

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

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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_2O_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_2O_5 and 1.5% K_2O , 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 complete 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 ($P \leq 0.05$). 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	27.0cdef	31.0bcd	24.2a	26.0bc	32.5cdef
NPK folia applied @50ml	19.7def	24.4efg	28.4de	21.3bc	25.1cd	31.6def
NPK folia applied @60ml	16.90f	31.4abc	33.4bcd	22.0b	25.7cd	32.4cdef
NPK soil applied @15g/plant	20.4de	23.8efg	29.8bcde	21.3bc	26.0bc	34.0cde
NPK soil applied @20g/plant	20.9cde	22.6fg	23.8e	25.0a	28.4b	36.2bc

NPK soil applied @25g/plant	22.7bcd	26.4def	28.8cde	21.2bc	25.7bcd	33.4cde
Organo-mineral fertilizer@40g/plant	20.2de	30.4abcd	35.6b	24.0ab	28.5b	37.5bc
Organo-mineral fertilizer@50g/plant	22.0bcde	27.8bcde	35.8b	20.0bc	25.3cd	37.8bc
Organo-mineral fertilizer@60g/plant	20.1de	24.8efg	29.6bcde	21.4bc	27.5b	37.0bc
Poultry Manure@40g/plant	26.6ab	33.8.a	42.6a	24.8a	30.3a	43.6ab
Poultry Manure@50g/plant	24.6ab	32.0ab	48.0a	25.1a	32.6a	44.2ab
Poultry Manure@60g/plant	24.6ab	21.6g	31.6bcd	22.3b	33.3a	46.7a
Control	23.9abc	27.8bcde	31.8bcd	21.9bc	26.0bc	32.5cdef

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

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 ($P \leq 0.05$).

Seedling stem girth

In 2011 experiment, with ($P \leq 0.05$) 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).

Table 2. Effects of varying rates of fertilizer application on number of leaves

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	10.8bcde	6.7ab	8.6a	11.0bcd
Organo-mineral fertilizer@60g/plant	5.8bcde	6.8cd	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	7.4abcd	8.2def	7.0ab	8.1abc	8.9def

Means in same column followed by same letter(s) are not significantly different $P \leq 0.05$ 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 $P \leq 0.05$ 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 ($P \leq 0.05$).

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	18.6bcde	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	16.7bcde	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 $P \leq 0.05$ 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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