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Impact of Simulated Acid Rain on the Growth, Yield and Plant Component of *Abelmoschus caillei*

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Authors' contributions

This work was carried out in collaboration between all authors. Author MOE designed the study and performed the statistical analysis. Author RPA supplied us with viable seedlings for the experiment. Authors KOO and OOO managed literature search and also supported author MOE to write the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This study was undertaken to observe the effects of simulated acid rain (SAR) on the growth, yield and plant component of *Abelmoschus caillei.* The plants were exposed to different levels of simulated acid rain acidified at pH 6.0 (control), 5.5, 4.5, 3.5 and 2.5. The results indicated that under the stress of simulated acid rain, growth parameters measured such as leaf number, shoot height, fresh and dry weight and stem girth were significantly reduced in plant subjected to SAR when compared with the control treatment. There was a gradual decline in chlorophyll content index as the level of acidity increased. Plants treated with pH 6.0 and pH 5.5 SAR had good growth and yield. Simulated acid rain (SAR) induced morphological changes such as chlorosis and necrosis in *A. caillei.* It was concluded that growth, yield and plant component were adversely affected when *A. caillei* was exposed to simulated acid rain with pH value 4.5 below.

Keywords: Simulated acid rain; Albemoschus caillei; growth parameters; morphological changes.

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1. INTRODUCTION

Acid rain occurs in many places all around the world. Acid rain and other types of acidic deposition, such as acid snow, hail, dew, and fog, form when sulfur dioxide (SO_2) and nitrogen oxides (NO_2) physically and chemically react with sunlight and water vapor [1,2]. SO_2 and NO_2 are emitted from both anthropogenic, or manmade, and natural sources. Some anthropogenic sources are motor vehicles, fossil fuels, factories, and power plants, while natural sources include volcanoes. Acid deposition penetrates deeply into the fabric of an ecosystem, changing the chemistry of the soil and streams and narrowing the space where certain plants and animals can survive [3]. The harmful effects of acid rain have been reported on many plants such as wheat, tomato, soya bean, lentil, coriander, pepper, cassava and cowpea [3,4,5,6,7,8,9,10]. The simulated acid rain has also caused reduction in plant growth and yield of field corn, green pepper, tomato etc [11,12,13,7,4]. The adverse effects of acid rain include chlorosis, necrosis, early senescence and stunting [14,8,7,4]. Acid rain deposition has serious effects on both biotic and abiotic components of the ecosystem. It damages buildings and monuments, corrodes copper and lead piping, kills aquatic animals, reduce soil fertility and also, it can cause metal leaching which will lead to ground water pollution.

Abelmoschus caillei, the West African Okra is a plant species in the family Malvaceae. It occurs in West and Central Africa where it is ued as a vegetable. The young immature fruits are usually cooked and eaten as a vegetable. The fruits can be dried whole or sliced for later use. Young leaves of the plants are sometimes eaten as spinach. A fibre obtained from this plant is used as a substitute for jute. It is also use in making paper and textiles. The reports available for rainfall acidity on crop plants are mainly derived from studies conducted in the temperate regions, with little or no research findings in the tropics. Therefore, the objective of the study was to ascertain the effects of simulated acid rain on the growth, yield and plant components of *A. caillei* which is an important tropical and subtropical vegetable.

2. MATERIALS AND METHODS

2.1 Planting Procedure

The experiment was conducted in the screen house of the Department of Plant Biology and Biotechnology, Faculty of Life Sciences, University of Benin. Seeds were planted directly into experimental pots (16 cm x 16 cm) with 6 perforations made at the bottom with a 3 mm diameter nail. Three viable seeds of *A. caillei* were sown into clay loam soil mixed with farm yard manure at a depth of 3 cm. The seedlings were watered and grown for two weeks after which thinning were carried out to reduce the plant to one per pot. The plants were there after grown for two weeks before treatments commenced. Each pH treatment had four replicates and was arranged in a completely randomized design (CRD).

Simulated acid rain was sprayed to the planted *A. caillei* plants twice weekly from the day acid spraying commenced according to their pH values of 2.5, 3.5, 4.5, 5.5, and 6.0 (control). The solutions were applied using a medium size pressurized sprayer on the plants. The plants grew for eight weeks before the experiment was terminated.

2.2 Preparation of Simulated Acid Rain

The acids used were an acidic mixture of concentrated sulphuric acid (H_2SO_4) and concentrated nitric acid (HNO_3) in 3:1 ratio [9]. The acidic solution was then deionized using distilled water with a Digital Hanna pH meter to get the desired pH (2.5, 3.5. 4.5, 5.5 and 6.0).

2.3 Data Collection

Several parameters were used in assessing the growth and productivity of the plant. The height of shoot of the plants from the soil level to the top of the plant stems were measured using a meter rule. The measurements were taken weekly from the week acid spraying commenced to day of harvest. The number of leaves and pods on the plant were determined by counting. Leaf area was determined by the proportional method of weighing a cut-out of traced area of the leaves on graph paper with standard paper of known weight to area ratio [7]. The stem girth was determined with the aid of the vernier caliper. The Chlorophyll content index of the leaves was measured using the Apogee chlorophyll content meter CCM-200 plus. Measurement was done by holding down the arm of the sample head on the intact leaf until a beep was heard. The chlorophyll content was displayed on the screen of the device. The fresh and dry weights were determined after eight weeks of treatment.

2.4 Statistical Analysis

Data obtained were subjected to analysis using the Statistical Package for Social Sciences, Version 16.0. Treatment means were separated using the Duncan's multiple range test

3. RESULTS

Figs. 1 and 2 shows the effects of simulated acid rain on the plant height and number of leaves of *A. caillei*, respectively. There was a significant decline in height and number of leaves of the test plants as concentrations decreased in pH value. pH 6.0 and 5.5 had almost the same value. The test plant was not affected by pH 5.5 as seen in the Fig. 1.

Fig. 3 shows the stem girth of *A. caillei* when exposed to simulated acid rain. From the Fig. 3, it was observed that before treatment all plants had almost the same value for stem girth but when the stem girth was taken after the experiment, there was an increase for plants treated with pH 6.0 and pH 5.5.

Table 1 shows the effects of SAR on leaf area of *A. caillei*. There was a decrease in value as pH of SAR reduced.

Table 1. Leaf area of *A. caillei* after exposure to different concentration of simulated acid rain

pH of SAR	Leaf area (cm^2)
6.0	19.31±0.76[c]
5.5	19.32±0.77[c]
4.5	15.10±0.65[b]
3.5	15.01±0.35[b]
2.5	10.55±0.10[a]
	*

Key: Each value is a mean ± standard error of five replicates. Means within the same column followed by the same letter are not significantly different at (P>0.05) from each other using new Duncan multiple range test

Tables 2, 3 and 4 shows the effects of SAR on the biomass, chlorophyll content and number of pods of *A. caillei* respectively. From the Tables 2, 3 and 4, it was observed that there was a reduction in value with increasing acidity.

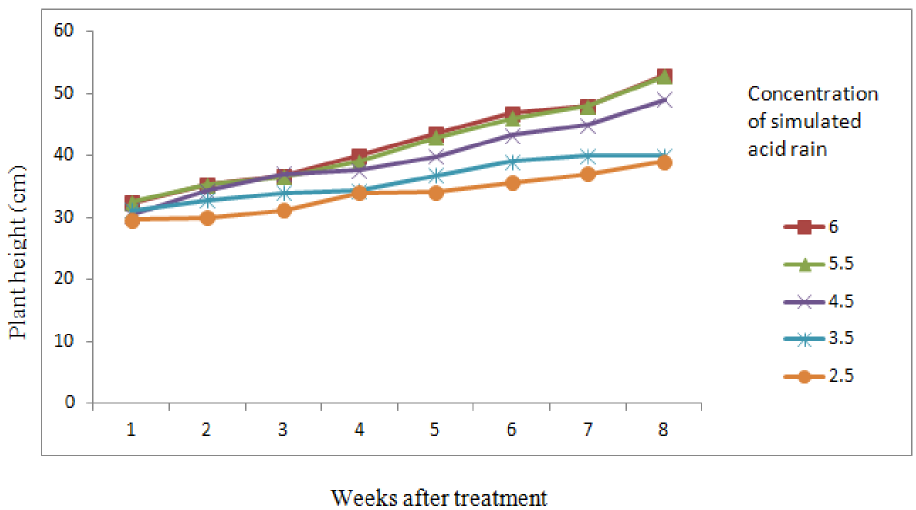

Fig. 1. Effects of simulated acid rain on the height of *A. caillei*

Table 2. Fresh weight and dry weight of *A. caillei* after exposure to simulated acid rain

pH of SAR	Fresh weight (g)	Dry weight (g)
6.0	28.01±1.11[b]	14.98±0.87[b]
5.5	28.51±1.01[b]	14.78±0.88[b]
4.5	20.89±0.88[b]	9.80±0.34[a]
3.5	17.70±0.51[a]	7.98±0.44[a]
2.5	15.55±0.78[a]	5.97±0.31[a]
	*	*

Key: Each value is a mean ± standard error of five replicates. Means within the same column followed by the same letter are not significantly different at (P>0.05) from each other using new Duncan multiple range test

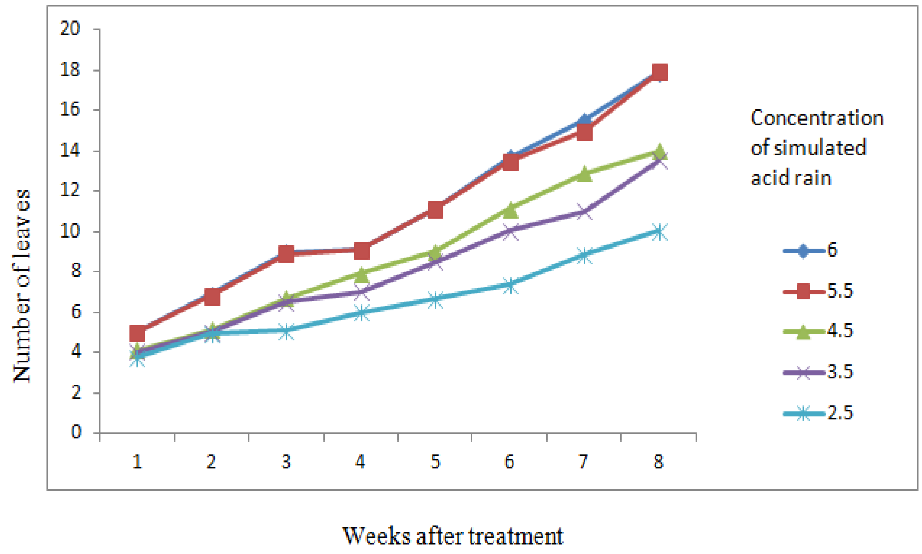

Fig. 2. Effects of simulated acid rain on the number of leaves of *A. caillei*

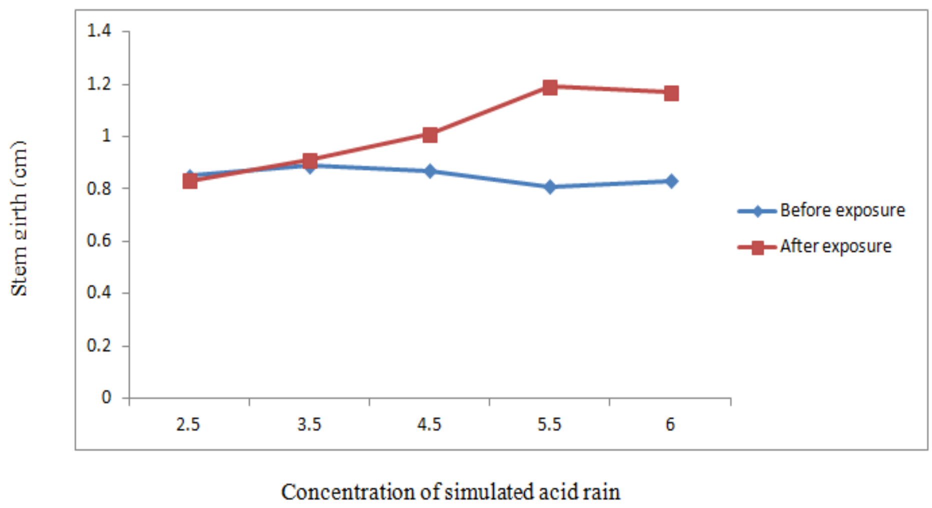

Fig. 3. Effects of simulated acid rain on the stem girth of *A. caillei*

Table 3. Chlorophyll content of *A. caillei* before and after exposure to simulated acid rain

pH of SAR	Before exposure (cci)	After exposure (cci)
6.0	24.80±1.19^{c}	26.99±0.96^{c}
5.5	25.51±0.99^{c}	25.91±1.09^{c}
4.5	24.90±1.01^{c}	21.90±0.78^{b}
3.5	25.78±0.76^{c}	20.76±0.71^{b}
2.5	25.90±0.60^{c}	18.67±0.65^{a}
	N.S	*

Key: Each value is a mean ± standard error of five replicates. Means within the same column followed by the same letter are not significantly different at (P>0.05) from each other using new Duncan multiple range test

Table 4. Effects of simulated acid rain on the number of pods of *A caillei*

pH of SAR	Number of pods
6.0	2.31±0.11[b]
5.5	2.32±0.19[b]
4.5	1.77±0.09[a]
3.5	1.01±0.10[a]
2.5	0.59±0.06[a]
	*

4. DISCUSSION

Figs. 1 and 2 shows the effect of simulated acid rain (SAR) exposure at different pH on plant height (cm) and leaf number of *A. caillei.* The results indicated that under the stress of simulated acid rain, the shoot height and number of leaves decreased with the declining pH value of acid rain. This is in agreement with the work of [13]. Size of the leaves also decrease due to thinner mesophyll cells. Reduction in leaf size conforms to observation of [15]. From the figures it was observed that both pH 6.0 and pH 5.5 did not have any effect on the height and number of leaves of the plant. Plants treated with pH 2.5 had the most decreased plant height and number of leaves compared to plants treated with pH 4.5 and 3.5. Decrease in stem girth was proportional to increasing acidity as observed in Fig. 3. Plants treated with pH 5.5 and 6.0 (control) had almost the same value. When subjected to statistical analysis, there was significant difference between treatments and control plants. The result accords with the result of [15]. Decrease in biomass (fresh and dry weight) of *A. caillei* was correlated to increasing acidity as observed in Table 2, which is in agreement to the findings of [11]. A decrease in the biomass might be due to chlorophyll impairment which leads to stunted growth of plants and chlorois of leaves. This is in agreement with the works of [7,4] who noted a decrease in chlorophyll content when tomato and pepper plants were exposed to different concentration of SAR. Photosynthetic rate also decreased which might be due to reduction in leaf size or chlorophyll content [16]. This also agrees with the work of [9,10]. From Table 3 it was noticed that the higher the acidity, the more the leaf chlorophyll content was inhibited. Plants treated with the lowest pH 2.5 had the lowest chlorophyll content index value while the control treatment had the highest chlorophyll content index value. The reason for this decrease in chlorophyll value was due to the aggregation of H+ ions in the plant tissue displacing magnesium ions in the chlorophyll molecule thereby retarding the chlorophyll pigment by converting chlorophyll to pheophytin molecule, which cannot carry out photosynthesis. This result was in agreement to the result of [17]. Uneven distribution of chlorophyll pigments were also observed on the test plant. This is in accordance with the works of [18,19].

5. CONCLUSION

The present paper shows that simulated acid rain with pH value 4.5 and below had negative effect on the growth and the yield component of *A. caillei* due to the reduction of photosynthesis as a result of chlorosis, necrosis and leaf abscission. From the study plants treated with pH 6.0 and 5.5 had good growth. There is need to observe more crops to the sensitivity of acidic precipitation due to uncontrolled industrialization and urbanization that is currently experienced in Nigeria. Some of the ways of reducing the incidence of acidic precipitation are educating the local and international communities on the negative impacts of burning fossil fuels which emits gases that can result in acidic deposition, vehicles that do not emit oxides of sulphur and nitrogen should be mass produced and made affordable, vehicle owners should maintain their vehicle to meet emission standards, and factories and industries should device a means of safely collecting the gases emitted from their plants so that it does not contaminate the atmosphere.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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