Int. j. adv. multidisc. res. stud. 2022; 2(5):343-347

Received: 07-08-2022
Accepted: 17-09-2022

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Response of mineral fertilization on cocoa productivity

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Abstract

A cocoa fertilization trial was conducted on one of the experimental sites of the Togolese Institute for Agronomic Research / Center for Agronomic Research in the Forest Zone (ITRA/CRA-F) located in Zozokondji in the Agou prefecture. The tests took place in a cocoa plantation of hybrids in production, planted according to the 3 m x 2.5 m rectangular scheme and at a density of 1333 cocoa trees/ha. The trial was set up in a completely randomized design with four repetitions. The objective is to test the effectiveness of two fertilizer formulas (NPK-3-21-20+5MgO+5SO3+0.5B+0.5Zn+10CaO+PHYSIO S and PK 25-20+10CaO+5MgO+ 0.5B+0.5Zn) and to compare their performances with those of Ghanaian cocoa fertilizer (NPK 0-22-18+9CaO+7S+6MgO) and NPK 15-15-15 fertilizer in order to improve the fertility of the soils of the cocoa plantations for an increase in their production. The treatments consisted of the types of fertilizers to be tested and their different application doses to be able to harvest 0.5; 1 and 1.5 tonnes of commercial cocoa per hectare based on the export of the different mineral elements by the plant. The fertilizer application was made in two stages each year (2020 and 2021) and spaced two months apart. The fertilizer was applied in a 40 cm crown around the cocoa tree over a radius of 60 to 100 cm. The results obtained showed that the PK 25-20+10CaO+5MgO+0.5B+0.5Zn and NPK 0-22-18+9CaO+7S+6MgO fertilizer formulas which are devoid of nitrogen remain the best in term of the number of pods and the yield of marketable cocoa.

Keywords: Fertilizer, Performance, Cocoa, Improvement

1. Introduction

Cocoa, Theobroma cacao L (var Haut Amazoniens) is Togo's third export crop after cotton and coffee. It is mainly grown in the south-west of the plateau region, particularly in the prefectures of Agou Kloto Daye Amou Akebou and Wawa by more than 27,000 producers (DCID 2001 CCFCC 2007) [8]. It is mainly grown for its fruits called beans and contributes an average of 0.57% to real GDP in 2002 (CCFCC (2002) [7]. enormous problems: aging of the plantations diseases (pod rot, swollen shoot etc.) harmful insects (mirids trunk borers scale insects etc.) and the use of plant material not adapted to the new pedoclimatic conditions constitute a real threat to Togolese cocoa farming, leading to a drop in production (GTZ 1986 [13]; Bohé Gui *et al*., 2009). After independence, the national cultivation area covered 40,000 ha (Deuss and Meatchi 1981) [9] but today, it only covers 25,335 ha (DSID 2013) [12] a reduction of more than 63% with a production of less than 10,000 tonnes (DCLM 2013) [10]. In addition to these problems, the decline in fertility and soil degradation to vocation are one of the major constraints to obtaining good yields of marketable cocoa (Mawussi G., 2008) [26]. Indeed, since the beginning of cocoa cultivation the problem of manure has not really arisen but for nearly twenty years there has been a drastic drop in soil fertility following the non-restitution of mineral elements exported during several decades of harvesting and to the degradation of the forest environment in which the plant grows (Agbobli et *al*., 2007) [1].

Mineral fertilization trials are very numerous. In Togo, fertilization trials were carried out in the production sub-zones but did not give significant results (IRCC-Togo 1990; Jadin and Vaast 1990; Jagoret et *al*., 1992). In addition, from 2005 to 2010 the Priority Solidarity Fund projects of the French Ministry of Foreign Affairs and Com Stabex of the European Union supported the improvement component of soil fertility management in the cocoa growing areas of Togo. Unfortunately, the ongoing work in this direction has not yet yielded the expected results.

With a view to finding a palliative, a local chemical sales company called Arysta Life Science and recognized in the sale of chemical products offers to have two fertilizer formulas tested on cocoa trees: NPK3-21-20+5MgO +5SO3+0.5B+0.5Zn+10CaO+Physio S and PK 25-20+10CaO+5MgO+0.5B+0.5Zn. In addition, the "soil diagnosis" tool was used to determine the quantities of fertilizer needed to correct the imbalances revealed by the results of analysis of soil samples and compensate for the elements exported by a yield of 500 kg/ha market cocoa (Koudjega 2013) [23]. The experiments were carried out in three (03) areas: Litime Akebou and Kloto-Agou in 2011 and 2012 and until then the results of this work have not yet been validated. In this study, the performance of a control without manure was evaluated for comparison of results. It is in this sense that this study was conducted and has the general objective of improving the soil fertility of cocoa plantations for an increase in the production of these plants in Togo. To do this the effectiveness of these two fertilizer formulas on cocoa yield was evaluated in order to compare their performance with that of the cocoa fertilizer popularized in Ghana (NPK 0-22-18+9CaO+7S+6MgO) and NPK15-15-15 fertilizer.

2. Materials and method

2.1 Study site

The site used for the study is the CRA-F test point located in the south-west of the Plateau region at Zozokondji in the Agou prefecture 35 km from Kpalimé. The Zozokondji test point has a varied terrain including Mount Agou (986 m above sea level) and its foothills. The area benefits from an equatorial climate with a bimodal regime with an average annual rainfall of 1200 mm (Assih 2013) [24]. The vegetation consists of wooded savannas and gallery forests along the Zio River (Lamouroux 1965).

Ferralitic soils are represented in the coffee and cocoa zone in the west of the Plateaux region. They have a relatively deep, uniform and well-drained profile, red in color. They have physical properties favorable to crops but are relatively poor in fertilizing elements (Lamouroux 1965, Agbobli *et al*., 2007) [1]. The level of organic matter varies according to the plant cover. Up to 5% under forest and 0.5 to 1% under cultivation. The exchangeable bases are generally quite low 2 to 5 meq with saturation rates of 25 to 40% which can go up to 60 and even 80% sometimes (Lévêque 1979) [27].

2.2 Analysis of soil samples

Table 1: Physical and chemical characteristics of the soil

A +L	C	N	Pt	P ass	K	Ca	Mg	CEC	pH
(%)	(%)	(%)	(ppm)	(ppm)	(méq%)	Ph			
42.6	2.2	0.2	455.8	67.3	0.2	16.5	3.5	12.8	7.5
51.8	2.4	0.2	864.4	21.9	0.3	13.4	5.9	21.1	6.7

Table 2: Types of fertilizers used

Types of fertilizers used
A: NPK 3-21-20+5MgO+5SO_3+0,5B+0,5Zn+10CaO+PhysioS
B: PK 25-20+10CaO+5MgO+0,5B+0,5Zn,
C: NPK 15-15-15
D: NPK 0-22-18+9CaO+7S+6MgO

Composite soil samples were taken from the 0-20 cm soil layer using a 5 cm diameter auger. These soil samples were analyzed in the laboratory to determine the texture and some chemical characteristics of the soil were determined. These are soil organic carbon (C) total soil nitrogen, total phosphorus available phosphorus exchangeable bases (K Na Ca and Mg) potassium sodium and pH-water.

2.3 Conduct of the trial

The trial was conducted over the two agricultural campaigns of 2020 and 2021. The tests took place in a cocoa plantation of hybrids of Theobroma cacao Haut Amazoniens precisely on plot Z16 in production planted according to the 3 m x 2.5 m cropping pattern. The completely randomized device used consists of 11 treatments (table 2 and table 3) repeated 4 times. The elementary plot (PE) has an area of 135m2 and carries twenty-eight (28) cocoa trees including ten (10) useful feet (PU) and eighteen (18) of border. The treatments consist of the types of fertilizers to be tested and their different application rates.

Fertilizer was applied in two stages each year, and half the amount of fertilizer was applied at each stage. Fertilizer was added in a 40 cm crown around the cocoa tree over a radius of 60 cm to 100 cm. It is a question of delimiting two concentric circles of respective radii of 60 cm 100 cm around the cocoa tree thus delimiting a crown of 40 cm in which the fertilizer has been spread.

Other agricultural operations such as weeding pruning and top dressing were carried out before fertilizer application.

2.4 Determining the amount of each type of fertilizer to apply

Table 3: Quantities of different types of fertilizers per hectare, per plant and per treatment

Treatments and proportion of fertilizers used	Quantity of fertilizer (kg/ha)	Quantity /plant (kg/ha)
T0 : Témoin	0.0	0.0
T1 : Ax1.5	487.5	0,38
T2 : Ax1.0	325.0	0.25
T3 : Ax0.5	162.5	0.13
T4 : Bx1.5	487.5	0.38
T5 : Bx1.0	325.0	0.25
T6 : Bx0.5	162,5	0.13
T7 : Cx1.5	650.0	0.50
T8 : Cx1.0	433.33	0.33
T9 : Cx0.5	216.67	0.17
T10 : Dx1.0	375.0	0.29

Note: A=B=325kg/ha; C=433.33kg/ha and D=375kg/ha. The letters A B C and D represent the formulas of the fertilizers used in table 2

The determination of the quantity of fertilizer was based on the exports of the major elements (N; P2O5; K2O; CaO and

MgO) by the cocoa trees per hectare. It is a question of calculating for each element the quantity of fertilizer capable of bringing this element in sufficient quantity to satisfy its export per hectare. The average exports retained for a ton of commercial cocoa were fixed by Jadin and Lotodé (1981) as being 45 kg of N; 13Kg of P2O5; 65Kg of K2O; 10Kg of CaO and 13K g of MgO.

The quantity of each type of fertilizer to be applied was determined by the following formula:

$X = (E/Y) *100$

X = Quantity of fertilizer per hectare;

Y = Quantity of the element in 100Kg of fertilizer and

E= Export of the element per hectare.

For each type of fertilizer, the largest value of X was taken as the amount of that fertilizer per hectare. This quantity will provide a sufficient quantity of exports of the various major elements per hectare. The application of these formulas made it possible to calculate the quantities of the different types of fertilizers to be spread.

2.5 Observations and data collection

The observations focused on the useful feet and the data collection focused on:

- The number of pods produced per treatment per hectare
- The yield of marketable cocoa after depodding fermentation and drying

The data was processed using STATISTICA software. The analysis of variances (ANOVA) was carried out and if the differences were statistically significant, the means are discriminated with the Newman and Keuls test at the 5% threshold.

3. Results and discussion

3.1 Results

3.1.1 Soil test results

The results of analysis of soil samples from fertilization tests conducted under cocoa trees (Table 1) showed that these soils have an average clay plus silt content varying from 42.6 to 51.8%.

Chemically, these soils, moderately supplied with carbon (2.2 to 2.4%) are generally poor in total nitrogen (0.2%) assimilable phosphorus (21.9 ppm). They are low in potassium (0.3 meq%) and are rich in calcium (13.4 meq%) and magnesium (5.9 meq%). The soils are otherwise neutral to slightly basic (pH 6.7-7.5).

The soils are deficient in assimilable phosphorus (21.9 ppm) and total nitrogen (0.2%). The N/P ratio which is 9.13 is quite far from the optimum between 1.5 and 2 (Konan and Jadin, 1989) [22]. These soils therefore present an imbalance between N and P which, to be corrected, requires the addition of phosphate fertilizers in order to bring the content of these soils in assimilable P to the optimum level which is 100 ppm. In addition, the soils of the study area are deficient in potassium (K).

3.1.2 Effect of fertilizers on the number of pods produced

Table 4: Average number of pods per hectare

Traitments	Number of pods per hectare		
	Harvest1	**Harvest 2**	**Average**
T0	4875c	8416b	6646bc
T1	5362bc	6143bc	5753bc
T2	7930b	7670bc	7800bc
T3	5785bc	5428c	5606c
T4	7735b	8288b	8011b
T5	6012bc	9263b	7638bc
T6	6727b	8678b	7703b
T7	4777c	6500bc	5639c
T8	7150b	8970b	8060b
T9	6305b	6923bc	6614bc
T10	12220a	14335a	11278a
Average	6807	7874	7341

Fertilization treatments (Table 3) influenced the number of pods during each season. The number of pods for all the treatments varied from 4777 pods/ha (T7) to 12220 pods/ha (T10) and from 5428 pods/ha (T3) to 14335 pods/ha (T10) respectively during the first season and the second season, i.e., an average varying between 5606 pods/ha (T3) and 11278 pods/ha (T10).

At the first harvest the best performance was obtained with the T10 treatment (12220 pods/ha). Then come the T4 treatments (7735 pods/ha) T8 (7150 pods/ha) T6 (6727 pods/ha) T9 (6305 pods/ha) and T5 (6012 pods/ha) which are statistically identical. At the end of the second harvest, the same trend was observed where the T10 treatment comes first with 14.335 pods/ha followed by the T5 treatments (9,263 pods/ha) T8 (8970 pods/ha) T6 (8678 pods/ha) and T4 (8228 pods/ha) which are also statistically equivalent.

For all of the two harvests (2020-2021) the T10 treatment made it possible to obtain more pods (11.78 pods/ha) and is statistically superior to all the other treatments. Then come the treatments T8 (8060) T4 (8011) T6 (7703) and T5 (7638) which are statistically equivalent to each other and superior to the other treatments (table 4).

3.1.3 Effect of fertilizers on the yields of marketable cocoa obtained

Table 5: Market cocoa yields

Traitments	Yields (Kg/ha)		
	Harvest 1	**Harvest 2**	**Average**
T0	163.63ab	217.97b	190.81ab
T1	13.6b	207.25b	169.93b
T2	162.63ab	184.08c	173.36bc
T3	153.30b	173.55c	163.43bc
T4	201.85a	242.67ab	222.27ab
T5	226.68a	279.63ab	253.16ab
T6	204.39a	267.89ab	236.15ab
T7	130.19b	191.49c	160.84bc
T8	160.12ab	199.51c	179.82bc
T9	112.54b	205.14b	158.84b
T10	274.75a	362.6a	318.68a
Average	174.79	230.16	202.48

The different fertilization formulas (Table 2) influenced the yields of marketable cocoa during each season. The yield of marketable cocoa for all the treatments varied from 112.54 kg/ha (T9) to 274.75 kg/ha (T10) and from 173.55/ha (T3) to 362.60 kg/ha (T10), respectively during the first season and the second season is an average varying between 158.84 kg/ha (T3) and 318.68 kg/ha (T10) (Table 5).

At the first harvest, the best performances were obtained with the treatments T10 (274.75 kg/ha) T5 (226.68 kg/ha) T6 (204.39 kg/ha) and T4 (201.85 kg/ha) statistically equivalent to each other and superior to the other treatments. At the second harvest, the same trend was observed at the

level of treatments T10 T5 T6 and T4 which have the best yields of marketable cocoa with respectively 362.60 kg/ha 279.63 kg/ha 267.89 kg/ha and 242.67 kg/ha.
Considering the average of the two harvests we conclude that the treatments T10 T5 T6 and T4 are better with respectively 318.68 kg/ha 253.16 kg/ha 23615 kg/ha and 222.27 kg/ha.

3.2 Discussion

The results show that the NPK 0-22-18+9CaO+7S+6MgO (T10) formula optimizes both the production of pods and the yield of marketable cocoa, followed by the treatments resulting from the PK 25-20+10CaO+5MgO+0.5B+0.5Zn (T4 T5 and T6). This would be due to the absence of nitrogen in these formulas and that the production of pods and marketable cocoa would be influenced by phosphorus and potassium. Indeed, it has been proven that phosphorus significantly increases flowering and therefore the production of pods while potassium improves the rate of fruit set (Anonymous 2002). Furthermore, various trials (Ahenkorah and Akrofi 1969 [3], Jadin 1975 [16]) have shown that with shade nitrogen has no effect and that the fertilizer to be applied will be predominantly phosphorus or potassium depending on the soil, but that the potash only has a positive effect if the phosphorus nutrition is correct. The positive effects of phosphorus on yields in merchant cocoa have been observed by Ahenkorah et *al*., (1981) [2] who report that in Ghana phosphorus contributes to an average increase of 32% in marketable cocoa yields, whereas the effect of potassium is negligible and that of nitrogen is generally depressive.
The average number of pods at the second harvest (7874 pods) is 16% higher than the average number of pods at the first harvest (6807 pods). This same trend was observed for the average yield of marketable cocoa obtained. In fact, at the second harvest, the average yield of commercial cocoa obtained (230.16 kg/ha) is 32% higher than the average yield of commercial cocoa obtained at the first harvest (174.79 kg/ha). This situation would be due to the low rainfall recorded during the first year of the test (925.80 mm) compared to the second year (1164 mm). This low rainfall in the first year of the trial would have reduced the effective assimilation of the nutrients applied.
Furthermore, it was found that the number of pods and the yield of marketable cocoa for all treatments were higher in the second harvest. This would be due to the residual effect of the fertilizers applied in the first season. These results confirm the mineral fertilization work carried out by IRCC-Togo (1990) under cocoa trees based on TSP and NPK15-15-15 in certain cocoa sub-zones of Togo. The results obtained varied according to the sub-zones. Indeed, in Litime (Koudjega 2013) [23] these fertilizers did not lead to a significant increase in the yield of marketable cocoa in the first year. But it was from the second year that they contributed to a significant increase in the yield of marketable cocoa, which means that the plants did not absorb the fertilizers the first year of application.
It is clear from all this analysis that there is no standard fertilizer for all cocoa growing areas because fertilizers are manufactured to meet specific soil conditions that differ from one growing area to another.

4. Conclusion

This work of mineral fertilization of the cocoa tree made it possible to evaluate the performance of the fertilizers tested at the level of the pods and the merchant cocoa. A total of four types of fertilizers were applied at different doses to be able to harvest 0.5 tons 1 ton and 1.5 tons per hectare. The results obtained showed that the fertilizer formulas B (PK 25-20+10CaO+5MgO+0.5B+0.5Zn) and D (NPK 0-22-18+9CaO+7S+6MgO) which are devoid of nitrogen remain the best in terms of the number of pods and the yield of marketable cocoa.

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