DOI: 10.22620/agrisci.2024.41.001

GROWTH RESPONSE OF CACAO (*THEOBROMA CACAO* L.) SEEDLING AFTER AN INORGANIC FERTILIZER APPLICATION

Hazel Kendra Mendez[1], Dionie Barrientos[2]*

[1]Central Luzon State University, Science City of Muñoz, Philippines
[2]Aklan State University, College of Agriculture, Philippines
***Corresponding author's Email: dioniebarrientos@clsu.edu.ph**

Abstract

Fertilization of cacao seedlings is not yet a widely accepted practice in the Philippines and research studies are needed to define sources, rates and timing of application. The use of fertilizer as an agricultural technique for supplying the nutrients necessary for the development of cacao seedling in the nursery is an option. The objective of this study was to determine how different doses of the fertilizer can affect the growth of cacao seedlings in terms of days of emergence, plant height, stem girth, and number of leaves. The study was conducted at Buhangin Baler in Aurora province, the Philippines from June 2022 to December 2022. The experiment used a randomized complete block design with three treatments and four replications. The treatments were: T1 – Control (No inorganic fertilizer); T2 – Recommended Rate of Inorganic Fertilizer (RRIF) based on soil analysis result; and T3 – Double the Recommended Rate of Inorganic Fertilizer based on soil analysis result. The variant T2 or Recommended Rate of Inorganic Fertilizer applied had the best response out of the three treatments in terms of plant height, and stem girth and has a high percentage of survival after grafting and fertilization. The results showed that the grafted seedlings (BR 25 cacao variety as rootstock and Criollo cacao variety as scion) responded well in terms of plant height, and stem girth and has a high number of survival rate (60-65%) after grafting and application of 25% and 50% fertilizer. In terms of number of leaves, the grafted BR 25 cacao variety as rootstock and Criollo cacao variety as scion and grafted BR 25 cacao variety as rootstock and UF 18 cacao variety as scion were best performing at both single (T2) and double (T3) rate of fertilizers applied.

Keywords: cacao seedlings, Recommended Rate of Inorganic Fertilizer, rootstock, scion

INTRODUCTION

During 2016-2020 the volume of production of dried cacao beans in the Philippines recorded an increasing trend from 6,262.34 to 9,340.74 MT (PSA, 2020). The Department of Agriculture in the Philippines reported that the country's cacao bean consumption annually was 50,000 MT but the local supply is said to be somewhere between 10,000 -15,000 MT (Department of Agriculture, 2021). Such shortage of supply could be addressed through the production and planting of more cacao seedlings/trees that will later produce beans and by the expansion of areas that can also meet the demand through increased local supply consumption.

Cacao seedlings are grown typically in nurseries for almost six months before they are transplanted in the field. The commercial nurseries use the best-guess fertilizer schedule, but do not measure the plant growth and other performance indicators, seeking mainly to minimize the costs of production. In cacao seedling production the adequate nutrients supply is necessary for optimum growth and development (Egbe, 1968). There is a need to supply sufficient nutrients to cacao seedlings at

the nursery stage to aid the development of root and shoot (Famuwagun & Agele, 2011). Many field reports showed an average of less than 40% survival in most cases, which has resulted in significant losses for cacao farmers (Ibiremo et al., 2012). The effective management of cacao seedlings in the nursery by using appropriate agronomic practices such as dry season irrigation and fertilization to enhance root development will enhance the seedling growth of cacao and will give the optimum field establishment (Smith, 1994).

In Aurora province, Philippines, a total of six cacao nurseries are operating, four of them are small scale, one is a commercial type-BPI registered nursery, and one that is still ongoing. Cacao seedlings are one of the crops grown by the farm nurseries in Aurora. It is one of the bestselling seedlings due to its wide adaptation in the province. It produces a high profit once it bears fruits and the beans are processed into nibs, tablea or chocolate. It is one of the major crops in the province, since it has available local and national markets in general. It is also one of the crops that has been prioritized by the national government. There are six-cacao growers' associations and eight processing facilities for all the products made of cacao (OPA-Aurora personal communication). Aurora is one of the biggest producers of cacao beans in region III which resulted to the declaration of Central Luzon as one of the top producing regions of cacao beans in 2020 with a total volume of production of 338.91 MT (PSA, 2020).

In cacao production, the planting of seedling from desirable mother trees has been a practice. More new methods of vegetative propagation were found to give more advantages in terms of reproduction of true to type trees, high productivity, more uniform growth, early to bear flowers, and the clone perpetuates most, if not all, important characters of the original seedling mother tree. The adoption of vegetative propagation requires the availability of the source of bud wood materials/scions of approved recommended varieties (Magsasaka, 2020). Grafting is an asexual plant propagation technique. It is most commonly done by connecting two plant segments, the shoot piece known as 'scion' and the root piece called 'rootstock' (Goldschmidt, 2014). It is undertaken as a means of vegetative propagation of woody plants for any or all of the following reasons: to dwarf the scion making both its height and shape more convenient for fruit harvesting; to shorten the time of the first production of flowers or fruits by the scion, in some cases by many years; to impart disease resistance or hardiness, contributed by the rootstock; tao allow the scion cultivars to retain their desirable leaf, floral, or fruit`s characters, without the risk of these being lost through sexual reproduction; and to provide the most economic use of scion material, in cases where there is some difficulty with stem cuttings producing roots (JRank, 2020).

Fertilizer is the most important factor that influences the crop's quality and quantity. Inorganic fertilizer is immediately available to the plants and provides essential nourishment. Due to the increase in the world population, the crop production needs to be enhanced manifold. Hence, the nursery growers are making a best-guess fertilizer schedule to provide an optimum growth of their crop.

Cacao seedlings are one of the commodities suitable for smallholders, which could serve as a source of daily or weekly income for the growers. Thus, suitable fertilizer, rates and timely application that could enhance the vigor of seedlings is crucial for continual cacao production. However, there are no studies published online that are adapted by the local cacao nursery growers. Therefore, this study tried to determine and recommend application rates of the inorganic fertilizer in the nursery in the Philippine context.

MATERIALS AND METHODS

The study was conducted in June 2022 to December 2022 at Brgy, Buhangin Baler, Aurora province, the Philippines. Soil samples including soil, sawdust, and compost were collected and mixed. A kilogram of soil sample was tested at the Regional Soils Laboratory in San Fernando, Pampanga, the Philippines (Table 1). Cacao pods were collected from Fabros Farm, Maria Aurora, the Philippines. Seeds of the same size from matured pods of BR 25 were used as planting material. The small or deformed seeds were discarded. The Ragdoll method was used to determine the seed germination; it was done using a paper towel, soft and absorbent. Removing the mucilage that covers the seeds was done by rubbing with sawdust, washed in a pail of water then drained in a strainer. After straining, the seed were placed in a towel, fold and rolled into a round tube. The recommended rate of the inorganic fertilizer was 14g complete fertilizer, 10g of ammonium phosphate, and 10g urea per plant. Before filling each bag, the soil was mixed with 25% of the fertilizer treatment and the remainder wase applied on the soil surface - 25% after grafting, and the 50% four weeks later (Table 2). The fertilizer was applied late in the afternoon.

Table. 1. Soil physic-chemical analysis provided by the Regional Soils laboratory

Parameter	Value	Method
Texture	Medium	Feel method
pH	5.98	1:1=Soil: Water
Phosphorus	5.24	Olsen method (ppm)
Potassium	0.24	Ammonium acetate extraction method, pH 7 (cmol)

Table 2. Type and Percentage of Inorganic Fertilizer

Fertilizer	**Single Rate (% and g)**			**Double Rate (% and g)**		
	25%	25%	50%	25%	25%	50%
Complete	3.5	3.5	7	7	7	14
Urea	2.5	2.5	5	5	5	10
Ammonium phosphate	2.5	2.5	5	5	5	10

The polyethylene bags (152.4mm x 254mm) were filled with a mixture of soil, sawdust and compost. The germinated seeds were planted when the germs were 1 cm long. The single pre-germinated seed of BR 25 variety was placed in each bag in no more than 1 cm deep. Mealy bugs (*Planococcus minor*) and hairy caterpillars (*Spilarctia obliqua*) were the insect pest found on the set-up, while a leaf blight was the disease found. Neem oil and liquid soap was mixed with a gallon of water, steeped overnight and sprayed to the seedlings to get rid of the insect pests after handpicking failed to eradicate it. The treatment was laid out in a randomized complete block design (RCBD), with three treatments and four replications. Each replicate per treatment consisted of five seedlings. The treatments had three levels of applied recommended fertilizer based on the soil test analysis result: T1) No fertilizer, T2) Recommended rate and T3) Double the recommended rate. Mini net house was established as essential for the seedling growth. It served as a barrier to the direct sunlight, as well as the insect pests. A minimum of 2.44m of net was used, with a shading of between 30-40%. The seedlings were watered three times a week to keep the soil moist. Watering with too much pressure was avoided. Watering of seedlings in the afternoon was done

before the scheduled fertilizer application. Skipping the next round was done after the application of fertilizer. The cacao seedlings were grafted using the cleft grafting method.

Figure 2. Collecting data on the 35th day after the emergence

In preparing the rootstock, a three to four months old rootstock was used. The scion was selected from Fabros Farm at Maria Aurora, Aurora, the Philippines. The rootstock sawed perpendicular to the stem's main axis using a knife, and created a split through the center of the rootstock. Using a sharp and clean grafting knife, it was started near the base of the lowest bud and made two opposing smooth-tapered cuts with the lowest bud somewhat thicker than the opposite side. The scion was included on each end of the cleft. The cambium of each scion came in contact with the cambium of the rootstock. All cut surfaces were thoroughly sealed with cellophane to keep out the water and to prevent drying. After grafting, the seedlings were placed in the mini net house with a roof to ensure that it was protected from rainfall and direct sunlight for around twenty-one days. The data gathered were analyzed using analysis of variance (ANOVA). The comparisons among the means were done using the least significant difference (LSD) at 5% level of significance and performed using STAR (Statistical Tool for Agricultural Research) version 2.0.1.

RESULTS AND DISCUSSION

Plant height (cm)

The plant height of the three treatments is presented in Table 2. The results show significant differences among the three treatments on days 35 and 65 day after the emergence. The variant T2 had the highest height, resulting in 46.16 cm and 58.20 cm, followed by T3 with 41.02 cm and 54.12 cm, and T1 had the lowest height, measuring 37.69 cm and 41.98 cm, respectively.

Table 3. Plant height (cm) on days 35 and 65 after the emergence

Treatment	Day 35*	Day 65*
T1 - Control	37.69^{c}	41.98^{c}
T2 - Single Rate of RRIF	46.16^{a}	58.20^{a}
T3 – Double Rate of RRIF	41.02^{b}	54.12^{b}
CV%	10.27	9.21

Legend: */: Means with the same letter are not significantly different.

Stem girth (mm)

The stem girth measured on 35th and 65th day after the emergence (DAE) was influenced by the application of a different rate of the inorganic fertilizer as shown in Table 3. The stem girth of the seedlings on 35 days after the emergence under single and double rates showed no significant differences, with the highest mean of 1.66 mm on both T2 and T3, however, at 65 days after the emergence, the average mean for T2 and T3 was 2.28 mm and 2.27 mm, respectively. The variant T1 differed significantly from the other two treatments with an average mean of 1.55 mm on 35th day and 2.08 mm on 65th day.

Number of leaves

The number of leaves was influenced by the application of inorganic fertilizer. Table 4 shows the number of cacao leaves. It was recorded that T2 and T3 revealed no significant differences on days 35 and 65 after the emergence, resulting an average mean for T2 of 7.94 and 12.33 and T3 with 8.25 and 12.67. The variant T1 was significantly different from the other two treatments with an average mean of 6.99 and 8.42 on 35 and 65 days after the emergence, respectively.

Table 4. Stem girth (mm) on 35 and 65 days after the emergence

Treatment	Day 35*	Day 65*
T1 – Control	1.55[b]	2.08[b]
T2 - Single Rate of RRIF	1.66[a]	2.28[a]
T3 – Double Rate of RRIF	1.66[a]	2.27[a]
CV%	5.03	5.43

*/: Means with the same letter are not significantly different.

Table 5. Number of leaves on 35 and 65 days after the emergence

Treatment	Day 35*	Day 65*
T1 – Control	6.99[b]	8.42[b]
T2 - Single Rate of RRIF	7.94[a]	12.33[a]
T3 – Double Rate of RRIF	8.25[a]	12.67[a]
CV%	13.38	14.72

*/: Means with the same letter are not significantly different.

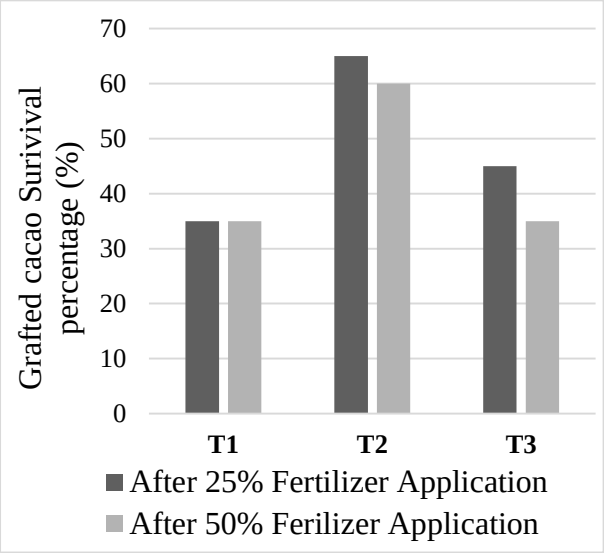

Figure 2. Survival percentage after 25% and 50% fertilizer application

Survival rate of grafted cacao seedlings

Figure 2 shows the percent of survival for grafted cacao seedlings per treatment. Only seven of the twenty grafted seedlings in T1 survived, which recorded a survival percentage of 35 after 25% and 50% fertilizer application. Thirteen grafted seedlings in T2 survived, which represents a survival rate of 65% after 25% fertilizer application, and eleven grafted seedlings survived, which denotes a survival rate of 60% after 50% fertilizer application. Only nine out of twenty in T3, which represents a survival rate of 45% after 25% fertilizer application and only seven grafted seedlings survived, which constitute a survival rate of 35%, after 50% fertilizer application.

The seedling vigor of BR 25 variety of cacao seedlings was greater in the soil applied with a single rate of recommended inorganic fertilizer. According to Famuwagun & Agele (2011) and Willson (1999) the key factor in cacao seedling quality is the seedling vigor, which is determined by the number of leaves, plant height, stem girth, and root system. The plant height was higher at a single rate of the recommended inorganic fertilizer compared to the double rate and no fertilizer application. The increase in plant height with NPK fertilization can be attributed to the fact that the macro elements, and specifically the nitrogen increases the number and length of the internodes and promotes plant growth, which results in a progressive increase in the plant height (Gasim, 2001; Saigusa et al., 1999; Turkhede & Rajendra, 1978). In the study of Trevisan et al. (2021), the application of 2g of urea per plant resulted in greater increments in the plant height of the cacao seedlings. Ferreira et al. (2019) reported that in the plant, the nitrogen has a structural function that is necessary for vegetative growth. The inorganic fertilizer used in the study contained nitrogen and helped the growth of the cacao seedlings under the split fertilizer application. In terms of stem girth and number of leaves, the variants treated with a single or a double rate of the recommended inorganic fertilizer were comparable. The result of the study was also similar to the study done by Xu et al. (2020) about a loquat rootstock seedling under fertilization where the plant height and stem diameter and absorption of N and P by the seedling showed a positive synergistic effect. Increasing the proportion of N in the fertilizer can promote the rapid growth and new shoots sprouting of rootstocks. While in terms of the number of leaves, Ferreira et al. (2019) pointed out that the seedling with a greater number of leaves, represent plants with a better nutrition. Almeida et al., (2014) stated that the nitrogen plays an important role in the cacao plants nutrition. Cacao plants are very sensitive to the variation of this nutrient, causing deficiency symptoms such as a reduction in the plant size, chlorosis on the leaves, and the green pale color of the leaves. The survival percentage of the grafted cacao seedlings ranged from 35 to 65%. The scions used were BR-25 variety for T1, Criollo variety for T2, and UF18 variety for T3. The highest survival rate was recorded in T2 (60-65%) which exhibited a higher compatibility over other treatments. The factor responsible for the low survival percentage of the grafted cacao seedlings has not been yet identified. The highest temperature was recorded during the second week of September (28.9°C) and the lowest was during the last week of October (25.4°C) in Baler, Aurora, the Philippines (PAGASA, Aurora personal communication, November 15, 2022). Through this period, some cacao seedlings suffered a leaf and stem damage during the highest temperature. Because only a limited number of samples survived after grafting, the parameters like plant height, number of internodes, and number of leaves for 156 days after the emergence were not analyzed.

CONCLUSION

It can be concluded that the variant T2 (the single rate of the inorganic fertilizer) had the best response out of the three treatments in terms of plant height, and stem girth and also had a high percentage of survival after grafting and fertilization. The results showed that the grafted BR 25 cacao variety as rootstock and Criollo cacao variety as scion responded well in terms of plant height, and stem girth and had a high number of survival rate after grafting and application of 25% and 50% fertilizer. In terms of the number of leaves, the grafted BR 25 cacao variety as rootstock and Criollo cacao variety as scion and grafted BR 25 cacao variety as rootstock and UF 18 cacao variety as scion were the best performing at both, single and double, fertilizer rate. Since the study was conducted as pot experiment, it is recommended to conduct a similar study including additional parameters

such as temperature and relative humidity, and to explore the different Philippine cacao varieties using different rates of the fertilizer, and if it is possible to reduce the amount of the RRIF as in the current study.

ACKNOWLEDGMENTS

The author would like to offer particular thanks to the Office of Provincial Agriculturist – Aurora, Philippines for the technical assistance and free-soil analysis given to the researcher during the conduct of the experiment. In addition, to Fabros Farm Training and Assessment Center Inc. staff for offering free cacao pods, and for sharing knowledge and expertise about nursery management of cacao seedlings.

REFERENCES

Almeida, R. L. S. Da, Chaves, L. H. G., Bonomo, P., Almeida Júnior, R. L. S. Da, & Fernandes, J. D. (2014) Produção do cacaueiro submetido a diferentes lâminas de irrigação e dose de nitrogênio. Revista Caatinga, 27(4), 171 –182

Department of Agriculture. (2021). Investment Guide for Cacao. Retrieved from https://www.da.gov.ph/wp-content/uploads/2021/04/Investment-Guide-forCacao.pdf

Egbe, N.E. (1968). Fertilizer on growth and yield of cocoa in Cocoa Research, Institute of Nigeria annual report. https://www.scipress.com/ILNS.58.54.pdf

Famuwagun, I.B., and Agele, S.O. (2011). Effects of Sowing Methods and Plant Population Densities on Root Development of Cacao (*Theobroma cacao* L.) Seedlings in the Nursery. International Journal of Agricultural Research, 5:445-452. https://scialert.net/abstract/?doi=ijar.2010.445.452

Ferreira, K. S. Rufini, J.C.M. Fagundes, M.C.P. Moreira, S.G. Ferreira, E.V.O. and Barbosa, M.A.P. (2019). Crescimento e acúmulo de nutrientes em mudas de aceroleiras em função da aplicação de diferentes doses de nitrogênio e potássio. Colloquium Agrariae, 15(2), 37-50. 10.5747/ca.2019.v15.n2.a283.

Gasim, S. H. (2001). Effect of nitrogen, phosphorus and seed rate on growth, yield and quality of forage maize (*Zea mays* L.). https://www.sciencedirect.com/science/article/pii/S1658077X10000044

Goldschmidt, E. E. (2014). Plant grafting: new mechanisms, evolutionary implications. Retrieved from https://www.frontiersin.org/articles/10.3389/fpls.2014.00727/full

Ibiremo, O. S., Oduwole, O. O., Fagbayide, J.A., & Nduka, B. A. (2012). Effect of root mat management and phosphate fertilizer application on the field establishment of cocoa in Ondo state, Nigeria, 2(2) 18-25. Retrieved from http://www.ijpaes.com/admin/php/uploads/153_pdf

JRank (2020). Graft – Advantages of Grafting. Retrieved from https://science.jrank.org/pages/3089/Graft-Advantages-grafting.html

Magsasaka, J. (2020). Cacao Production: Establishment of Budwood Garden or Scion Grove. https://www.juanmagsasaka.com/2020/11/cacao-production-establishment-of.html

PSA. (2020). Agriculture, Forestry and Fishery. https://openstat.psa.gov.ph/PXWeb/pxweb/en/DB/DB__2E__CS/0062E4EVCP1.px/table/tableViewLayout1/?rxid=bdf9d8da-96f1-4100-ae09-18cb3eaeb313

Saigusa M., Kasagaya Y., Watarable, and Shibuya, K. (1999). Ecology of apple of

pru (Nieandra physalodes L.). Press and Velvet Leaf (Abudtilon avicennae Garth). Retrieved from https://www.researchgate.net/publication/317348734_Review_on_the_Effect_of_organic_fertilizers_Biofertilizers_and_Inorganic_Fertilizers_NPK_on_Growth_and_Flower_Yield_of_Marigold_Targets'_erecta_L

Smith, J.N. (1994). Cocoa production systems, option and constraints, Cocoa Growers' Bulletin. https://www.scipress.com/ILNS.58.54.pdf

Trevisan, M.H. da Salva, S.A.S. de Araujo, M. L. M. Farias, V. D. Junior, M. A. Corderio, C. B. Araujo, V. L. Araujo, E. V., & da Silva, R. O. (2021). Application of different nitrogen doses in fertirrigated cacao seedlings. https://rsdjournal.org/index.php/rsd/article/view/19396/17372

Turkhede, B. B., & Rajendra, P. (1978). Effect of rates and timing of nitrogen application on hybrid sorghum. Indian Journal of Agronomy 23 (2): 113–126.

Willson, K. (1999). Coffee, Cocoa and Tea. https://www.cabdirect.org/cabdirect/abstract/19990303788

Xu, F., Chu, C., & Xu, Z. (2020). Effects of different fertilizer formulas on the growth of loquat rootstocks and stem lignification. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6978351/