicate on photosynthetic pigment of maize (TZm-223) grown under African Armyworm infestation

Calcium silicate at different concentration significantly influences the photosynthetic pigment of the two varieties of maize. The chlorophyll a, b, total chlorophyll, and carotenoid content of the two varieties of maize at 100, 150 and 200 mM of Calcium silicate were found to be higher than the untreated maize plant, except for the chlorophyll b and total chlorophyll of TZm-224 variety. Meanwhile, the photosynthetic pigments of the two varieties of maize vary differently with different concentration of Calcium silicate. Significant difference ($p \leq 0.05$) was observed among the treated plants of the two varieties (Table 2).

Calcium silicate at different concentration had significant effect on the photosynthetic pigment of the two varieties of maize grown under African armyworm infestation. Though there was variation in which Calcium silicate had at different concentration on photosynthetic pigments of the two varieties of maize as affected by army worms. Chlorophyll a content of TZm-223 and TZm-224 under African armyworm infestation was found to be highest in plants treated with 0 mM of Calcium silicate, and 200mM of Calcium silicate. Chlorophyll a, b, total chlorophyll, and carotenoid content of TZm-223 and TZm-224 under African armyworm infestation was found to be highest in plants treated with 0 mM of Calcium silicate, and 200mM of Calcium silicate. There was significant difference ($p \leq 0.05$) in Chlorophyll a, b, total chlorophyll, and carotenoid content of TZm-223 and TZm-224 among the treatment under African armyworm infestation (Table 2).

Means with the same subscripts within the same column are not significantly different at $p \leq 0.05$. TZm 223-TZm-223, VAr.2-TZm-224. Ca1W1- Without African Armyworm at 0mM of Calcium silicate, Ca2W1- Without African Armyworm at 100mM of Calcium silicate, Ca3W1- Without African Armyworm at 150mM of Calcium silicate, Ca4W1- Without African Armyworm at 200 mM of Calcium silicate. Ca1W2- With African Armyworm at 0mM of Calcium silicate, Ca2W2- With African Armyworm at 100 mM of Calcium silicate, Ca3W2- With African Armyworm at 150 mM of Calcium silicate, Ca4W2- With African Armyworm at 200 mM of Calcium silicate.

Table 2: Effect of Calcium silicate on Photosynthetic Pigments of Maize (TZm-223 and TZm-224) Grown under African Armyworm Infestation

Photosynthetic Pigments								
Treatments	Chlorophyll a (µg/mL)		Chlorophyll b (µg/mL)		Total Chlorophyll (µg/mL)		Carotenoid (µg/mL)	
Without armyworm infestation								
	TZm 223	TZm 224	TZm 223	TZm 224	TZm 223	TZm 224	TZm 223	TZm 224
Ca1W1	25.43b	25.77b	15.78c	17.44a	46.07c	48.32a	5.62c	4.85d
Ca2W1	24.94d	27.44a	24.20b	3.19d	55.00b	34.14d	6.92b	9.88a
Ca3W1	25.36c	25.71c	27.55a	13.03b	59.24a	43.28b	0.23d	5.38c
Ca4W1	27.09a	25.63d	11.83d	11.22c	42.42d	41.16c	22.04a	6.41b
LSD	0.0001	0.0001	0.0001	0.0001	194E-9	0.0001	0.0001	0.0001
With armyworm infestation								
Ca1W2	26.01a	25.14b	22.95c	25.67a	54.78c	56.88a	1.88a	2.14b
Ca2W2	24.50d	25.49ab	28.50b	17.68bc	59.35b	48.24bc	0.19c	4.76a
Ca3W2	26.00b	25.72a	22.94d	19.82ab	54.78d	50.93ab	1.88a	3.46ab
Ca4W2	24.52c	25.90a	30.27a	13.05d	61.37a	43.52c	1.01b	5.56a
LSD	28E-9	0.52	0.0001	6.71	0.0001	6.97	0.0001	2.21

3.3. Effect of Calcium silicate on antioxidant activities of maize (TZm-223) grown under armyworm infestation

The antioxidant system such as TSS, protein, phenol, and proline of the two varieties of maize were greatly improved by the application of Calcium silicate at different concentrations. Calcium silicate at 150 mM was more effective in improving the TSS content TZm-224, and likewise protein, phenol and proline content of TZm-223. Calcium silicate at 100 and 200 mM was more effective in improving the phenol and protein content of TZm-224. Meanwhile, the TSS and proline content were not affected as the value obtained for these systems were lower in TZm-224 treated with different concentrations of Calcium silicate as compared to those grown under control condition (0 mM of Calcium silicate) (Table 3).

Table 3: Effect of Calcium silicate on Antioxidant Contents of Maize (TZm-223 and TZm-224) Grown under African Armyworm Infestation

Antioxidant Contents								
Treatments	% TSS		%Protein		Phenol (mg/100g)		Proline (mg/100g)	
Without armyworm infestation								
	TZm 223	TZm 224	TZm 223	TZm 224	TZm 223	TZm 224	TZm 223	TZm 224
Ca1W1	28.85a	29.34c	3.93b	4.34b	38.06c	11.97d	141.25b	163.34a
Ca2W1	26.96c	21.23d	1.25d	3.75c	10.70d	68.19a	43.92d	125.25c
Ca3W1	28.12b	33.58a	5.83a	3.60d	52.26a	32.39c	212.55a	140.40b
Ca4W1	25.46d	31.20b	3.79c	4.97a	40.92b	39.95b	134.46c	65.89d
LSD	0.23	0.14	0.056	0.08	1.77	1.42	2.08	2.44
With armyworm infestation								
Ca1W2	23.06d	25.16a	3.76b	1.96c	10.83d	40.83b	131.61b	62.70b
Ca2W2	28.02a	21.07c	2.43c	4.18a	31.03c	63.41a	84.25c	145.54a
Ca3W2	26.92b	19.05d	5.40a	2.00c	34.15b	22.82c	178.54a	58.46c
Ca4W2	24.30c	23.84b	1.13d	3.74b	38.88a	19.72d	63.31d	144.12a
LSD	0.11	0.18	0.08	0.09	1.69	1.84	2.11	1.53

A significant increase ($p \leq 0.001$) was recorded in the concentration of TSS, protein, phenol, and proline of both varieties of maize grown under African armyworm infestation as influenced by different concentration of Calcium silicate. TSS of TZm-223, protein, phenol, and proline content of TZm-224 were present at higher concentration in those plants treated with 100 mM of Calcium silicate under African armyworm infestation. Protein and proline content were higher in TZm-223 treated with 150 mM of Calcium silicate, while 200 mM of

Calcium silicate greatly influenced the phenol content of TZm-223 and proline content of TZm-224 under armyworm infestation. Meanwhile TSS of TZm-223 and proline content of TZm-224 were less in those treated with Calcium silicate at different concentration compared to the untreated plants (Table 3).
Means with the same subscripts within the same column are not significantly different at $p \leq 0.05$. TZm 223-TZm-223, VAr.2-TZm-224. Ca1W1- Without African Armyworm at 0mM of Calcium silicate, Ca2W1- Without African Armyworm at 100mM of Calcium silicate, Ca3W1- Without African Armyworm at 150mM of Calcium silicate, Ca4W1- Without African Armyworm at 200 mM of Calcium silicate. Ca1W2- With African Armyworm at 0mM of Calcium silicate, Ca2W2- With African Armyworm at 100 mM of Calcium silicate, Ca3W2- With African Armyworm at 150 mM of Calcium silicate, Ca4W2- With African Armyworm at 200 mM of Calcium silicate.

3.4. Effect of Calcium silicate on enzyme activities of maize (TZm-223) grown under African Armyworm infestation

A considerable increase in the activities of MDA, SOD, POD and APX was recorded in both studied maize cultivars as affected by different concentration of Calcium silicate. The activity of MDA was noticed to be more in TZm-223 treated with 200 mM of Calcium silicate compared to plants other treatment. The activity of MDA in TZm-224, SOD, POD and APX in TZm-223 were observed to be highest in those treated with 150 mM of Calcium silicate. Higher activities of SOD, POD and APX in TZm-224 were obtained in those treated with 100 mM of Calcium silicate (Table 4).
Application of different concentration of Calcium silicate further enhanced the activities of MDA, SOD, POD and APX under African armyworm infestation. Calcium silicate at 150 and 200 mM were helpful in increasing the MDA activity of TZm-223 and TZm-223 grown under African armyworm infestation. Calcium silicate at 100 mM was more helpful in increasing the activity of POD and APX in TZm-224. Meanwhile the activities of SOD, POD and APX in TZm-223 were significantly lower in those treated with different concentration of Calcium silicate under African armyworm infestation as compared to those grown under control conditions (Table 4).

Table 4: Effect of Calcium silicate on Enzyme Activities of Maize (TZm-223 and TZm-224) Grown under African Armyworm Infestation

Enzyme Activities								
Without armyworm infestation								
Treatments	MDA (uM/g)		SOD (mg/100g)		POD mg/100g		APX mg/100g	
	TZm 223	TZm 224	TZm 223	TZm 224	TZm 223	TZm 224	TZm 223	TZm 224
Ca1W1	8.27c	5.72b	15.73b	27.67b	322.58b	585.35b	121.73b	221.38b
Ca2W1	40.87b	2.50c	10.27c	33.60a	216.11c	698.08a	81.31c	264.04a
Ca3W1	7.50c	11.64a	31.19a	10.96c	639.95a	225.27c	242.04a	84.84c
Ca4W1	136.24a	11.34a	7.42d	9.21d	149.15d	192.34d	56.32d	72.19d
LSD	2.17	0.34	0.29	1.14	2.91	1.86	1.16	1.90
With armyworm infestation								
Ca1W2	1.71d	16.57b	29.25a	11.90c	621.25a	245.19c	234.43a	64.94c
Ca2W2	12.03c	6.74c	10.28b	30.78a	205.69c	620.69a	77.43c	235.98a
Ca3W2	87.55a	4.51d	9.28c	14.43b	187.45d	299.78b	70.03d	112.32b
Ca4W2	19.143b	39.50a	11.08b	9.26d	226.28b	187.62d	85.25b	71.73bc
LSD	0.54	1.45	0.98	0.37	2.14	2.38	1.41	44.91

Means with the same subscripts within the same column are not significantly different at $p \leq 0.05$. TZm 223-TZm-223, VAr.2-TZm-224. Ca1W1- Without African Armyworm at 0mM of Calcium silicate, Ca2W1- Without African Armyworm at 100mM of Calcium silicate, Ca3W1- Without African Armyworm at 150mM of Calcium silicate, Ca4W1- Without African Armyworm at 200 mM of Calcium silicate. Ca1W2- With African Armyworm at 0mM of Calcium silicate, Ca2W2- With African Armyworm at 100 mM of Calcium silicate, Ca3W2- With African Armyworm at 150 mM of Calcium silicate, Ca4W2- With African Armyworm at 200 mM of Calcium silicate.

3.5. Anova results on the effect of Calcium silicate on growth traits and photosynthetic pigments of maize (tzm-223) grown under armyworm infestation

Overall, Calcium silicate at different concentrations significantly affected plant heights, chlorophyll b, total chlorophyll, and the enzyme activities of the two varieties of maize. Little or no effect was observed on the leaf area, net assimilation rate, leaf area ratio, chlorophyll a, carotenoid, TSS, protein, phenol and proline contents (Table 5 and 6). Application of different concentration of Calcium silicate significantly enhanced the leaf area, net assimilation, leaf area ratio, chlorophyll b, total chlorophyll, carotenoid, TSS, SOD and APX of the two varieties of maize under African armyworm infestation. There was no significant difference in the plant heights, leaf area, leaf area ratio, the photosynthetic pigments accumulation, antioxidant contents, MDA, POD and APX among the two varieties of maize in response to different concentration of Calcium silicate.

Treatment of maize with Calcium silicate and varietal interaction affected leaf area, leaf area ratio, chlorophyll a, chlorophyll b, carotenoids, total chlorophyll, phenol, SOD, POD and APX. Also, Treatment of maize with Calcium silicate under African armyworm infestation and varietal interaction significantly influenced leaf area, net assimilation rate, chlorophyll b, total chlorophyll, TSS, phenol and proline. Little effects of this interaction were observed on the plant heights, net assimilation rate, chlorophyll a, carotenoids, and the activity of SOD (Table 5 and 6).

Table 5: ANOVA Results on the Effect of Calcium silicate on Growth Traits and Photosynthetic Pigments of maize (TZm-223) Grown under African Armyworm Infestation

Source	PH (cm)	LA (cm2)	NAR	LAR (cm^2/g)
Calcium silicate without army worm (CW)	0.007**	0.53	0.15	0.62
Calcium silicate with army worm (CW1)	0.06	0.0002**	0.024*	0.05*
Variety (V)	0.11	0.27	0.034*	0.23
CW × V	0.94	0.028*	0.12	0.88
CW1× V	0.28	0.006**	0.21	0.02*
	Chl a	Chl b	Total Chl	Caro
Calcium silicate without army worm (CW)	0.12	0.0008**	0.00075**	0.32
Calcium silicate with army worm (CW1)	0.97	0.00035**	0.00016**	3.09E-05**
Variety (V)	0.22	0.46	0.37	0.28
CW × V	0.003**	0.03*	0.02*	0.002**
CW1× V	0.09	0.015*	0.013*	0.14

Table 6: ANOVA results on the Effect of Calcium silicate on Antioxidants and Enzyme Activities of Maize (TZm-223) Grown under African Armyworm Infestation

Source	% TSS	% Protein	Phenol(mg/100g)	Proline(mg/100g)
Calcium silicate without army worm (CW)	0.31	0.40	0.73	0.66
Calcium silicate with army worm (CW1)	3.32E-05**	0.54	0.3	0.54
Variety (V)	0.87	0.71	0.11	0.81
CW × V	0.13	0.81	0.38	0.12
CW1× V	0.003**	0.28	0.003**	0.31
	MDA	SOD	POD	APX
Calcium silicate without army worm (CW)	0.002**	0.007**	0.04**	0.04**
Calcium silicate with army worm (CW1)	0.19	0.03*	0.08	0.02*
Variety (V)	0.13	0.002**	0.22	0.22
CW × V	0.017*	0.02*	0.01**	0.02*
CW1× V	0.09	0.01**	0.11	0.11

In the current study, positive effects of different concentrations of Calcium silicate treatment were observed on the growth traits such as plant heights, leaf area, lea area ratio and net assimilation rate of the two varieties of maize. This might be attributed to the role that Calcium silicate play in improving plant growth. These results are in line with previous finding of [12] who observed increase in elongation of internodes and

stem length by the application of Calcium silicate. Furthermore, Calcium silicate affected plant biomass of the two cultivars of maize. Maize plants treated with higher concentrations of Calcium silicate resulted in an increase in total fresh and dry weight compared to those treated with lower concentrations. It was reported in many studies that Calcium silicate has a positive effect on the growth development and yield of plants. This corroborates the reports of [12] who observed an increase in the dry weight of barley when treated with Calcium silicate to those receiving no Si application. [3] also reported that Calcium silicate at different concentration resulted in an increase in mass and volume of plants parts such as the roots, stems, and leaves.

Applications of Calcium silicate significantly increased chlorophyll contents of the two cultivars of maize. This might be as a result of increased in the activity of H+-ATPase, an enzyme which enhanced the photosynthetic apparatus of leaves. Accumulation of Calcium silicate in the leaves caused activation of H^+-ATPase. This result is similar with the reports of [23] who stated that application of Calcium silicate minimized damage to the chloroplast thereby increasing chlorophyll and photosynthetic activity of leaves. Moreso, defense mechanism of antioxidants is critical for eliminating reactive oxygen species by various enzymatic and non-enzymatic antioxidant molecules [21]. If this system does not work correctly, plants can be suffered by reactive oxygen species damage [20]. The results of the current study showed that antioxidant such as TSS, protein, phenol and proline, and enzymatic activity were increased in maize with different concentration of Calcium silicate application. [24] and [43] further reported that superoxide dismutase, peroxidase, and catalase activity were significantly increased in barley leaves with Si application. Plants that were also exposed to Calcium silicate showed a significant increase in the activity of CAT.

In the present study, the two cultivars of maize to responded differently to different concentrations under African armyworm infestation. Meanwhile, [15] reported that the absorption of Calcium silicate by plants from the soil at differing rates depend on genotype, its concentration in the soil and environmental conditions. In plant tissues, the contents of Ca and silicon varies considerably with the species, ranging from 0.1 -10% on a dry weight basis [27]. This brought about varietal variations in the growth traits, pigments accumulation, antioxidants contents and enzymatic activities.

Further application of Calcium silicate increased the plant heights, leaf area, leaf area ratio and net assimilation rate of the two cultivars of maize under African armyworm infestation. This might be as a result of the ability of Calcium silicate to cause reduction in the fecundity rates, nymph production and feeding times of African armyworm. These significantly influence the plant heights, leaf area, lea area ratio and net assimilation rate of the two cultivars of maize. Similar results were observed by [8, 18, 19]. Sublethal effects of Calcium silicate on African armyworm and on their reproductive ability were also detected on the maize cultivars. This might be due to the increase in content of antioxidants such as TSS, protein, phenol and proline, and enzymatic activity such as MDA, SOD, POD and APX due to the application of Calcium silicate. Silicon acts to boost the expression of defense related genes, which activates the plant defensive enzymes, resulting in higher amounts of defensive chemicals [35]. Similar observations were reported by [6, 7, 28]. The results are consistent with those of [33], who found that Calcium silicate application, and plant growth regulators all had a significant impact on larval survival, with the lowest larval survival rate (70%) being the outcome. Also, [37], found out that silicate soil fertilization raised the amount of silicate in maize leaves or stocks and encouraged the plant's resistance to African armyworm attack.

4. Conclusion

Calcium silicate application at different concentration caused an increase in growth traits and plant biomass and improves antioxidant contents and enzyme activities of maize. Calcium silicate cause reduction in the reproductive period, longevity, fecundity rates, nymph production and feeding times of African army worm, and also induce the resistance of maize to the pest. This significantly influences the plant heights, leaf area, lea area ratio and net assimilation rate of the two cultivars of maize. As a result, application of Calcium silicate can be seen as an environmentally sound strategy because it negatively impacted health of both human and animals. In addition to reducing the use of chemical pesticides which are hazardous, African armyworm population and damage to different sections of maize were both greatly reduced. Therefore, Calcium silicate therefore stand to be effective measures for improving the yield and productivity of maize and controlling African armyworm infestation.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflict of Interest

The authors declare that they have no conflict of interest.

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