Influence of Varying Rates of Fertilizers on the Performance of Cacao (Theobroma cacao) Seedlings in the Nursery

Idowu B. Famuwagun¹* and Oladitan Titilayo O.²

¹Department of Crop, Soil and Pest Management, Federal University of Technology, Akure Nigeria
²Rufus Giwa Polytechnic, Owo, Nigeria

*ibfamuwagun@futa.edu.ng

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Abstracts. Effects of application of poultry manure, organo-mineral fertilizer, NPK soil or foliar applied at varying rates on cacao seedlings were studied in the nursery between January-May 2011 and December to April, 2012. Poultry manure at 40, 50 and 60g/plant significantly influenced cacao seedlings height and number of leaves over other treatments. The effect of organo-mineral fertilizer application at 50 and 60g per plant on the number of leaves was also significantly better than NPK soil or foliar applied, starting from 12 weeks after treatment application. The stem girth development under poultry manure at 50 and 60g per plant application had the best performance followed by poultry manure at 40g per plant. There were no significant differences in almost all the treatments at 5 weeks after sowing on seedlings stem girth. NPK has the longest tap root length while poultry manure had the largest average number of lateral roots followed by organo-mineral. The results thereby indicated that the use of poultry manure at 40 to 50g per plant and organo-mineral fertilizer as sources of nutrients had significant effects on cacao seedling quality.

Introduction

Cacao (Theobroma cacao L.) is a tropical woody species which belong to the family Malvaceae [1]. The geographical origin of cacao is South America [2], where several wild populations can be found in the Amazon and Guyanian regions. It is considered one of the most important perennial crops with an estimated world output of 3.5 million tonnes in 2006 [3]. It is one of the tropical crops that required raising the seedlings in the nursery before transplanting to the permanent field [4]. In cacao seedling production, adequate nutrients supply is essential for optimum growth and development both at nursery and in the field after transplanting [5]. In recent years, several reports revealed decrease in establishment percentage of transplanted cacao seedlings due to poor seedling development from the nursery, poor farm management practices and soil and air moisture stresses [6]. These problems were also compounded by deficiencies of both macro and micro nutrients [7], which had resulted in drastic reduction in the yield of such plantations. Also there is need to supply adequate nutrients to cacao seedling at the nursery stage to aid root and shoot development [6]. Many field reports gives an average of less than 40% survival in most cases, which has resulted in significant losses for farmers [8]. Effective management of cacao seedlings in the nursery using appropriate agronomic practices like fertilization, dry season irrigation, and appropriate self-multiplying bio fertilizer like AMF to enhance root development will enhance seedling growth and gives optimum field establishment [9]. However, very few studies have tried to determine the appropriate fertilizer products and the application rates in the nursery in the Nigerian context. The objective of the study was therefore to: assess proper fertilization of cacao in nursery to raise healthy and vigorous seedlings so as to provide good transplantable seedlings that can well adapt to field conditions so as to facilitate early establishment of the just transplanted seedlings and growth. Various fertilizer materials were used at variable rates to determine the suitable product and rates.
Materials and Methods

An experiment was conducted between January and May 2011 and repeated in 2012 in the Teaching and Research Farm of the Federal University of Technology, Akure, Nigeria within the rainforest zone to investigate the effects of fertilizers application on cacao seedling growth and development in the nursery. The treatments involved were N:P:K (15:15:15) soil applied at 15g, 20g, 25g per seedling), N:P:K (15:15:15) folia applied (40, 50 and 60ml/litre of water), Sunshine organo-mineral fertilizer (40, 50 and 60g/plant) and poultry manure (40, 50, 60g/plant). The forms of the NPK in the fertilizers were ammonium nitrate for N, single superphosphate (SSP) 20 % P$_2$O$_5$ for P and potassium chloride (KCl) for K. The Sunshine organo-mineral used was an organic fertilizer that was fortified with essential nutrient to meet various crop demands with 3.5% N, 2.5% P$_2$O$_5$ and 1.5% K$_2$O, while the poultry manure contained 3.2 % N. It is worth mentioning that the application rates used in this study were not adjusted to supply the equivalent amount of nutrients in each treatment. Black polythene pots of 4.5 x10 cm were filled with top soil from a well fallowed forest. The planting materials (cacao bean from freshly harvested pod) from the Cacao Research Institute of Nigeria (CRIN), Owena sub-station, Akure, Ondo State and were sown at one seed per pot. The experiments were set up in a randomized compete block design (RCBD) with each treatment having five replicates. Watering was carried out at two days interval throughout the period of the experiment. The fertilizer treatments were applied at two weeks after sowing at the specified rates for the soil application and folia fertilizers in a two split application at 2 and 12 weeks after sowing to enhance timely availability and reduce loss due to leaching and oxidation of essential nutrients.

Data collection from the raised seedlings was scheduled at every 2 weeks interval after the application of the fertilizers; however, only data at 4 weeks interval are presented. Data collected include plant height, number of leaves and stem girth as well as root parameters The root parameters were taken at 16 weeks after sowing and include tap root, length and number of lateral roots,. The data were subjected to analysis of variance (ANOVA) using SPSS and the means were separated using Duncan’s New Multiple Range Test (DNMRT).

Results

Seedling height

Application of poultry manure positively influenced cacao seedlings development in term of plant height which is significantly higher compared with other fertilizer treatments across the various rates of application in 2011 experiment. In 2012 experiment, a similar trend was observed, except for the data sets collected at 8 weeks after sowing (WAS). NPK folia applied at 40ml/litre, NPK soil applied at 20g/plant and organo-mineral fertilizer applied at 40g/plant were not significantly different from those recorded with poultry manure applied at 40g and 50g per plant at 8 WAS as shown in Table 1 (P≤0.05). Organo-mineral fertilizer application significantly enhanced cacao seedlings plant height compared to NPK folia applied, NPK soil applied and the control but were significantly lower compared with those recorded in poultry manure treated seedlings (Table 1).

Table 1. Effects of varying rates of fertilizer application on plant height (cm) of cacao seedlings in the nursery

| Treatments            | Weeks after sowing in 2011 | Weeks after sowing in 2012 |
|-----------------------|----------------------------|----------------------------|
|                       | 8  | 12 | 16 | 8  | 12 | 16 |
| NPK folia applied @40ml | 22.0cde | 27.0cdf | 31.0bcd | 24.2a | 26.0bc | 32.5cdf |
| NPK folia applied @50ml | 19.7def | 24.4efg | 28.4de | 21.3bc | 25.1cd | 31.6def |
| NPK folia applied @60ml | 16.9ef | 31.4abc | 33.4bcd | 22.0b | 25.7cd | 32.4cdef |
| NPK soil applied @15g/plant | 20.4de | 23.8efg | 29.8bcd | 21.3bc | 26.0bc | 34.0cde |
| NPK soil applied @20g/plant | 20.9cde | 22.6fg | 23.8e | 25.0a | 28.4b | 36.2bc |
Number of leaves of the seedlings

Poultry manure treated seedlings producing a significantly higher number of leaves in the two trials compared with other fertilizer treatments (Table 2). However, no marked difference among the three rates of fertilizer application in term of number of leaves produced for NPK soil and foliar applied, poultry manure, and the organo-mineral fertilizers (P≤0.05).

Seedling stem girth

In 2011 experiment, with (P≤0.05) NPK foliar applied showed a significantly thicker seedling stem girth compared with the other treatments, while in 2012 experiment, the stem girth development was significantly higher in seedlings treated with poultry manure (40, 50 and 60g/plant), NPK foliar applied (40g/litre), and organo-mineral fertilizer (40 and 50g/plant) compared with the other treatments (Table 3).

| Treatments                          | Weeks after sowing in 2011 | Weeks after sowing in 2012 |
|-------------------------------------|-----------------------------|-----------------------------|
|                                     | 8  | 12  | 16  | 8  | 10  | 16  |
| NPK folia applied @40ml             | 5.8bcde | 7.0bcd | 8.4def | 6.2bc | 7.5bcd | 8.8def |
| NPK folia applied @50ml             | 6.8abcd | 8.0abcd | 9.0cdef | 6.1bcd | 7.3bcd | 9.4cdef |
| NPK folia applied @60ml             | 5.2de | 8.0abcd | 9.0cdef | 6.0bcd | 7.6bcd | 8.9def |
| NPK soil applied @15g/plant         | 6.2bcde | 8.4abcd | 11.1abcd | 6.2bc | 7.8abcd | 10.6cde |
| NPK soil applied @20g/plant         | 7.6abc | 9.0abc | 8.2def | 6.3bc | 8.2abc | 11.6bc |
| NPK soil applied @25g/plant         | 7.8a | 9.0abc | 9.0cdef | 7.5a | 8.6a | 11.3bc |
| Organo-mineral fertilizer@40g/plant | 6.6abcd | 7.8abcd | 10.2cdef | 6.0bcd | 8.1abc | 11.2bcd |
| Organo-mineral fertilizer@50g/plant | 6.6abcd | 8.4abcd | 10.8bcd | 6.7ab | 8.6a | 11.0bcd |
| Organo-mineral fertilizer@60g/plant | 5.8bcde | 6.8c | 6.8f | 6.1bcd | 7.7bcd | 10.8cde |
| Poultry Manure@40g/plant            | 7.2abc | 9.6ab | 14.0ab | 6.5abc | 8.4ab | 12.6ab |
| Poultry Manure@50g/plant            | 8.0a | 9.8a | 14.4a | 6.8abc | 8.3ab | 13.5a |
| Poultry Manure@60g/plant            | 6.2abcd | 6.0d | 12.4abc | 6.5abc | 7.8abcd | 12.4ab |
| Control                             | 6.8abcd | 7.4abc | 8.2def | 7.0ab | 8.1abc | 8.9def |

Means in same column followed by same letter(s) are not significantly different P≤0.05 using Tukey Test.
Table 3. Effects of varying rates of fertilizer application on stem girth (cm)

| Treatments                      | Weeks after sowing in 2011 | Weeks after sowing in 2012 |
|---------------------------------|-----------------------------|-----------------------------|
|                                 | 8              | 12             | 16             | 8              | 12             | 16             |
| NPK folia applied @40ml         | 0.62a          | 0.82a          | 0.90b          | 0.72a          | 0.87ab         | 0.99a          |
| NPK folia applied @50ml         | 0.46de         | 0.65cde        | 0.76b          | 0.58b          | 0.75bcd        | 0.82abc        |
| NPK folia applied @60ml         | 0.42def        | 0.64cde        | 1.18a          | 0.58a          | 0.78abcd       | 0.86abc        |
| NPK soil applied @15g/plant     | 0.48def        | 0.58de         | 0.89b          | 0.62a          | 0.74bcd        | 0.81abc        |
| NPK soil applied @20g/plant     | 0.42def        | 0.56b          | 0.62b          | 0.59a          | 0.58e          | 0.62d          |
| NPK soil applied @25g/plant     | 0.52bcd        | 0.66cde        | 0.76b          | 0.64a          | 0.76bcd        | 0.79cd         |
| Organo-mineral fertilizer@40g/plant | 0.42def    | 0.71bc         | 0.83b          | 0.56a          | 0.78abcd       | 0.85abc        |
| Organo-mineral fertilizer@50g/plant | 0.52bcd    | 0.71bc         | 0.83b          | 0.66a          | 0.78abcd       | 0.90ab         |
| Organo-mineral fertilizer@60g/plant | 0.40ef     | 0.58de         | 0.70b          | 0.58a          | 0.66de         | 0.78cd         |
| Poultry Manure@40g/plant        | 0.58ab         | 0.70bc         | 0.88b          | 0.64a          | 0.84abc        | 0.93ab         |
| Poultry Manure@50g/plant        | 0.48cde        | 0.70bc         | 1.13b          | 0.63a          | 0.85abc        | 0.99a          |
| Poultry Manure@60g/plant        | 0.36f          | 0.68bcd        | 1.12b          | 0.52a          | 0.90a          | 1.0a           |
| Control                         | 0.56abc        | 0.77ab         | 0.96b          | 0.67a          | 0.90a          | 0.75cd         |

Means in same column followed by same letter(s) are not significantly different P≤0.05 using Tukey Test.

Seedling root system

In both 2011 and 2012 experiments, tap root length was enhanced significantly through the application of organo-mineral fertilizer at 60g/plant, NPK soil applied at 15g/plant and the control compared with other treatments. No significant difference in the tap root length among poultry manure and organo-mineral treated seedlings (Table 4). Lateral root number were significantly higher with treatments involving organo-mineral fertilizer at 60g/plant and poultry manure at 60g/plant compared with other treatments (P≤0.05).

Table 4: Effects of fertilizers application on root parameters of cacao seedlings

| Treatments                          | 2011 season | 2012 season |
|-------------------------------------|-------------|-------------|
|                                     | Tap root length (cm) | Number of lateral root | Average length of lateral root (cm) | Tap root length (cm) | Number of lateral root | Average length of lateral root (cm) |
| NPK folia applied @40ml             | 18.3abc     | 54.0d       | 11.3d         | 16.2abc       | 59.0d       | 13.4d         |
| NPK folia applied @50ml             | 13.3f       | 65.7c       | 13.3abcd      | 12.5f         | 61.6c       | 13.7abcd      |
| NPK folia applied @60ml             | 20.3a       | 63.7c       | 12.0cd        | 22.14a        | 73.7c       | 11.6cd        |
| NPK soil applied @15g/plant         | 18.3abc     | 44.0e       | 8.3e          | 18.0abc       | 55.0e       | 9.2e          |
| NPK soil applied @20g/plant         | 17.0bcd     | 52.3d       | 12.7bcd       | 17.25bcd      | 57.3d       | 10.3bcd       |
| NPK soil applied @25g/plant         | 16.7bc      | 52.0d       | 12.3bcd       | 18.6bcd       | 65.0d       | 11.1bcd       |
| Organo-mineral fertilizer@40g/plant | 16.0cd      | 61.0c       | 12.2cd        | 17.2de        | 72.3c       | 13.5cd        |
| Organo-mineral fertilizer@50g/plant | 14.7ef      | 52.3d       | 12.2cd        | 16.7ef        | 76.5d       | 13.8cd        |
| Organo-mineral fertilizer@60g/plant | 16.3bc      | 85.0a       | 15.7a         | 17.25a        | 87.0a       | 15.6a         |
| Poultry Manure@40g/plant            | 15.3cde     | 63.3c       | 12.0cd        | 15.5def       | 83.3c       | 12.5cd        |
| Poultry Manure@50g/plant            | 16.3bc      | 74.3b       | 11.7cd        | 16.7bcd       | 78.5b       | 11.4cd        |
| Poultry Manure@60g/plant            | 16.2bc      | 82.7a       | 15.0ab        | 17.7cde       | 86.7a       | 15.3ab        |
| Control                             | 18.5abc     | 65.0c       | 14.2abc       | 18.0ab        | 45.0c       | 12.0abc       |

Means in same column followed by same letter(s) are not significantly different P≤0.05 using Tukey Test.
Discussion

The significantly higher plant height obtained in poultry manure application at 40, 50 and 60g per plant was attributed to the fact that poultry manure contains reasonable amount of nitrogen and other essential nutrients that are essential for plant growth and development [10]. More so, it contain reasonable amount of calcium and magnesium which increases the elemental content of the soil [11]. [12, 6] reported seedling vigour as a key factor in cacao seedling quality which is determine by plant height, stem girth, number of leaves, and root system. The non-significant seedlings plant height under NPK soil applied may be due to the effects of watering method which imposed a leaching effect on the elemental nutrients supplied by the mineral fertilizer which was in line with the findings of [13] that top watering in potted plants enhances increased leaching losses. Foliar applied NPK has the lowest performance in term of plant height; this may be as a result of volatile nature of the nitrogen which reduced its availability to the seedlings or minimum intake of the foliar applied nutrients. Poultry manure may also present a competitive advantage of slow released nutrients, which would minimize losses during watering compared to NPK soil and foliar applied. This was in conformity with the earlier findings that organic manures are usually slow in mineralization [14]. NPK soil applied and NPK foliar applied have reduced number of leaves which may be accounted for by the ammonium ion present as nitrogen source that may reduce soil pH thereby causing soil acidity ([15], [16]. This assumption seems valid as the control showed better performance than the NPK treatments, although further studies may be required to validate the observation. Changes in soil pH such as acidification might cause nutrient unavailability to the seedling and consequently affect the seedling quality.

The poultry manure performance on seedling stem girths in the study was in line with the report of [17] that poultry manure contains high percentage of nitrogen, phosphorus and potassium at steady state. The gradual release of nutrient in poultry manure and organo-minerals fertilizer pave way for uniform growth and development in term of increased number of lateral roots both at the lower and the upper part of the tap root and higher average length of the lateral roots.

The fertilizer application rates were not adjusted to deliver the same rates of nutrients such as N, P, or K. Hence, there is a need to cross-validate the findings of this study in a similar assessment where the fertilizer rates are adjusted for at least one of the major nutrients. This will be useful to fine-tune the fertilizer recommendations for cacao seedlings. It is particularly important as the best performance was obtained with poultry manure whose quality may be affect by seasonal and feeding variability in addition to the manure management. An economic analysis of the various fertilizer products when applied at the rate adjusted based on the nutrient content of at least one of the major nutrients would also be necessary to determine the most cost-effective treatment.

Conclusion

Application of different types of fertilizer has enhanced cacao seedlings development in the nursery with appreciable effects. The poultry manure and the organo-mineral fertilizer did perform better than the inorganic NPK soil or foliar applied as at the study rates for production of high quality seedlings based on height, leaf numbers, stem girth, and root system. This finding should be validated through application of equivalent amount of at least one of the major nutrients (N, P, or K) in all the fertilizer treatments for robust recommendation.

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