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Investigating the influence of Eggshells on the Growth and Yield performance of Green Pepper *(Capsicum Annum)*

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Abstract

Green pepper (*Capsicum annum*) is one of the most important vegetables that are consumed worldwide after tomatoes and onions. It is among the most grown crops throughout Africa because of its utilization in soup stews and salads. Therefore, this study aims at investigating the influence of eggshell on the growth and yield performance of green pepper. The experiment was conducted in Lusaka district for three months under the following objectives; (i) to evaluate the growth of green pepper plants treated with eggshell fertilizer under smallholder farming system in Lusaka, (ii) to determine the effect of eggshell soil amendment on soil pH in a green pepper field under smallholder management in Lusaka and compare the results between plots treated with eggshell amendments and those left untreated, (iii) to compare the yield of green pepper plants grown with eggshell soil supplementation to those grown without the eggshell amendments in Lusaka district. The experimental field layout was arranged in a Randomized complete block design (RCBD) with three replications and two treatments; T1 untreated control, T2 treated eggshells amendment respectively. Statistical package for social science (SPSS) was used to test Growth and yield parameters. One-way Anova was used to statistically analyze data. The result shows that in week six and twelve plant height, leaf count, leaf size, stem diameter and weight were not statistically not significant meaning the p value was ($p \leq 0.05$). In week eight and ten it was discovered that leaf count and stem diameter week eight were statistically significant respectively with 0.019, ($p \leq 0.05$), 0.007, ($p \leq 0.01$) and leaf count week ten was statistically significant with 0.049, ($p \leq 0.05$). The pH value increased from 6.5 to 7 meaning that the soil become less acidic and slightly more alkaline. The result revealed that the application of eggshell powder to green pepper can improve plant growth.

Keywords: *Capsicum Annum*, Eggshells, Organic Fertilizer, Soil Amendment, Sustainable Agricultural Practice

1. Introduction

Green pepper (*Capsicum annum*) is one of the most important Vegetables that are consumed worldwide after tomatoes and onions. It is among the most grown crops throughout Africa because of its utilization in soup stews and salads. It has three to six times more vitamin C than orange *(Cirrus sinensis*) (Bosland and Votive, 2007).

Pepper is a major solanaceous crop distributed throughout the warm climatic areas of Asia, North and South America, Europe and Africa (Thampi, 2004). It requires similar growing conditions to tomatoes and eggplants. During the past decades, global total pepper production has expanded by approximately 33%, whereas green and dry pepper production has increased by 32% and 40%, respectively during the last decade (FAOSTAT, 2019).

Around 38.03 million tons of fresh pepper and 4.25 million tons of dry pepper were produced around the globe in 2019. China, with (19.00 million tons) was the highest producer of green pepper followed by Mexico with 3.23 million tons and Indonesia with 2.59 million tons" India dominated the dry pepper production in the world with 1.74 million tons (FAOSTAT, 2019).

In Africa, green pepper cultivation is dominated by smallholder farmers. According to FAOSTAT (2021), average yields of green pepper were recorded for southern Africa (1.9 t \ha), west Africa (7.0 t\ ha), eastern Africa (5.8 t \ha) and central Africa (2.1 t\ ha).

However, smallholder pepper productivity is constrained by abiotic, biotic and socio-economic factors. Biotic factors are defined as the living components within an ecosystem which include organisms such as grains, insects, mites and microflora like fungi, bacteria and yeast. Socio-economic factors are known as attributes that related to the social environment of individuals, which include financial situation, family economy and parental occupation.

According to World bank (2017) unemployment coupled with the rising population are among the economic problems that most underdeveloped countries and some developing countries face. The situation in less developed countries has increased because of white collar jobs (World bank, 2015).

Abiotic factors are non-living components of an ecosystem that influence the environment and living organisms (Begon, *et al* 2006). Some of the factors can be physical or chemical in nature such as temperature, light, water, soil, salinity and nutrients availability.

Among the abiotic stresses, yield loss due to soil acidity in Zambia is an important factor. Which can be caused as a result of nutrient deficiency, a good example is excessive application of inorganic fertilizer and leaching. One of the most common physiological disorder of pepper is blossom_ end rot, a calcium deficiency disorders that appears only at the blossom end of the fruit (Hochmuth, 2009).

Inorganic fertilizers, commonly used in agriculture to enhance crop yield play a significant role in soil acidification. The primary mechanism through which inorganic can cause acidification is through their chemical composition (Michael 2021). Inorganic fertilizers typically contain ammonium (NH_4^+) or urea (NH_2CONH_2) as their main nitrogen(N) source. When these fertilizers are applied to the soil, they undergo chemical transformations that release H^+ into the soil solution, thereby decreasing soil pH (Zhang *et al*, 2022b).

Generally, NH_4+-based fertilizers, such as ammonium nitrate (NH_4NO_3) and ammonium sulphate $NH_4)$ $_2SO_4$), contribute to soil acidification through a process called nitrification that is conversion of NH_4+ to NO_3^-. During the conversion process H+ is released as a byproduct, leading to increased soil acidity (Wang *et al*. 2020). Urea, another commonly used N fertilizer, also contributes to soil acidity, though through a slightly different mechanism. When urea is applied to the soil, it is first hydrolyzed by the enzyme urease into ammonium carbonate. This compound then decomposes into ammonium bicarbonate and CO2 (Yao *et al*, 2021).

The ammonium carbonate dissociates into NH_4+ and HCO3‾. The NH_4+ are eventually converted to NO_3^- through nitrification. In addition to NH_4+ and urea-based fertilizers, superphosphate fertilizers also contribute to soil acidification, though to a lesser extent (Gao *et al*. 2021). Superphosphate fertilizers, which are derived from phosphate rock, contain H_2SO_4 as a byproduct. When superphosphate fertilizers are applied to soil, the sulfuric acid dissociates into H+ and SO4‾, which can contribute to soil acidification (Kubheka *et al*. 2020).

The loss of soil particles is one of the main ways erosions cause soil acidity. Topsoil, which has a higher concentration of organic matter and vital nutrients, is more prone to erosion. The top fertile soil layer often includes elevated levels of alkaline cations such as Ca, Mg, K, and Na (Horn *et al*. 2021). Erosion leads to the removal of these cations, exposing underlying soil layers with elevated levels of acidic cations, including Al and H+ (Babur *et al*. 2021). As a result, the buffering capacity of the soil is decreased, resulting in an overall rise in soil acidity.

Water erosion intensifies the process of leaking essential ions as water flows through the eroded soil. The depletion of essential nutrients disturbs the equilibrium of the soil, increasing its vulnerability to acidity. Leaching is more pronounced in areas with abundant rainfall or irrigation, where water infiltration occurs often (Jeon and Nam, 2019). The soil, which has been washed away, is now deficient in vital nutrients, making it more susceptible to acidification since it is unable to adequately neutralize the presence of acidic substances.

In addition, erosion-induced gathering of soil organic matter (SOM) in downstream or lower elevations in agriculture landscapes cause its decomposition and contribution to soil acidification. Nowadays there are many choices of recyclable waste products used to produce soil amendment. The food industry classifies fruit peels and chicken eggshells as food waste products.

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Statement of the Problem

Green pepper is a globally grown crop mainly for its fruit which can be used in stews and salads. The increasing demand for green pepper has led farmers to rely heavily on chemical fertilizer to boost crop yield (Adikari *et al*., 2016). However, the excessive use of chemical fertilizer poses significant environmental and health risks, including soil degradation, water pollution, and reduced crop nutritional value. (Singh *et al* 2020). Soil acidity poses a major constraint to green pepper production by limiting nutrient availability, disrupting microbial activity, and ultimately reducing crop yields (Fageria *et al*., 2010). Calcium is an essential nutrient for *Capsicum annuum*, and its deficiency can lead to blossom end rot a physiological disorder that affects fruit quality and marketability of green pepper (Lopez-Serrano, 2022). Green pepper thrives in slightly acidic to neutral soils, with an optimal pH range of 6.0 to 7.0. Eggshells, which are rich in calcium carbonate, have the potential to enhance soil fertility and mitigate calcium deficiency without contributing to the soil's acidity. However, the effects of eggshell soil amendments on the growth and yield performance of green pepper under smallholder production in Zambia require further understanding.

Objective of the study Main Objective

To investigate the effect of the application of eggshells on the growth and yield performance of green pepper.

Specific Objectives

1. *To evaluate the growth of green pepper plants treated with eggshell fertilizer under smallholder farming system in Lusaka.*
2. *To determine the effect of eggshell soil amendment on soil pH in a green pepper field under stallholder management in Lusaka and compare the results between plots treated with eggshell amendments and those left untreated.*
3. *To compare the yield of green pepper plants grown with eggshell soil supplementation to those grown without the eggshell amendments in Lusaka district.*

Null Hypothesis (H_0): There is no significant difference in the growth and yield of green pepper plants grown in soils treated with eggshell amendments compared to those grown without the amendments.

Alternative Hypothesis (H_a): There is a significant difference in the growth and yield of green pepper plants grown in soils treated with eggshell amendments compared to those grown without the amendments.

Significance of the study

This study will contribute to the promotion of sustainable agricultural practices by exploring the potential of using eggshells as organic fertilizer. The findings will be valuable to farmers and the systems that support them.

Conceptual Framework

The conceptual framework in this study of investigating the influence of eggshell on the growth and yield performance of green pepper provides a visualized representation of the study.

Key components of framework are independent, dependent and mediated variables.

Independent variables: eggshells

Dependent variables: green pepper growth and yield performance.

Mediating Variables: preparation method, timing, environmental factors. Soil fertility.

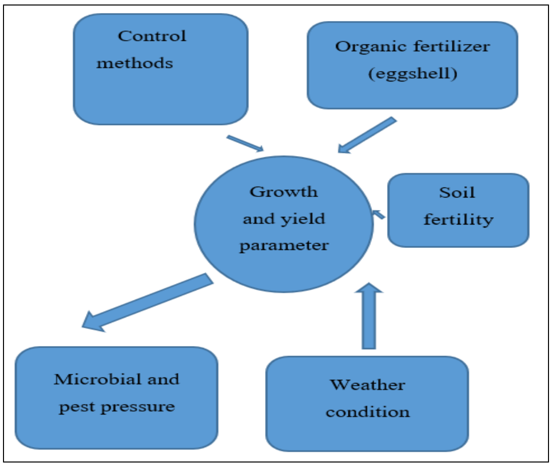


Fig 1: Conceptual framework

Ethical Considerations

The study prioritized the safety of participants and contributed to waste management by utilizing eggshells that would otherwise have been discarded. Additionally, the research actively engaged the local community, fostering collaboration and building trust. This approach ensured that the research outcomes were not only scientifically valid but also socially accepted.

2. Materials and Methods

Location of the study site

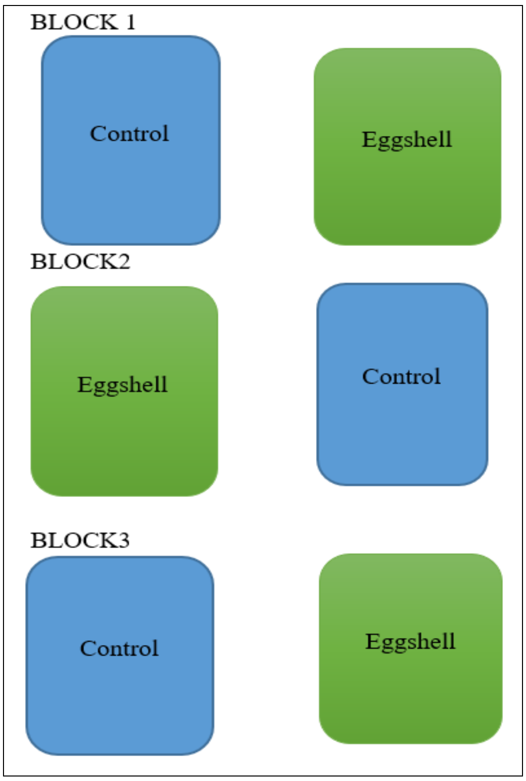
The field experiment was carried out in Kanyama compound of Lusaka District. To investigate the influence of eggshell on the growth and yield of green pepper (*Capsicum annum*). Kanyama compound is located in Agro-ecological Region II. This region receives medium annual rainfall of between 800 and 1000mm. Rainfall is generally well distributed and the length of the growing season at 70% probability ranges from 100 to 140 days. The growing season may however contain one to three 10-days dry periods of less than 30mm rainfall. These can significantly reduce crop yield especially on sandy soil. However, in normal years the climatic conditions are very favorable and together with the generally good soils make the region the most productive according to (Muliokela, 1995: 21).

The average temperature ranges may reach 32°c in October and 10°c in July. Severe frost maybe experienced in some parts of region II during the period of June to August.

Experimental design material, layout, trial establishment and management

Uniformed – plot size of 2m, intra spacing was 30cm and inter spacing was 60cm.

The experimental field layout was arranged in a Randomized Complete Block Design (RCBD), under irrigated conditions with three replications. This design was chosen to account for field variability and to ensure the accuracy and reliability of the results. RCBD helps minimize the effect of environmental heterogeneity such as soil texture, slope, and fertility differences across the experimental site.



Data Collection Compilation And Analysis

Systematic data collection was conducted during the experiment to collect the plant height, leaf count, leaf size and weight. A note book for recording observations manually in the field and a cellphone was - used for recording data to have it as soft copy. The research experiment on the growth and yield of green pepper was subjected to statistical analysis of variance (ANOVA) to test for significant differences among treatments. The data analysis -were performed using - SPSS (statistical package for social science) software. Data on plant height, leaf count, stem diameter and leaf size we collected in week six, data on weight was collected in week eight. The unit of measurement was collected in centimeters and kg.

3. Result

The results failed to revealed a significant difference among plant height, leaf count, leaf size, stem and diameter the readings were obtained from the plots treated with powered eggshell and the untreated control. The asterisk (ns) means there was no statistically significant (Table 1).

Table 1: Week six: Analysis of variance for Plant height, Leaf count, Leaf size, stem diameter and Flower across the two treatments the untreated control and the treated eggshell

Variable	Mean	Sd	F	Sig
Plant height	9.83	0.983	0.143^{ns}	0.725
Leaf count	15.33	1.366	7.200^{ns}	0.055
Leaf size	3.383	0.3764	2.641^{ns}	0.179
Stem diameter	3	0.4427	0.000^{ns}	1.000

^{ns} No statistically significant ($p \leq 0.05$)

There was a positive correlation between the application of the treatment and plant height. The treated eggshell shows a greater mean value for plant height compared to the untreated. The figure shows the difference in the performance of plant heigh using a mean plot.

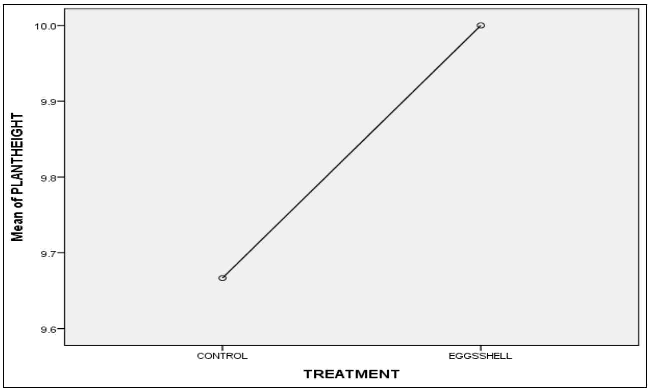


Fig 1: Graphical representation of plant height week 6

There was a positive correlation between the application of the treatment and leaf count. The treated eggshell shows a greater mean value for leaf count compared to the untreated control. The figure shows the difference in the performance of leaf count using a mean plot.

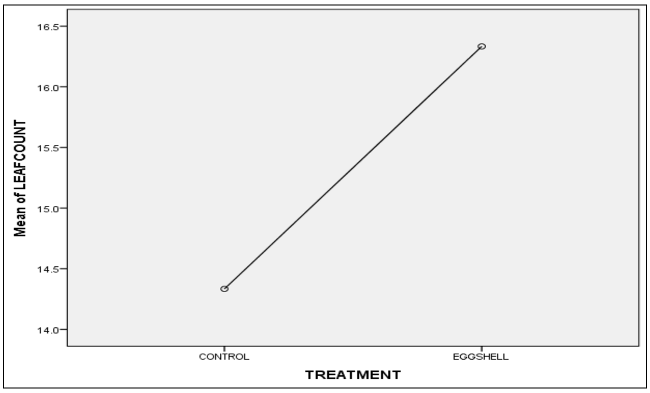


Fig 2: The graphical representation of leaf count week 6

The results revealed a significant difference among leaf count and stem diameter readings obtained from the plot treated with powder ed eggshell, and the readings for plant height, leaf size, and weight revealed no significant different from plot treated with powdered eggshell and untreated control the readings were obtained from the plots treated with powered eggshell and the untreated control. The asterisk (**) means there was moderate significant, the asterisk (*) and asterisk (^{ns}) non-significant different. Table 4

Table 2: Week Eight: Analysis of variance for Plant height, Leaf count, Leaf size, stem diameter, weight across the two treatments untreated control and treated eggshells

Variable	Mean	Sd	F	Sig
Plant height	12.283	1.1321	0.325^{ns}	0.599
Leaf count	22.33	2.066	14.29^{*}	0.019
Leaf size	5.750	0.7714	0.418^{ns}	0.553
Stem diameter	2.083	0.0983	25.00^{**}	0.007
Weight	0.07625	0.019738	0.101^{ns}	0.781

^{ns} No statistically significant ($p \leq 0.05$), *significant($p \leq 0.05$), **moderate significant($p \leq 0.01$)

There was a positive correlation between the application of the treatment and leaf size. The treated eggshell shows a greater mean value for leaf size compared to the untreated control. The figure shows the difference in the performance of leaf size using a mean plot.

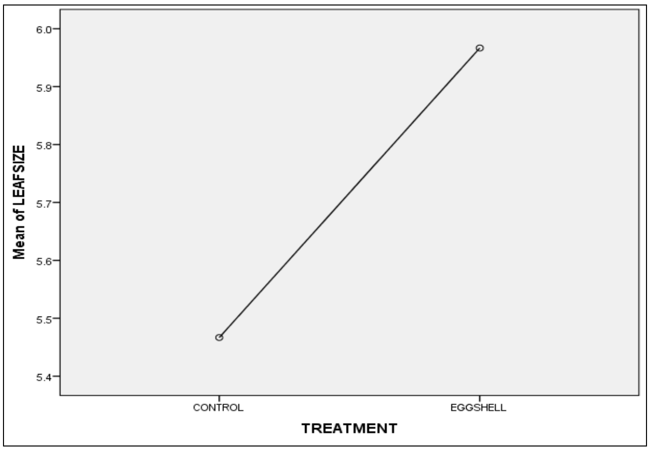


Fig 3: The graphical representation for stem diameter week 8

There was a positive correlation between the application of the treatment and stem diameter. The treated eggshell shows a greater mean value for stem diameter compared to the untreated control. The figure shows the difference in the performance of using a mean plot.

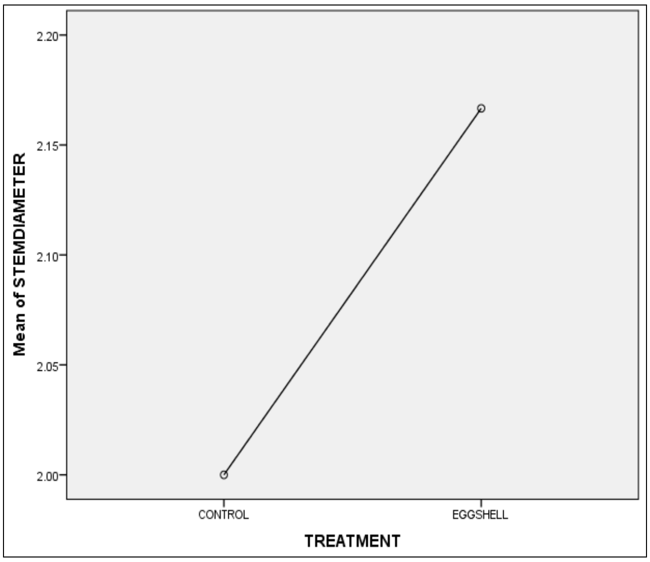


Fig 4: The graphical representation for stem diameter week 8

There was a positive correlation between the application of the treatment and weight. The treated eggshell shows a greater mean value for weight compared to the untreated control. Figure 10 shows the difference in the performance of weight using a mean plot.

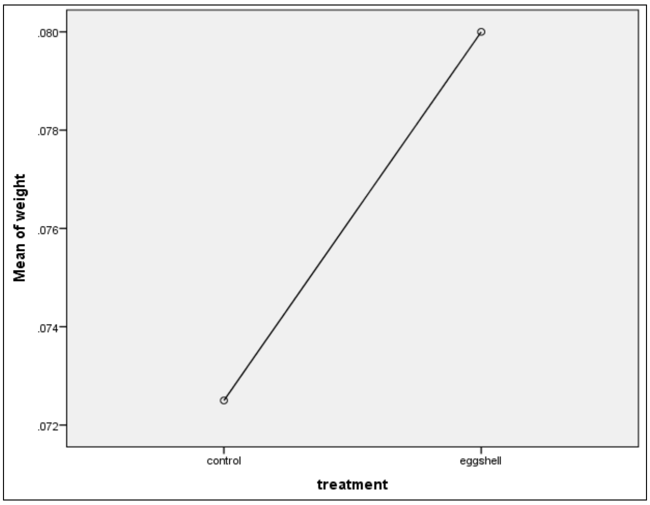


Fig 5: The graphical representation of weight week 8

4. Discussion and Conclusion

4.1 Discussion

Organic fertilizers are widely used to enhance soil quality and supply essential nutrients for plant growth. In the present study, soil was supplemented with eggshells commonly regarded as household waste as a natural fertilizer for green pepper (*Capsicum annuum*). Based on the first objective, the performance of green pepper plants treated with eggshells was superior to that of the control group in the mean plots for plant height, leaf count, leaf size stem, diameter and weight. Eggshells are known to be rich in calcium, comprising approximately 96% calcium carbonate, as reported by Oliveira *et al*. (2013).

The results showed a significant increase in soil pH, because before the application of eggshell the soil pH was 6.5 and after application the soil pH increased to 7.0, demonstrating that eggshells can effectively function as a soil amendment. These findings align with those of Boron (2004), who noted that eggshells are commonly used in agriculture to correct soil acidity and serve as a natural source of calcium, thereby reducing reliance on limestone. Similarly, research by Nurjayanti *et al*. (2012) indicated that eggshells can substitute lime in improving the pH of alluvial soils.

There was a noticeable improvement in plant growth, particularly in leaf count and stem diameter in week eight and week ten leaf count. These findings particularly answer objective three and aligns with the work of Taufique *et al*. (2014), who reported that the application of eggshell powder on various crops significantly enhanced growth and yield. Similarly, Hamester *et al*. (2012) recommended eggshells as an effective organic fertilizer, citing their role in improving nutrient uptake in plants. In agricultural practice, eggshells contribute to soil fertility and act as a sustainable amendment that promotes plant development. Moreover, studies on tomato cultivation have shown that eggshell application reduces the incidence of plant diseases, mitigates blossom-end rot, and lowers production costs. Hochmuth (2009).

4.2 Conclusion

The results indicate that the application of eggshell powder can improve plant growth. These findings suggest that eggshells are a valuable, sustainable, organic fertilizer for green peppers and can also serve as a soil amendment to improve pH. As a nation, it is important to prioritize organic farming, educate farmers, and apply the insights revealed by this and other research supporting organic practices. By doing so, we can protect our land and ensure a sustainable future for the next generations.

5. Recommendations/suggestions for further research

Based on the finding's eggshell can be used as a fertilizer to enhance green pepper growth and soil PH small-scale farmers can crush eggshells and incorporate the powder into the soil early before plant, the next crop as it is a slow-release soil amendment.

Further Research: Should focus on using different concentration of powered eggshells and liquid fertilizer of powered eggshell which can be made by soaking powdered eggshell in vinegar water or just water.

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