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Research Article

Cocoa (*Theobroma cacao* L.) Fertilization Pattern with Four Balanced Principles in Deli Serdang Regency, Indonesia

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Abstract

Background and Objective: Although, cocoa productivity has recently increased in some countries such as Ghana, it is still low compared to other countries such as Ivory Coast, Malaysia and Indonesia. The reason for this situation is the limited implementation of technological advancements in cocoa production. To increase productivity through fertilization, testing was carried out N, P, K , Ca and Mg balanced with the correct four principles of formula, dosage, timing and manner. **Materials and Methods:** The study was conducted in 4 stages of field experiments in a cocoa seed garden (TSH 858 clone) owned by IOPRI in Sei Pancur, Deli Serdang, at an altitude of 72 m above sea level. The study-1 tested six levels of the formula N, P, K, Ca and Mg balanced with the design of random group non-factorial, in the study-2 tested two levels of the best formula and four levels of dosage with the design of random group factorial nested, study-3 (consisting of 2 parallel experiments) tested four levels of dose increase in product crops and unproductive plants with random group non-factorial design and study-4 tested four levels of fertilizer application random design of non-factorial groups. **Results:** Used the fertilizer formula N, P, K, Ca and Mg 12.9: 11.4: 16.8: 10.6: 4.8 and a balanced amount of flush, flowers and cherelle (37.5 cherelle/tree) as well as weight/seed was achieved. Next, a dose of 1.120 g/tree was administered. Retrieved 39.7 cherelle/tree and higher doses of pa da 1.344 g/tree, there was a decrease in the number of cherelles to 39.7 cherelles/tree (34.2 cherelle/trees). The best time for fertilizer application N, P, K, Ca and Mg 12.9: 11.4: 16.8: 10.6: 4.8 balanced with a dose of 1.120.0 g/tree is 2 weeks after pruning, producing 56.7 cherelle/tree. In non-productive plants, the cherelle formed is less (24.0 cherelle/tree) than in production plants. **Conclusion:** The formula fertilizer N, P, K, Ca and Mg 12.9: 11.4: 16.8: 10.6: 4.8 balanced, dose 1.120 g/tree, application 2 weeks after pruning and fertilizer application planting system is well applied to productive cocoa, but not recommended on non-productive cocoa plants.

Key words: Fertilizer, cocoa, pruning, productivity, Ghana, Indonesia

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

While cocoa productivity has seen some growth in countries like Ghana, it remains comparatively lower than that of other countries like Ivory Coast, Malaysia and Indonesia. This can be attributed to the inadequate uptake of advanced cocoa production technologies[1]. Cocoa productivity is still low in some countries (<2 t ha^{-1}), caused by some factors, among others, *Conopomorpha cramerella* (cacao moth), *Helopeltis* sp., disease *vascular streak dieback*, *Phytophthora palmivora*, fertilization, shading, pruning, fermentation of seeds and drying of yields[2]. Under optimal conditions, production potential can be achieved at 5.000 kg of dry seeds/ha/year in Ghana and 6.100 kg of dried seed/ha/year in Malaysia[3]. Through fertilization, supplied for the development of new flush/leaves, growth and increase in yields[4].

Taxiran nutrients in 1 ton of dry seeds and 1.4 t of dried fruit peels there are N nutrients. The P, K, Ca and Mg with composition 36.6: 6.2: 61.2: 7.2: and 6.3 kg[3]. Timing and intensity of pruning are crucial for balancing light and water availability under seasonally varying environmental conditions in order to preserve micro environments for cocoa production with less exposure to unfavorable climate conditions[5]. Study results from[6], indicated that cocoa yield obtained with the compost plus NPK fertilization was significantly higher than with sole compost, NPK applications and control in all locations.

Principle 4 is right in balanced fertilization, namely: Proper dosage, punctuality, the right way and the right formula[7]. Fertilizer recommendations encouraging balanced fertilization should include liming in the nutrient application package[8]. Balanced fertilization is combined with a proportion of nutrients by the soil condition, plants and climate[9]. According to Abdul Wakeel *et al.*[10], farmer's interest in using N, P and K fertilizers has recently increased with increasing knowledge of the concept of balanced fertilization and technological developments in fertilization applications. This study aims to determine the effectiveness of cocoa fertilization through the formula, dosage, method of fertilizer application and time of fertilizer application.

MATERIALS AND METHODS

Materials: Time, location, materials and tools: Study took place from March, 2019 to July, 2020 in the cloned cocoa plantation TSH 858 (4 year old plant), Sei Pancur Deli Serdang Indonesia, owned by IOPRI (Indonesian Oil Palm Research Institute), at an altitude of 72 m above sea level, with soil type ultisol. The fertilizers used were phonska (15-15-15), urea (46% N), MOP (60% K_2O), dolomite (40% CaO and 18% MgO) and kieserite (27% MgO). Tools used include an altimeter, meter, measuring cup, oven, caliper, digital scales and other measuring instruments (tested at the Laboratory of the University of North Sumatra, Indonesia).

Methods

Research methods: The study consists of 4 stages, with treatment as in (Table 1):

- **Study-1:** Tested six levels of formula (F) N, P, K, Ca and Mg balanced, with the design of random group non-factorial, repeated four times so that there are 6×4 = 24 experimental units
- **Study-2:** Tested two levels of the best formula (F) of the study-1 and four levels of dose (D), with a design of a grouping of factorial clusters, repeated four times so that there were 2×4×4 = 32 experimental units
- **Study-3:** Consisting of 2 parallel experiments, tested four levels of dose increase in product plants (DP) and non-productive plants (DnP), with a design of random group non-factorial, repeated six times so that there were 4×6 = 24 experimental units
- **Study-4:** Tested four levels of application time (A), with the design of random group non-factorial, repeated six times so that there were 4×6 = 24 experimental units. For the study was analyzed with fingerprints and the average difference test[11]

Research implementation: The experimental plant units were determined based on the stem coils' size, plant spacing (3×3 m^2 or 1.100 ha/plants) and coconut protective plants and *Gliricidia*. Plant maintenance carried out is frequent harvesting, pruning and plant protection. Harvesting is carried out once a week. Trimming includes heavy trimming, maintenance trimming and wiwilan trimming. Heavy pruning was carried out at the beginning of the study (for research-1 and research-4), the plant canopy was arranged so that it did not intersect and its height was no more than 4 m. Maintenance pruning is carried out at three months by removing useless shoots and branches. Wiwilan pruning is carried out once a month by removing the growing wiwilan. Protective plants are pruned to 1 m high above the cocoa canopy and the light intensity is set at about 40-60%, characterized by a light spot under the plant canopy. Manual weed control (clean disk criteria) and pest control with meditation insecticides[12]. Before fertilizing, the disk (diameter 3 m) is cleaned with a hoe until weed-free. The application and recommendations of fertilization treatment as in (Table 1 and Fig. 1). The average number of flush, flower, cherelle, fruit volume, dried seeds and potential yields on various fertilizing treatments N, P, K, Ca and Mg balanced, (Table 2). Fertilizer

Table 1: Fertilization treatment N, P, K, Ca and Mg balanced in 4 stages of research

Treatment fertilization N, P, K, Ca and Mg	Quantity (g/tree)	Phonska (15-15-15)	Urea (46% N)	MOP (60% K_2O)	Dolomite (14% CaO, 18% MgO)	Kieserite (27% MgO)	Information
Research-1 (March, 2019-September, 2019-February, 2020)							
F_1 = 13.7:11.0:13.8:0:4.4*	369.5	270.0	22.0	17.5	-	60.0	Application March-19
F_2 = 12.5:10.9:16.4:10.3:4.6**	825.0	599.8	28.7	75.5	121.0	-	
F_3 = 12.9:11.4:16.8:10.6:4.8**	800.0	608.0	26.1	72.1	93.8	-	
F_4 = 13.4:9.1:17.4:8.6:3.9**	775.0	470.5	72.4	106.9	125.2	-	
F_5 = 13.8:9.4:18.0:8.7:3.9**	750.0	470.3	71.7	107.5	100.5	-	
F_6 = 13.9:5.0:18.9:6.2:5.1***	800.0	267.6	154.5	184.9	123.1	69.9	
F_1 = 13.7:11.0:13.8:0:4.4*	369.5	270.0	22.0	17.5	-	60.0	
F_2 = 12.5:10.9:16.4:10.3:4.6**	825.0	599.8	28.7	75.5	121.0	-	Application September-19
F_3 = 12.9:11.4:16.8:10.6:4.8**	800.0	608.0	26.1	72.1	93.8	-	
F_4 = 13.4:9.1:17.4:8.6:3.9**	775.0	470.5	72.4	106.9	125.2	-	
F_5 = 13.8:9.4:18.0:8.7:3.9**	750.0	470.3	71.7	107.5	100.5	-	
F_6 = 13.9:5.0:18.9:6.2:5.1***	800.0	267.6	154.5	184.9	123.1	69.9	
Research-2 (September, 2019-February, 2020)							
F_2D_1 = 1.25:10.9:16.4:10.3:4.6**	660.0	479.8	23.0	60.5	96.8	-	Application September-19
F_2D_2 = 1.25:10.9:16.4:10.3:4.6**	825.0	599.8	28.7	75.6	121.0	-	
F_2D_3 = 1.25:10.9:16.4:10.3:4.6**	990.0	719.7	34.6	90.7	145.1	-	
F_2D_4 = 1.25:10.9:16.4:10.3:4.6**	1155.0	839.7	40.2	105.8	169.3	-	
F_3D_1 = 1.29:11.4:16.8:10.6:4.8**	640.0	486.4	20.9	57.6	75.1	-	
F_3D_2 = 1.29:11.4:16.8:10.6:4.8**	800.0	608.0	26.1	72.1	93.9	-	
F_3D_3 = 1.29:11.4:16.8:10.6:4.8**	960.0	729.6	31.3	86.5	112.7	-	
F_3D_4 = 1.29:11.4:16.8:10.6:4.8**	1120.0	851.2	36.5	100.9	131.4	-	
Research-3 (January, 2020-June, 2020)							
D_1P = 1.29:11.4:16.8:10.6:4.8**	896.0	681.0	29.2	80.7	105.1	-	Application January-20
D_2P = 1.29:11.4:16.8:10.6:4.8**	1120.0	851.2	36.5	100.9	131.4	-	
D_3P = 1.29:11.4:16.8:10.6:4.8**	1344.0	1021.4	43.8	121.1	157.7	-	
D_4P = 1.29:11.4:16.8:10.6:4.8**	1568.0	1191.7	51.1	141.3	183.9	-	
D_1nP = 1.29:11.4:16.8:10.6:4.8**	896.0	681.0	29.2	80.7	105.1	-	
D_2nP = 1.29:11.4:16.8:10.6:4.8**	1120.0	851.2	36.5	100.9	131.4	-	
D_3nP = 1.29:11.4:16.8:10.6:4.8**	1344.0	1021.4	43.8	121.1	157.7	-	
D_4nP = 1.29:11.4:16.8:10.6:4.8**	1568.0	1191.7	51.1	141.3	183.9	-	
Research-4 (January, 2020-June, 2020)							
A_0 = Without fertilizer (Control)	-	-	-	-	-		
A_1 = 2 weeks before pruning	1120.0	851.2	36.5	100.9	131.4	-	Application January
A_2 = When pruning	1120.0	851.2	36.5	100.9	131.4	-	
A_3 = 2 weeks after pruning	1120.0	851.2	36.5	100.9	131.4	-	

Information:*2), **Panjaitan *et al*., 1987 dan***3

Table 2: Average number of flush, flower, cherelle, fruit volume, dried seeds and potential yields on various fertilizing treatments N, P, K, Ca and Mg balanced

Treatment fertilization N, P, K, Ca and Mg	Dose (g)	Quantity flush	Quantity flower	Quantity cherelle	Volume fruit (mL)	Dried seeds/pod (g)	Weight/seed (g)	Potential result* (g/tree)
Research-1: Application I (March, 2019-August, 2019)								
F_1 = 13.7:11.0:13.8:0:4.4	369.5	299.8^{a}	226.3^{a}	19.8^{a}	739.4^{a}	38.19^{a}	0.967^{a}	339.9
F_2 = 12.5:10.9:16.4:10.3:4.6	825.0	296.8^{a}	340.9^{ab}	35.6^{a}	605.8^{a}	37.53^{a}	0.981^{a}	649.3
F_3 = 12.9:11.4:16.8:10.6:4.8	800.0	336.9^{a}	416.0^{b}	37.5^{a}	621.3^{a}	25.89^{a}	0.793^{a}	416.8
F_4 = 13.4:9.1:17.4:8.6:3.9	775.0	285.4^{a}	247.0^{a}	16.0^{a}	618.0^{a}	31.84^{a}	0.829^{a}	184.7
F_5 = 13.8:9.4:18.0:8.7:3.9	750.0	287.0^{a}	308.6^{ab}	29.1^{a}	649.2^{a}	35.86^{a}	0.941^{a}	502.0
F_6 = 13.9:5.0:18.9:6.2:5.1	800.0	299.9^{a}	296.3^{ab}	27.1^{a}	721.8^{a}	40.68^{a}	1.049^{a}	561.4
	$HSD_{0.05}$	NS	162.56	NS	NS	NS	NS	-
Research-1: Application II (September, 2019-February, 2020)								
F_1 = 13.7:11.0:13.8:0:4.4	369.5	66.0^{a}	201.8^{a}	22.6^{a}	749.87^{a}	44.23^{a}	1.012^{a}	1000.7
F_2 = 12.5:10.9:16.4:10.3:4.6	825.0	37.3^{a}	237.8^{a}	29.8^{a}	690.51^{a}	41.74^{a}	0.963^{a}	1241.8
F_3 = 12.9:11.4:16.8:10.6:4.8	800.0	40.4^{a}	332.1^{a}	35.6^{a}	679.82^{a}	39.08^{a}	0.920^{a}	1392.2
F_4 = 13.4:9.1:17.4:8.6:3.9	775.0	48.3^{a}	310.9^{a}	25.3^{a}	719.80^{a}	42.32^{a}	0.975^{a}	1068.6
F_5 = 13.8:9.4:18.0:8.7:3.9	750.0	38.3^{a}	292.5^{a}	23.9^{a}	688.88^{a}	43.96^{a}	1.017^{a}	1049.6
F_6 = 13.9:5.0:18.9:6.2:5.1	800.0	38.0^{a}	257.0^{a}	26.1^{a}	739.31^{a}	47.11^{a}	1.055^{a}	1230.8
	$HSD_{0.05}$	NS	NS	NS	NS	NS	NS	-
Research-1: Application I and II (March, 2019-February, 2020)								
F_1 = 13.7:11.0:13.8:0:4.4	739.0	365.8^{a}	428.0^{aA}	42.4^{a}	-	-	-	-
F_2 = 12.5:10.9:16.4:10.3:4.6	1650.0	334.0^{a}	578.6^{abAB}	65.4^{a}	-	-	-	-
F_3 = 12.9:11.4:16.8:10.6:4.8	1600.0	377.3^{a}	748.1^{bB}	73.1^{a}	-	-	-	-
F_4 = 13.4:9.1:17.4:8.6:3.9	1550.0	333.6^{a}	557.9^{abAB}	41.3^{a}	-	-	-	-
F_5 = 13.8:9.4:18.0:8.7:3.9	1500.0	325.3^{a}	606.1^{abAB}	53.0^{a}	-	-	-	-
F_6 = 13.9:5.0:18.9:6.2:5.1	1600.0	337.9^{a}	553.3^{abAB}	53.3^{a}	-	-	-	-
	$HSD_{0.05}$	NS	215.90	NS	-	-	-	-
	$HSD_{0.01}$	-	272.22	-	-	-	-	-
Research-2 (September, 2019-February, 2020)								
F_2D_1 = 12.5:10.9:16.4:10.3:4.6	660.0	52.5^{a}	121.8^{a}	19.0^{a}	809.2^{a}	40.87-	0.930-	776.5
F_2D_2 = 12.5:10.9:16.4:10.3:4.6	825.0	54.3^{a}	112.3^{a}	20.0^{a}	804.2^{a}	42.83-	0.949-	856.6
F_3D_1 = 12.5:10.9:16.4:10.3:4.6	990.0	66.0^{a}	73.0^{a}	19.3^{a}	755.0^{a}	49.80-	1.151-	958.7
F_2D_4 = 12.5:10.9:16.4:10.3:4.6	1155.0	53.0^{a}	129.8^{a}	19.8^{a}	616.7^{a}	35.52-	0.676-	701.5
F_1D_1 = 12.9:11.4:16.8:10.6:4.8	640.0	50.8^{a}	52.0^{a}	13.8^{a}	831.0^{a}	51.96-	1.120-	714.5
F_3D_2 = 12.9:11.4:16.8:10.6:4.8	800.0	92.8^{a}	75.3^{a}	17.0^{a}	800.3^{a}	49.03-	1.109-	833.5
F_3D_3 = 12.9:11.4:16.8:10.6:4.8	960.0	79.8^{a}	101.5^{a}	23.0^{a}	839.4^{a}	55.02-	1.147-	1265.5
F_3D_4 = 12.9:11.4:16.8:10.6:4.8	1120.0	73.3^{a}	147.0^{a}	31.5^{a}	783.5^{a}	54.51-	1.200-	1717.1
	$HSD_{0.05}$	NS	NS	NS	NS	-	-	-

Table 2: Continue

Treatment fertilization N, P, K, Ca and Mg	Dose (g)	Quantity flush	Quantity flower	Quantity cherelle	Volume fruit (mL)	Dried seeds/pod (g)	Weight/seed (g)	Potential result* (g/tree)
Research-3 (January, 2019-June, 2020)								
D_1P = 12.9:11.4:16.8:10.6:4.8	896.0	297.8^{a}	336.5^{a}	34.2^{a}	774.5^{a}	47.1^{a}	1.097^{a}	1610.8
D_2P = 12.9:11.4:16.8:10.6:4.8	1120.0	241.0^{a}	266.2^{a}	26.7^{a}	798.8^{a}	48.4^{a}	1.093^{a}	1292.3
D_3P = 12.9:11.4:16.8:10.6:4.8	1344.0	285.5^{a}	321.7^{a}	39.7^{a}	919.8^{a}	49.0^{a}	1.075^{a}	1945.3
D_4P = 12.9:11.4:16.8:10.6:4.8	1568.0	256.5^{a}	326.8^{a}	34.2^{a}	779.1^{a}	41.9^{a}	0.912^{a}	1433.0
	$HSD_{0.05}$	NS	NS	NS	NS	NS	NS	-
D_1nP = 12.9:11.4:16.8:10.6:4.8	896.0	147.8^{a}	167.5^{a}	10.7^{a}	-	-	-	-
D_2nP = 12.9:11.4:16.8:10.6:4.8	1120.0	119.8^{a}	170.0^{a}	13.2^{a}	-	-	-	-
D_3nP = 12.9:11.4:16.8:10.6:4.8	1344.0	119.3^{a}	173.0^{a}	24.0^{a}	-	-	-	-
D_4nP = 12.9:11.4:16.8:1o.6:4.8	1568.0	137.3^{a}	233.8^{a}	19.3^{a}	-	-	-	-
	$HSD_{0.05}$	NS	NS	NS	-	-	-	-
Research-4 (January, 2020-June, 2020)								
A_0 = Without fertilizer (control)	-	226.8^{a}	360.3^{a}	31.8^{aA}	-	-	-	-
A_1 = 2 weeks before pruning	1120.0	239.3^{a}	649.5^{b}	38.0^{aAB}	-	-	-	-
A_2 = When pruning	1120.0	221.8^{a}	645.8^{b}	44.3^{abAB}	-	-	-	-
A_3 = 2 weeks after pruning	1120.0	237.3^{a}	691.0^{b}	56.7^{bB}	-	-	-	-
	$HSD_{0.05}$	NS	325.05	17.12				
	$HSD_{0.01}$	-	-	22.03	-	-	-	-

Information: *Dried seed weight/pod×cherelle, ^{a,b,AB}Order of significance from higher to lower at α = 0.05 and α = 0.01 level probability and NS: Not significant

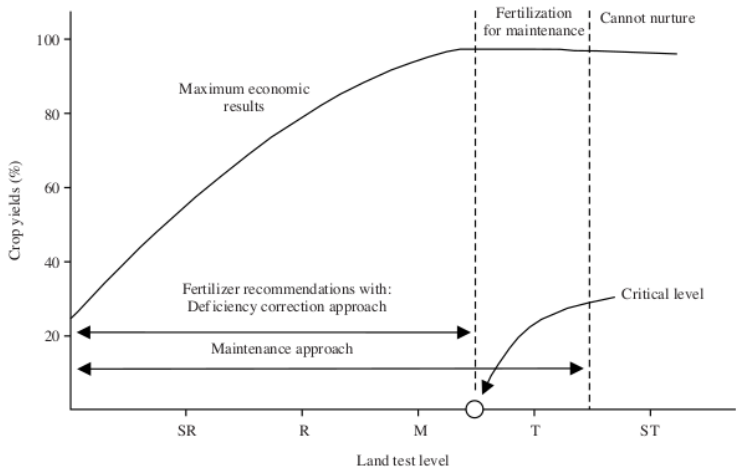

Fig. 1: Approach fertilization recommendations according to de Souza Júnior *et al.*[20]

phonska, urea, MOP (Muriate of Potash), dolomite and kieserite mixed evenly and then divided into four parts. Fertilizers are planted 5 cm deep at 4 points at a distance of 70 cm from the plant tree to avoid evaporation and fertilizer erosion. Specifically, in study-2, the young fruit size <8 cm was gloved with transparent plastic to prevent cacao moth infestation early on.

Variable observations: Measurements were made against agronomic *variables*: The number of flushes, the number of flowers, the number of cherelles, the volume of fruit, the seeds of the dry/pod and seed/weights. The amount of flush, flowers and cherelle is calculated as a time 4 weeks during the study. Harvesting is carried out once a week and the volume of fruit is measured by volumetric method, pod dry seed/weight and weight/seed weighed after the seeds are washed and dried in the oven at 70°C for 48 hrs. The content of N, P, K, Ca and Mg in the leaves was observed at the end of study-1 and study-2.

Statistical analysis: Non-factorial randomized block design method, repeated four times. The analytical tool used is Excel and statistical program for Social Science (SPSS) software. As a description of the significance in this study, namely: a,b,A,B The order of significance from high to low at the probability level $\alpha = 0.05$ and $\alpha = 0.01$ and NS: Not significant.

RESULTS

Fertilizer formula: In study-1 (application II September, 2019), fruit volume, seed weight and potential yield were increased. The amount of phonska fertilizer varies in formulas F_1 to F_6 and it is intended to meet the P element of phonska fertilizer, while N and K elements were still added from urea and MOP fertilizers. Although, the total dose of fertilizer in formula F_3 (800 g) was lower than F_2 (825 g), the type of phonska fertilizer is more in formula F_3 (608 g) compared to F_2 (599.8 g) (Table 1), this proves that the availability of P is better in formula F_3.

The study-1 (an application I March, 2019) showed that with the formula F_3 that is N, P, K, Ca and Mg 12.9: 11.4: 16.8: 10.6: 4.8 resulting in a more significant amount of flush, flowers and cherelle compared to F_1 (as a control) and other formulas (Table 2 and Fig. 2a-c). Formula F_2 (N, P, K, Ca and Mg 12.5: 10.9: 16.4: 10.3: 4.6) and F_3 were the best treatments with no different results, further tested and compared in research-1 application II and study-2, consistently, the formula.

The F_3 tends to outperform better than F_2. The number of flushes is relatively high, driven by heavy pruning at the beginning of the study and sufficient rainfall. The number of flowers and cherelle looks noticeably different in the presence of fertilizing.

In study-2 (September, 2019 application), the treatment of F_3D_4 produced the amount of flush, flowers, cherelle and weight (quality) of seeds tended to be better (Table 2 and Fig. 2a-c). The total dose at F_3D_4 (1.120. g) was lower than F_2D_4 (1.55 g), but phonska fertilizer types were more at F_3D_4 (851.2 g) than at F_2D_4 (839.7 g) (Table 1), this consistently proves better P availability on formula F_3D_4. Thus, the right formula and type of fertilizer is an important principle to pay attention to achieve the benefits of fertilizing.

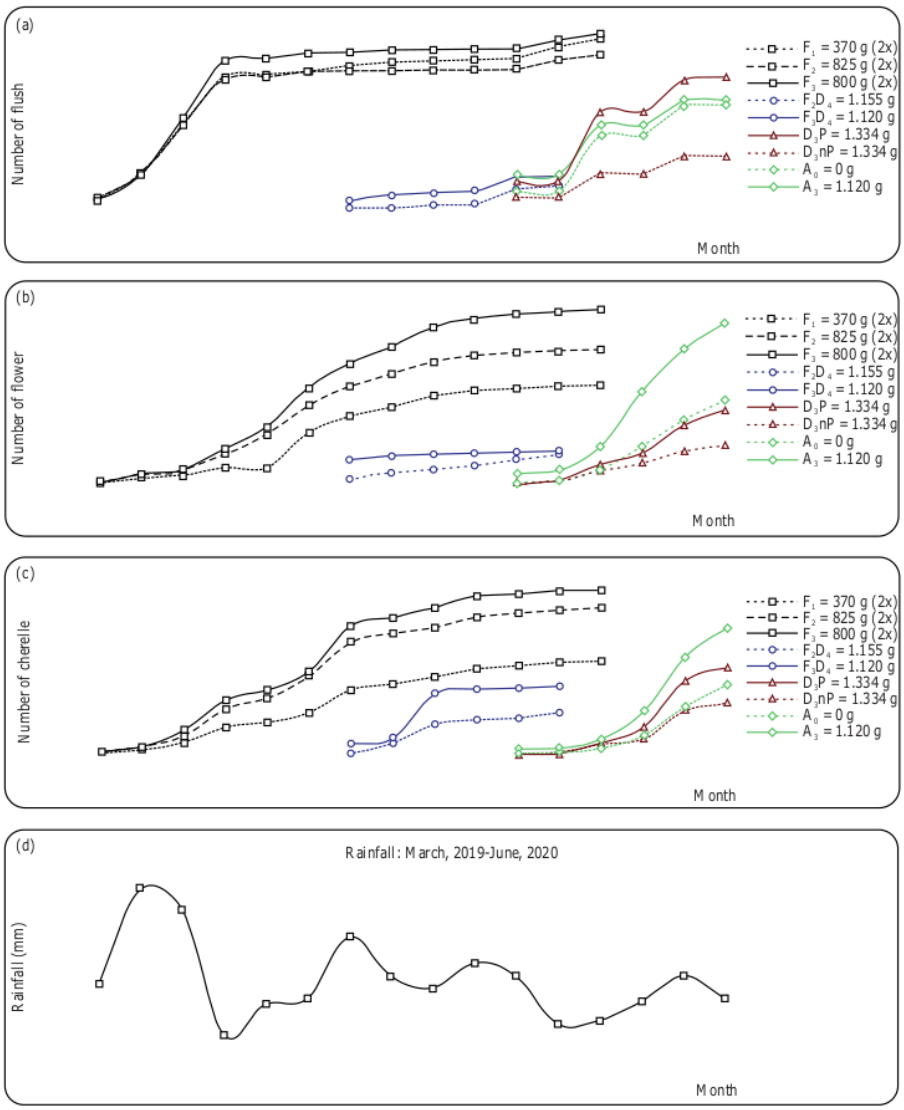

Fig. 2(a-d): (a) Development of flush, (b) Development of flowers, (c) Development of cherelle and (d) Rainfall

Fertilizer dosage: In the study-2 (September, 2019 application), it was shown that with a dose of F_3D_4 (1.120 g) as, the highest dose produced the amount of flush, flowers, cherelle and weight (quality) of seeds tended to be better (Table 2 and Fig. 2a-c), so it needs to be further tested for higher dose increases in study-3. The number of flushes and flowers is relatively low compared to study-1 because heavy pruning was not carried out at the beginning of the study. Still, the number of fruits tends to increase with increasing doses of fertilizer.

Testing of increased fertilizer doses in study-3 (application January, 2020) showed that dose increases of up to 1.344 g in production plants (D_3P) resulted in the amount of cherelle and the weight (quality) of seeds tending to be better

Table 3: Results of soil and leaf analysis at the research stage

Nutrient analysis	N (%)	P	K	Ca	Mg
Before research					
Soil	0.11	6.37 ppm	0.43 me/100 g	1.51 me/100 g	0.38 me/100 g
Leaf (F_0)	2.25	0.16	1.73	0.62	0.32
Phase research-1 (%)					
Leaf (F_1)	2.45	0.19	1.46	0.93	0.43
Leaf (F_2)	2.32	0.18	1.50	0.87	0.47
Leaf (F_3)	2.38	0.19	1.61	0.92	0.43
Leaf (F_4)	2.49	0.20	1.52	1.00	0.49
Leaf (F_5)	2.29	0.19	1.59	0.81	0.44
Leaf (F_6)	2.52	0.19	1.45	0.85	0.45
Phase research-2 (%)					
Leaf (F_2D_4)	2.10	0.15	1.31	1.38	0.50
Phase research-3 (%)					
Leaf (D_3P)	2.40	0.16	1.80	1.53	0.49
Leaf (D_3nP)	2.60	0.15	1.55	1.23	0.44
Soil nutrient criteria					
Soil (Low)	0.10	8 ppm	0.10 me/100 g	1.50 me/100 g	0.30 me/100 g
Soil (High)	0.50	35 ppm	0.80 me/100 g	10.00 me/100 g	1.80 me/100 g
Leaf nutrient criteria (%)					
Leaf (Low)	1.80	0.17	1.20	0.30	0.20
Leaf (High)	2.50	0.25	2.40	1.50	0.70

(Table 2 and Fig. 2c). Likewise, dose increases of up to 1.344 g in non-product plants (D_3nP) resulting in cherelle amounts tend to be better but less than f-produced plants.

Fertilizer application time: On study-4 (application January 2020) showed that with the application of fertilizer 2 weeks after pruning (A_3), a better number of flowers and cherelle was produced (Table 2 and Fig. 2a-c). Heavy pruning without fertilizing (A_0) is not recommended, pruning will encourage the formation of flush, flowers and cherelle but does not increase the size of the leaves, the formation of flowers and the formation of cherelle and fruit. This confirms the importance of fertilizing has pruned weight. Fertilizer application 2 weeks before pruning (A_1) tends to increase the amount of flush, wiwilan and leaf size. Simultaneous fertilizer application with pruning (A_2) increases the number of flowers and cherelle and the best result with fertilizer application time is 2 weeks after pruning (A_3).

Soil and leaf analysis before the study: Hacyl, a soil analysis, shows a relatively low N status, low P, medium K, relatively low Ca and Mg rather low. Furthermore, leaf analysis results (F_0) showed the status of N normal, P low, K low, Ca normal and Mg low. After study-1, study-2 and study-3, leaf analysis results showed normal N, low P, low K, regular Ca and Mg status at normal limits (Table 3). Overall fertilization N, P, K, Ca and Mg 12.9 : 11.4: 16.8: 10.6: 4.8 causes normal N, Ca and Mg nutrient content, but P and K nutrient content is still low. The optimum upper macronutrients in cocoa leaves are nitrogen (N) 1.8-2.5%, phosphorus (P) 0.17-0.25%, potassium (K) 1.2-2.4%, calcium (Ca) 0.3-1.5%, magnesium (Mg) 0.2-0.7%, (Table 3). The P no research-1 and research-2 analysis leaves at the end of the study showed that the nutrient content of N, Ca and Mg is normal, the nutrient content of K is close to the lower limit and the nutrient content of P is partially below the low limit. So an increase in P and K doses is still needed through extra fertilization.

DISCUSSION

Fertilizer formula in study one, a total dose of F_3D_4 (1.120.0 g) is lower than F_2D_4 (1.155.0 g), however, the types of phonska fertilizers are more on F_3D_4 (851.2 g) compared into F_2D_4 in (839.7 In g). In (Table 1), In this consistently proves the better availability of P on formulas F_3D_4. Thus, the right formula and type of fertilizer is an important principle to pay attention to achieve the benefits of fertilizing. In tropical regions, nitrogen (N) deficiency in soil is common, which is necessary for plant growth and food production. Commercial N fertilizers are costly and have low efficiency, leading to water contamination, as investigated by the study[13].

Fertilizer doses in study two (September, 2019 application), namely (Table 2 and Fig. 2c). In product-fed crops, an increase in the dose of fertilizer is followed by an increase in yield potential so that an optimum dose (usually below the maximum dose) can be determined that is economically beneficial and, at the same time, maintains the quality of the environment. In non-product crops, an increase

in the dose of fertilizer can increase the amount of cherelle, but it is not beneficial because it is not as good as the response of the production plant. The application of the right dose of fertilizer should be considered to achieve optimum results. According to Djuideu *et al.*[14], cacao plants will experience deficiency if they receive a below-optimal fertilizer dose and they will experience toxicity when they receive an above-optimal fertilizer dose.

Testing of increased doses of fertilizer in study three (application January, 2020) showed that the increase in doses was up to 1.344 g on production plants (D_3P). The resulting amount of cherelle and the weight (quality) of the seeds tend to be better (Table 2 and Fig. 2c). Likewise, an increase in dose up to 1.344 g in non-product plants (D_3nP) resulting amount of cherelle tends to be better, however, less compared to plants of product.

In study-4 (January, 2020 application), we need further testing to determine the best fertilizer application time, whether before or 2 weeks after pruning. Pruning factors should be a reference in determining the timing of fertilizer application and other factors such as rainfall, plant development cycles, weeds, pests and diseases. Cocoa pruning should be followed by fertilizing so the leaf size is better and the number of flowers and cherelle is higher. Proper timing and intensity of pruning are essential in maintaining balanced light and water availability, especially under seasonally changing environmental conditions. This helps to create a suitable micro-environment for cocoa production with reduced exposure to unfavorable climates[5]. Rehabilitation pruning is a suitable practice to rejuvenate aging trees and increase short-term cocoa yield while mitigating the negative effects of insect pests such as termites[15]. Fertilization increases fruit production and suppresses the control of plant-disturbing organisms[16].

Phase 1, 2, 3 and 4 research was carried out with a planting system or pocket. The fertilizer mixture is planted 5 cm deep at 4 points 70 cm away from the plant tree. Fertilizer the application directly into the soil close to the root. Fertilizer application in a pocket or spot placement is good if the planting distance is wide enough, this method can be applied to cocoa with a density of <1.000 plants ha^{-1}. To achieve the fertilisation effectiveness goal, the fertiliser application method is carried out in several ways, namely how to sow/spread, run/hole/bag, spray, infusion, a: Howon. Assessment of the effectiveness of fertilisation is a complex, multistage procedure[17].

In the period March, 2019-August, 2020 (study-1), heavyweight at the beginning of the study played an important role in encouraging the flush formation and increased rainfall in April is expected to contribute to the flush formation in May, 2019. In September, 2019-February, 2020 (study-1 and study-2), a small number of flushes formed and the development of flowers into cherelle was also slight. In the period February to June, 2020 (study-3 and study-4), the number of flushes, flowers and cherelles again increased (as in study-1). Fertilization N, P, K, Ca and Mg 12.9: 11.4: 16.8: 10.6: 4.8 balanced on the product plant tip shows a better amount of flush, flowers and cherelle at all stages of testing, best dosage 1.120 g/tree (maximum 1.344 g/tree) and the best application time is 2 weeks after pruning. Balanced fertilization testing on non-product crops did not show good results (Fig. 2d). The time of fertilizer application is good to do at 100-250 mm of precipitation per month when the soil conditions are moderately wet (but not yet saturated) for plants. Rainfall and temperature show variability between months and between years and lower fluctuations between months of both rainfall and temperature[18].

The amount of the best cherelle 56.7 cherelle (Table 2), which is equivalent to potential results of 3.090,7 g/tree for 6 months, can be achieved by formulation N, P, K, Ca and Mg balanced 12.9: 11.4: 16.8: 10.6: 4.8 doses 1.120 g/tree, application time 2 weeks after pruning (A_3) and how to apply the planting system or spot placement. In the long run, maximum gains can be achieved with the right type of fertilizer and applying a dose slightly below the maximum dose to manage lower nutrient loss for the environment. The use of mineral fertilizers in agriculture has significantly increased to support the growing global food demand[19]. Over-fertilization increases the probability of nutrient loss from erosion or leaching whereas under-fertilization limits yield and grain or forage quality[9]. According to de Souza Junior *et al.*[20] Foliar fertilization is an interesting strategy for nutrition with micronutrients in perennial plants, among the micronutrients, zinc (Zn) deficiency is the most frequent in cocoa trees (*Theobroma cacao* L.). Cocoa tree leaves functioned as a sink of nutrients, while shade tree leaves functioned predominantly as a source[21].

Research implications used the fertilizer formula N, P, K, Ca and Mg 12.9: 11.4: 16.8: 10.6: 4.8 and a balanced amount of flush, flowers and cherelle (37.5 cherelle/tree), as well as weight/seed was achieved. Next, a dose of 1.120 g of tree was administered. Retrieved 39.7 cherelle/tree and higher doses of pa da 1.344 g/tree, there was a decrease in the number of cherelles to 39.7 cherelles/tree (34.2 cherelle/trees). Suggestions for research include using the recommended practices of fertilizer application and 2 week pruning on

productive cocoa. However, balanced fertilization is not advised for unproductive cocoa plants due to certain constraints. Further research is necessary to determine the most effective formula, dosage, method and timing for balanced fertilization in unproductive cocoa plantations.

CONCLUSION

Some of the findings in the testing of balanced fertilization N, P, K, Ca and Mg on cocoa plants with principle four exactly are outlined in the following sections. The formula fertilizer N, P, K, Ca and Mg 12.9: 11.4: 16.8: 10.6: 4.8 balanced resulting in the number of flushes, flowers, cherelle and weights/seed the best. The number of cherelles increased from 19.8 on F_1 to 37.5 cherelle on F_3 (research-1 application I) and from 22.6 cherelle on F_1 to 35.6 cherelle on F_2 (research-1 application II). The dose 1.120,0 g/tree increase the amount of cherelle to 31.5 fruit (study-2) and 39.7 pieces (study-3). At higher doses of 1.344 g/tree (study-3), there was a decrease in cherelles to 34.2 pieces. Fertilizer application N, P, K, Ca and Mg 12.9: 11.4: 16.8: 10.6: 4.8 balanced with dosage 1.120 g/tree By the time 2 weeks after pruning increases the amount of cherelle very noticeably to 56.7 cherelle/tree. Especially in non-product plants, the amount of cherelle formed is between 10.7 and 24.0 cherelle, this figure is low compared to the amount of cherelle in the production plant. Fertilizer must be applied with a planting system (pocket) can be applied to cocoa with a density of >1.000 ha/plants to increase the effectiveness of fertilizers.

SIGNIFICANCE STATEMENTS

The study evaluates the effectiveness of cocoa fertilization by examining the formula, dosage, method and timing. It found that the best approach is to apply a balanced fertilizer formula of N, P, K, Ca and Mg Balanced 12.9:11.4:16.8:10.6:4.8, with a dosage of 1.120 g/tree in the form of Phonska (15-15-15) 851.2 g, Urea 36.5 g, MOP 100.9 g and Dolomite 131.4 g, 2 weeks after pruning, using a planting or spot placement system, resulting in a cherelle yield of 56.7/tree and potency dry seed yield of 3.090 g/tree over six months in cocoa clones TSH 858. However, balanced fertilization is not recommended for non-productive cocoa plants and further research is necessary to identify the optimal formula, dosage, method and timing for balanced fertilization in unproductive cocoa farms.

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