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FERTILIZER INTEGRATION ON CACAO CUM RUBBER: IMPLICATIONS ON CACAO GROWTH, YIELD, DISEASE OCCURRENCE AND PROFITABILITYNoe S. Mamon Jr.¹DOI: <https://doi.org/10.5281/zenodo.5546369>**ABSTRACT**

This study was conducted to enhance the growth and yield performance of cacao trees under mature rubber for one (1) fruiting season through the integration of urea and vermicompost. The experimental design was set in factorial Randomized Complete Block Design with a total of 15 treatment combinations. The treatments were three rates of urea (0, 100 and 200 g/tree) and five rates of vermicompost (0, 1.5, 3.0, 4.5 and 6.0 kg/tree). The trunk circumference, leaf length and width, number of pods developed and harvested, pod and bean character, soil OM%, leaf Nitrogen content and prevalence of pest and diseases were evaluated. The application of 200g urea per tree produced significant increase from 4.86 to 8.44 kg (73.66% increase) in weight of harvested pods and from 23.32 to 26.40 g/pod (13.21% increase) dry bean weight and significant decrease in the pod index from 43.39 to 38.45 (11.36% decrease). Moreover, the heaviest and thickest pod husk was obtained from plants applied with 100 grams urea + 1.5 kg vermicompost. The highest mean number of beans/pod was obtained from trees applied with 100 – 200 g urea + 1.5 – 3.0 kg vermicompost. The soil organic matter content (%) and leaf N was slightly increased by application of fertilizer treatments. Pod borer infestation and nematode population were significantly affected by application of urea and vermicompost. Application of 100 g urea/tree or 3.5 bags/ha gave the highest return of investment and was the most profitable source of nutrient.

Keywords: integrated, profitability, urea, vermicompost, yield.

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INTRODUCTION

Today, the demand for cacao beans in the local and export market is increasing due to inadequate supply and high domestic consumption of chocolate (AFRIM, 2014). Nutrient deficiency is the major reason for low yield of cacao trees and can be solved by applying nutrient-containing fertilizers. Application of organic fertilizer is known to improve the soil properties, but the nutrient content is very low. The nutrient requirement of the plant may not be satisfied by applying organic fertilizer alone. Whereas, synthetic fertilizer contains higher amount of nutrient, however its continuous use may badly affect the soil. Baah, et.al. (2011) suggested that cocoa yield could be further enhanced by farmers maintaining the fertility status of their soil through application of fertilizers. Mature rubber trees had close canopies and their roots spread into the inter row space interfering the growth of intercrops (Pathiratna, 2006) and the peak of flushing and flowering in cocoa coincide with the period of maximum daily sunshine, thus it is recommended to reduce the shade (Adomako et.al. 1990).

Hypothesis

The null hypotheses of this study are the following:

1. The application of urea and vermicompost and their combination has no significant effect on cacao's morphological attribute in terms of trunk girth, length and width of leaves.
2. The application of urea and vermicompost and their combination has no significant effect on yield and pod characters of cacao in terms of number of pods per tree, fresh weight of pods and wet beans and weight of dry bean.
3. The application of urea and vermicompost and their combination has no significant effect on soil and leaf chemical properties.
4. The application of urea and vermicompost and their combination has no significant effect on pest and disease incidence.
5. The application of urea and vermicompost and their combination has no significant influence on profitability of fertilizer use.

Objectives of the study

Generally, this study aimed to increase yield of cacao grown under mature rubber through application of urea and vermicompost. Specifically, it aimed to:

1. evaluate the effects of application of varying proportions of urea and vermicompost on the growth and yield of cacao (var. BR 25) grown under mature rubber;
2. determine the best fertilizer combination that would give the highest yield and fastest growth of cacao (var. BR 25) grown under mature rubber;

3. evaluate the nutritional status of the soil and N content of leaves of cacao in response to application of urea and vermicompost,
4. determine the most profitable combinations of urea and vermicompost fertilizers in cacao production; and
5. evaluate the incidence of pests and diseases of cacao applied with varying proportions of urea and vermicompost.

REVIEW OF RELATED LITERATURE

Origin and Botanical Description of Cacao

Theobroma cacao L., the scientific name of cacao, literally translates as “Food of the Gods” in Greek. Cacao trees have a very distinctive appearance, though not especially tall trees, with an average height of 10 to 20 ft. Their stems, like many rainforest trees, have a rough, grayish-brown bark that is usually covered with patches of different colored lichen and fungus. Mature leaves are large and glossy, but young leaves are limp and reddish, gradually turning green and strong as they mature (DTI-RODG, 2012).

Cacao is a rainforest, understory tree that requires shade and wind protection. It is being grown in all humid tropical lowland regions around the equator, most notably Central and South America, West Africa and Sri Lanka, Indonesia and the Philippines. Cacao is being grown for their seeds called cocoa beans that are being processed into fermented/unfermented dried beans, roasted nibs, cocoa liquor, compound and couverture chocolate, confectionery, cocoa powder, chocolate and cocoa butter, a raw material that is heavily used in the cosmetic and pharmaceutical industries. Aside from its medicinal uses, the increasing awareness among individuals about the benefits of eating chocolates is the major factor that is driving the market growth of cacao globally. There are four major types of cacao cultivated around the world: Criollo, Forastero, Trinitario and Nacional. The Criollo tree originates in Mexico and Central America and gives very high quality cacao beans and is mainly cultivated in South and Central America. Criollo beans are often mixed with other varieties of cacao when making chocolate (Cacao-web.net). Cacao is a tree crop that is highly suitable or compatible under different production systems (intercropping or multistory farming, agroforestry, etc). It is grown mainly for its beans, processed into cacao powder, cake and cocoa butter. These products are largely used in the manufacture of chocolates, soaps, cosmetics, shampoo and other pharmaceutical products. It is also a high value crop wherein the potential is not yet explored in our country with an extensive area suitable for cacao growing as a monocrop or intercrop of coconut. In fact, over 1M ha highly suitable or wet zone of coconut areas (except

in coastal areas excessively high in Na or saline soils) are suitable for coconut-cacao intercropping. Its cultivation could promote an agro-industrial development aimed at value-adding export products, as well as reduction of importation of cacao beans from countries like Indonesia, Papua New Guinea, and Malaysia (PCARRD, 2000).

Cacao Industry in the Philippines

At present, the Philippine cacao industry is undergoing resurgence. In 2008, cacao was given a priority and officially regarded as a High-Value Crop by the Department of Agriculture. Local farmers have increased their interest in the cultivation of cacao due to the huge demand in the local and international markets, and with persistently favorable prices (RA-7900: High-Value Crops Development Act of 1995). According to Bureau of Agricultural Statistics, in 2005 until the present, local consumption reached almost 40,000 metric tons; however, production was only nearly 5,000 metric tons. This resulted in a supply deficit of about 35,000 metric tons that has to be imported. The opportunity presented by the cacao industry is an advantage for local farmers to improve cacao bean production. The growth of the industry will contribute in making available livelihood opportunities and the creation of much needed jobs, at the same time increase agricultural value when the increase in cocoa production with low cost but high quality yields will be materialized. With the support of the stakeholders involved in the cacao industry, coupled with appropriate strategic action planning and implementation, the Philippines can compete globally (Cacao Industry, DTI-RODG, 2012). The Department of Agriculture reported that the area planted to cacao in 1990 was about 18,388 hectares, with most of the crops growing in Davao, Zamboanga Peninsula, Western Visayas, Northern Mindanao, Autonomous Region in Muslim Mindanao, and the Caraga region. By 2006, the area declined to less than 10,000 hectares. From that year, planted areas were continuously decreasing by an average of 2.22% and the number of bearing trees by 2.87% annually. Production fell by an average of 1.87% per annum from 5,415 metric tons in 2006 to 5,019 tons in 2010. Mindanao dominated cacao bean production in the country. The island has always been the historical capital of cacao as it does not have typhoons and has good rainfall and soil condition. Of the total cacao output in 2010, 70% came from Davao Region, 11% from Northern Mindanao, and 6% from CARAGA, Eastern Visayas, and Zamboanga Peninsula. The major cacao-producing provinces were Davao del Sur (1,664 tons), Davao City (836 tons), Davao Oriental (491 tons), Bukidnon (462 tons), and 332 tons for Davao del Norte (BAS, 2010). According to Cacao Industry Development Association of Mindanao (CIDAMI), Davao Region prices in 2015 stand at P115 to P125 per

kilo for dried cacao and P38 to P40 per kilo for wet beans. Cacao tree can yield around 1.5 to two kilos of dried beans or around a ton of dried cacao beans per hectare.

Cacao Industry Constraints

Poor and limited supply of planting and grafting materials. Good production starts with ensuring the best quality planting materials available for the variety of the crop being produced. At present, Philippines is experiencing a poor and limited supply of planting materials for cacao resulting in low quality of cacao beans produced.

Limited supply of cacao. Most farmers are “resource-poor”. Markets require producers to deliver consistent quality and sufficient quantity. Meeting these conditions requires a certain level of infrastructure, land, inputs, technology, knowledge, and capacities and skills, which simply may not exist among communities of asset-poor producers.

Technical capacity and technology intervention. Technical know-how has always been a constraint in high value crop production such as cacao. Farmers in the country have limited technical skills and are dependent on the traditional and conventional ways of cultivating cacao. These are some reasons why improvement in cultivation and production are very minimal in the industry.

Agrochemical Use in the Philippines

The use of chemical fertilizers in the Philippines started to increase exponentially in the late 1950s; between 1961 and 2005 fertilizer applications increased by 1000% (FAOSTAT data, 2007). In spite of this massive increase in chemical fertilizer use, the yield of rice and maize increased only by 200 and 280%, doubled and tripled respectively, while the yield of pulses remained about the same. This indicates a tremendous loss of fertilizers into the environment due to their imbalanced use and poor management. While fertilizer sales almost doubled in the 1990s, the improvement in crop yield was minimal. The major reason for the low response of crops, particularly grain, is the imbalance in the use of nitrogen (N) and phosphorus (P), and also the deficiency in sulphur caused by the extensive use of urea. However, under the current model, farmers also struggle with rising costs of farm inputs and recommended technology (NEDA, 2004). According to Arboleda (1998), the excessive and inappropriate use of chemical fertilizers in crop soils causes land degradation and losses in soil fertility worldwide. Philippine farmers are starting to see these problems and while the government Fertilizer and Pesticide Authority (FPA) acknowledges that the need for finding the right “balance” in fertilizer application is one of the current priorities.

It is worthwhile to note that past experience has shown that yields and food supply do not respond exclusively to synthetic fertilizer use and that organic materials are the key to

maintaining and restoring soil nutrient exchange capacity; thus, the need for a modern approach that considers sustainable ways of securing future soil fertility (FPA, 2007).

Fertilizer Balance, Efficiency and Integrated Nutrient Management (INM)

According to Gruhn et al. (2000), the notion of declining efficiency of fertilizer use in Asia is overly simplistic. Possible reasons for apparent diminished returns from increased fertilizer applications in this region include:

1. more fertilizers are being used on lands with poorer soils or uncertain water supply
2. the increased intensity of cropping, especially changes in crop sequences, makes current management practices, including fertilizer use, less effective
3. there is an imbalance in the supply of N, P, and K, with applications of the latter two nutrients often being too low
4. deficiencies of secondary nutrients and micronutrients are beginning to appear
5. there is an overall decrease of soil organic matter and an increase in soil degradation in general
6. adverse effects from pests and diseases are increasing in the region.

The sufficient and balanced application of organic and inorganic fertilizers is a major component of Integrated Nutrient Management (INM). Sustainable agricultural production incorporates the idea that natural resources should be used to generate increased output and incomes, especially for low-income groups, without depleting the natural resource base. In this perspective, INM maintains soil as storehouses of plant nutrients that are essential for vegetative growth. INM's goal is to integrate the use of all natural and man-made sources of plant nutrients, so that crop productivity increases in an efficient and environmentally safe manner, without sacrificing soil productivity of future generations (International Food Policy Research Institute, 2000). Baah et al (2011) stated that the productivity on cocoa farms in the Eastern Region of Ghana are low but could be raised through a combination of enhanced husbandry practices such as effective weed, pest and disease control, pruning and shade management. The findings of this study suggest that the positive effects of these practices on cocoa yield could be further enhanced by farmers maintaining the fertility status of their soils. While farmers do undertake soil fertility management practices such as application of crop residue and control of run-off water, the dominant practice which has significant impact on cocoa yield is application of fertilizers.

Based on Sub-Regional Workshop on Soil Fertility Management for Cocoa Production sponsored by World Cocoa Foundation in 2013, most farmers are aware of the benefits in

applying fertilizer and other soil fertility practices but do not use them due to high cost of fertilizer versus low price of cocoa and fertilizers are generally not available and accessible to smallholder farmers. According to Uribe et al (2001), fertilization of shade cocoa commonly produces only modest yield increments. Fertilization of sunlight-exposed plantations generally results in significant yield responses because of greater photosynthetic activity. The highest yield was produced with 150 kg of N, 90 kg of P₂O₅ and 200 kg K₂O/ha and affirms that adequate and balanced fertilization of cocoa is not only profitable, but also sustains and builds high yields over time. On the study conducted by Oyewole et al (2012), the performance of cocoa seedlings across the two locations as demonstrated by the results showed that the organic fertilizers (CPH and KPH) could be used as sources of nutrient. However, these materials are not sufficient to meet the nutritional demand of the crop, hence; there is need for fortification with mineral fertilizer. CPH or KPH fortified with mineral fertilizers will aid the growth of cocoa seedling on old cocoa soil irrespective of the location. The percentage germination of the cocoa seedlings was enhanced by the use of this organic material 73 and 95% for Ibadan and Mayo-Selbe, respectively. The treatment had a positive effect on the nitrogen level of the soil as CPH (8.14) and is slightly higher than NPK (6.99). According to Noordiana et al (2007), organic-based fertilizer + NPK gave relatively higher mean value with 690.96 for pod weight. Single dry bean weight for both clones was between 1.2 to 1.6 g, which was beyond the expected average bean weight of 1 g to 1.2 g. This shows that bigger bean size has been produced and this gives a rough indication of a good yield. Novita et al (2014) concluded that combination treatment of vermicompost fertilizer at a dose of 75 g/polybag and urea .750 g/polybag affect leaf area and ratio feature roots. Vermicompost fertilizer factor at a dose of 75 g/polybag on cocoa seedling affect seedlings height, girth, leaf area, ratio feature roots and dry weight, but had no effect on the number of leaves. Urea fertilizer factor at a dose of 0.750 g/polybag on cocoa seedlings affect seedling height, leaf area and ratio feature roots, but did not effect the number of leaves, girth and dry weight.

Economically important pests of cacao

Cacao black pod is a particularly economically serious problem in all cacao producing regions of the world. Annual yield losses due to black pod may range from 20% to 30%, although individual farms may suffer from 30% to 90%, being especially severe in West and Central Africa, causing up to 64% of losses in plantations, although it is reported to also be one of the main causes of pod losses in Southeast Asia (Acebo-Guerrero et al. 2012).

Practices that increase pod number per tree also increase cherelle wilt. However, plantations in which the solar radiation incidence is increased are more productive because of a decrease in cherelle wilt (Asomaning et al. 1971).

Initial characteristic symptoms of VSD include the leaf chlorosis on the second or third flush behind the tip, spreading internally to other branches or the trunk, ultimately causing death of the tree. Appearance of white, flat and velvety fungal hyphal mat on the leaf scar due to fall of leaf during the rainy season may be prominent (Guest et al., 2007). VSD is a very destructive disease capable of causing yield losses of 25-50%, even reaching to 100% in very susceptible plants (Efron et al., 2002). The population of nematode was reduced when applied with fertilizer treatments. The use of soil amendment not only enhanced soil fertility but also increased microbial diversity and depressed population densities of plant-parasitic nematodes (Orisajo et al., 2012). Cocoa pod borer (CPB) causes losses to cocoa by boring through the wall and into the pod, feeding on the pulp of bean and placenta of the pod. The beans from seriously infested pods are completely unusable, and over half the potential crop can be lost in heavy infestations and in Malaysia, annual yield loss was ranged from 22 to 54% (Day, 1989). Twig borer was observed in the experimental area and caused damage and eventually death of cacao upper branches in severe cases. The larvae attack stems that are from 1.5-20.0cm in diameter causing damage to seedlings and mature trees. The tunnel bored by the larva has a single entrance hole at its base and it runs length-ways inside the stem and is not normally longer than 30cms. The entrance hole is the same width as the tunnel (Crop Protection Compendium, 2014).

Methodology

In order to investigate the effect of urea and vermicompost on the growth and yield of cacao grown under mature rubber, an experiment was conducted in Industrial Crop Research Institute (PICRI), USM, Kabacan, Cotabato for one fruiting season. Cacao var.BR25 at its fruiting age, spaced in 3 x 3 m and intercropped with a decade old RRIM 600 rubber clone planted in 3 x 9 m distance. The experimental design was a randomized complete block design in factorial arrangement with three replications and fifteen treatment combinations with a total of 180 cacao trees. The treatments were three rates of urea (0, 100 and 200 g/tree) and five rates of vermicompost (0, 1.5, 3.0, 4.5 and 6.0 kg/tree).

Before the onset of fertilizer application, pruning was employed and an initial soil nutrient status was evaluated using Walkley-Black Method for %OM, Hot H₂SO₄ for K, Bray-2 Olsen's for P (Table 1) and leaf N assessment by Kjeldahl method (Table 2). Vermicompost

was purchased in a registered vermiculture farm and its nutrient content was analyzed (Table 3).

Table I. Chemical properties of the soil.

Test Requested	Analyses	RESULTS	RANGES				
			VL	L	M	H	VH
Organic Matter (%) (Walkley-Black Method)		2.56	0 - 2	2.1 – 3.5	3.6 – 4.5	>4.5	
Potassium (Hot H2SO4) (ppm)		624	0 - 75	76 - 113	114 - 150	>150	
Phosphorous (ppm) Bray-2 P Olsen's		32.06	<5	5 - 14	14.1 - 20	20.1 - 30	>30
Ph		4.49	0 – 6	7 - 10	11 - 15	16 - 20	>20

Table 2. Cacao leaf tissue analysis.

Test Analyses Requested	RESULTS
Nitrogen (%) (Kjeldahl method)	1.82
Phosphorus (%)	0.22
Potassium (%)	1.75

Table 3. Chemical properties of the vermicompost

Test Analyses Requested	RESULTS
Nitrogen (%)	0.88
Phosphorus (%)	1.21
Potassium (%)	0.22

Urea fertilizer at 100 or 200 g/tree was applied in two split doses: half of the total rate was applied by ring method at 50 cm from the tree base during the start of the study, and the remaining half was applied after three months. The vermicompost was applied once by ring method following the rates as stated earlier. Two factor analyses of variance (ANOVA) and Tukey's tests (test at 1 and 5% level of probability) were used to partition the variance into the main effects and the interaction between urea and vermicompost. Statistical analysis was performed using Assistat statistical package 7.7 beta.

RESULTS AND DISCUSSION

Effect on Growth Parameters

Trunk girth increment

The trunk increment of cacao for six months as affected by application of urea, vermicompost and its combination in different proportions was not differed significantly with the lowest mean of 3.80 mm in trees without fertilizer application and reached the highest increment of 7.66 mm in treatments applied with 4.5 kg of vermicompost. Figure 1 showed the increase of trunk girth within six months. Novita et al (2014) concluded that the vermicompost fertilizer factor at a dose of 75 g/polybag on cocoa seedling affect seedlings girth and other growth parameters. However, in mature cacao trees under shaded condition fertilizer treatments did not affect its girth.

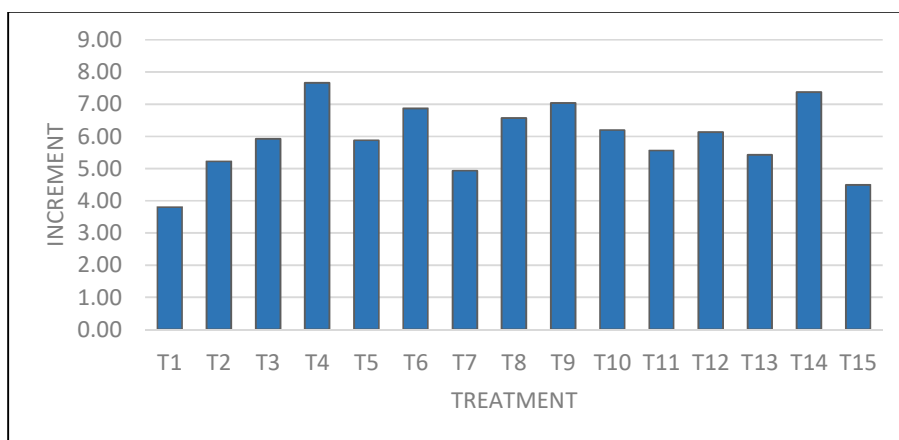


Figure 1. Trunk girth increment in six months of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

Leaf length and width of cacao

Table 1 presents the leaf length and width of cacao gathered six months after application of fertilizer treatments. Analysis of variance showed no significant differences between trees applied with urea, vermicompost and its combination. Leaf length was ranged from 29.95 cm to 33.57 cm and its width from 11.95 cm to 13.55 cm. Leaf morphological appearance was not affected by application of fertilizer treatments but noticeably larger leaf area compared to its genetic features. Based on NSIC approved cacao variety, BR25 (CC-99-05) leaf length was 11.0 cm and its width was 4.04 cm. Moreover, the size of a cacao leaf varies with the amount of shade, being greatest in dense shade. The larger leaf size partly compensates for the lower rate of photosynthesis under shade (Piringer, 1959).

Effects on Yield Parameters

Number of developed pods

The development of pods to maturity took 5-6 months from flowering to its first harvest. Fig.2 showed the number of successful pods developed on its peak season of pod production. Data revealed that the developed pods did not differ significantly among two factors. In graph below, application of 100g urea (T6) recorded the highest number of developed pods followed by the combination of 200g urea + 6kg vermicompost (T15) and T1 (no fertilizer) developed the lowest number of pods. Number of pods developed were 63, 62 and 32 respectively. Since the cacao trees were intensified in the area and closely spaced in rubber tree, current management practices, including fertilizer use was less effective thus affecting pod development. A possible reasons for apparent diminished returns from increased fertilizer applications (Gruhn et al. 2000).

Table 1. Leaf length and width (cm) of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

Factor A (Urea)	Factor B (Vermi)	Variable	
		Leaf Length (cm)	Leaf Width (cm)
SF1	OF1	30.91 ^a	11.95 ^a
	OF2	32.79 ^a	12.70 ^a
	OF3	32.57 ^a	12.56 ^a
	OF4	33.57 ^a	13.03 ^a
	OF5	31.09 ^a	11.97 ^a
SF2	OF1	29.95 ^a	12.32 ^a
	OF2	33.58 ^a	12.89 ^a
	OF3	33.35 ^a	13.04 ^a
	OF4	33.16 ^a	13.55 ^a
	OF5	32.05 ^a	12.91 ^a
SF3	OF1	33.41 ^a	12.89 ^a
	OF2	34.31 ^a	13.41 ^a
	OF3	31.89 ^a	12.85 ^a
	OF4	31.13 ^a	12.47 ^a
	OF5	32.41 ^a	12.00 ^a

(Means followed by a common letter in the row are not significantly different at 5 % level by Tukey Test)

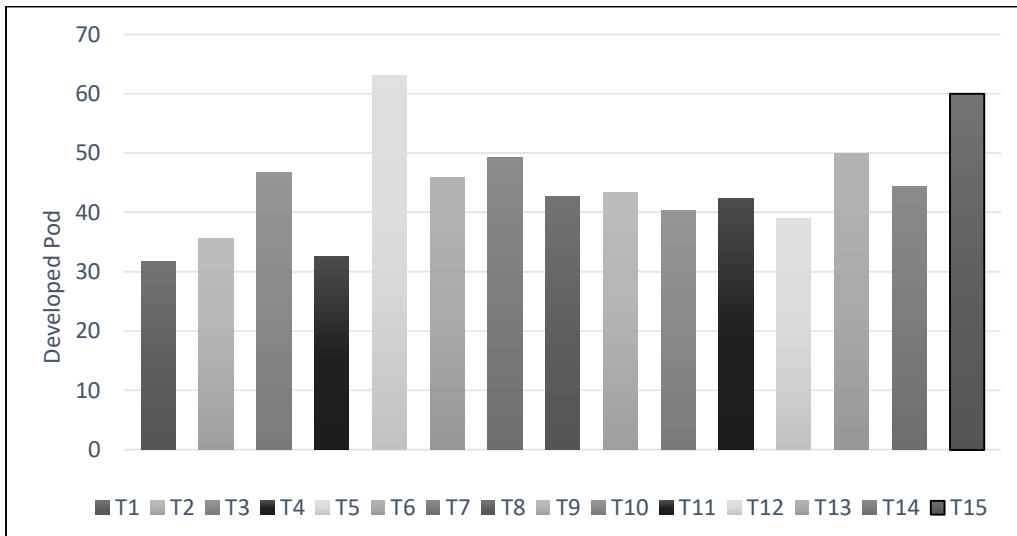


Figure 2. Total number of developed pods of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

Number of harvested pod

Harvesting of ripe pods was done when it showed change in color from reddish-green to yellow, a ripening index for BR 25 cacao variety. Harvesting was started in October 04, 2015 and continued at 15 days interval. The yield data was recorded up to its fifth harvest. In Figure 3, harvested pods per treatment reached the highest yield on its second harvest.

Difference in total number of pods harvested within five harvesting was presented in Figure 4. Analysis of variance did not differed significantly on the yield of cacao. The highest yield was obtained from trees applied with 6 kg. of vermicompost alone (T5) and the lowest came from trees without fertilizer application (T1). Mean harvested pods per treatments were 50 and 22 respectively. According to National Seed Industry Council (NSIC) BR 25 cacao clone can produce 30 pods per tree/year. Fertilization of shade cocoa commonly produces only modest yield increments. Fertilization of sunlight-exposed plantations generally results in significant yield responses because of greater photosynthetic activity (Uribe, 2001).

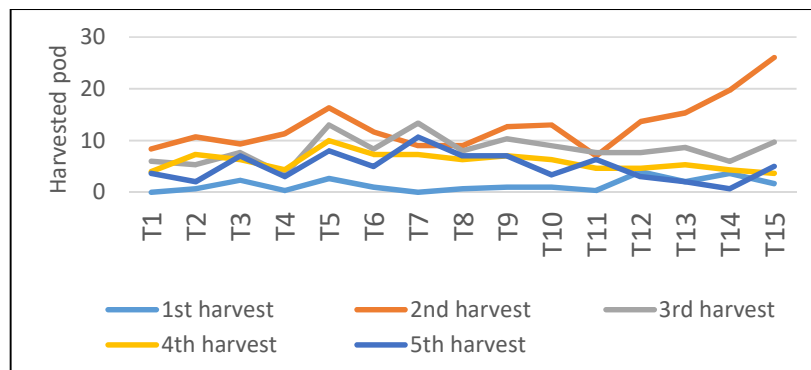


Figure 3. Pod harvesting per plot in 15 days interval (Oct. 04 - Dec. 04, 2015).

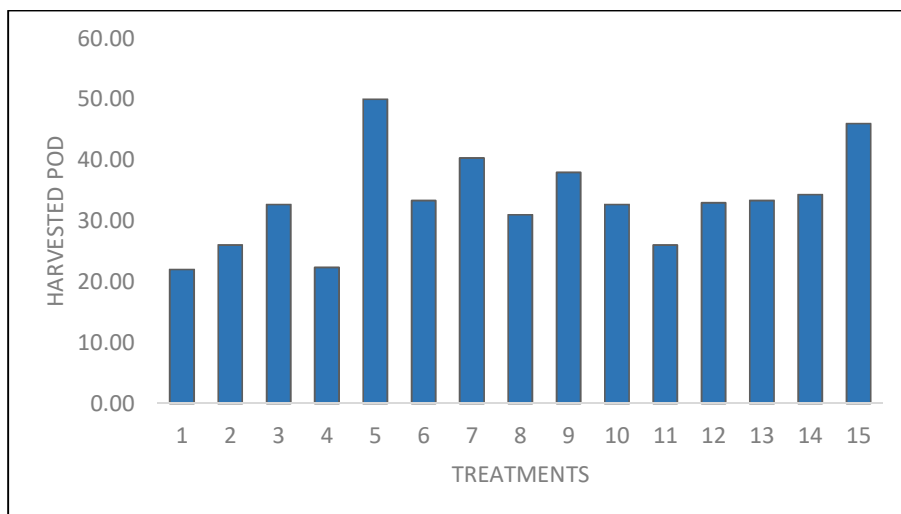


Figure 4. Total number of harvested pod of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

Weight of harvested pods

The weight of harvested pods presented in Table 4 revealed that there was a significant effect at 5% level on trees applied with urea at varying proportions. Heaviest harvested pods were observed in trees applied with 200 g of urea with the weight of 8,444.6 g.

However, no significant differences were observed between different rates of vermicompost whose means were ranged from 4,770 g to 8,869 g. There was no interaction effect between urea and vermicompost used in the experiment. Means were ranged from 3,903 g to 13,590 g. It was expected that the number of harvested pods would be directly proportional to its weight. Hence, as the result opposed this assumption it can be due to the reason of other yield component such as pod size, bean number per pod and bean size which contributed to the total weight of pod (Noordiana, 2007).

Table 4. Total harvested pod weight (g) of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

UREA	VERMICOMPOST					Mean ^{1/2}
	0	1.5 kg	3 kg	4.5 kg	6 kg	
0	3,903	4,880	4,770	3,983	6,767	4860.6 ^b
100 g	5,015	6,850	5,245	7,150	6,250	6102 ^{ab}
200 g	5,392	6,933	8,358	7,950	13,590	8444.6 ^a
Mean ^{ns}	4770	6221	6124.3	6361	8869	

(Means followed by a common letter in the row are not significantly different at 5 % level by Tukey Test)

Potential yield

Dry bean (g) per pod in two months harvesting period were significantly different in 1% level among treatments applied with 0g, 100g and 200g urea. Means in Table 4 revealed that trees applied with 200g and 100g urea were statistically different in 0g urea whose means were 26.26 g, 24.31 g and 23.16 g respectively.

While the potential yield of trees applied with different rates of vermicompost were comparable among treatments whose yield ranged from 23.41g to 25.48g dry bean per pod/year. The mean interaction between urea and vermicompost had no significant effect on potential yield whose dry bean weight ranged from 22.19g to 27.71g.

Potential yield was computed based on other yield parameter like weight of fresh bean, weight of fermented beans and dry bean weight. When these factors differed significantly, the potential yield would follow. Thus, weight difference of beans determines the potential yield. Baah et al (2011) stated that the dominant practice which has significant impact on cocoa yield productivity on cocoa farms is the application of fertilizers

Table 4. Potential yield (dry bean-g/pod/yr) of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

UREA	VERMICOMPOST					Mean ²⁻¹
	0	1.5 kg	3 kg	4.5 kg	6 kg	
0	22.35	22.57	24.68	22.19	24.01	23.16 ^b
100 g	26.05	23.93	24.06	24.27	23.26	24.31 ^a
200 g	25.77	27.26	27.71	23.76	26.81	26.26 ^a
Mean ^{ns}	24.72	24.59	25.48	23.41	24.69	

(Means followed by a common letter in the row are not significantly different at 1 % level by Tukey Test)

Effect on Pod Character

Pod weight, diameter and length

Table 5 represents the pod weight, pod diameter and pod length that were not affected by application of urea, vermicompost and its combination in varying proportions. Pod weight

was ranged from 257 g to 327.33 g. Pod diameter was measured from 22.04 cm to 23.52 cm and its length was ranged 10.67 cm to 16.83 cm.

Table 5. Pod weight (g), pod diameter (cm) and pod length of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

Treatment	Pod weight (g)	Pod diameter (cm)	Pod length (cm)
T1	257.00 ^a	22.04 ^a	15.27 ^a
T2	299.67 ^a	23.06 ^a	16.36 ^a
T3	298.00 ^a	22.75 ^a	15.55 ^a
T4	327.33 ^a	23.37 ^a	15.84 ^a
T5	313.33 ^a	22.87 ^a	16.53 ^a
T6	324.00 ^a	22.63 ^a	16.19 ^a
T7	318.33 ^a	23.37 ^a	16.83 ^a
T8	305.33 ^a	22.61 ^a	15.72 ^a
T9	282.33 ^a	22.75 ^a	16.07 ^a
T10	316.33 ^a	22.76 ^a	16.03 ^a
T11	315.33 ^a	23.23 ^a	16.30 ^a
T12	305.00 ^a	22.89 ^a	15.91 ^a
T13	316.00 ^a	23.40 ^a	16.61 ^a
T14	318.67 ^a	23.52 ^a	10.67 ^a
T15	309.67 ^a	23.15 ^a	16.41 ^a

(Means followed by a common letter in the row are not significantly different at 5 % level by Tukey Test)

Pod shell thickness

Pod shell thickness presented in Table 7 showed no significant difference in Factor A (urea) with the mean of 1cm. Factor B (vermicompost) did not also differed significantly whose means ranged from 0.9cm to 1cm. There is a positive interaction between two factors as it was differed significantly on its husk weight. Pod shell with less thickness was recorded in trees without application of fertilizer (0.89 cm) and it was increased to 1.07cm when applied with 200g of urea. Trees applied with 1.5 kg of vermicompost differed significantly when applied with 100 g urea and 200 g urea, with means of 1.21 cm and 0.87 cm respectively.

In addition, trees without fertilizer being applied had 0.89 cm shell thickness and differed significantly when applied with 6kg vermicompost (1.12 cm). Application of 100 g urea

together with 3 kg and 4.5 kg vermicompost showed comparable effect with each other (0.97cm and 0.94 cm) and were differed significantly when applied with 1.5 kg vermicompost (1.21 cm).

Table 7. Pod shell thickness (cm) of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

UREA	VERMICOMPOST					
	0	1.5 kg	3 kg	4.5 kg	6 kg	Mean ^{ns}
0	0.89 ^{BB}	1.05 ^{abAB}	1.02 ^{aAB}	1.06 ^{aAB}	1.12 ^{aA}	1.03
100 g	1.03 ^{abAB}	1.21 ^{aA}	0.97 ^{aB}	0.94 ^{aB}	1.03 ^{aAB}	1.04
200 g	1.07 ^{aA}	0.87 ^{bA}	1.08 ^{aA}	1.04 ^{aA}	1.01 ^{aA}	1.01
Mean ^{ns}	0.99	1.04	1.02	1.01	1.05	

(Means followed by a common letter in the row are not significantly different at 5 % level by Tukey Test)

Pod shell weight

Analysis of variance revealed no significant difference in Factor A (urea) on the shell weight of cacao pod. Weight was ranged from 195.73 g to 205.6 g. On the other hand, Factor B (vermicompost) did not differed significantly whose weight was ranged from 193.22 g to 208.67 g. Moreover, there was a positive interaction at 5% level of significance between urea and vermicompost. Data presented in Table 6 showed that trees without fertilizer applied (T1) had the lowest weight of 153.33 g and it was differed statistically when applied with 4.5kg of vermicompost (T4) which had recorded the highest shell weight of 226.67 g. Also recorded a significant effects when applied with 100g and 200g urea alone with the means of 209 g and 217.33 g respectively. Weight of shell was directly affected by its thickness.

Table 6. Pod shell weight of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

UREA	VERMICOMPOST					
	0	1.5 kg	3 kg	4.5 kg	6 kg	Mean ^{ns}
0	153.33 ^{BB}	203.33 ^{aAB}	196.33 ^{aAB}	226.67 ^{aA}	199.00 ^{aAB}	195.73
100 g	209.00 ^{aA}	237.00 ^{aA}	196.00 ^{aA}	184.00 ^{aA}	202.00 ^{aA}	205.6
200 g	217.33 ^{aA}	185.67 ^{aA}	207.33 ^{aA}	206.67 ^{aA}	201.33 ^{aA}	203.67
Mean ^{ns}	193.22	208.67	199.89	205.78	200.78	

(Means followed by a common letter in the row are not significantly different at 5 % level by Tukey Test)

Pod index

Table 8 showed the number of pods to produce one kilogram of dry beans. There was a significant difference in Factor A (urea) at 1% level. Trees applied with 200 g of urea recorded the lowest mean number of pods at 38.33 and significantly different in trees without the application of urea that reached the highest number of pods at 43.45 to produce 1 kg of dried beans. While, the Factor B (vermicompost) revealed no significant difference in pod index whose means were ranged from 39.47 to 42.86. There was also no interaction between urea and vermicompost with means ranging from 36.12 to 45.11. According to McMahan, et al. (2006) cacao clone BR25 would reached 43.8 pod index, relatively the same with the treatments without any fertilizer applied (43.45) on this study. Lower pod index (38.33) was recorded and implied that the bean quality was improved and significantly increased by application of urea fertilizer.

Table 8. Pod index (#pods/1kgDB) of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

UREA	VERMICOMPOST					Mean ^{2/}
	0	1.5 kg	3 kg	4.5 kg	6 kg	
0	45.08	44.61	40.53	45.11	41.90	43.45 ^a
100 g	38.49	41.92	42.05	41.30	43.47	41.45 ^{ab}
200 g	38.96	36.73	36.12	42.16	37.69	38.33 ^b
Mean ^{ns}	40.84	41.09	39.57	42.86	41.02	

(Means followed by a common letter in the row are not significantly different at 1% level by Tukey Test)

Effect on Bean Character

Fresh bean weight per pod

In Table 9, the weight freshly extracted beans as affected by application of urea, vermicompost and its combination in different proportions was not differed significantly. Recorded the lowest mean weight of 91 g in trees applied with 100g urea + 4.5kg vermicompost (T9) and reached the highest weight of 119 g in treatments applied with 4.5 kg of vermicompost.

Table 9. Fresh bean weight/pod of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

Treatment	Fresh Bean Weight / Pod (g)
T1 - W/o fertilizer	91.33 ^a
T2 - 1.5kg vermi	96.33 ^a
T3 - 3kg vermi	100.67 ^a
T4 - 4.5kg vermi	119.00 ^a
T5 - 6kg vermi	98.67 ^a
T6 - 100g urea	115.00 ^a
T7 - 100g urea + 1.5kg vermi	115.67 ^a
T8 - 100g urea + 3kg vermi	104.67 ^a
T9 - 100g urea + 4.5kg vermi	91.00 ^a
T10 - 100g urea + 6kg vermi	98.33 ^a
T11 - 200g urea	109.67 ^a
T12 - 200g urea + 1.5kg vermi	112.33 ^a
T13 - 200g urea + 3kg vermi	98.67 ^a
T14 - 200g urea + 4.5kg vermi	107.00 ^a
T15 - 200g urea + 6kg vermi	97.00 ^a

(Means followed by a common letter in the row are not significantly different at 5 % level by Tukey Test)

Number of beans per pod

Number of beans per pod did not differ significantly in Factor A (urea) that were presented in Table 10. Beans number were in 31.9 up to 32.88 pieces in every pod. In addition, Factor B (vermicompost) also showed no significant difference in bean number whose means were ranged from 31.4 to 34.

There was a positive interaction between two factors in affecting the number of beans per pod. Table 10 revealed that in trees applied with 3 kg vermicompost + 200 g urea the number of beans were decreased to 29.5 and significantly increased to 34.7 when applied with 100 g urea. Consequently, 4.5 kg vermicompost + 100 g urea differed significantly in trees without application of vermicompost with the mean of 27.6 and 34.4 respectively. Furthermore, 100 g urea + 3 kg vermicompost significantly increased the number of beans per pod compared to trees applied with 100 g urea + 4.5 kg vermicompost, whose means were 34.7 and 27.6 respectively.

Table 10. Number of beans/pod of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

UREA	VERMICOMPOST					
	0	1.5 kg	3 kg	4.5 kg	6 kg	Mean ^{ns}
0	30.3 ^{aA}	33.3 ^{aA}	33.3 ^{abA}	34.4 ^{aA}	33.1 ^{aA}	32.88
100 g	33.1 ^{aAB}	33.7 ^{aA}	34.7 ^{aA}	27.6 ^{bB}	31 ^{aAB}	32.02
200 g	31.6 ^{aA}	34.9 ^{aA}	29.5 ^{bA}	32.1 ^{bA}	31.4 ^{aA}	31.9
Mean ^{ns}	31.7	34.0	32.5	31.4	31.8	

(Means followed by a common letter in the row are not significantly different at 5 % level by Tukey Test)

Fermented bean weight (100 beans)

Fermented 100 beans presented in Table 11 revealed a significant difference in Factor A (urea). Cacao trees applied with 200 g of urea significantly increased its fermented bean weight to 213.3 g compared to 0 g and 100 g urea with the weight of 188.2 and 193.6. However, factor A (vermicompost) did not differ significantly and recorded the mean weight ranging from 191.3 g to 207.4 g.

There was a positive interaction recorded between the application of urea and vermicompost. Trees applied with 1.5 kg vermicompost + 200 g urea significantly had higher weight compared to trees applied with 100 g urea with the mean of 214.5 g and 174.13 g respectively. It had also revealed a significant difference in 6 kg vermicompost + 200 g urea (229.7g) compared to 0 urea + 6 kg vermicompost (170.63g) and 100 g urea + 6 kg (181g) vermicompost combination. In addition, fertilizer combination of 100 g urea + 4.5 kg vermicompost significantly increased the fermented bean weight to 223.03 g compared to 174.13 g weight of 100 g urea + 1.5 kg vermicompost combination.

Single dry bean weight

Individual bean weight differed significantly in cacao trees applied with urea (Factor A). Table 12 showed that the higher amount of urea applied the heavier its bean can become. Trees applied with 200 g of urea was statistically significant on trees with lower rate of urea (100 g, 0 g), whose means were 0.96 g, 0.86 g and 0.80 g respectively. Whereas, vermicompost (Factor B) applied trees recorded no significant difference on single dry bean weight with means ranged from 0.85 g to 0.92 g.

There was no interaction between urea and vermicompost recorded whose means were ranged from 0.77 g to 0.97 g.

Table 11. Fermented bean weight (100beans) of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

UREA	VERMICOMPOST					Mean ^{2/}
	0	1.5 kg	3 kg	4.5 kg	6 kg	
0	202.2 ^{aA}	185.07 ^{abA}	183.4 ^{aA}	199.53 ^{aA}	170.63 ^{bA}	188.2 ^b
100 g	211.17 ^{aAB}	174.13 ^{bB}	178.77 ^{aAB}	223.03 ^{aA}	181 ^{bAB}	193.6 ^b
200 g	208.9 ^{aA}	214.77 ^{aA}	214.5 ^{aA}	198.83 ^{aA}	229.7 ^{aA}	213.3 ^a
Mean ^{ns}	207.4	191.3	192.2	207.1	193.8	

^{1/}(Means followed by a common letter in the row are not significantly different at 5 % level by Tukey Test)

^{2/}(Means followed by a common letter in the row are not significantly different at 1 % level by Tukey Test)

Table 12. Single dry bean weight of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

UREA	VERMICOMPOST					Mean ^{2/}
	0	1.5 kg	3 kg	4.5 kg	6 kg	
0	0.86	0.77	0.83	0.79	0.77	0.804 ^b
100 g	0.93	0.83	0.83	0.89	0.84	0.864 ^b
200 g	0.97	0.95	0.94	0.93	1.02	0.962 ^a
Mean ^{ns}	0.92	0.85	0.87	0.87	0.88	

^{2/}(Means followed by a common letter in the row are not significantly different at 1 % level by Tukey Test)

Dry bean weight (100 beans)

Since the single dry bean weight was statistically significant as discussed earlier then its 100 bean weight would follow correspondingly. Analysis of variance revealed a significant difference in 100 dry bean weight of pods sampled in trees applied with urea (Factor A). Data in Table 13 showed that application of urea at 200 g statistically increased its weight to 82.80 g and comparable to 100 g urea with the weight of 78.39 g. These two rates of urea were significantly different to trees without the application of urea and recorded the dry bean weight of 71.02. On the other hand, vermicompost (Factor B) showed no significant difference in 100 dry bean weight whose means were ranged from 75.78 g to 79.39 g.

Moreover, there was no interaction reflected between the two factors. One hundred dry bean weight means were ranged from 69.07 g to 89.23 g.

Table 13. Dry bean weight (100beans) of cacao var. BR25 in response to application of urea and vermicompost at varying proportions.

UREA	VERMICOMPOST					Mean ²⁻¹
	0	1.5 kg	3 kg	4.5 kg	6 kg	
0	71.57	69.07	71.27	74.13	69.07	71.02 ^b
100 g	80.90	76.80	74.77	84.00	75.47	78.39 ^a
200 g	82.13	79.80	89.23	80.03	82.80	82.80 ^a
Mean ^{ns}	78.20	75.22	78.42	79.39	75.78	

²⁻¹(Means followed by a common letter in the row are not significantly different at 1 % level by Tukey Test)

Effect on Soil and Plant Nutrient Status

Soil percentage organic matter (OM%)

Bar graph below showed the soil organic matter of the experimental area before and after the application of fertilizer treatments. Laboratory soil analysis revealed that the initial status of organic matter of the area which was 2.5 was below the moderate range (3.6 – 4.5).

Oyewole et al (2012) stated that organic fertilizers could be used as sources of nutrient. However, these materials are not sufficient to meet the nutritional demand of the crop, hence; there is need for fortification with mineral fertilizer. Application of urea, vermicompost and its combination noticeably increased the % organic matter of the experimental site compared on its initial analysis. However, it did not surpassed the moderate range of soil %OM. Analyzed soil %OM were ranged from 2.66 (200g urea + 6kg vermi) to 3.5 (200g urea).

Nitrogen content of leaf (%)

Bar graph below showed the nitrogen status of the leaves before the application of fertilizer treatments were moderately deficient (1.82) and remarkably below the normal adequate nitrogen content. According to Snoeck et al (1984), the normal % nitrogen range of a near mature cacao leaves were 2.35 – 2.50, moderately deficient: 1.80 – 2.00 and severely deficient: <1.80. Leaf tissue analysis revealed after the application of urea, vermicompost and its combination somewhat increased the % nitrogen ranging from 1.83 to 2.08 compared to its initial analysis (1.82). Contrastingly, some treatments were remarkably decreased into severely deficient range status whose range were from 1.27 to 1.70.

Since the collection of leaf sample was done at the peak season of fruiting it was expected that the nitrogen status of the leaves would relatively decreased as the number of developed pods increased (sink-source relationship). The greatest variation in concentration of nutrients in the leaves was due to the time of year the leaves were collected. The lowest concentrations of nitrogen, phosphorus, and potassium were found in the leaves collected during the peak of the main season harvest. The highest levels of these elements were found in leaves collected near the end or a few weeks after the end of the main harvest (Burrige, 1964).

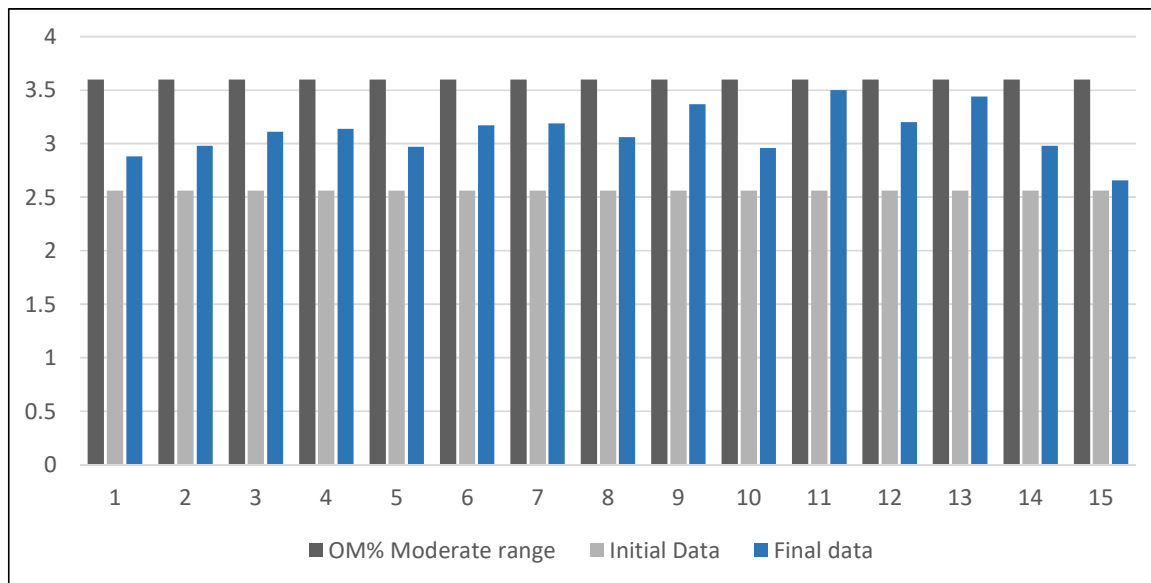


Figure 5. Soil % organic matter in response to application of urea and vermicompost at varying proportions.

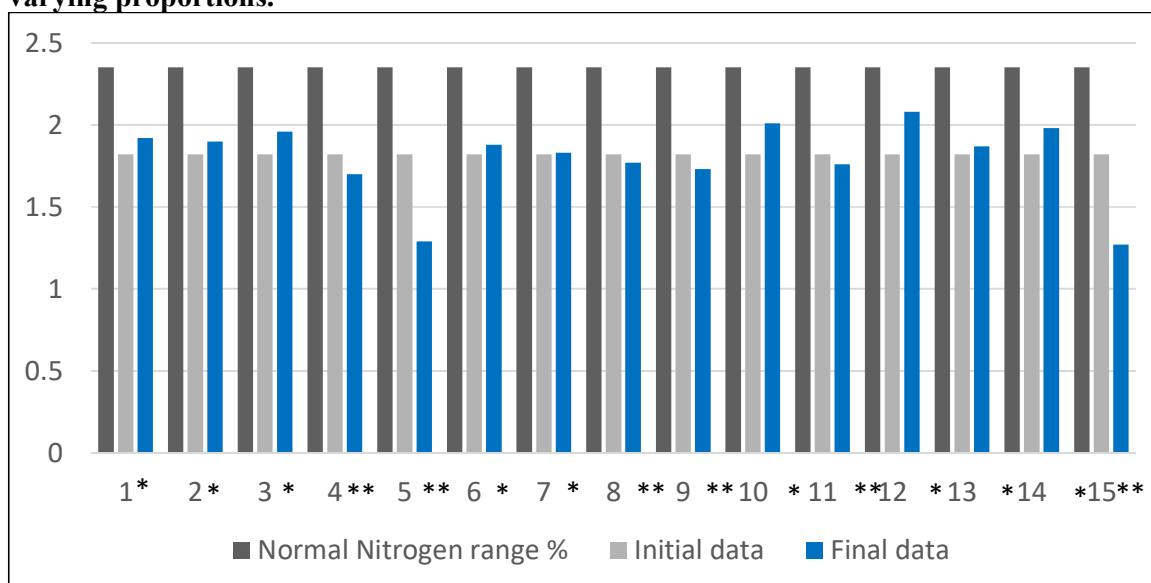


Figure 6. Leaf nitrogen (%) content in response to application of urea and vermicompost at varying proportions.

*Treatment numbers followed by * were Moderately Deficient (1.8 – 2.0) and ** were Severely Deficient (< 1.8) according to Loué, Murray, Spector in Snoeck,1984.*

Effect on Cost and Return

Economic analysis

Table 14 below represents the economic analysis of cacao production as affected by application of urea, vermicompost and its combinations. It was revealed that the cost of production was expensive on treatments applied with the combination of urea and vermicompost. This estimated production cost was ranged from 25,073.37 (T1=0 fertilizer) to 108,967.67 (T15=200g urea+6kg vermi).

Gross income was calculated and showed that T15 (200g urea+6kg vermi) reached the highest gross of 217,498.65 and T1 recorded the lowest gross of 81,307.94. Gross income was directly influenced by number of pod harvested and its dry bean recovery.

The difference in gross income and its production cost would correspond to the net income. Application of 200g+6kg vermi (T15) had reached the highest net income of 108,530.98, and recorded the lowest net income on trees applied with sole 4.5 kg vermicompost (19,963.63).

Whereas, the return of investment (%ROI) was calculated and treatment 6 (100g urea) showed the highest return of 245.16% and in every Php1.00 cost in production the benefit would be Php3.45 (Benefit Cost ratio).

Application of urea at 100g/tree was economical as it showed the highest % ROI and BCR compared to application of vermicompost. It was due to its costly price and based on its nutrient level analysis that fall down as a soil amendment and not as a fertilizer. However, all treatments had recorded a positive increase in investment.

Based on Cacao Industry Development Association of Mindanao (CIDAMI) in 2015, cacao tree can yield around 1.5 to 2 kilos of dried beans or around a ton of dried cacao beans per hectare. Current Davao Region prices stand at P115 to P125 per kilo for dried cacao and P38 to P40 per kilo for wet beans.

Table 14. Economic analysis in producing cacao as applied with urea and vermicompost.

TREATMENT COMBINATI ON	COMPUTED YIELD (kg/ha/fruitin g)	GROSS INCOME/ ha (Php)	ESTIMATED PRODUCTIO N COST/ ha.(Php)	NET INCOME/ ha (Php)	% RETURN ON INVESTMEN T	BENEFI T COST RATIO
T1 – 0	761.4	91,371	25,073	66,297	264.4	3.6
T2 – 0 + 1.5	1010.6	121,273	44,413	76,859	173.1	2.7
T3 – 0 + 3.0	1325.6	159,067	59,310	99,756	168.2	2.7
T4 – 0 + 4.5	980.8	117,691	65,712	51,979	79.1	1.8
T5 – 0 + 6.0	1892.5	227,094	101,710	125,383	123.3	2.2
T6 – 100 + 0	1458.2	174,984	42,633	132,350	310.4	4.1
T7 – 100 + 1.5	1760.5	211,258	56,394	154,863	274.6	3.8
T8 – 100 + 3.0	1321.3	158,551	61,670	96,880	157.1	2.6
T9 – 100 + 4.5	1506.6	180,790	80,65	100,134	124.1	2.2
T10 – 100 + 6.0	1224.6	146,949	91,852	55,096	59.9	1.6
T11 – 200 + 0	1035.0	124,319	36,395	87,923	241.6	3.4
T12 – 200 + 1.5	1552.6	186,315	60,975	125,339	205.6	3.0
T13 – 200 + 3.0	1509.3	181,116	73,777	107,339	145.5	2.5
T14 – 200 + 4.5	1441.1	172,925	89,015	83,910	94.3	1.9
T15 – 200 + 6.0	2015.6	241,870	108,967	132,903	121.9	2.2

^{1/} Computed Yield – Number of pods/tree x dry bean wt (kg/pod)

^{2/} Gross Income – Computed yield/ha x current price of dry beans (P120/kg)

^{3/} Production Cost: see Appendix Table 25

^{4/} Net Income: Gross income – Production cost

^{5/} Return of Investment (%) – Net income / Production cost x 100

^{6/}Benefit Cost Ratio – Gross income / Production cost Fermentation and Drying @ Php3.00/kg dry beans

Disease and pest occurrence

Cacao Pod Rot (*Phytophthora palmivora*) revealed no significant difference among trees applied with different rates of fertilizers with means ranging from 24.07 to 48.15%. Based on the rating scale all treatments except T3 (3 kg vermi) were described as heavily infected.

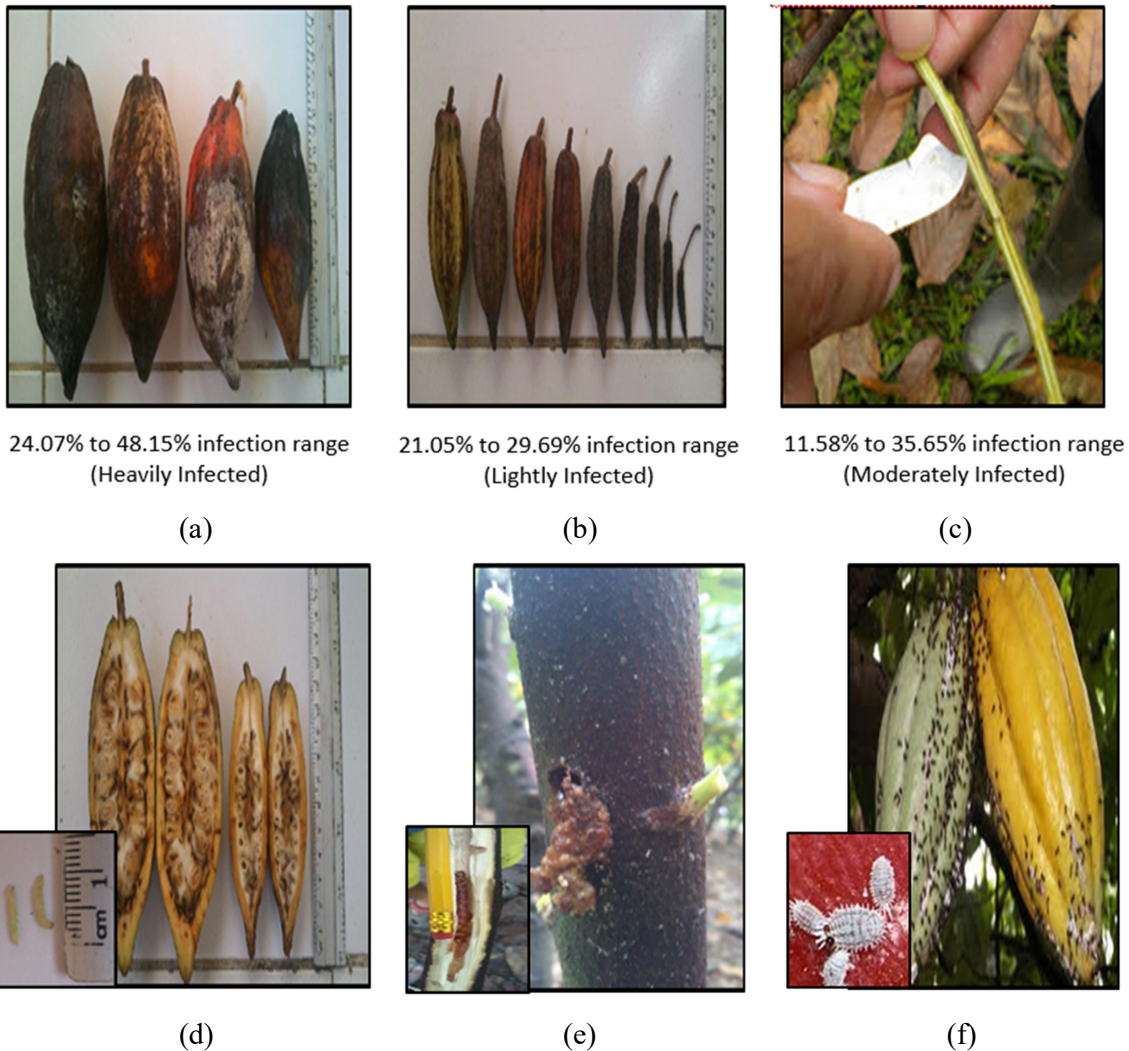
Cherelle Wilt (*Colletotrichum* Pod Rot) showed no significant difference among trees applied with different rates of fertilizers with mean infection of 21.05 up to 29.69 %. Occurrence of cherelle wilt is a natural occurrence and considered a physiological disease.

Vascular-Streak Dieback (*Oncobasidium theobromae*) was moderate and did not differ significantly among treatment combinations with the ranged of 11.58 to 35.65 %.

The plant parasitic nematode population was significantly affected by urea, vermicompost and its combination. Control plot (Treatment 1, w/o fertilizer application) gave the highest

number of nematode population which was significantly higher than the rest of the plot with the range of 11.33 to 19.33. There were 10 genera of parasitic nematodes encountered. The most widely distributed genera were *Pratylenchus* sp. followed by *Helicotylenchus* sp and *Meloidogyne* sp. with the frequency rating of 30.14, 27.02 and 25.34%, respectively.

Cacao Pod Borer (*Conopomorpha cramerella*) infestation was significantly decreased by the application of fertilizer treatments. Control plants (T1, w/o fertilizer) gave the highest incidence of pod borer of 50%. Twig Borer (*Zeuzera coffeae*) and Mealybugs (*Pseudococcidae*), were found attacking the cacao trees in the experimental area but caused minor damage to the trees.



Cacao pod rot - *Phytophthora palmivora* (a), Cherelle wilt - *Colletotrichum* Pod Rot (b), Vascular-streak dieback - *Oncobasidium theobromae* (c), Cacao pod borer - *Conopomorpha cramerella* (d), Twig borer - *Zeuzera coffeae* (e), and Mealybugs –

Figure 7. Disease infections and insect infestations.

CONCLUSION

Based on the findings, the following conclusions were drawn:

1. for the growth parameters evaluated, the application of different rates of urea and vermicompost in cacao trees grown under mature rubber has no effect in trunk girth increment, leaf length and leaf width.
2. yield components like weight of harvested pods, single dry bean weight, dry bean weight per pod, and pod index are significantly affected by application of 200 g urea, a positive indication that the quality of cacao beans is improved.
3. pod husk weight and husk thickness are significantly affected when applied with the combination of 100 g urea + 1.5 kg vermicompost. Combination of 100 – 200 g urea + 1.5 – 3.0 kg vermicompost have increased significantly the number of beans/pod. Application of these treatments gives higher percentage increase.
4. there is a general increase in soil organic matter after the application of fertilizer, yet does not surpass the normal soil %OM. It is due to the low nutrient content of vermicompost used based on its analysis and short duration of the study.
5. the leaf N (%) content is not increased by application of different rates of urea and vermicompost. In fact, some trees have decreased the N content at this time since the collection of leaf sample was done during the fruiting season.
6. cacao pods are heavily infected by *Phytophthora* pod rot, lightly infected by cherville wilt, moderately infected by Vascular-streak dieback (VSD) and other insect infestation is caused by mealy bug and twig borer.
7. there is a significant decrease in pod borer incidence when applied with fertilizer compared to control, due to the increase in pod husk thickness since the unfertilized control recorded the lowest pod husk. In addition, the parasitic nematode population is reduced since the application of vermicompost increased the population of beneficial microbes competing the pathogens for available food resources.
8. application of urea at 100 g/tree is the most economical fertilizer rate as it showed the highest % ROI and BCR compared to the control and trees applied with vermicompost. Application of vermicompost is costly because of the large volume required per hectare.

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