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# Assessing the Impact of Selected Soil and Climatic Variabilities on Yellow Bell Pepper Growth for Enhanced Food Security in Bayelsa State, Nigeria

**Isaac U. I. and Adekunle, I. M.**

*AgriChemTech Research Group, Department of Chemistry, Faculty of Agriculture, Federal University, Otuoke.*

Corresponding Author: isaacui@fuotuoke.edu.ng

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## ABSTRACT

*Food insecurity and declining agricultural productivity remain major challenges in the Niger Delta region of Nigeria, particularly in Bayelsa State, where soil heterogeneity, flooding, salinity, and fluctuating climatic conditions adversely affect crop performance. This study assessed the impact of soil and climatic variabilities on the growth of yellow bell pepper (Capsicum annuum L.) with a view to enhancing sustainable food security in Bayelsa State, Nigeria. Key soil physicochemical properties, including soil pH, electrical conductivity (EC), and salinity, alongside climatic parameters such as temperatures, were evaluated using a replicated screen-house experimental design. Major growth indicators, including plant height and stem girth, were monitored and statistically analyzed. The findings revealed that variations in soil physicochemical properties influenced the growth of yellow bell pepper. Rising soil temperatures exerted adverse effects on crop growth. This study further demonstrated that optimized soil management and climate-smart agricultural practices could substantially improve yellow bell pepper productivity in the region. The research highlights the importance of integrated soil–climate assessments in crop production planning and recommends bioresource-based adaptive technologies as sustainable mitigation strategies for improving crop resilience, rural livelihoods, and food security under changing climatic conditions. The findings provide information for sustainable vegetable cultivation in coastal agro-ecosystems and support policy development, agricultural extension services and climate adaptation programmes aimed at improving productivity and sustainability in the Delta region*

**Key words:** Yellow bell pepper, Soil and climatic variabilities, Food security, Sustainable agriculture, Bayelsa State.

## INTRODUCTION

Agriculture remains a critical driver of economic development, rural livelihoods, and food security in Nigeria, particularly in the Niger Delta region where increasing population growth and environmental pressures continue to threaten sustainable food production. Vegetable crops constitute an essential component of human nutrition because they provide vitamins, minerals, antioxidants, and dietary fiber required for healthy living (FAO, 2022). Among these vegetables, yellow bell pepper (*Capsicum annuum* L.) has gained considerable agricultural and economic importance due to its nutritional value, culinary applications, and growing market demand. Yellow bell pepper is rich in vitamins A and C, carotenoids, flavonoids, and other bioactive compounds that contribute significantly to human health and nutritional security (Bosland & Votava, 2012). Consequently, improving its cultivation has become increasingly important for enhancing food availability and income generation in developing economies such as Nigeria.

Despite the economic and nutritional significance of yellow bell pepper, its productivity is strongly influenced by environmental conditions, especially soil characteristics and climatic factors. Soil serves as the primary medium for plant growth and development by supplying nutrients, water, oxygen, and structural support to crops (Brady & Weil, 2016). Variations in soil properties such as pH, texture, organic matter, nutrient availability, and moisture content can significantly affect seed germination, root development, nutrient uptake, and overall crop yield. Similarly, climatic conditions including temperature, rainfall distribution, humidity, and solar radiation exert considerable influence on plant physiological processes such as photosynthesis, transpiration, flowering, and fruit formation (Hatfield & Prueger, 2015). In tropical coastal environments such as Bayelsa State, these factors are highly variable and often exacerbated by flooding, erosion, saline intrusion, and climate change-related disturbances.

Bayelsa State, located within the humid Niger Delta region of Nigeria, is characterized by high annual rainfall, fluctuating temperatures, and predominantly hydromorphic soils that are prone to nutrient depletion and poor drainage. While these ecological conditions support diverse agricultural activities, they also create significant constraints to sustainable crop production. Excessive rainfall and prolonged waterlogging often reduce soil aeration and microbial activity, thereby impairing nutrient cycling and plant growth (Lal, 2015). Furthermore, soil variability across different locations within the state contributes to inconsistent crop performance and low agricultural productivity. These environmental limitations have intensified concerns regarding food insecurity, poverty, and reduced agricultural resilience in the region.

Climate variability and environmental degradation have become major threats to global food systems, particularly in sub-Saharan Africa where smallholder farmers depend heavily on rain-fed agriculture (IPCC, 2021). Changes in rainfall patterns, increasing temperatures, and extreme weather events are increasingly affecting crop productivity and soil fertility. In Nigeria, the combined effects of climate variability and poor soil management practices have contributed to declining yields of many economically important crops, including vegetables (Ayanlade *et al*., 2018). Given the increasing demand for nutrient-rich vegetables and the urgent need to improve local food production, there is a growing necessity to evaluate how environmental factors influence crop growth under local agro-ecological conditions.

Assessing the interaction between soil properties and climatic variables is essential for developing climate-smart and sustainable agricultural strategies capable of improving crop productivity and food security. Such assessments provide valuable information for selecting suitable cultivation sites, improving soil management practices, optimizing irrigation scheduling, and enhancing adaptive capacity to climate-related stressors. Although several studies have examined the effects of climate and soil conditions on crop production globally, limited empirical data exist regarding the combined influence of these factors on yellow bell pepper cultivation in Bayelsa State. This knowledge gap limits the development of evidence-based agricultural interventions tailored to the ecological realities of the Niger Delta region. Therefore, this study seeks to assess the impact of selected soil and climatic variabilities on yellow bell pepper growth in Bayelsa State, Nigeria. Specifically, the study evaluates key soil physicochemical properties and climatic parameters influencing crop performance, while examining their implications for sustainable food production and agricultural resilience. The findings are expected to contribute to improved agronomic practices, enhanced vegetable productivity, and strengthened food security strategies in Bayelsa State and similar coastal agro-ecosystems.

## MATERIALS AND METHODS

### Study Area

This study was conducted in the Golden Food Research Facility of Federal University Otuoke, Bayelsa State. Otuoke is located within Bayelsa State, Nigeria, situated in the Niger Delta region between latitudes 4°15′N and 5°23′N and longitudes 5°22′E and 6°45′E. Bayelsa State is characterized by a humid tropical climate with high annual rainfall ranging from 2,000 to 4,000 mm, average temperatures between 25°C and 32°C, and high relative humidity throughout the year (NIMET, 2023). The region experiences two major seasons: the rainy season (March-October) and the dry season (November-February). The soils are predominantly hydromorphic, alluvial, clayey and sandy loam in nature, with varying degrees of organic matter accumulation, acidity, and drainage conditions due to periodic flooding and coastal influences.

### Experimental Design and Field Layout

A field experiment was established in controlled screen house (24 m x 8 m)using a Randomized Complete Block Design (RCBD) with sixty - three replicates across the house representing varying

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soil and climatic conditions within the house. Healthy and certified seeds of yellow bell pepper (*Capsicum annuum* L.) were obtained from a reputable agricultural seed supplier and raised in a nursery for four weeks before transplanting into the experimental fields. Uniform agronomic practices including land preparation, manual weeding, irrigation where necessary and pest management were applied across all plots to minimize experimental bias. A constant quantity of organic soil amendment was used to stabilize the soil at a uniform rate prior to transplanting to improve soil fertility and enhance microbial activity in order to sustain growth as the natural conditions in the study area do not easily support the growth of the indicator crop (Bell pepper).

### Soil Sampling and Analysis

Composite soil samples were collected from each experimental site at a depth of 0-30 cm at regular time intervals during the study using a stainless-steel soil auger. The samples were air-dried, crushed, sieved through a 2 mm mesh, and analyzed in the laboratory following standard procedures described by Brady and Weil (2016).The physicochemical parameters analyzed included soil pH, electrical conductivity, temperature and salinity using a digital multifunctional meter (Model EZ-9910) in a soil-water suspension ratio. Climatic factor measured were real-time indoor and outdoor atmospheric temperatures using digital thermometer. Growth parameters plant height and stem girth. There were no chemical inputs. Study adhered to environmentally sustainable agricultural practices by adopting green approaches in crop growth management.

### Data Analysis

Data obtained from soil analysis, climatic measurements, and plant growth assessments were subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) version 25. Descriptive statistics including mean and standard deviation were calculated for all measured parameters. Analysis of Variance (ANOVA) was used to determine significant differences among treatments and experimental locations at a 95% confidence level ($p < 0.05$). Pearson correlation and regression analyses were further employed to examine the relationships between soil properties, climatic variables, and yellow bell pepper growth performance. Graphical representations were generated using Microsoft Excel.

## RESULTS

### Soil Temperature Versus Plant Height

The relationship between soil temperature and plant height is illustrated in the scatter plot in Fig.1. The regression equation shown on the graph is: $Y=-0.0732x+10.994$. The negative slope (−0.0732) is an indication of a slight inverse relationship between soil temperature and plant

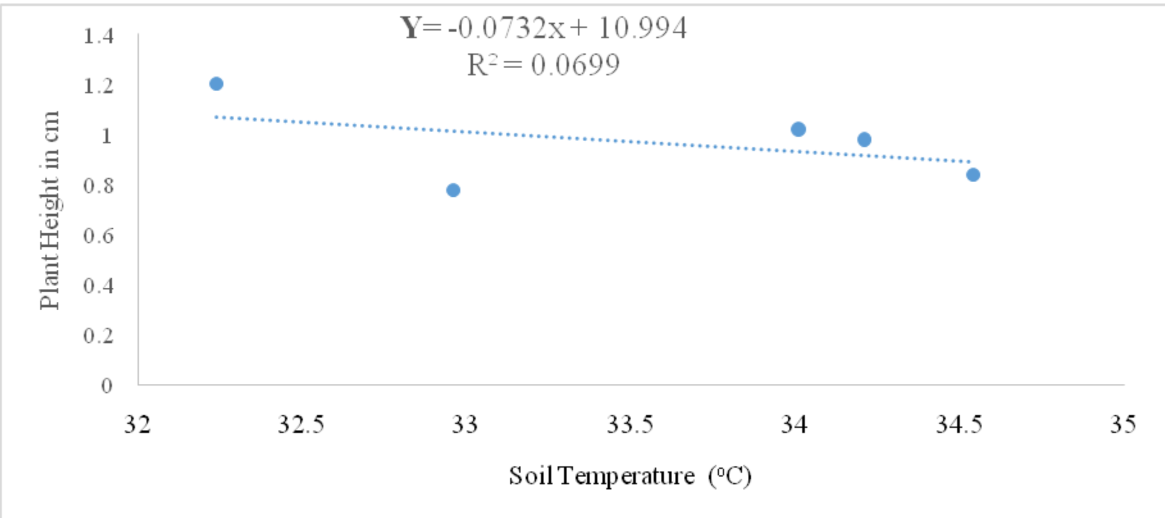


**Fig.1: Influence of soil temperature on plant height of yellow bell pepper bioresource**

height, meaning that as soil temperature increased, plant height decreased marginally. Specifically, for every 1°C increase in soil temperature, plant height decreased by approximately 0.073 cm.

However, a very low coefficient of determination ($R^2$=0.0699) was obtained. This implied that only about 6.99% of the variation in plant height was explained by soil temperature. Therefore, soil temperature had a very weak influence on plant height within the observed range. The scattered distribution of the data points further supports the weak correlation, suggesting that other environmental or biological factors likely played a more dominant role in determining plant growth. The highest plant height (approximately 8.88 cm) occurred at a relatively lower soil temperature (~32.2°C), while the lowest plant height (~8.16 cm) was recorded around 32.9°C. At higher temperatures (34.0 to 34.5°C), plant heights remained moderately stable between approximately 8.43 and 8.64 cm. Overall, the trend suggests that increasing soil temperature may slightly suppress plant growth, but the effect is minimal and not statistically strong based on the low $R^2$ value.

**Soil Temperature Versus Stem Girth**

The scatter plot in Fig.2 shows the relationship between soil temperature and stem girth. The regression equation presented is: Y=−0.0779x+3.582. The negative slope (−0.0779) indicates a slight decrease in stem girth as soil temperature increases. This suggests that higher soil temperatures may have a suppressive effect on stem thickening. Specifically, for every 1°C increase in soil temperature, stem girth decreases by approximately 0.078 cm. The coefficient of determination is:$R^2$=0.2065.

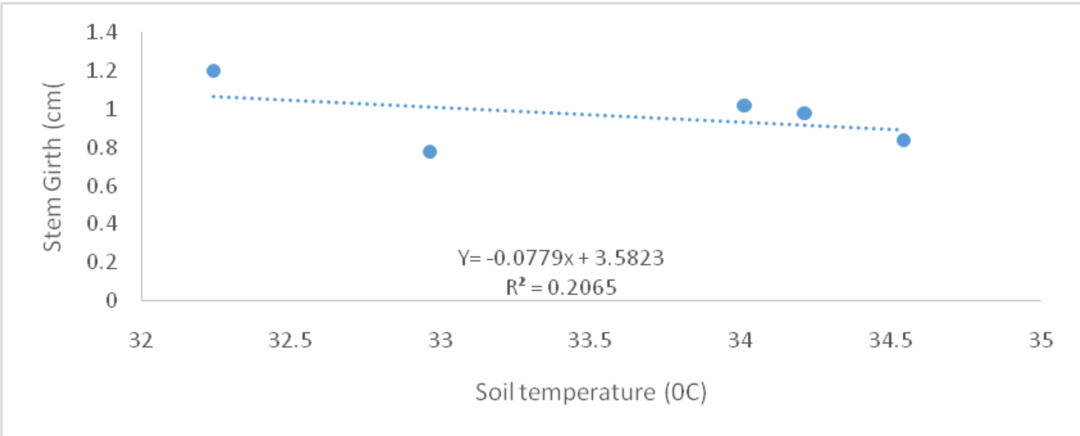


**Fig.2: Influence of soil temperature on stem girth of yellow bell pepper bioresource**

This indicates that about 20.65% of the variation in stem girth is explained by soil temperature, while nearly 79.35% of the variation is influenced by other factors such as nutrient availability, soil moisture, genetic characteristics, or environmental conditions. Compared with the previous plant height relationship, this correlation is slightly stronger, although still relatively weak. The highest stem girth (approximately 1.20 cm) occurred at the lowest soil temperature (~32.2°C), whereas lower stem girth values were generally observed at higher temperatures. Nevertheless, the data points remain moderately scattered, indicating that the relationship is not strongly predictive. Altogether, the graph suggests a weak negative relationship between soil temperature and stem girth, implying that moderate increases in soil temperature may slightly reduce stem development, though the effect is limited and not sufficiently strong to be considered a dominant growth determinant.

**Influence of Growth Period on Performance of Yellow Bell Pepper Bioresource**

**Growth Period Versus Plant Height**

The scatter plot in Fig.3 is an illustration of the relationship between growth period (days) and plant height. The regression equation is: Y = 0.165x+ 8.1039. The positive slope (+0.165) indicates a direct relationship between growth period and plant height. Indicating that as the number of growth days increased, plant height also increased. Specifically, plant height increased by approximately 0.17 cm for each additional day of growth. The coefficient of determination is: $R^2$=0.9643. This shows that approximately 96.43% of the variation in plant height is explained by the growth period. This represents a strong positive correlation, suggesting that growth duration had a noticeable influence on plant height compared with the weaker relationships previously observed with soil

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temperature. The graph also showed that plant height generally increased from Week 2 onward, with values clustering between approximately 8.1 and 8.9 cm. Although the trend line predicts continued growth over time, the relatively clustered heights between Weeks 2 and 6 suggest that growth may begin to stabilize after early rapid development. The slight fluctuations among later days could be attributed to environmental variability, nutrient availability, or physiological adaptation. Altogether, Fig.3 is a demonstration that increasing growth period positively influenced plant height, with time serving as a moderately important factor in plant development.

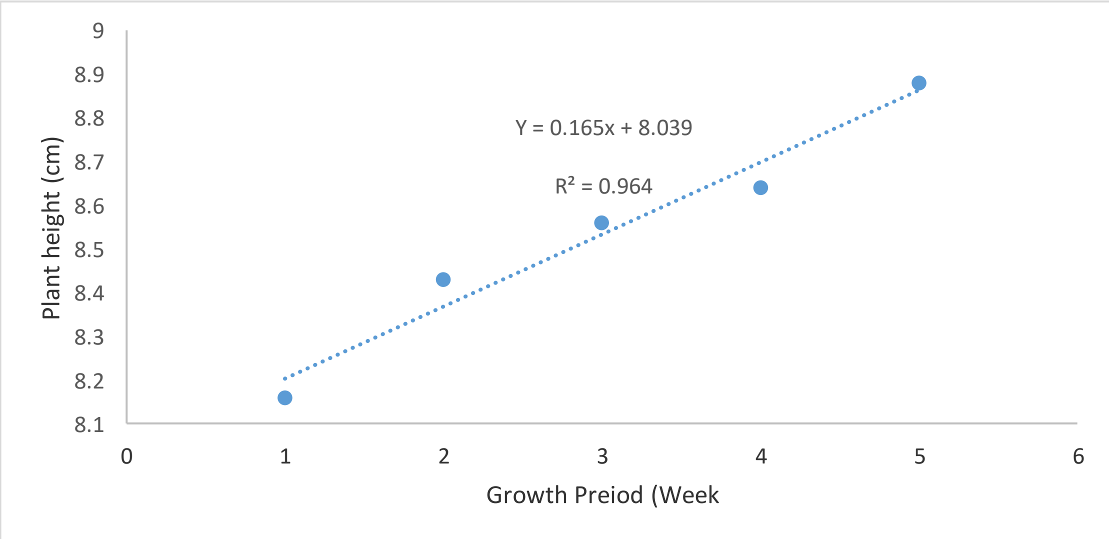


**Fig.3: Influence of growth period height of yellow bell pepper bioresource**

**Growth Period Versus Stem Girth**

The relationship between growth period (days) and stem girth is presented in the scatter plot in Fig.4. The regression equation is: $Y = 0.102x + 0.658$. The positive slope (+0.102) indicates a direct relationship between growth period and stem girth, indicating that as the number of growth days increased, stem girth also increased. Specifically, plant height increased by approximately 0.17 cm for each additional day of growth. The coefficient of determination is: $R^2=0.9605$. This showed that approximately 96.05% of the variation in stem girth was explained by the growth period. This represents a strong positive correlation, suggesting that growth duration had a noticeable influence on stem girth compared with the weaker relationships previously observed with soil temperature. The graph also showed that plant height generally increased from Week 2 onward.

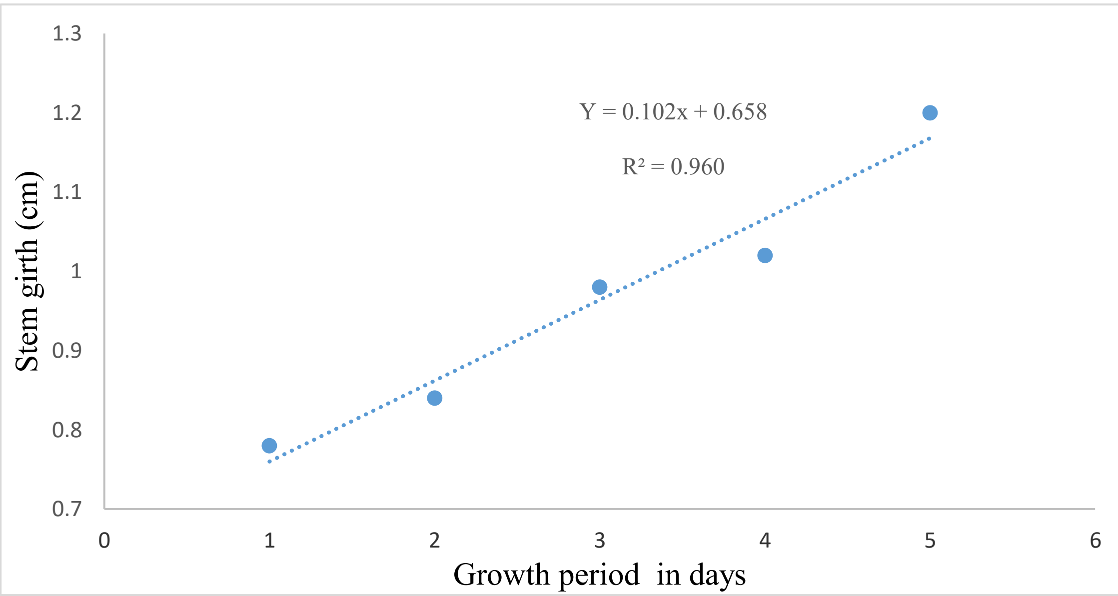


**Fig.4: Influence of growth stem girth of yellow bell pepper bioresource**

**Correlation between Selected Soil Variables and Rising Temperatures**

The correlations between selected soil variables and rising temperatures (soil and atmospheric temperatures) are presented in Figures 5 to7. Results presented in Figure 5 showed that increasing soil temperature adversely affected soil electrical conductivity (EC), soil pH, and soil salinity by 65.06%, 68.06%, and 60.27%, respectively, under rising indoor soil temperature conditions. The negative influence of increasing soil temperature was therefore greatest on soil pH and least on soil salinity. The correlations between selected soil variables and rising temperatures (soil and atmospheric temperatures) are presented in Figures 5 to 7. Results presented in Figure 6 showed that indoor atmospheric temperature did not adversely affect soil electrical conductivity (EC), soil pH, and soil salinity as positive correlations were obtained. Similar trends were obtained for the influence of rising outdoor atmospheric temperature and soil variables (pH, EC and salinity) as presented in Fig. 7.

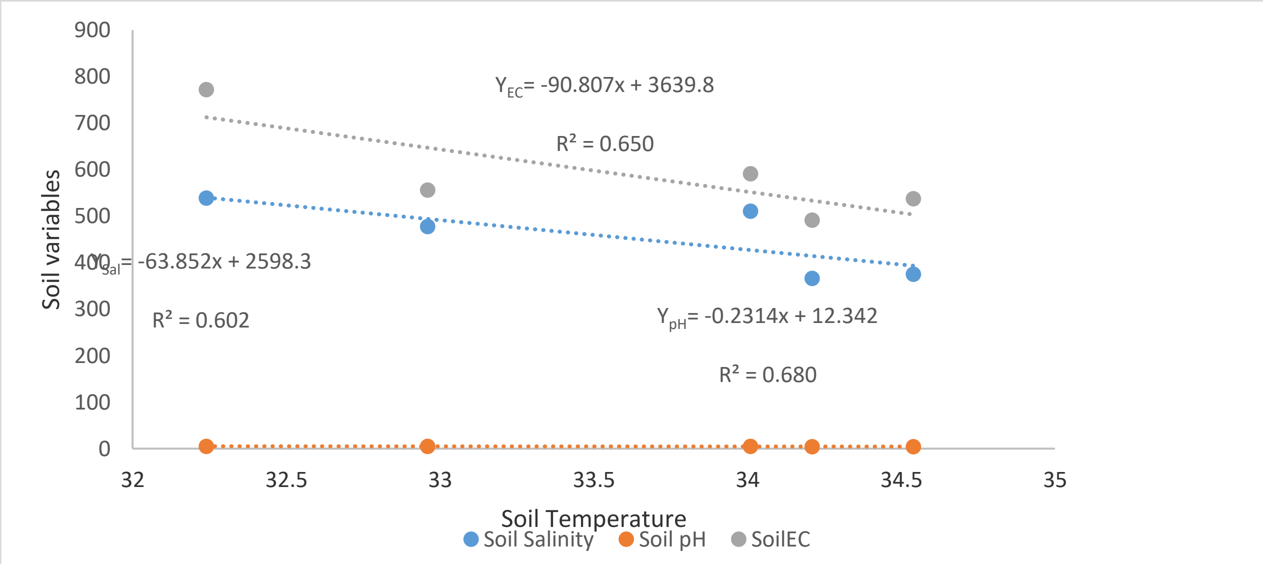


**Fig.5: Relationship between soil temperature and selected soil variable (soil pH, electrical conductivity)**

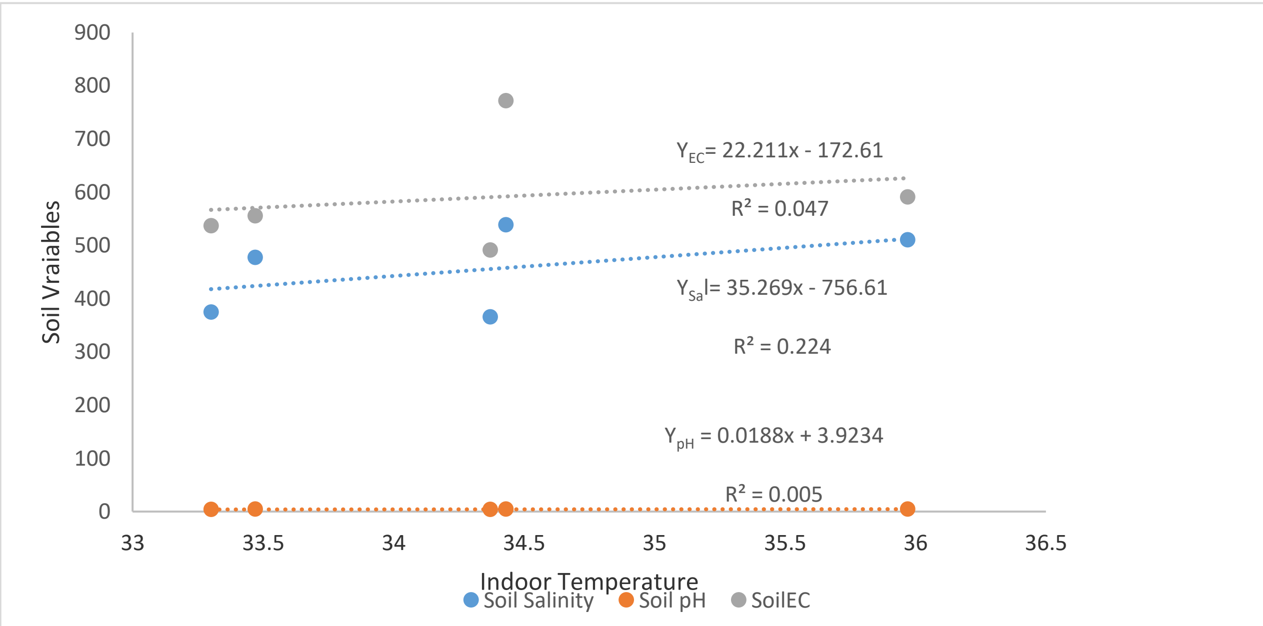


**Fig.6: Relationship between indoor atmospheric temperature and selected soil variable (soil pH, electrical conductivity**

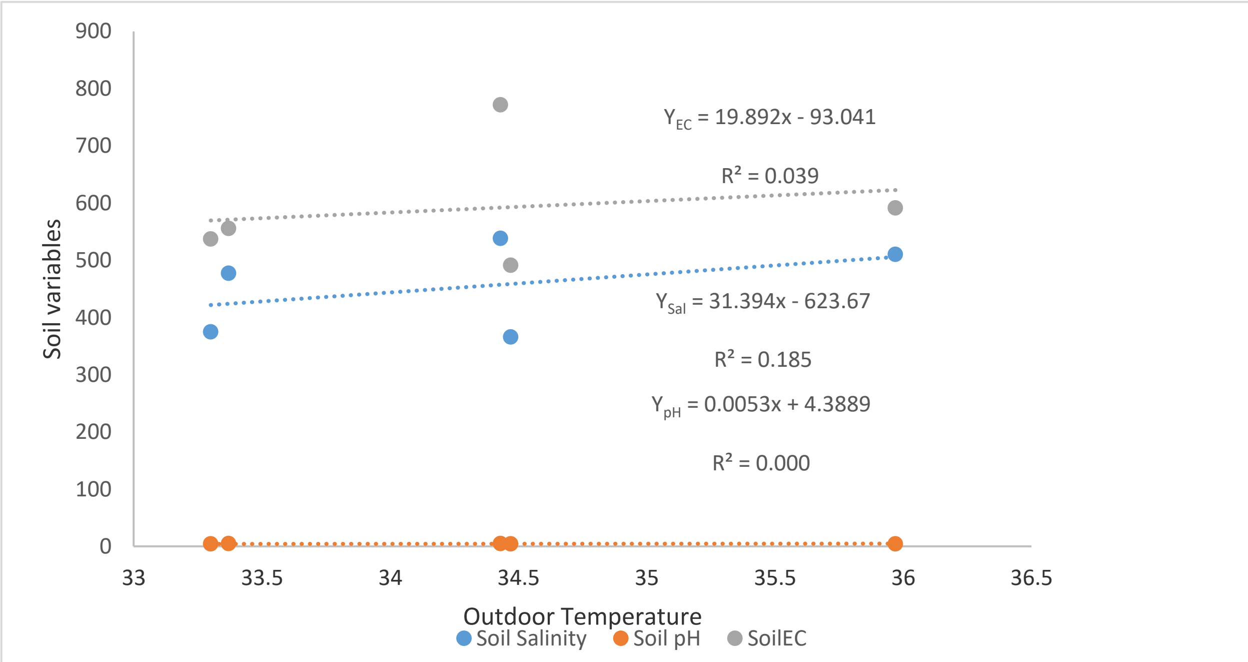


**Fig.7: Relationship between outdoor atmospheric temperature and selected soil variable (soil pH, electrical conductivity)**

### Correlation between Selected Soil Variables and Crop Growth Performance

The correlation between selected soil variables and crop growth performance (plant height and stem girth) are presented in Figs. 8 and 9. Results showed positive correlations between plant height and stem girth versus soil variables.

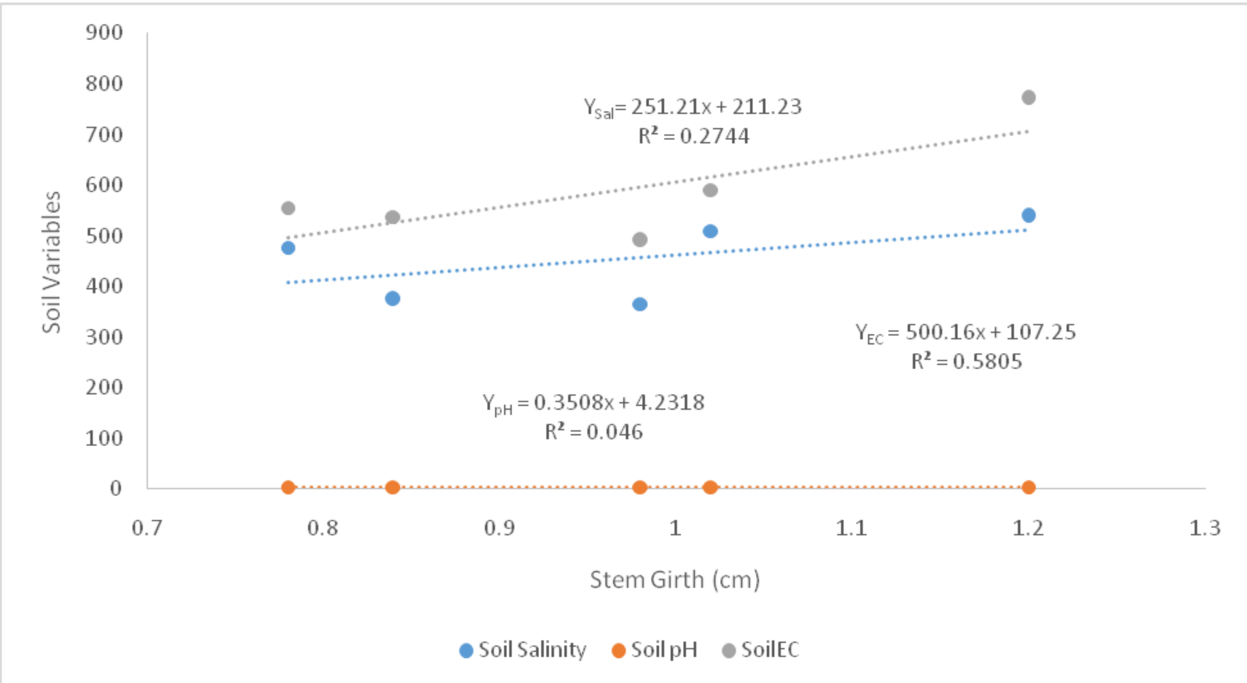


**Fig.8: Relationship between stem girth and selected soil variable (soil pH, electrical conductivity)**

## DISCUSSION

The findings of this study demonstrated that soil and climatic variabilities significantly influenced the growth and productivity of yellow bell pepper (*Capsicum annuum* L.) in Bayelsa State, Nigeria. Variations in key soil physicochemical properties, particularly soil pH, electrical conductivity (EC), and salinity, affected vegetative growth parameters such as plant height and stem girth. This observation agrees with the report of Brady and Weil (2016), who stated that optimal soil pH and nutrient availability enhance nutrient uptake and plant physiological performance.

Rising soil and atmospheric temperatures can substantially alter soil physicochemical properties, thereby affecting crop growth and productivity. Increased temperatures accelerate soil biochemical reactions, organic matter decomposition, evaporation rates, and microbial activities, all of which influence nutrient dynamics and plant performance (Lal, 2015). Elevated temperatures may modify soil pH through enhanced mineralization, intensified microbial respiration, and accelerated chemical weathering. In some soils, rising temperatures increase acidity due to rapid nitrification and organic acid production, whereas in coastal or poorly drained environments, evaporation may concentrate alkaline salts and increase alkalinity (Brady & Weil, 2016). Changes in soil pH directly affect nutrient availability, microbial activity, root development, and crop yield. Extreme pH conditions may reduce the availability of essential nutrients such as phosphorus and nitrogen, resulting in poor crop performance.

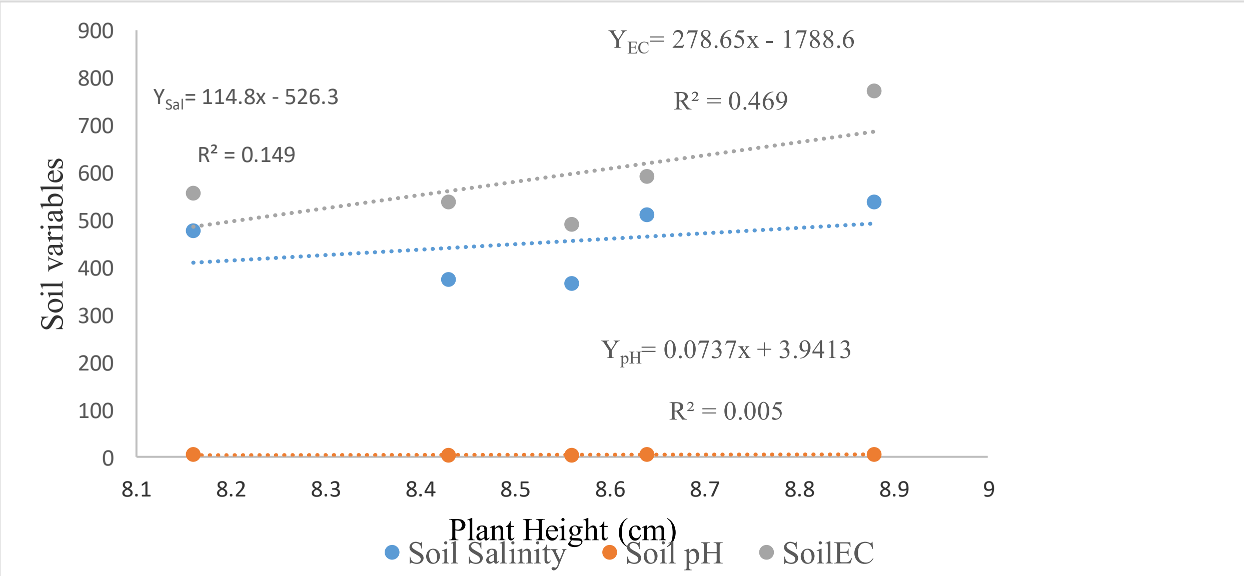


**Fig.9: Relationship between stem girth and selected soil variable (soil pH, electrical conductivity)**

Higher temperatures also increase soil electrical conductivity because elevated evaporation rates concentrate dissolved ions and soluble salts within the soil solution (Rhoades *et al.*, 1999). Although moderate EC levels may indicate nutrient availability, excessive EC creates osmotic stress that limits plant water uptake, impairs seed germination and photosynthesis, and reduces overall plant growth. Temperature-sensitive crops such as yellow bell pepper are particularly vulnerable to such stress conditions.

Similarly, rising temperatures contribute to soil salinity through enhanced evapotranspiration and reduced soil moisture, especially in coastal and flood-prone areas. As water evaporates from the soil surface, salts accumulate within the root zone, increasing salinity levels (Shrivastava & Kumar, 2015). High salinity disrupts plant-water relations, causes ion toxicity, inhibits nutrient absorption, and ultimately reduces growth and yield. In coastal regions such as Bayelsa State, sea-level rise and saltwater intrusion associated with climate change may further intensify soil salinization.

The combined effects of altered soil pH, elevated EC, and increased salinity under rising temperature conditions can substantially reduce crop productivity. These soil changes adversely affect root physiology, nutrient availability, microbial interactions, and water relations necessary for healthy plant development. Heat stress, coupled with salinity and nutrient imbalance, may reduce flowering, fruit formation, biomass accumulation, and final yield. Consequently, sustainable soil management practices, climate-smart agricultural approaches, and salinity mitigation strategies are essential for maintaining crop productivity and ensuring food security under changing climatic conditions.

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This study emphasizes the need for integrated soil-climate assessments in agricultural planning to improve crop resilience, sustainable productivity, and rural livelihoods under changing environmental conditions. The research is highly relevant within the context of climate change, sustainable agriculture, and food security in the Niger Delta region. A major strength of the study lies in its multidisciplinary approach, integrating soil science, climatology, crop physiology, environmental management, and food security within a unified framework. Scientifically, the study established important relationships among soil physicochemical properties, climatic variables, and crop performance, while generating localized data for the Niger Delta, where significant research gaps still exist. Overall, the findings support climate-smart agriculture and provide valuable information for agricultural policy, extension services, and climate adaptation planning.

## CONCLUSIONS AND RECOMMENDATIONS

This study demonstrated that soil and climatic variabilities significantly influence the growth, development, and yield performance of yellow bell pepper (*Capsicum annuum* L.) in Bayelsa State, Nigeria. Variations in key soil physicochemical properties, particularly soil pH, electrical conductivity (EC), and salinity, were found to directly affect plant growth and productivity. Rising soil temperatures exerted more adverse effects on crop growth performance by altering soil conditions essential for nutrient availability and water uptake. The study further highlighted the importance of integrated soil and climate management approaches in improving vegetable cultivation and strengthening food security in coastal agro-ecosystems such as Bayelsa State. Further studies on the application of bioresource-based adaptive technologies are recommended as potential mitigation strategies for enhancing crop resilience and sustainable agricultural productivity under changing climatic conditions.

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