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RESEARCH ARTICLE

Growth response of Cacao (*Theobroma cacao* L.) varieties to different soil amendments combined with inorganic fertilizers

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ABSTRACT

Cacao is essential because of its high domestic and foreign demand. Nutrient supply to cacao varieties is required to enhance their growth. Thus, this study was conducted to assess the growth response of four NSIC-approved cacao (*Theobroma cacao* L.) varieties: ICSS 40, UF 18, BR 25, and K 2 to chicken dung and vermicompost combined with inorganic fertilizer. An area of 1,620 m^2 was laid out in a 4 x 3 factorial experiment adopting the Randomized Complete Block Design (RCBD) with three (3) replications. The existing Cacao plants were used in the experiment. Cacao varieties (V_1 - ICS 40, V_2 - UF 18, V_3 - BR 25, and V_4 - K 2) were designated as factor A, while soil amendments (A_0 – inorganic fertilizer alone, A_1 - chicken dung + complete fertilizer, and A_2 – vermicompost + complete fertilizer) were as factor B. The application of both chicken and vermicompost + complete fertilizers gave a significantly tall, number of leaves and branches of cacao varieties than the application of inorganic fertilizers alone. The BR 25 variety applied with chicken dung + inorganic fertilizer (T_8) had significantly performed in terms of stem girth 90 days after the application of treatments. The BR 25 + chicken dung + complete fertilizer (T_8) and ICS 40 applied with chicken dung + complete fertilizers (T_2) treatment combinations are the best for growth.

Keywords: animal manure, organic fertilizer, growth increment, inorganic fertilizer, nutrient management, soil nutrient.

INTRODUCTION

Cacao (*Theobroma cacao*), primarily grown for chocolate production, is a tropical, understory crop from the South and Central American rainforest (Entuni et al., 2022). It thrives well in the country because it is a tropical crop that grows in the tropics between 10 to 20 degrees north and south of the equator (DENR, 2015; DA-BPI, 2017; UNEP-FAO, 2018). In recent years, the Cacao Industry has been gaining recognition in the domestic and export markets as cocoa beans' supply and demand gap is increasing. The world demand for Cacao has nearly tripled since 1970, growing at an annual rate of 3%, with China and India growing at 7.9%. One of the primary drivers of this increase is the growing middle class, increasing discretionary household income in developing countries, new and innovative uses of cocoa in the food, cosmetics, and pharmaceutical industries, and the positioning of Cacao as health food. The Philippines' location, conducive to cacao production and accessible to domestic and foreign trade, heightened the interest of local farmers and exporters to push for a more dynamic and competitive cacao industry that can compete with other major cacao-growing nations. Despite its competitive advantage, the Philippine cacao production currently only stands at 10,000–12,000 MT from the 20,000–25,000 hectares (ha) of land planted with cacao per industry estimate (www.da.gov.ph).

The government still encourages farmers to grow Cacao to support the cacao industry continually. One of the intensive cultivation managements of cacao production is applying fertilizers. While there is increased advocacy for the use of inorganic fertilizers, their excessive use is associated with soil, water, and air pollution (Diacono and Montemurro, 2010; Savci, 2012; Abayomi and Adebayo, 2014; Komakech et al., 2015). Furthermore, inorganic fertilizers are expensive, and their use may not be economically justifiable, especially for smallholder farmers who mainly practice subsistence farming. The use of organic amendments is an alternative to these detrimental effects of inorganic fertilizers because of their widespread availability, added value for soil carbon sequestration, and capacity for storing and releasing nutrients over a longer period (Diacono and Montemurro, 2010). However, organic amendments alone cannot meet the nutritional requirements of Cacao since they release organic nutrients slower, and not all the time organic fertilizers are fully available. To compensate, they still need to integrate them with inorganic fertilizers.

The use of chicken dung as fertilizer for many crops is rampant nowadays, for it contributed to significant growth and yield of many crops, including fruit trees and plantation crops. Moreover, poultry manure significantly reduced soil bulk density, and significantly increased soil organic matter, soil and leaf N, P, K, Ca, and Mg concentrations. One of the crops that has been found to be positively responsive to chicken dung is sorghum as Agbede et al. (2008) reported that its plant height, leaf area, culm girth, weight of roots, shoot, and the grain yield were significantly increased.

Moreover, Vermicomposting was the most economically viable manure treatment method due to low operating costs and higher returns on investment, thus, it was recommended to farmers for the production of an organic fertilizer to increase maize yields with the assurance of economic returns (Jjagwe, et al., 2020). Likewise, the application of vermicompost resulted in increased soil organic matter content, and soil physical properties (Demir, 2019). Similar results were also observed that the addition of vermicompost resulted in a substantial increase in soil total organic carbon, total N, P, K, Ca, Zn and Mn contents, a decrease in soil pH, and the physical properties such as bulk density and total porosity (Azarmi, et al., 2008). Though there are several studies of chicken dung and vermicompost on the growth response and productivity of different crops, there is still a need to study the growth of Cacao applied with these organic amendments with the combination of inorganic fertilizers, hence this study.

MATERIAL AND METHODS

Preparation of Experimental Area

The area of 1,620 m^2 had already eight months old cacao plants located at the College of Agriculture and Forestry, JRMSU-TC experimental area. This was utilized and used in the study. The surroundings were cleared and weeding, and brushing were done before the start of the study. This commodity was also utilized in the previous study. To avoid bias, the succeeding treatments applied were the same as the preceding ones.

Experimental Design and Treatments

The experimental area was laid out in a 4 x 3 factorial experiment adopting a Randomized Complete Block Design (RCBD) with three (3) replications. The existing cacao plants from the previous study were used in the experiment. Each replication was composed of 12 treatments using 5 sample plants per treatment. The distance between both plants and rows was 3 meters.

Cacao varieties (ICS 40, UF 18, BR 25, and K 2) were designated as factor A, while soil amendments (control, chicken dung, and vermicompost) were as factor B.

The treatments were designated as follows:

Factor A. Cacao Varieties	Factor A. Cacao Varieties
V_1 – ICS 40	A_0 –No soil amendment + complete fertilizer
V_2 – UF 18	A_1 –Chicken dung + complete fertilizer
V_3 – BR 25	A_2 – Vermicompost + complete fertilizer
V_4 – K 2	

The treatment combinations were as follows:

T_1 – (V_1A_0) – ICS 40 no soil amendment + complete fertilizer
T_2 – (V_1A_1) – ICS 40 applied with chicken dung + complete fertilizer
T_3 – (V_1A_2) – ICS 40 applied with vermicompost + complete fertilizer
T_4 – (V_2A_0) – UF 18 no soil amendment + complete fertilizer
T_5 – (V_2A_1) – UF 18 applied with chicken dung + complete fertilizer
T_6 – (V_2A_2) – UF 18 applied with vermicompost + complete fertilizer
T_7 – (V_3A_0) – BR 25 no soil amendment + complete fertilizer
T_8 – (V_3A_1) – BR 25 applied with chicken dung + complete fertilizer
T_9 – (V_3A_2) – BR 25 applied with vermicompost + complete fertilizer
T_{10} – (V_4A_0) – K 2 no soil amendment + complete fertilizer
T_{11} – (V_4A_1) – K 2 applied with chicken dung + complete fertilizer
T_{12} – (V_4A_2) – K 2 applied with vermicompost + complete fertilizer

Application of Soil Amendments and Inorganic Fertilizers

After ring-weeding, each sample plant in treatments under A_1 and A_2 was applied with one (1) kg of chicken dung and vermicompost, respectively at the start of the study and another 1 kg after six weeks. These were applied by spreading the amendments around the base of the plant and incorporating them into the soil. Each experimental plant were applied with 120g inorganic fertilizer (14-14-14).

Growth Parameters

Data on plant height and number of leaves were gathered at 30, 60, and 90 days after the treatment application (DATA). A day before the application of amendments, initial data on plant height and number of leaves were gathered and subtracted from the data collected at 30, 60, and 90 DATA to obtain the increment on growth in terms of the said growth parameters. The number of branches and stem girth were also gathered at 90 DATA.

Statistical Analysis

Analysis of variance was performed to analyze the data gathered. Treatment means were compared using Tukey's Honestly Significant Difference (HSD) Test. Statistical analyses were done using the Statistical Tool for Agricultural Research (STAR Version 2.0.1).

RESULTS AND DISCUSSION

The average increment in plant height, number of leaves, number of branches, and stem girth of cacao varieties as applied with different soil amendments and inorganic fertilizers is presented in Table 1. The results revealed that the BR 25 (V_3) variety performed significantly only on the stem girth regardless of the combination of soil amendments and inorganic fertilizers, as it obtained a larger stem girth of 7.35 cm, which is comparable to ICS 40 (V_1) with a mean of 6.5 cm and significantly different from UF 18 and K 2 (V_4). This conforms to the findings of Vallecer et al. (2018), as they also found that BR 25 significantly responds to different applications of fertilizer in terms of stem girth. Ofori and Padi (2020) also reported that the BR 25 variety of cacao is more significantly responsive to any fertilizers in any growth performance compared to other varieties.

On the other hand, the chicken dung + complete fertilizer (A_1) gave the best height, number of leaves, and branches at 90 DATA for cacao varieties but comparable with vermicompost + inorganic fertilizer (V_2). Purbaante et al. (2019) also reported that combining chicken dung and inorganic fertilizer makes the cacao plants taller and produces more branches and leaves compared to other manures combined with inorganic fertilizers. Wayouno et al. (2019) also reported a similar finding that the vermicompost plus inorganic fertilizer improves the growth of cacao seedlings. These are supported by Biñas and Cagasan (2018) that the combinations of both chicken dung and vermicompost and inorganic fertilizers contributed to a significant performance not only of cacao but also the other crops compared to the application of inorganic fertilizer alone (A_0).

The treatments affected the plants except for the plant height at 90 DATA and the number of leaves at 30, 60, and 90 DATA. At 30 DATA, the ICS 40 variety that was applied with chicken dung and complete fertilizer (T_2) was growing taller but comparable to all other varieties applied with or without chicken dung and vermicompost combined with a complete fertilizer except for the BR 25 with no soil amendment but was applied with complete fertilizer (T_7). This implies that BR 25 also needs the amount of inorganic fertilizer to hasten its height at 30 DATA. At 60 DATA, all Cacao varieties respond similarly to the fertilizers regardless of the materials.

On the other hand, BR 25 variety that was applied with chicken dung and complete fertilizer (T_8) obtained a bigger stem girth with a mean of 9.04 cm, which is significantly different from the UF 18 variety that was applied with vermicompost and complete fertilizer (T_6) with a mean of 4.44 cm, but comparable to other treatments. This result indicates that chicken dung is slightly more favorable to Cacao growth than vermicompost in terms of stem development of the UF 18 variety. The comparable results from those plants without soil amendments may be due to some factors like soil fertility, adequate soil moisture, etc. Oresajo et al. (2012) also reported that poultry manure improves the growth of cacao seedlings and even their vegetative stage. Likewise, Bangun et al. (2018) found that poultry manure contributes to the improvement of the stem diameter of cacao. Moreover, Yap (2019) also reported that inorganic fertilizers could boost the growth performance of any cacao variety. It means that the chicken dung plus inorganic fertilizers are more favorable for cacao farming, preferably with the BR 25 and ICS 40 varieties in plant height and stem girth, respectively.

Table 1. Summary of plant height, number of leaves, number of branches, and stem girth of cacao applied with soil amendments and inorganic fertilizer.

Treatment	Plant Height (cm)			Number of Leaves			Number of branches	Stem Girth (cm)
	Days after the application of treatments							
	30	60	90	30	60	90	90	90
Factor A – Varieties								
V_1	4.01	6.48	11.59	6.60	12.98	29.20	2.24	6.52^{ab}
V_2	4.14	6.92	12.21	4.84	10.09	19.82	1.29	5.30^{b}
V_3	3.54	6.46	11.26	5.39	17.97	33.85	2.05	7.35^{a}
V_4	3.63	5.47	10.00	4.69	11.96	21.36	1.36	5.33^{b}
P-Value	0.5698^{ns}	0.3715^{ns}	0.5864^{ns}	0.4757^{ns}	0.1805^{ns}	0.1802^{ns}	0.0828^{ns}	0.0250*
Factor B – Soil Amendments								
A_0	2.58^{b}	4.49^{b}	8.16^{b}	4.42	9.50	16.90^{b}	1.18^{b}	5.30
A_1	4.71^{a}	7.42^{a}	12.97^{a}	6.09	15.48	33.34^{a}	2.14^{a}	6.89
A_2	4.20^{a}	7.08^{a}	12.66^{a}	5.64	14.76	27.93^{ab}	1.88^{a}	6.18
P-Value	0.0001**	0.0008**	0.0035**	0.2560^{ns}	0.1284^{ns}	0.0342*	0.0175*	0.0574^{ns}

Interaction Effects of Factor A and Factor B

Treatment	Plant Height (cm)			Number of Leaves			Number of branches	Stem Girth (cm)
	Days after the application of treatments							
	30	60	90	30	60	90	90	90
T_1	2.40^{ab}	3.65^{a}	5.96	5.33	8.60	18.40	1.53^{a}	5.76^{ab}

T_2	5.17^{a}	8.27^{a}	13.94	6.20	11.53	30.13	1.87^{a}	7.21^{ab}
T_3	4.46^{ab}	7.51^{a}	14.87	8.27	18.80	39.07	3.33^{a}	6.57^{ab}
T_4	3.11^{ab}	5.16^{a}	10.87	4.27	10.20	16.73	0.87^{a}	5.67^{ab}
T_5	4.65^{ab}	7.74^{a}	13.25	6.93	11.93	26.67	1.40^{a}	5.79^{ab}
T_6	4.65^{ab}	7.85^{a}	12.51	3.33	8.13	16.07	1.60^{a}	4.44^{b}
T_7	1.94^{b}	3.85^{a}	6.61	4.07	9.33	15.87	1.40^{a}	4.65^{ab}
T_8	4.64^{ab}	8.66^{a}	14.52	6.57	26.18	53.75	3.37^{a}	9.04^{a}
T_9	4.05^{ab}	6.86^{a}	12.66	5.55	18.38	31.93	1.38^{a}	8.35^{ab}
T_{10}	2.88^{ab}	5.27^{a}	9.21	4.00	9.87	16.60	0.93^{a}	5.11^{ab}
T_{11}	4.38^{ab}	5.02^{a}	10.18	4.67	12.27	22.80	1.93^{a}	5.52^{ab}
T_{12}	3.63^{ab}	6.11^{a}	10.61	5.40	13.73	24.67	1.20^{a}	5.37^{ab}
P-Value	0.0164*	0.0163*	0.0586^{ns}	0.4310^{ns}	0.2209^{ns}	0.1087^{ns}	0.0269*	0.0274*
CV (%)	27.35	27.74	30.50	44.57	58.07	56.12	50.61	25.00

Means with the same letter designations are not significant with each other at the 5% level.

Note, ns – not significant; * - significant at 5% level; ** - significant at 1% level; CV - coefficient of variation.

CONCLUSION

The application of both chicken dung and vermicompost combined with inorganic fertilizers contributes to the significant growth of Cacao of any variety in terms of plant height, number of leaves, and number of branches. The ICS 40 (T_2) and BR 25 (T_8) varieties applied with chicken dung and complete fertilizer are the best for the growth in terms of plant height at 30 DATA and stem girth at 90 DATA, respectively.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by Authors.

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