The influence of time in fertilizing with N.P.K.Ca.Mg 12,9 : 11,4 : 16,8 : 0,6 : 4,8 by pruning on flushing, flowering, and pod reserves of TSH 858 clone cocoa

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Abstract. Hard pruning on cocoa trees needs to be followed by fertilizing and maintaining them in order to get the expected development of leaves, flowers, fruits and production. The objective of the research was to determine the right time for applying the best fertilization for the pruned TSH 858 clone cocoa. The research used non-factorial group random design with the application time treatment of N.P.K.Ca.Mg 12,9 : 11,4 : 16,8 : 10,6 : 4,8 fertilizers at the dosage of 1.120,1 grams per tree. They consisted of 4 stages: (1) without applying fertilizers as control, (2) applying them 2 weeks before pruning,( 3) applying and pruning simultaneously, and (4) applying once in 2 weeks after pruning. The parameter of flush, leaf size, the number of water shoots, flowers, cherelles, and pods were observed in 24 weeks. The time for applying fertilization with pruning has significance influence on the number of flowers and cherelles. Pruning with fertilization increases the forming of better flushes and increases leaf size. Application of fertilization in 2 weeks after pruning indicates the best result with 691 flowers, 56.7 cherelles, and 31.5 pods. Fertilization after pruning should be done to increase the number of flowers and pods.

1. Introduction
Indonesia ranks the third in producing cocoa throughout the world after the Ivory Coast and Ghana [1]. Nationally, cocoa productivity is low, with the average of 834 kg ha⁻¹, and about 497 kg ha⁻¹ (or < 2 tons ha⁻¹) in the smallholder plantations. This is caused by various factors such as inadequate fertilization and pruning [2]. Pruning cocoa trees is one of the three important components for
achieving maximum production after fertilization and pest/deseases controlling [3]. Pruning cocoa trees is intended to increase the production and to prolong the survival of the trees because it will widen assimilation surface and stimulate flowering/pollination due to vegetative and generative balances [4]. It is also intended to remove a large number of branches without damaging the trees and to limit the size and the shape of canopy. The supply of fertilizers (nitrogen and phosphor) determines vegetative growth (leaves and roots) of plants, while photosynthesis (function of leaves) determines the supply of plant carbohydrate [5]. Principally, pruning is functioned to prevent the plants from the loss of nutrition in the vegetative phase (leaves and flushes) and generative phase (flowers and beans). Plant response to applying fertilizers generally increases cocoa production and its quality [6]. Fertilization becomes an important factor in maximizing productivity in which nutritive substances which are carried away during the harvest should be changed with new fertilizers. One ton of dried cocoa beans with 1.4 tons of dried husk contain 36.6 kg N; 6.2 kg P; 61.2 kg K; 7.2 kg Ca and 6.3 kg Mg respectively [7]. Combined fertilizers [8] or balanced fertilization [9] is mostly applied to fulfill the need for optimal plant fertilizers which are different from one to another according to the types of plant, age, types of soil, and climate [10]. At Mariendal (North of Sumatra Indonesia) 450 grams of urea, 150-200 grams of TSP, 200-250 grams of RP, 450 grams of MOP, and 250-300 grams of kieserit are recommended to be used per tree per year in cocoa plants at the age of 6 to 8 years in order to achieve the productivity of 1.5 to 3 tons of dried beans per hectare [11]. Experimental fertilization on 5 year-old cocoa in Columbia indicated that 150 kg N, 90 kg P2O5, and 200 kg K2O fertilizers per hectare, and 200 grams of dolomite per tree would give the best production 1,160 kg of dried beans per year [12]. Balanced fertilization of 250 grams of Urea (N), 180 grams of SP-36 (P), 150 grams of KCl (K), 75 grams of dolomite (Ca and Mg), and 3 kg of compost per tree would increase cocoa production of about 78% and curb the attack of pest and diseases [13]. The testing of balanced fertilization formulation of N.P.K.Ca.Mg 12.9 : 11.4 : 16.8 : 10.6 : 4.8 (Sitohang, 2018; process of publication) yields the best reserves of flowers and pods.

Since pruning influences the condition of leaves and photosynthesis, its regularity is very important to increase productivity. Hard pruning can improve the spread of canopy and light transmission and can influence simultaneous flush [3]. It can also decrease carbohydrate and plant N level and increase carbohydrate and N back to higher N ratio which will increase the production of leaves, flushes, and water shoots [5]. The production of new leaves which is in accordance with the development of flush needs nutritional translocation from old leaves which encourages leaves to fall and to change to new ones [14]. The forming of flowers occurs every month with varied intensities, followed by the forming of cherelles. Flowers and pods are usually attached on stems or branches so that removing young branches will stimulate flowering and pod production [5].

It is important to supply plant nutrition to increase the growth and harvest. In cocoa, nitrogen (N) is continuously needed for vegetative (twigs and leaves) and generative (flowers and pods). Phosphor (P) should be applied in the very beginning for root development, and the availability of potassium (K) is very important for pod development. Calcium (Ca) should be available for the development of terminal flushes and flowers while magnesium (Mg) is important for leaf retention [15]. Cocoa response to fertilization is influenced by some factors such as maintenance, availability of soil nutritive substances, environmental condition, pest/deseases, shade tree management, and pruning. Nitrogen nutritive substance is needed for vegetative growth in the early rainy season or in the post-pruning, phosphor nutritive substance is needed to form new roots and flower primordial, and potassium nutritive substance is needed to fill up and to ripen pods by the end of rainy season. Productive cocoa fertilization is generally carried out once or twice a year or more than twice a year if it is needed in a certain condition [16]. Calcium is especially needed to strengthen cocoa trees, and magnesium is needed for leaf retention and to slow down leaf aging through the role of chlorophyll [7]. In rubber, the most effective fertilization is when rubber plants begin to form new leaves after the leaves fall naturally even though the time is varied according to the location and clone [17].

Hardpruning and balanced fertilization need to be optimized for cocoa vegetative growth due that good productivity can be achieved. The formation of the flush, flowering, and the development of pod
takes place almost in tandem, each organ requires different nutrients. Thus, cocoa plants need to be fertilized at the right time related to cocoa pruning. The aim of the study was to determine the right time for the application of balanced N.P.K.Ca.Mg fertilization, which is more suitable for flush development and fruit development to improve cocoa yield. The research hypothesis, the time of application of N.P.K.Ca.Mg fertilization affects the growth, flowering, cherelle wilt and number of pods in cocoa productive.

2. Method
The research was conducted within 24 weeks, from January until July, 2018 in 6 year-old TSH 858 clone cocoa plants (planted in 2011). The location was at the experimental plantation of PPKS (Oil Palm Research Institute) Sei Pancur, Deli Serdang, on the altitude of 70 meters. The materials used in the research were fertilizers made by phonska (15-15-15), urea (46 % N), MOP (60 % K₂O), dolomite (40% CaO & 18% MgO) and kieserit (27% MgO). The equipment used was altimeter, oven, digital scales, and other measuring devices.

The research used non-factorial block random design with the treatment of the time of applying (A) N.P.K.Ca.Mg 12.9 : 11.4 : 16.8 : 10.6 : 4.8 fertilizers, consisted of 4 levels (Table 1), replication 6 times so that there would be 6 x 4 = 24 experimental units. Mathematical model in the analysis of research data was Y = μ + α + β + ϵ ij where: Yij = observable values in fertilizing formulation treatment-i, and block (replication)-j; μ = general average; α = influence of balanced fertilizing formulation treatment of level–i; β = influence of block (replication)-j; and ϵ ij = the influence of error of experimental unit in balanced fertilizing formulation treatment–i and block (replication)-j. The data were analyzed by using variance and paired-t-test [18].

| Fertilizer Application Time                  | Phonska 15-15-15 | Urea 46% N | MOP 60% K₂O | Dolomite 40% CaO & 18% MgO | Total (g/plk) |
|---------------------------------------------|------------------|------------|-------------|---------------------------|---------------|
| A₀ = Without Fertilizer Application(control) |      -            |         -  |           -  |                          |              |
| A₁ = Application 2 weeks before pruning     | 851.2            | 36.5       | 100.9       | 131.5                     | 1,120.1       |
| A₂ = Application and pruning simultaneously  | 851.2            | 36.5       | 100.9       | 131.5                     | 1,120.1       |
| A₃ = Application 2 weeks after pruning      | 851.2            | 36.5       | 100.9       | 131.5                     | 1,120.1       |

Explanation: Composition of N-P-K-Ca-Mg : 12.9 : 11.4 : 16.8 : 10.6 : 4.8

The units of experimental plants were determined according to their similarity in the size of stem coil [19] in ultisol with the planting distance of 3 x 3 m² or 1,100 trees per hectare with coconut and gliricidia shade trees. Standardized maintenance was done during the experiment such as harvesting, pruning, weed control, pest, and diseases. Thick harvest was carried out in a week intervals, while pruning was carried out by (1) hard pruning, (2) water shoot pruning, and (3) maintenance pruning. Hard pruning was carried out in January, 2018, before the research had been done; it was aimed to arrange the canopy so that it did not contact each other and its height was not more than 4 meters, indicated by light spots on the ground. It was used as the reference for the time of the application of N.P.K.Ca.Mg 12.9 : 11.4 : 16.8 : 10.6 : 4.8 fertilization according to the treatment. Before fertilization was applied, row space between plants were cleaned up manually by hoes in order to be free from weeds. Phonska, urea, MOP, dolomite, and kieserit fertilizers were equally mixed in each treatment, divided into six parts, and buried in 5 centimeter deep at 6 distance points of 70 centimeters from the plants which was aimed to prevent from fertilizer evaporation and erosion. Fertilization was carried out only once in January. Pruning water shoots was carried out 3 months in the post-heavy pruning (April), and after that it was carried out every month so that water shoots which grew on the main stems could be removed. Gliricidia and coconut shade trees were pruned 1 meter from cocoa canopy until the intensity of 40% to 60%, identified by adequate light on the plants. Weed control was done manually with clean discs, and standardized maintenance included harvest, pruning, weed control, and diseases. Measurement on agronomic variables such as (1) the number of
flushes, (2) leaf size, (3) water shoots, (4) the number of flowers, (5) the number of cherelles, and (6) the number of pods was done each month within 24 weeks (6 months).

3. Results and Discussions
Based on Table 2 below, the time for applying N.P.K.Ca.Mg fertilizers (1) had non significant influence on the number of flushes, leaf size, the number of water shoots, withered cherelles, and pod reserves, (2) had significant influence on the number of flowers, and (3) had very significant influence on the number of cherelles within 24 weeks. Pruning without fertilization (A0) would form 226.8 flushes, 360.3 flowers, 31.8 cherelles, and 19.8 pod reserves. Pruning with fertilization (A1, A2, and A3) would increase the forming of flowers and cherelles. Fertilization pre-pruning (A1) tended to form better flushes with 239.3 flushes and to increase leaf size to 162.92 cm² for flush-1 and 218.97 cm² for flush-2. Fertilization in the post-pruning (A3) indicated the best production 691 flowers, 56.7 cherelles, and 31.5 pod reserves.

Table 2. Average observation on the number of flushes, leaf size, the number of water shoots, the number of flowers, the number of cherelles, and pod reserves in 24 weeks.

| Treatment | Number of Flushes | Leaf Size (cm²) | Number of Water Shoots | Number of Flowers | Number of Cherelles | Withered Cherelles | Pod Reserves |
|-----------|-------------------|----------------|------------------------|-------------------|---------------------|-------------------|--------------|
| A0        | 226.8 a           | 116.27 a       | 139.61 a               | 27.0 a            | 360.3 a            | 31.8 aA          | 8.2 a        | 19.8 a       |
| A1        | 239.3 a           | 162.92 a       | 218.97 a               | 23.2 a            | 649.5 b           | 38.0 aAB         | 13.2 a       | 20.8 a       |
| A2        | 221.8 a           | 134.40 a       | 207.87 a               | 31.2 a            | 645.8 b           | 44.3 abAB       | 11.8 a       | 22.3 a       |
| A3        | 237.3 a           | 156.70 a       | 191.01 a               | 36.7 a            | 691.0 b           | 56.7 bB         | 11.7 a       | 31.5 a       |

HSD_{.05} | 135.66            | 64.18          | 82.29                  | 18.62             | 325.05            | 17.12            | 8.71         | 12.90         |

HSD_{.01} | -                 | -              | -                      | -                 | -                  | -                 | -             | -             |

Explanat: Notation of the same letters which follow the mean figure in A0, A1, A2 and A3 columns indicated non significant difference at α = 5% (small letter) and at α = 1% (capital letter).

In Figure 1, it could be seen that the number of flushes (i) and leaf size were the highest in A1 (application of fertilization was 2 weeks pre-pruning), the number of water shoots (iii), flowers (iv), cherelles (v), and pods (vi) were mostly found in A3 (application of fertilization was 2 weeks post-pruning). Pruning without fertilization (A0) indicated that the forming of flush still went on normally, but the forming of flowers, cherelles, and pod reserves were lower than those when they were fertilized(A1, A2, and A3).

Figure 2 indicated that the forming of flush (i) went on simultaneously in the 4th week, the 12th week, and the 20th week in all treatments. The forming of flowers (ii) went on in 24 weeks; in the 4th week and the 8th week the number of flowers was relatively fewer than in the following week. The forming of cherelles (iii) also went on in 24 weeks; in the 4th week, the 8th week, and the 12th week the number of cherelles was relatively fewer than that in the following week. Figure 2 indicated that the forming of flush (i) went on simultaneously in the 4th week, the 12th week, and the 20th week in all treatments. The forming of flowers (ii) went on in 24 weeks; in the 4th week and the 8th week the number of flowers was relatively fewer than in the following week. The forming of cherelles (iii) also went on in 24 weeks; in the 4th week, the 8th week, and the 12th week the number of cherelles was relatively fewer than that in the following week. The application of fertilization 2 weeks after pruning (A3) indicated that the development of graph pattern of flush, flowers, and cherelles was better than the other treatments, and pruning without fertilization (A0) indicated the lowest development of flowers and cherelles.
Figure 1. Graph of the number of flushes, leaf size, the number of water shoots, flowers, and pods

Correlation among the observations (Table 3) indicated that the number of flushes had strong correlation with leaf size of flush-1. The number of flowers had strong correlation with the number of cherelles, leaf size of flush-1 and flush-2, withered cherelles, and pod reserves. The number of cherelles had strong correlation with water shoots and pod reserves. There was the significant correlation between leaf size of flush-2 and withered cherelles and between the number of cherelles and pod reserves.

Table 3. Correlation among the observed variables

| Variabel | ΣFL | ΣFW | ΣCH | ΣWS | FL1  | FL2  | WC  | PR  |
|----------|-----|-----|-----|-----|------|------|-----|-----|
| ΣFL      |  1  |      |     |     |      |      |     |     |
| ΣFW      | 0.414 | 1      |     |     |      |      |     |     |
| ΣCH      | 0.300  | 0.767  | 1      |     |      |      |     |     |
| ΣWS      | -0.083  | 0.386  | 0.868  | 1      |      |      |     |     |
| FL1      | 0.825  | 0.842  | 0.551  | 0.068  | 1      |      |     |     |
| FL2      | 0.334  | 0.897  | 0.407  | -0.031  | 0.792  | 1      |     |     |
| WC       | 0.501  | 0.917  | 0.460  | -0.013  | 0.891  | 0.983  | 1      |     |
| PR       | 0.404  | 0.584  | 0.952  | 0.877  | 0.480  | 0.168  | 0.262  | 1      |

Explanation: ΣFL (number of flush), ΣFW (number of flowers), ΣCH (number of cherelles), ΣWS (number of water shoots), FL1 (leaf size of flush 1), FL2 (leaf size of flush 2), WC (withered cherelles), and PR (pod reserves).
Figure 2. Flush development (i), flower development (ii), and the number of cherelles (iii) in 24 weeks.

Hard pruning without fertilization (A0) can stimulate the forming of flushes although it cannot optimally increase leaf size, forming of flowers, forming of cherelles and pods. Pruning without fertilization does not give much benefit since it is not able to give productivity; even though there are sufficient flushes, but their leaf size is not good. Pruning with fertilization (A1, A2, and A3) stimulates the forming of flushes although it is not different from pruning without fertilization (A0). Fertilization with N.P.K.Ca.Mg 12.9 : 11.4 : 16.8 : 10.6 : 4.8 can increase leaf size, the number of flowers, the number of cherelles, and the number of pods. Applying fertilizers two weeks pre-pruning (A1) tends to increase the number of flushes, and leaf size is getting better. Applying fertilizers two weeks post-pruning (A3) gives the best production of the number of flowers, cherelles, and pods, followed by applying fertilizers with pruning (A2) simultaneously. Hard pruning without fertilization is not good for cocoa; it should be followed by fertilization in order to make better leaf size and more number of flowers and pods.
Cocoa flushing can increase the number of leaves for the balance between hormone as flush stimulant (citokinin, auxin, and gibberellins) and hormone as dormant stimulant, aging, and fall leaves (abscisic acid or ABA). Flushing yields new leaves for photosynthesis; photosynthesizing active leaves are about 2 or 3 months old. It is influenced by environmental factor and maintenance. Temperature amplitude which is more than 9°C can stimulate cocoa flush in dry months. When it is raining after dry season, the roots will actively grow and stimulate flushing intensively. Long drawn rainy season or too thick shade trees can curb the development of flowers and pods. Flushing will be intensive when the number of leaves is small because they fall during the dry season or because of pruning [20]. Cocoa flushes 3 to 4 cycles a year, the main flush occurs at the beginning of rainy season, preceded by dry season or water stress. Cocoa flushing ends when apical shoots enter dormant period and produce many new flowers [21].

Cocoa flowering and pollination pattern are influenced by the factors of climate; long drawn drought or cold weather hampers the growth of flowers; on the other hand, warm rainfall and weather will trigger cocoa flowering and pollination. Some of the cherelles will be withered and dead (cherelle wilt) in the period of 1-2 months after their growth. Physiologically, cherelles are withered because of nutritional competition between cherelles with vegetative and other reproductive organs which are actively growing. Cocoa pollination has positive correlation with the distribution of rainfall, while pod vacuum period occurs in dry months. Intensive flushing can cause cherelle wilt due to the effect of nutritional competition, and cherelles do not grow well. It can also be caused by Phytophthora palmivora which is very difficult to be controlled [20].

Cocoa pruning as maintenance affect net photosynthesis because new leaves influence the acceleration of photosynthesis; therefore, regular pruning is important to increase tree productivity [22]. Pruning branches will remove domination of shoots so that new lateral shoots will grow. By pruning, ideal canopy will be obtained so that optimal and qualified production can be maintained. Hard pruning produces many lateral shoots while slight pruning will produce wider leaves [23]. Hard pruning (30% of secondary branches) improves the spread of canopy and light transmission, while moderate pruning is the best way to produce a large number of flowers and pods in a tree, the weight of dried beans per pod, and the weight of pods [24]. Moderate pruning (20% of secondary branches) will increase the whole beneficial parameter which leads to the increase in cocoa production and quality [25]. Pruning cocoa trees will change the balance of hormone as the stimulant (abscisic acid or ABA) for flushing; the harder the pruning is, the more intensive they flush due to low ABA content in new flushes. The cycle of ABA in leaves is as follows: leaves develop into maturity along with the increase in the amount of ABA which causes leaves to fall. Cocoa flush which carries 3 to 6 leaves is sink strength [20]. Cocoa plant pruning contains the residue of N 0.06 – 0.10 Mg ha⁻¹. Appropriate tree density, implementation of pruning, and arrangement of sunlight intensity are identified as important factors for the growth of cocoa trees [26].

In orange, pruning for decreasing flushes will give flowering effect; direct effect will be seen with the number of flowers which are formed on the flower buds; the next set of oranges will be determined by the success in pollination [27]. In manggo, flush initiation can be stimulated by anthropogenic factors such as pruning, irrigation, nitrogen application, or ethylene. Flush induction is arranged by florigenic promoter (FP), beginning with exposure to coldness without water stress, followed by flower defoliation and induction. Vegetative promoter (VP) is assumed to stimulate flush and to deter the influence of florigenic promoter, either by using gibberellins or by gibberellins synthesis deterrent. Pruning is useful for arranging vegetative canopy and nitrate fertilizers to help flower initiation and to improve it [28]. In avocado, the first pruning (in February) does not produce many flowers, but in the second pruning (in March and April) it produces many flowers; it takes two times of flush to get many flowers. Pruning which is done by dry season seems good enough for the appearance of flush which stimulates flowering [29]. In macadamia, pruning has direct influence on the forming of flush and the decreasing in flowers. Pruning means arranging flush, vegetative, flowers, and fruit dynamics. Hard pruning can cause flush variation and flowering variation. Pruning can have the influence in some ways: (1) production is directly influenced by pruning, (2) production is influenced by flush after
pruning, and (3) production is influenced by new branches and their flowers as the result of pruning [30]. Management on canopy needs full attention because leaf N reserves disappear 25 to 50% in the outer canopy in every spring time [31]. In apple, pruning will weaken the plants; even though vegetative plants have been improved, if flowers are weak, the set of apples will be bothered and cannot be improved [32]. Leaves are functioned for photosynthesis; heavy pruning on leaves can cause the whole photosynthesis is trans-located to fruit and roots. The increase in the ratio of roots toward flush will encourage the growth of new vegetative plants. Moderate pruning can cause the ratio of fruit to be bigger than that with hard pruning. In pruning, it is very necessary to cut off water shoots because they absorb photosynthesis at the expense of reproduction [33].

Balanced essential nutrition supply is a very important factor in increasing growth and harvest. Nitrogen (N) plays an important part in plant metabolism; it dominates inorganic nutrition and increases the quantity and the quality of production. Phosphor (P) is a restrictive factor for the production of plants on acid and alkaline soil. Potassium (K) is important nutrition in various processes of plant metabolism such as enzyme activation, osmosis turgor cells, open-close stomata, and balanced anion (especially carbohydrate metabolism organic acid) in plant cells [34]. In mango, nitrogen (N) is needed for the production of fruit as the basic material of chlorophyll, protein, hormone for growth, and enzyme. Phosphor (P) is closely related to the growth of roots, strong stems, fruit set, the time of ripening [28]. In rubber, the most effective fertilization time is when the plants begin to form new leaves after the old ones have fallen; the time is varied according its location and clone [17]. In apple, since the application of N is low in August, it has some advantages in increasing apple production and quality [35].

4. Conclusions
Application time of N.P.K.Ca.Mg 12.9 : 11.4 : 16.8 : 10.6 : 4.8 fertilization with pruning in TSH 858 clone cocoa plants have significant influence on the number of flowers and the number of cherelles in 24 weeks. Pruning without fertilization (A0) forms 226.8 normal flushes. Pruning with fertilization can increase forming flowers and cherelles. Application of fertilizers pre-pruning (A1) tends to produce more flushes and to increase leaf size. Fertilization post-pruning (A3) indicates the best result with 691.0 flowers, 56.7 cherelles, and 31.5 pod reserves. Fertilization after pruning (A3) should be done to increase the number of flowers and pods.

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