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Growth response of nursery raised cashew seedlings to light clay soil amended with inorganic fertilizers

Aremu-Dele Olufemi[1+]
Sobowale Ibrahim Olalekan[2]
Nduka Beatrice Abanum[3]
Ogbeide Christerbeth Edugie[4]
Salisu, Umar[5]

[1,3,4,5]*Agronomy & Soil Division, Cocoa Research Institute of Nigeria, Idi-Ayunre, Ibadan, Oyo State, Nigeria.*
[1]*Email: aremudeleolufemi@gmail.com*
[3]*Email: beatricenduka@yahoo.com*
[4]*Email: ogbehidechristerbet@yahoo.com*
[5]*Email: likitabuna@gmail.com*
[2]*Crop Improvement Division, Cocoa Research Institute of Nigeria, Idi-Ayunre, Ibadan, Oyo State Nigeria.*
[2]*Email: sobolekky@gmail.com*


(+ Corresponding author)

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ABSTRACT

This study aims to evaluate the performance of light clay soil amended with inorganic fertilizer in the early cashew seedling growth phase. The two month experiment was set up in a screenhouse at the Cocoa Research Institute of Nigeria. The experiment was laid out in Complete Randomized Design. The first factor consists of cashew biotypes (large and medium) while the second factor includes 2 fertilizer combinations (Urea and Single-Super-Phosphate (SSP)). The treatments include Large + 0 (L0 as control), Large + 40kg/ha Urea + 30kg/ha SSP (L1), Large + 80kg/ha Urea + 60kg/ha SSP (L2), Medium + 0 (M0 as control), Medium + 40kg/ha Urea + 30kg/ha SSP (M1), and Medium + 80kg/ha Urea + 60kg/ha SSP (M2). We applied the treatments one month after sowing. One nut seed per nursery polythene bag was sown using a light clay soil growing medium. The physicochemical properties of the growing media were analyzed while data on seedling emergence, growth parameters, and % seedling survival were recorded. Data was analyzed using Analysis of Variance, and treatment means were separated using Duncan Multiple Range Test (DMRT) at 0.05% probability level. Seedlings with no fertilizer treatments, L0 (4.5) and M0 (4.0), had the best seedling vigour, while L2 (2.5) and M2 (2.0) had the lowest, respectively, in a 5-grade score. The control, jumbo, and medium biotypes recorded a survival rate of 100%, 33.33%, and 16.67%, respectively. The application of the inorganic fertilizers to the light clay soil used negatively influenced cashew seedling growth.

Contribution/Originality: The preliminary results from this study show that the application of Urea and Single-Super-Phosphate inorganic fertilizers is not suitable for raising cashew seedlings when using light clay soil as the growing medium in the nursery. The use of organic fertilizers is recommended for cashew-growing areas in Nigeria with such soils.

1. INTRODUCTION

Cashew (*Anacardium occidentale*) is an economically important tropical crop that has found a thriving home in Nigeria's diverse agro-ecological zones [1]. It is a commercially important nut-bearing tree, known for its high nutritional value and economic significance. As one of the leading cashew-producing countries in the world, Nigeria

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has recognized the potential of cashew, not only as a source of foreign exchange but also as an essential driver of rural development and poverty reduction [2].

As the demand for cashew products continues to rise globally [3] there is a growing need to enhance cashew cultivation methods to meet market demands. One critical aspect of successful cashew cultivation lies in the production of healthy and vigorous seedlings in nurseries, as nursery management plays a crucial role in the early stages of cashew production, influencing the overall growth, vigour, and productivity of the trees in later stages on the field after field establishment [4].

Sandy loam and loamy soils are generally ideal for raising cashew seedlings [5] due to their good drainage, nutrient retention, aeration, and root penetration properties. These soil types provide a solid foundation for producing healthy and robust cashew seedlings ready for transplantation into the cashew orchard. Both sandy loam and loamy soils provide favorable conditions for cashew seedlings to develop into vigorous young plants [6].

Light clay soils are soils within the range of 35% to 45% clay, according to Peverill [7]. Despite their preference for well-drained sandy loam or loamy soil, cashew trees can thrive in areas dominated by light clay soils, but they struggle to grow on heavy clay soils [8, 9]. It's important to note that while cashew trees can grow on light clay soils, proper soil management practices, such as improved drainage and soil fertility enhancement, are necessary to ensure successful cashew cultivation [10]. Despite poor aeration observed in clay soils, they are generally also known to be low in essential plant nutrients [11, 12].

In light clay-dominated areas where cashew is grown, bringing in sandy loam or loamy topsoil incurs additional labour and costs for the farmers. Furthermore, it is important to evaluate the performance of light clay soils in the early seedling growth phase to encourage the adoption of seedling production value chain for farmers in light clay-dominated areas as a tangible source of income. Therefore, this study aims to evaluate the growth and development of cashew seedlings raised using light clay soil in the nursery.

2. MATERIALS AND METHOD

The two-month experiment was set up in a screen house at Cocoa Research Institute of Nigeria (CRIN) Headquarters, Ibadan, located around the rainforest belt of Nigeria. The experiment was a two-factorial experiment laid out in Complete Randomized Design (CRD) with 3 replications. The first factor consists of cashew biotypes, which are large and medium nuts, while the soil amendment is the second factor, which consists of 2 fertilizer combinations (Urea and SSP) at 3 levels: 0 (control), 40kg/ha Urea + 30kg/ha SSP (to meet the critical nutrient level), and 80kg/ha Urea + 60kg/ha SSP (above critical nutrient level). The fertilizers were applied one month after sowing (MAS). The nuts were sown at 3cm depth using 1 nut seed per 25cm by 12.5cm polythene nursery bag using a 2mm sieved clay soil collected within 0-15cm from the soil surface as the growing medium. The treatments include Large + 0 (L0 as control), Large + 40kg/ha Urea + 30kg/ha SSP (L1), Large + 80kg/ha Urea + 60kg/ha SSP (L2), Medium + 0 (M0 as control), Medium + 40kg/ha Urea + 30kg/ha SSP (M1), and Medium + 80kg/ha Urea + 60kg/ha SSP (M2).

The physicochemical analysis of the soil used was carried out before sowing, while the report of Egbe, et al. [13] was used to check for the sufficiency level of the plant nutrients available in the soil. We recorded data on the percentage of emergence at 2 and 4 weeks after sowing (WAS) to verify the first factor. Data on growth traits such as plant height (cm), number of leaves, leaf area (cm^2), and stem diameter (cm) were taken at 4, 6, and 8 WAS, and also, seedling vigour (5-Excellent, 4-Good, 3-Average, 2-Below Average and 1-Poor) as used by Olasan, et al. [14] was observed at 8 WAS to check the second factor. Growth parameters collected were subjected to Analysis of Variance (ANOVA) using GenStat Statistical Software, while % emergence, seedling vigour, and % seedling survival were analyzed using descriptive analysis. Treatment means were separated using the Duncan Multiple Range Test ($P<0.05$). At 4th WAS, the medium-sized biotype had 91.67% mean emergence, while the jumbo biotype had 75.00%.

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3. RESULT AND DISCUSSIONS

3.1. Physicochemical Properties of the Clay Soil Used

Table 1 displays the physicochemical characteristics of the light clay soil utilized as the growth medium for this experiment, before the implementation of fertilizer treatments. The soil's pH measures 4.25, indicating acidity, though it falls within the pH range of 4 to 7, which [15] identifies as optimal for cashew growth. Referring to Egbe, et al. [13] findings, the soil's Organic Carbon (0.38g/kg), total Nitrogen (0.08g/kg), and available phosphorous (2.96mg/kg) levels were all below the critical threshold, indicating insufficiency, which corresponds to the findings of Salami and Osonubi [11] and Adeyemo, et al. [12]. On the other hand, Potassium (K) levels were adequate, surpassing the critical level. This outcome prompted the application of Urea to supply Nitrogen and Muriate of Potash to enhance Phosphorus supply in this research. The soil's textural classification places it within the light clay category, comprising 32.8% sand, 24.0% silt, and 43.2% clay.

Table 1. Physicochemical properties of the soil used.

Parameters	Values	Critical level
Chemical properties		
pH (1:2 H_2O)	4.25 (Acidic)	-
Organic carbon (g/kg)	0.38	Below
Total nitrogen (g/kg)	0.08	Below
Available phosphorous (mgkg-1)	2.96	Below
K (cmol kg-1)	0.49	Above
Soil texture		
Sand (%)	32.8	-
Silt (%)	24.0	-
Clay (%)	43.2	-
Textural class	Clay	-

3.2. Cashew Seedling Mean % Emergence

The emergence of seedlings from the two different cashew biotypes became evident two weeks after sowing (WAS), as illustrated in Figure 1.

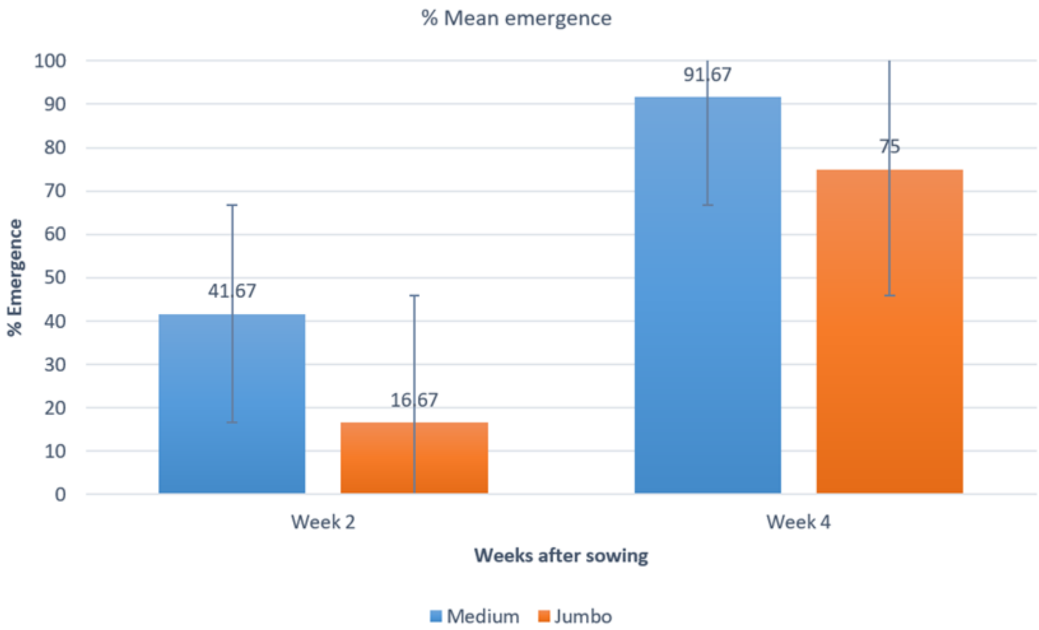

Figure 1. Cashew seedling % emergence as influenced by biotype.

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The medium-sized biotype exhibited a significantly higher % mean emergence rate of 41.67% compared to the jumbo biotype, which demonstrated an emergence rate of 16.67%. This observation suggests that the medium-sized biotype demonstrated a swifter emergence than the jumbo biotype. By the 4th WAS, the medium-sized biotype continued to maintain its dominance in % mean emergence, recording 91.67%, whereas the jumbo biotype exhibited an emergence rate of 75.00%.

This phenomenon aligns with findings from other studies indicating that medium-sized cashew biotypes tend to exhibit faster emergence than jumbo biotypes [16, 17] which is consistent with the outcomes of this current study. This suggests that the early emergence of medium-sized cashew seedlings is not primarily influenced by the properties of the growth medium, but rather represents an inherent trait of the cashew biotype. Additionally, research has shown that smaller cashew nut sizes tend to emerge faster than their larger counterparts [18].

3.3. The Inorganic Fertilizer Effect on Cashew Seedlings

Generally, the application of the inorganic fertilizers at both levels on the two biotypes was detrimental to cashew seedling morphology, vigour, and seedling survival as a result of this study.

One of the factors observed in this study that could be responsible for this negative result was poor infiltration of water into the soil after watering, creating a high concentration of the fertilizer on the soil surface and increasing the chances of fertilizer contact with the plant, which is injurious to the seedlings, and in very extreme cases, can lead to seedling death.

Water takes ample time to infiltrate clay-dominated soils due to poor porosity and compactness of the soil which is responsible for the poor infiltration of water experienced in this study after routine watering of the seedlings. Panda and Biswal [19] also observed similar results on clay soils in their study. Another factor could likely be an increase in soil acidity as a result of the inorganic fertilizers applied.

3.4. Cashew Seedlings Growth Parameters

Table 2 reveals that there were no statistically significant disparities in the height of cashew seedlings observed throughout the entire observation period. However, at the 8th week after sowing (WAS), the medium biotype treatments' control treatment M0 (20.7 cm) displayed the tallest seedling height among the medium biotype treatments, while a similar outcome was noted, while the three large biotype treatments showed a similar outcome, with L0 (21.0 cm) having the greatest seedling height.

This suggests that the two levels of inorganic fertilizer application did not yield improvements in the height of cashew seedlings for both biotypes when cultivated on light clay soil. The concentration of inorganic fertilizer solutions such as urea has been observed to cause acidity [20] which can be detrimental to the growth of crops [21].

Continuing with the findings from Table 2, no noteworthy distinctions in the stem diameter of cashew seedlings were observed among the treatments at 4 WAS and 6 WAS. However, by 8 WAS, comparable differences emerged among the treatments, while no substantial distinctions were observed within treatments of the same biotype. Within each biotype, M2 (5.90 mm) exhibited a slightly thicker stem diameter, but this difference was not markedly significant when compared to M0 (5.26 mm) and M1 (4.69 mm), while L2 (6.56 mm) displayed a slightly thicker stem diameter but was not notably different from L1 (6.55 mm) and L0 (6.54 mm). This suggests that the application of the two levels of inorganic fertilizers did not lead to noteworthy enhancements in the stem diameter of cashew seedlings when cultivated in light clay soils, as findings according to Akanbi, et al. [22] revealed otherwise, as NPK fertilizer applied, which is an inorganic fertilizer gave the best result in stem diameter when applied to sandy clay loam soil to raise cashew seedlings.

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Table 2. Cashew seedling height and stem diameter as influenced by amended clay soil.

Cashew biotype	Treat	Plant height (cm)			Stem diameter (mm)		
		WK 4	WK 6	WK 8	WK 4	WK 6	WK 8
Medium	M0	16.9^{a}	18.3^{a}	20.7^{a}	4.31^{a}	4.87^{a}	5.26^{ab}
	M1	11.5^{a}	12.0^{a}	13.3^{a}	2.24^{a}	3.37^{a}	4.69^{a}
	M2	15.3^{a}	16.6^{a}	17.4^{a}	4.78^{a}	5.31^{a}	5.90^{ab}
Large	L0	15.9^{a}	18.5^{a}	21.8^{a}	5.20^{a}	5.81^{a}	6.54^{b}
	L1	14.6^{a}	15.3^{a}	16.4^{a}	4.41^{a}	4.90^{a}	6.55^{b}
	L2	17.1^{a}	17.4^{a}	19.6^{a}	5.03^{a}	5.78^{a}	6.56^{b}

Note: M0= Medium + 0; M1= Medium + 40kg/ha Urea + 30kg/ha SSP; M2= Medium + 80kg/ha Urea + 60kg/ha SSP; L0= Large + 0; L1= Large + 40kg/ha Urea + 30kg/ha SSP; L2= Large + 80kg/ha Urea + 60kg/ha SSP; WK= Week; Treatments with the same letter (s) are not significantly different @ 0.05% probability level.

Table 3 shows significant difference was observed among the treatments in the number of leaves at 6 and 8 WAS. However, no significant variations in the number of leaves were observed among treatments of the same biotype. At 8WAS, M0 and M2 both had 7 leaves which was more than what M1 (4.5) had among the medium biotype treatments while L0 (9.5) had the highest number of leaves among the large biotype treatments. The two levels of fertilizers applied on both biotypes did not influence the cashew seedling leaf area all through the period of observation as further revealed in Table 3. Though no significant difference was observed, the fertilizer treatments all had smaller leaf areas in both biotypes when compared with their corresponding control treatments which could also be a result of the toxicity of the fertilizer applied as a result of poor infiltration experienced after watering on the light clay soil used. In addition, Xiang, et al. [21] reported that inorganic fertilizers tend to cause soil acidity which can affect plant growth negatively. The observations of the growth parameters generally suggest no improvement occurred in the growth and development of cashew seedlings of the two biotypes at both rates used in this study when inorganic fertilizers were used on clay soil growth medium.

Table 3. Cashew seedling height and stem diameter as influenced by amended clay soil.

Cashew biotype	Treat	No. of leaves			Leaf area (cm^{2})		
		WK 4	WK 6	WK 8	WK 4	WK 6	WK 8
Medium	M0	5.0^{a}	6.5^{ab}	7.0^{ab}	33.4^{a}	35.4^{a}	36.6^{a}
	M1	4.0^{a}	4.5^{a}	4.5^{a}	17.9^{a}	13.2^{a}	15.4^{a}
	M2	6.0^{a}	7.0^{ab}	7.0^{ab}	34.1^{a}	35.3^{a}	35.4^{a}
Large	L0	6.5^{a}	8.5^{b}	9.5^{b}	40.8^{a}	37.8^{a}	40.1^{a}
	L1	6.0^{a}	7.0^{ab}	7.5^{ab}	27.4^{a}	27.8^{a}	26.8^{a}
	L2	5.5^{a}	8.0^{b}	8.5^{b}	43.7^{a}	43.1^{a}	37.8^{a}

Note: M0= Medium + 0; M1= Medium + 40kg/ha Urea + 30kg/ha SSP; M2= Medium + 80kg/ha Urea + 60kg/ha SSP; L0= Large + 0; L1= Large + 40kg/ha Urea + 30kg/ha SSP; L2= Large + 80kg/ha Urea + 60kg/ha SSP; WK= Week; Treatments with the same letter (s) are not significantly different @ 0.05% probability level.

Figure 2 revealed that seedlings with no fertilizer treatments L0 (4.5) and M0 (4.0) had the best seedling vigour, with approximately excellent and good scores, respectively. Looking at the medium biotype treatments, M0 (4) was not notably different from M1 (2.5), which had an approximately average vigour score, but notably different from M2 (2.0), which had a below-average vigour score. A similar trend was also observed among the large biotype treatments, as L0 (4.5) was not significantly different from L1 (3.0) with an average vigour score but significantly different from L2 (2.5), which had an approximately average vigour score. From this result, it was observed that the application of the inorganic fertilizers negatively affected cashew seedling vigour, and in addition, an increase in the rate of the inorganic fertilizer applied decreased cashew seedling vigour of the two cashew biotypes. Inorganic fertilizers, such as urea as used in this experiment, have been observed to increase soil acidity when used over a period of time in excess [23, 24]. The decrease in cashew seedling vigour could be a result of the increase in the

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acidity of the soil, which has been observed to be acidic initially, as shown in Table 1. Cashews have also been shown to react negatively to extreme soil acidity.

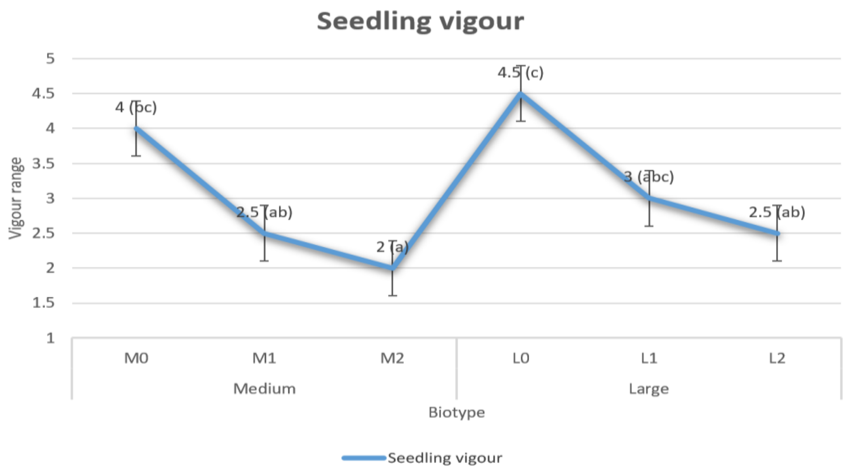

Figure 2. Cashew seedling vigour as influenced by amended clay soil.

Note: Treatments with the same letter (s) are not significantly different @ 0.05% probability level.

Figure 3 shows cashew seedling survival after the application of the inorganic fertilizer treatments. It was observed that no seedling loss was observed in M0 (100%), and L0 (100%) which were control treatments with no fertilizer applied through the period of observation. A significant decline in seedling survival was recorded in M1, with seedling losses ranging from 100% to 33.33% and 16.67% at 6 WAS and 8 WAS, respectively. M2 also experienced a significant decline in cashew seedling survival, as seedling loss from 100% at 4 WAS to 16.67% at 6 WAS and 8 WAS was observed. L1 and L2 both recorded seedling losses from 100% to 33.33% at 8 WAS. The acidic nature of the soil along with the acidic effect of the application of urea can be a factor behind this poor result, as inorganic fertilizers are capable of causing soil acidity [20, 21]. The influence of the inorganic fertilizers at both rates was more severe on the medium biotype, recording a survival rate of 16.67% than the large biotype, which had a survival rate of 33.33%. Other studies, such as those by Abinde, et al. [25] and Desai and Singh [26] have established that seedlings raised from larger nut sizes have more vigour and resistance to stress than seedlings raised from smaller nut sizes.

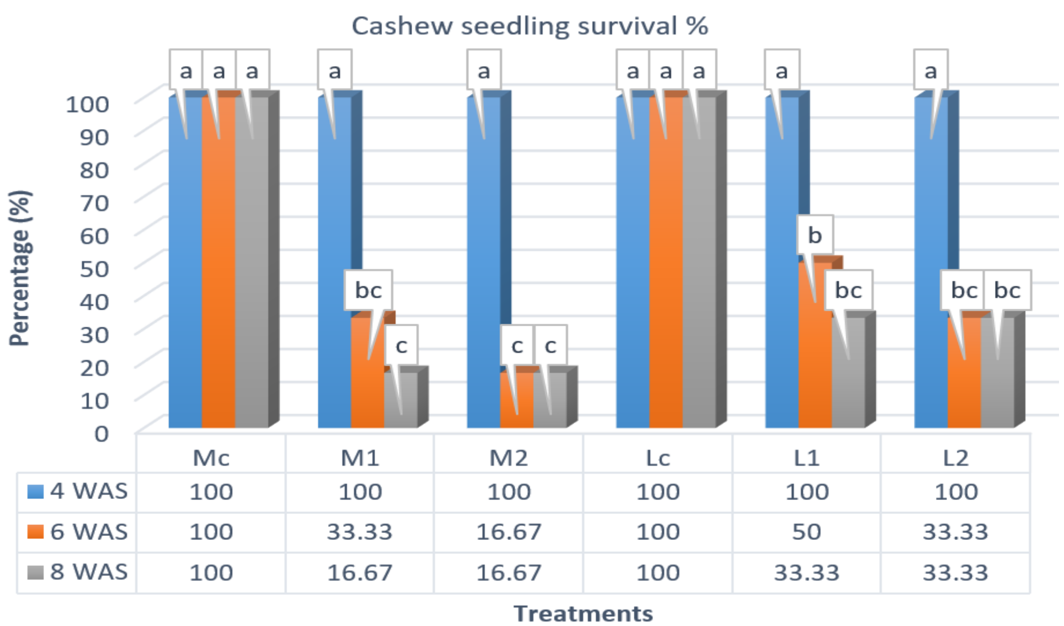

Figure 3. Survival count after the application of inorganic fertilizers.

Note: Treatments with the same letter (s) are not significantly different @ 0.05% probability level.

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4. CONCLUSION

Medium and large cashew biotype emergence was not influenced by the growing medium used in this study, as emergence was as expected as the medium biotype emerged faster and more than the large biotype. The inorganic fertilizers applied to the clay growth medium negatively influenced cashew seedling growth and also resulted in a seedling loss of 66.67% and 83.33% of large and medium cashew seedlings, respectively, when raised in nursery polythene bags. It is suggested that organic fertilizer can be used in place of the inorganic fertilizers used in this study due to the peculiarity of the soil type used, as organic fertilizers are known to also supply plant nutrients, buffer soils, increase soil porosity, and increase water infiltration.

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Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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