Original Research Article

~~**Effects of NPK fertilizer and wood-ash on flowering, cherelles performance and pod yield of cacao *(Theobroma cacao* L.)**~~

Performance of cacao (*Theobroma cacao* L.) varieties to wood ash and NPK fertilizer on flowering, cherelle wilt and pod yield

Abstract

It should be started with introduction of crop and some statement of problem and to address this

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The experiments ~~were~~ was conducted to determine optimum rates of

~~conducted to evaluate~~ NPK fertilizer and wood-ash application on flowering, cherelle performance and pod yield of cacao *(Theobobroma cacao* L). Treatments combination was consisted four levels of NPK with wood-ash ~~evaluated include~~ (NPK 15.1

5.15; NPK + wood-ash; sole wood-ash and control) with five cacao varieties (TC1, TC2, TC3, TC4, and TC6) in a 20 ~~4x5~~ factorial experiment with three replications. Phonological Data was ~~were~~ measured on flowering, cherelle formation, and pod development. From the results, flowering, cherelle formation and pod development were significantly enhanced by application of NPK, sole wood-ash and their combinations over control plots. Application of wood-ash alone significantly enhanced flowering, cherelle formation and pod development in both seasons over other fertilizer treatments. However, cherelle wilt under sole application of wood-ash was significantly higher compared to sole NPK and NPK+wood-ash combinations. Interaction effects of fertilizer and cacao varieties had significant positive effects on flower development and reduced cherelle wilt in both light and main crop seasons. Interactions of wood-ash and cacao varieties were found to significantly enhanced cherelle formation and pod development. The study concludes that NPK, NPK + wood-ash and sole wood-ash treatments significantly enhanced flowering, cherelle formation and pod development in cacao over the control. Also, cherelle with rate drop significantly with integration of NPK+wood-ash.

Keywords: Cacao, Cherelle, ~~Fertilizer~~, Flowering, NPK Fertilizer - Wood-ash.

Introduction

Cocoa (*Theobroma cacao* L.) is an important global commodity which is the main raw material used for the production of chocolate, beverage drinks, cocoa butter, cocoa liquor and the likes (van Vliet and Giller, 2017). Cocoa is grown in a warm climate and it is cultivated in 70 countries located within the 10°N and 10°S of the equator, that is, the tropical belt (van Vliet and Giller, 2017; Rafflegeau*et al*. 2015). The crop was discovered and first cultivated in the forest of the Americas. However, its production presently is now in Africa (mainly West Africa) and Asia (ICCO, 2021). Many smallholder farm families in West Africa have relied heavily on the cocoa industry as a source of income, and the region's cocoa-growing belt has

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relied heavily on the shipment of cocoa beans to generate foreign exchange Adejobi et al., 2014 and Charles *et al*., 2020).

The global annual production of cocoa is estimated to be about 4.7 million tonnes currently, and it has been forecasted to be above 5 million tonnes by the end of 2021 (ICCO, 2021). It was estimated that, for 2019/2020, about 4,787,000 tonnes of cocoa beans were produced globally with 75% (3,578,000 tonnes) of the beans being produced in Africa: Ivory Coast, Ghana, Nigeria and Cameroon being the largest producers, respectively (ICCO, 2021). The remaining 25% was shared between the Americas and Asia and Oceania, with Americas producing up to 19% (903, 000 tonnes) and Asia and Oceania producing about 6% (278,000 tonnes) collectively (ICCO, 2021). With an estimated total cultivation area of roughly 1.45 million hectares, the main cocoa-producing regions in Nigeria are centered in the country's western and eastern rainforests. In the 1960s and 1970s, cocoa was Nigeria's largest export and the sector occupied its peak position during this period (Famuwagun and Agele, 2010, Famuwagun*et al.,* 2016). However, from then till date, there has been marginal yield improvement in the production of cocoa. Some of the leading factors mitigating against yield improvement in cocoa production has been low farm inputs and soil fertility issues of which includes inadequate nutrient supply, soil moisture deficit especially at the early stage of establishment during the dry season, anomalies in seedling and transplanting management among others (Wessel and Quist-Wessel, 2015, Famuwagun*et al*., 2018, and Anand Park, 2021)). The use of fertilizer, either organic or inorganic has been a vital nutrient input source to the soil. It has maximized yield by providing the essential nutrients to plants needed for its growth (Arshad *et al*., 2012 and Roba, 2018).

~~Application of inorganic fertilizer is a fast remedy for the improvement of depleted soil fertility. Compared to organic fertilizer, it provides the soil with the necessary nutrient which are readily available for plants use. However, continuous application of inorganic fertilizers could lead to degradation of soil organic matter, increase soil acidity and could pollute the environment (Roba, 2018). One of the most popular inorganic fertilizers used over the years has been the NPK – 15-15-15 fertilizer. wood-ash, an organic amendment with a pH above 7 is obtained from the residue left after the burning of wood. It contains high amount of phosphorus and base cations. However, the nutrient composition of wood-ash differs across wood-ash samples (Wiklund, 2017).~~

One quick fix for replenishing decreased soil fertility is to apply inorganic fertilizer. It gives the soil the nutrients it needs that are easily accessible to plants, as opposed to organic fertilizer. On the other hand, persistent use of inorganic fertilizers may cause the environment to become contaminated, degrade soil organic matter, and raise soil acidity (Roba, 2018). Over the years, NPK – 15-15-15 fertilizer has been one of the most widely used inorganic fertilizers. Wood-ash, an organic supplement with a pH higher than 7, is made from the residue that remains after burning wood. Base cations and phosphorus are present in large concentrations. Nonetheless, different wood-ash samples have different nutritional compositions (Wiklund, 2017).

Organic amendment like wood-ash helps to improve biological activities, as well as physical activities of the soil, however, they do not contain as much nutrient as that of inorganic fertilizers and therefore requires larger amount for improving soil fertility (Nabeela et al., 2015, Olanipekun, 2012 and Roba, 2018).

Most Agricultural lands in Nigeria especially those found in the Southwestern zones of the country are characterized by low fertility status due largely to low level of activity clay, organic matter content, soil N, P, K, Ca and Mg (Awodun and Olafusi, 2007; Akanbi *et al.*, 2014) which result in continuous decline in bean yield of cocoa annually in Nigeria. In tropical countries, high cost, scarcity, nutrient imbalance and soil acidity are problems associated with the use of mineral fertilizer while bulkiness, low nutrient quality and late mineralization were the bottleneck to the sole use of organic manures for crop production. Some studies confirmed that combined application of organic manures and mineral fertilizers gave superior effects in terms of balanced plant nutrition and improved soil fertility (An, and Park, 2021; Nabeela et al., 2015). Other advantages of using combined application of organic and inorganic fertilizers, is that, it reduces the need for mineral fertilizer and aids time mineralization of nutrients from organic manures. Therefore, application of fertilizer and wood-ash to supplement the depleted nutrients in the soil is a viable alternative to revert the dwindling output from cocoa production.

~~The main objective of the study was to evaluate the effect of NPK fertilizer and wood-ash on flowering, cherelle's and pod yield of cacao (Theobroma cacao L.). While the specific objectives were to:~~

~~i. evaluate the effects of NPK 15:15:15 fertilizer, wood ash and NPK 15.15.15 with wood-ash combinations on canopy development in cacao;~~

~~ii. compare the effects of NPK 15:15:15 fertilizer, wood ash and NPK 15.15.15 with wood-ash combinations on flowering and cherelles formation in cacao; and~~

~~iii. evaluate the effects of NPK 15:15:15 fertilizer, wood ash and NPK 15.15.15 with wood-ash combinations on pod yield of cacao.~~

Materials and Methods

The experiment was conducted at the ~~Teaching and Research Farm of The Federal University of Technology~~, Akure Nigeria. The experiment site lies between latitude: 7.2972°N and longitude: 5.1461~~0~~ E. The experiment was set up on an existing 9 years old cocoa plantation (established in June, 2012) between August, 2021 and August, 2022 consisting of eight improved TC varieties in separate plots. The experiment was laid out in a 4 x 5 factorial arrangement fitted into a randomized complete block design (RCBD) with three replications. The treatments evaluated were; NPK 15:15:15 applied at the rate of 10 g per stand (11,000 g per hectare), wood-ash applied at the rate of 50 g per stand (55,000 g per hectare), NPK 15:15:15 (10 g) + wood-ash (50 g) applied per stand and Control (No fertilizer treatment). The varieties of cacao used include: TC1, TC2, TC3, TC4 and TC6.

Sixty cacao stands per variety were marked from the plantation for the experiment. The cacao stands were tagged and pruned in preparation for treatment application. The base of the selected plants was cleared and the fertilizer treatments were applied in ring form at 10 cm away from the base in August, 2021 and March, 2022. To cover the light and main crop seasons.

Regular agronomic practices for cacao plantation management were carried out on the plots throughout the period of the experiment. Pre treatment application soil analysis was conducted by sampling the soils of the various cacao plots for mineral analysis in the laboratoy.

Comment [h18]: Please put here clear thing that enforce you to conduct this research

Comment [h19]: What about response due to cacao varieties to application of inorganic fertilizer and environment factors?

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Comment [h22]: Where is treatment combinations?

Comment [h23]: Your study was set up on an existing 9 years old cocoa plantation? How you can randomize your treatments with (RCBD)?

Comment [h24]: How you can gate the different varieties (TC1, TC2, TC3, TC4 and TC6) in one replication? Due to this, total treatment combination and experimental design are false

Data were measured on the tagged cacao stands on the following parameters by physical count from the base of the cacao plant to two meters height fortnightly. Number of flowers, number of cherelles, number of wilted cherelles and number of pod.

Data collected were transformed using arc-sine transformation and the transformed data were subjected to Analysis of Variance (ANOVA) using SPSS 21 software package and significant treatment means were separated using Tukey's Honest Significant Difference (HSD) test.

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Results

~~**Effects of fertilizer types on the number of flower in cacao during light and main seasons of 2021/2022**~~

~~Effects of fertilizer types on flowering in cacao during light and main crop seasons is presented in tables 1a and 1b. At weeks 8, 10 and 12 after treatments application, significant (P<0.05) differences were observed in the number of flowers among cacao stands treated with sole NPK fertilizer (0.13, 2.33 and 2.00) and sole wood-ash (4.27, 7.07 and 9.13) respectively. Cacao stands treated with sole wood-ash produced higher number of flower compared with other treated plants at 14 weeks after treatment application during light crop season.~~

Comment [h29]: There was no clear treatment combination. So no clear result

~~During main crop season, cacao stands treated with sole wood-ash had the highest number of flowers (198.86) at 30 weeks after treatment application, though this was not significantly (P>0.05) different from other fertilizer treatments. However, it was also observed that cacao stands treated with combine application of NPK fertilizer and wood ash treatment had a significantly higher number of flower compared to other fertilizer treatments at 46 weeks after treatment application.~~

Varietal effects on numbers of flower in cacao during light and main seasons of 2021/2022

Varietal effects on flower production of cacao were presented in Tables 2a and 2b. Varieties had no significant (P>0.05) effect on flower development across the two seasons except at 6th weeks of data measurement during the light season where significant (P<0.05) difference was observed between TC2 (3.08) and TC4 (0.00) varieties. Also, at 18th weeks, significant (P<0.05) difference was observed between TC1 (2.33) and TC4 (11.75) varieties. Flower formation increased with time across all the varieties with TC6 recording the highest number of flower (183.25) at 30 weeks after treatments application but was not significantly (P>0.05) different from other varieties.

Comment [h30]: If your treatments may be affected by interaction effect of the both factors there no discussion on main effect. so this is due to lack of communication with experienced author

Interaction effects of fertilizers and varieties on the number flower in cacao during light and main seasons of 2021/2022

Interaction effects of fertilizer treatment and varieties of cacao on flower development are presented in Tables 3a and 3b. At 4 weeks after treatment application during light season, variety TC6 treated with combination of NPK with wood-ash recorded the highest number of flower (12.67), this was followed by TC4 (6.67) variety under cacao stands treated with sole wood-ash. At 6, 12, 14 and 16 weeks after treatment application, TC3 variety under wood-ash treatment had the highest number of flowers (9.99, 18.33, 19.33 and 20.33) respectively compared to other treatments. At 24 weeks after treatment application, TC6 variety treated

with sole wood-ash recorded the highest number of flowers (10.00) amongst all the applied treatments.

During main season of the experiment, variety TC3 treated with sole wood-ash had the highest number of flower development(119.33 and 276.67), respectively at 28 and 30 weeks after treatment application. However, flower production increased drastically across all the treatments and varieties in both weeks. From week 32 to 38 after treatment application, there was a gradual decrease in flower production amongst most of the varieties across the treatments. The trend in the number of flowers observed for variety TC3 at 28 weeks after treatment application was repeated at weeks 34, 36, 38, 40, 42 and 44 after treatment application, the number of flowers recorded were 100.00, 91.67, 114.33, 100.00, 133.33 and 106.67 respectively at weeks 34, 36, 38, 40, 42 and 44 after treatment application.

~~Effects of fertilizer types on the number of cherelle during light and main seasons of 2021/2022~~

~~Effects of fertilizer treatment on cherelle formation during light and main seasons are shown in Tables 4a and 4b. During light season, cacao stand treatment at 10 weeks after treatment application, significant difference was observed between cacao stands treated with sole of NPK fertilizer (2.00) and sole of wood ash (8.80). At 14 weeks after treatment application, cacao stands treated with sole NPK fertilizer (3.87) and control (2.27) had similar number of cherelles which was significantly ($P<0.05$) different from the number of cherelles (15.80) recorded on cacao treated with sole of wood ash. In main season, significant ($P<0.05$) difference was observed at 44 and 46 weeks after treatment application between cocoa stands where combine application of NPK fertilizer with wood ash treatment was applied (22.07, 12.07) and the control treatment (7.13 and 5.87) respectively. Though not significantly ($P>0.05$) different, cacao stands treated with sole wood ash had the highest number of cherelle (18.07) at week 0 after treatment application in light season and at week 44 after treatments application in main season (20.33). Control treatment had~~ the lowest number of cherelle development(0.87) at 32 weeks after treatment application.

~~Varietal effects on the number of cherelle during light and main seasons of 2021/2022~~

~~No significant ($P>0.05$) difference was observed among the tested varieties of cocoa in both seasons Tables 5a and 5b. Among the varieties during the light season, TC4 produced the highest number of cherelles while variety TC6 had the least number of cherelle (1.17) in week 24 after treatment application. In main season, the highest value of cherelle development was recorded under TC6 variety at week 44 after treatment application (18.75) while the lowest number of cherelle was recorded at week 32 after treatment application under TC1 variety (0.83).~~

Interaction effects of fertilizers and varieties on the number of cherelle during light and main seasons of 2021/2022

Interaction effects of fertilizer treatment and cacao varieties on the number of cherelle during light season and main season are shown in tables 6a and 6b. At 2 weeks after treatment application, the highest number of cherelle (23.33) was observed on variety TC4 treated with NPK fertilizer. This was followed by variety TC3 (18.33) treated with sole of wood-ash. Notwithstanding, TC6 variety treated with combination of NPK and wood-ash treatment had the highest number of cherelles among the varieties under the same treatment. At 10

weeks after treatment application, TC2, TC3 and TC6 varieties under wood-ash treatment had higher number of cherelles (10.33, 13.33 and 10.00) respectively, compare to other treatments. TC3 variety whose value was highest (13.33) under wood-ash treatment at 10 weeks after treatment application also recorded the highest number of cherelles (28.00 and 20.67) under same treatment at 14 and 16 weeks after treatment application respectively compared to other treatments. At 24 weeks after treatment application, variety TC4 treated with wood-ash had the highest number of cherelle (14.00).

During the main season, it was observed that TC4 variety under wood-ash treatment at 26 to 28 weeks after treatment application recorded the highest number of cherelle development (16.67 and 18.67) respectively. At 36 and 38 weeks after treatment application, variety TC1 under the same treatment had the highest values of cherelle development (19.67 and 25.67) respectively. Also, TC3 variety under wood-ash treatment produced the highest number of cherelle (29.33) at 42 weeks after treatment application. This was followed by TC4 variety (20.67) under NPK treatment. The number of cherelle greatly increased in main season compared with light season.

~~Effects of fertilizer types on the number of cherelle wilt in cacao during light and main seasons of 2021/2022~~

~~Data on the effect of fertilizers types on cherelle wilt in cacao as observed in the two experiments are recorded in Tables 7a and 7b. At 0 and 2 weeks after treatment application, application of wood ash increased the number of cherelle wilt (4.73). However, there was no significant (P>0.05) differences among treatments except at week 0 after treatment application where combine application of NPK fertilizer with wood ash and control treatments were significantly (P<0.05) different from sole application of wood ash treatment. The lowest number of cherelle wilt (0.00) was recorded under sole NPK fertilizer treatment, combination of NPK fertilizer with wood ash and sole application of wood ash treatment. In the main season, significant (P<0.05) difference was observed between NPK fertilizer treated cacao and the control treatment (0.00) and (0.40) respectively at 30 weeks after treatment application. Also, at 44 weeks after treatment application, combine application of NPK fertilizer with wood ash treatment (0.27) was significantly (P<0.05) different from sole application of wood ash treatment (2.47). Lowest value of (0.00) was recorded in all treatments aside the control treatment.~~

~~Varietal effects on the number of cherelle wilt during light and main seasons of 2021/2022~~

~~Tables 8a and 8b shows the response of varieties to cherelle wilt. No significant difference was observed in the varieties across the two seasons except week 46 where varieties TC1 (0.25), TC3 (0.00) and TC4 (0.17) were significantly (P<0.05) different from variety TC2 (1.67). Though not significantly (P>0.05) different, variety TC3 variety in week 0 after treatment application recorded the highest number of cherelle wilt (3.92) in light season, while TC4 variety in week 36 after treatment application had the highest number of cherelle wilt (3.08) in the main season. The lowest number of cherelle wilt (0.00) was observed across all the varieties in both seasons except in varieties TC4 and TC6 in main season~~.

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Table 1a: Effects of fertilizer types on the number of flower during off season of 2021/2022

Fertilizer	Weeks after treatment application												
	0	2	4	6	8	10	12	14	16	18	20	22	24
NPK 15-15-15	2.33a	3.47a	2.67a	0.53a	0.13b	2.33b	2.00b	6.40b	7.40a	8.60a	2.80a	0.93a	3.47a
NPK+wood-ash	2.47a	3.93a	6.53a	2.80a	3.00ab	5.47ab	4.40ab	5.87b	9.80a	7.93a	5.27a	3.13a	4.07a
wood-ash	3.60a	4.67a	3.40a	2.20a	4.27a	7.07a	9.13a	14.60a	12.47a	8.33a	5.40a	2.67a	7.07a
Control	0.87a	2.40a	1.87a	1.07a	1.33ab	3.93ab	3.07ab	6.00b	8.13a	7.13a	3.40a	1.20a	2.80a

Means in same column followed by same letter (s) are not significantly different at 0.05% probability

Comment [h32]: Where is LSD and CV value?

Table 1b: Effects of fertilizer types on the number of flower during main season of 2021/2022

Variety	Weeks after treatment application										
	26	28	30	32	34	36	38	40	42	44	46
TC1	5.42a	66.42a	143.17a	52.75a	28.75a	19.50a	42.67a	18.75a	24.50a	33.75a	1.25a
TC2	10.58a	43.50a	160.67a	72.25a	37.42a	30.00a	29.75a	23.75a	42.33a	58.17a	8.58a
TC3	7.08a	56.17a	175.83a	71.42a	42.58a	32.72a	41.67a	57.75a	60.08a	66.50a	6.92a
TC4	4.58a	68.33a	160.00a	57.08a	45.75a	56.08a	77.75a	34.83a	29.00a	46.58a	9.00a
TC6	4.17a	62.83a	183.25a	62.33a	57.58a	25.58a	81.75a	43.00a	41.25a	30.42a	8.42a

Means in same column followed by same letter (s) are not significantly different at 0.005% probability

Comment [h33]: Where is LSD and CV value?

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Table 2a: Varietal effects on the number of flower during off season of 2021/2022

Variety	Weeks after treatment application												
	0	2	4	6	8	10	12	14	16	18	20	22	24
TC1	2.58a	4.33a	3.42a	2.25ab	1.83a	3.25a	2.75a	5.08a	3.17a	2.33b	3.00a	0.67a	1.83a
TC2	2.08a	5.67a	3.00a	3.08a	1.92a	7.92a	4.67a	8.17a	7.58a	7.92ab	4.33a	3.33a	6.92a
TC3	2.67a	1.58a	3.08a	0.42ab	2.67a	5.75a	6.42a	11.00a	13.33a	10.17ab	3.58a	1.25a	2.67a
TC4	2.08a	5.42a	5.25a	0.00b	2.83a	3.25a	4.25a	7.92a	12.42a	11.75a	6.08a	3.00a	6.25a
TC6	2.17a	1.08a	3.33a	2.50ab	1.67a	3.33a	5.17a	8.92a	10.75a	7.83ab	4.08a	1.67a	4.08a

Means in same column followed by same letter (s) are not significantly different at 0.05% probability

Table2b: Varietal effects on the number of flower during main season of 2021/2022

Variety	Weeks after treatment application										
	26	28	30	32	34	36	38	40	42	44	46
TC1	5.42a	66.42a	143.17a	52.75a	28.75a	19.50a	42.67a	18.75a	24.50a	33.75a	1.25a
TC2	10.58a	43.50a	160.67a	72.25a	37.42a	30.00a	29.75a	23.75a	42.33a	58.17a	8.58a
TC3	7.08a	56.17a	175.83a	71.42a	42.58a	32.72a	41.67a	57.75a	60.08a	66.50a	6.92a
TC4	4.58a	68.33a	160.00a	57.08a	45.75a	56.08a	77.75a	34.83a	29.00a	46.58a	9.00a
TC6	4.17a	62.83a	183.25a	62.33a	57.58a	25.58a	81.75a	43.00a	41.25a	30.42a	8.42a

Means in same column followed by same letter (s) are not significantly different at 0.05% probability

Table 3a: Interaction effects of fertilizers and varieties on the number of flower during off season of 2021/2022

Fertilizer	Variety	Weeks after treatment application												
		0	2	4	6	8	10	12	14	16	18	20	22	24
NPK 15-15-15	TC1	0.33	1.67	1.33	0.33	7.22	1.33	1.78	4.67	3.33	3.00	2.33	1.30	5.00
	TC2	1.00	3.33	4.00	2.33	6.11	2.20	1.67	4.40	5.00	8.00	4.67	2.33	5.67
	TC3	5.00	1.00	1.67	8.90	2.22	3.33	1.33	5.00	5.67	4.67	1.00	1.67	3.00
	TC4	8.33	12.33	6.33	1.10	0.67	5.00	3.67	11.67	12.00	18.33	4.67	0.67	7.00
	TC6	2.00	2.30	4.44	2.20	1.61	2.00	3.33	10.67	11.00	9.00	1.33	5.27	1.67
NPK with wood-ash	TC1	5.33	8.00	7.33	3.33	2.33	4.00	4.33	4.00	3.67	3.67	3.67	8.33	0.67
	TC2	1.33	5.00	2.67	4.67	2.67	11.33	5.00	3.33	9.67	5.00	2.67	5.67	6.67
	TC3	1.00	2.00	6.33	1.10	3.33	2.67	2.66	13.67	12.00	8.33	6.00	1.33	2.33
	TC4	3.33	2.67	3.67	2.20	0.67	4.67	4.00	2.00	18.33	13.67	9.67	7.00	8.00
	TC6	4.67	2.00	12.67	6.00	6.00	4.67	8.67	6.33	5.33	9.00	4.33	1.67	2.67
wood-ash	TC1	4.67	7.33	4.67	4.67	5.00	5.67	6.67	11.67	5.67	2.67	6.00	2.67	6.67
	TC2	3.33	6.67	1.67	3.67	5.00	12.00	7.67	15.33	7.00	8.67	5.33	2.67	8.67
	TC3	8.33	4.33	4.00	9.99	7.33	9.33	18.33	19.33	20.33	12.33	3.00	9.81	3.33
	TC4	5.60	3.33	6.67	6.66	3.33	3.33	6.00	13.00	12.67	9.67	6.00	3.00	6.67
	TC6	1.67	1.67	2.11	2.67	0.67	5.00	7.00	13.67	16.67	8.33	6.67	5.00	10.00
Control	TC1	9.99	0.33	0.33	0.67	1.44	2.00	1.11	1.80	3.60	2.66	0.00	1.67	0.00
	TC2	2.67	7.67	3.67	1.67	1.50	8.33	4.33	14.00	8.67	10.00	4.67	2.67	6.67
	TC3	1.33	1.44	0.33	1.67	1.72	7.67	6.00	6.00	15.33	15.33	4.33	2.00	2.00
	TC4	5.60	3.33	4.33	1.10	6.67	6.70	3.33	5.00	6.67	5.33	4.00	1.33	3.33
	TC6	0.33	0.67	0.67	1.33	1.70	1.67	1.67	5.00	10.00	5.00	4.00	1.42	2.00
LSD 0.05		1.89	1.69	1.98	1.01	1.49	1.78	2.39	2.66	4.41	3.05	1.96	1.29	2.70

Comment [h35]: In the methodology this treatment combination shall be stated. But not. so how this result was recorded?

Table 3b: Interaction effects of fertilizers and varieties on the number of flower during main season of 2021/2022

		Weeks after treatment application										
Fertilizer	Variety	26	28	30	32	34	36	38	40	42	44	46
NPK 15-15-15	TC1	3.33	25.00	106.67	37.33	24.33	27.33	22.33	8.33	18.33	31.67	0.67
	TC2	16.67	20.33	96.00	26.00	11.67	21.67	7.67	4.00	19.33	21.00	1.33
	TC3	15.00	44.67	121.67	21.67	2.67	5.67	18.33	6.00	6.67	16.00	4.00
	TC4	4.00	70.00	233.33	70.00	43.33	63.33	75.33	16.33	53.33	60.00	8.67
	TC6	2.33	35.67	69.67	65.00	78.33	20.67	61.67	33.33	9.00	40.00	3.33
NPK with wood-ash	TC1	6.33	113.33	193.33	70.00	21.67	26.67	103.33	34.00	52.33	63.33	3.33
	TC2	15.67	38.67	93.33	33.00	26.67	36.67	29.33	50.00	50.00	81.67	25.00
	TC3	1.50	20.67	56.67	33.67	9.33	5.00	7.33	71.67	75.00	89.33	13.33
	TC4	9.33	80.00	80.00	46.67	81.67	46.67	82.00	26.67	29.00	70.00	16.33
	TC6	4.33	87.33	230.00	65.67	29.33	23.33	104.67	46.67	73.33	43.33	15.33
wood-ash	TC1	12.00	98.33	253.33	95.33	65.00	24.00	28.33	24.00	20.67	26.67	1.00
	TC2	1.67	51.67	236.67	123.33	74.33	40.00	48.33	15.00	60.00	66.67	5.67
	TC3	10.67	119.33	276.67	87.00	100.00	91.67	114.33	100.00	133.33	106.67	6.67
	TC4	1.67	30.00	110.00	51.67	16.33	10.33	30.33	41.33	16.67	32.00	5.67
	TC6	10.00	76.67	140.00	55.00	44.00	30.00	46.00	52.00	39.33	25.00	11.00
Control	TC1	2.30	29.00	19.33	8.33	4.00	1.42	6.67	8.67	6.67	13.33	8.90
	TC2	8.33	63.33	216.67	106.67	37.00	21.67	33.67	26.00	40.00	63.33	2.33
	TC3	2.67	40.00	288.33	143.33	58.33	28.67	36.67	53.33	25.33	54.00	3.67
	TC4	3.33	93.33	176.67	60.00	41.67	14.00	23.33	55.00	17.00	24.33	5.33
	TC6	2.51	51.67	223.33	63.67	78.67	28.33	14.67	40.00	43.33	13.33	4.00
LSD 005		4.09	20.07	58.48	23.98	20.29	15.49	26.03	14.11	14.06	18.14	3.14

Comment [h36]: In the methodology this treatment combination shall be stated. But not. so how this result was recorded?

~~**Table 4a: Effects of fertilizer types on the number of cherelle during off season of 2021/2022**~~

~~Fertilizer~~	~~Weeks after treatment application~~												
	~~0~~	~~2~~	~~4~~	~~6~~	~~8~~	~~10~~	~~12~~	~~14~~	~~16~~	~~18~~	~~20~~	~~22~~	~~24~~
~~NPK 15-15-15~~	~~10.20a~~	~~8.93a~~	~~6.33a~~	~~3.80a~~	~~2.47a~~	~~2.00b~~	~~2.13a~~	~~3.87b~~	~~3.80a~~	~~5.47a~~	~~4.93a~~	~~2.33a~~	~~1.33a~~
~~NPK + wood ash~~	~~8.60a~~	~~12.00a~~	~~10.27a~~	~~7.80a~~	~~5.20a~~	~~5.00ab~~	~~2.27a~~	~~4.67ab~~	~~5.47a~~	~~5.00a~~	~~6.87a~~	~~3.87a~~	~~3.00a~~
~~wood ash~~	~~18.07a~~	~~9.53a~~	~~6.40a~~	~~8.47a~~	~~4.73a~~	~~8.80a~~	~~6.00a~~	~~15.80a~~	~~11.93a~~	~~10.53a~~	~~6.47a~~	~~6.73a~~	~~4.47a~~
~~Control~~	~~9.07a~~	~~5.13a~~	~~5.13a~~	~~2.67a~~	~~1.60a~~	~~2.80ab~~	~~1.53a~~	~~2.27b~~	~~5.20a~~	~~5.87a~~	~~4.93a~~	~~2.40a~~	~~2.73a~~

~~Means in same column followed by same letter(s) are not significantly different at 0.05% probability~~

Table 4b: Effects of fertilizer types on the number of cherelle during main season of 2021/2022

Fertilizer	Weeks after treatment application										
	26	28	30	32	34	36	38	40	42	44	46
NPK 15-15-15	2.73a	3.53a	2.53a	2.33a	3.87a	6.47a	12.87a	8.27a	10.13a	12.67bc	9.93ab
NPK with wood-ash	4.27a	5.67a	3.93a	2.80a	7.20a	8.07a	11.13a	10.80a	14.33a	22.07a	12.07a
wood-ash	9.27a	9.00a	2.87a	3.73a	6.73a	9.07a	14.80a	17.07a	16.27a	20.33ab	10.20ab
Control	3.67a	1.60a	1.67a	0.87a	2.67a	4.00a	12.27a	15.27a	12.27a	7.13c	5.87b

Means in same column followed by same letter(s) are not significantly different at 0.05% probability

Table 5a: Varietal effects on the number of cherelle during off season of 2021/2022

Variety	Weeks after treatment application												
	0	2	4	6	8	10	12	14	16	18	20	22	24
TC1	13.33a	7.67a	5.75a	6.08a	4.50a	2.58a	1.67a	4.42a	2.67a	2.25a	3.17a	2.92a	1.83a
TC2	12.50a	7.08a	9.17a	7.50a	5.83a	6.92a	2.42a	3.17a	4.75a	7.92a	5.00a	3.00a	2.42a
TC3	8.92a	8.75a	6.92a	6.17a	2.00a	5.50a	3.25a	10.17a	9.83a	6.58a	7.08a	1.92a	2.42a
TC4	14.25a	12.25a	6.75a	4.17a	1.83a	4.25a	3.17a	8.00a	7.67a	9.58a	8.25a	6.42a	6.58a
TC6	8.42a	8.75a	6.58a	4.50a	3.33a	4.00a	4.42a	7.50a	8.08a	7.25a	5.50a	4.92a	1.17a

Means in same column followed by same letter (s) are not significantly different at 0.005% probability

Table 5b: Varietal effects on the number of cherelle during main seasonof 2021/2022

Variety	Weeks after treatment application										
	26	28	30	32	34	36	38	40	42	44	46
TC1	3.92a	1.25a	1.75a	0.83a	5.08a	6.00a	10.75a	8.25a	10.75a	15.25a	7.17a
TC2	5.42a	7.42a	4.42a	3.33a	8.33a	5.50a	11.33a	11.00a	8.00a	12.50a	7.92a
TC3	2.75a	4.08a	2.42a	1.92a	4.00a	7.00a	9.67a	13.00a	15.42a	14.33a	9.92a
TC4	8.75a	8.33a	3.75a	2.92a	4.00a	6.67a	15.75a	15.75a	15.42a	16.92a	11.25a
TC6	4.08a	3.67a	1.42a	3.17a	4.17a	9.33a	16.33a	16.25a	16.67a	18.75a	11.33a

Means in same column followed by same letter (s) are not significantly different at 0.05% probability.

Table 6a: Interaction effects of fertilizers and varieties on the number of cherelle during off season of cacao

Fertilizer	Variety	Weeks after treatment application												
		0	2	4	6	8	10	12	14	16	18	20	22	24
NPK 15-15-15	TC1	12.67	4.00	4.00	3.00	2.67	0.33	0.67	0.67	0.67	0.67	2.33	1.00	7.77
	TC2	9.33	7.67	4.00	5.33	2.67	1.67	0.00	3.33	1.67	5.33	2.67	2.33	2.33
	TC3	2.00	3.33	2.67	2.00	1.00	0.33	0.67	1.33	2.00	3.00	1.00	3.33	0.67
	TC4	20.67	23.33	11.00	3.33	3.00	6.00	7.00	8.33	9.00	12.00	8.00	4.00	2.33
	TC6	6.33	6.33	10.00	5.33	3.00	1.67	2.33	5.67	5.67	6.33	10.67	4.33	1.33
NPK with wood-ash	TC1	6.33	10.33	8.67	8.67	6.67	4.00	2.67	4.33	0.67	3.00	5.67	4.00	1.33
	TC2	6.33	8.67	17.33	16.00	12.67	9.00	3.33	5.33	4.00	4.67	5.67	1.67	2.00
	TC3	7.67	8.33	11.00	2.00	1.33	1.67	1.33	1.33	6.67	5.33	10.00	4.67	4.00
	TC4	13.33	15.67	8.00	7.00	1.33	6.00	2.33	7.00	9.67	9.33	9.67	6.00	6.33
	TC6	9.33	17.00	6.33	5.33	4.00	4.33	1.67	5.33	6.33	2.67	3.33	3.00	1.33
wood-ash	TC1	26.00	13.00	7.00	11.00	6.33	5.67	3.00	12.67	9.33	5.33	4.67	6.67	6.00
	TC2	24.00	5.67	8.00	3.67	4.67	10.33	2.67	4.00	5.33	10.67	5.67	4.33	1.00
	TC3	20.67	18.33	7.67	19.33	4.00	13.33	7.67	28.00	20.67	9.33	4.67	3.00	2.30
	TC4	11.33	5.00	4.33	3.67	3.00	4.67	3.33	16.67	11.00	10.67	10.33	12.00	14.00
	TC6	8.33	5.67	5.00	4.67	5.67	10.00	13.33	17.67	13.33	16.67	7.00	7.67	1.33
Control	TC1	8.33	3.33	3.33	1.67	2.33	0.33	0.33	1.11	1.78	5.33	1.89	8.90	1.67
	TC2	10.33	6.33	7.33	5.00	3.33	6.67	3.67	0.00	8.00	11.00	6.00	3.67	4.33
	TC3	5.33	5.00	6.33	1.33	1.67	6.67	3.33	10.00	10.00	8.67	12.67	0.00	5.00
	TC4	11.67	5.00	3.67	2.67	3.30	0.33	6.11	1.33	1.00	6.33	5.00	3.67	3.67
	TC6	9.67	6.00	5.00	2.67	0.67	6.78	0.33	1.33	7.00	3.33	1.00	4.67	0.67
LSD 0.05		4.61	3.95	2.59	2.72	2.11	2.53	2.52	4.49	3.69	3.76	2.87	2.54	2.58

#

Comment [h37]: In the methodology this treatment combination shall be stated. But not. so how this result was recorded?

Table 6b: Interaction effects of fertilizers and varieties on the number of cherelle during main season of cacao

Fertilizer	Variety	Weeks after treatment application										
		26	28	30	32	34	36	38	40	42	44	46
NPK 15-15-15	TC1	8.88	5.55	0.00	2.20	3.77	8.90	7.67	7.67	9.33	13.67	9.33
	TC2	5.33	5.67	7.67	5.67	9.33	3.67	6.33	1.00	5.00	5.00	5.33
	TC3	1.67	5.33	2.67	1.67	1.33	14.00	7.00	2.33	2.33	4.67	5.67
	TC4	5.00	5.00	1.00	3.00	3.33	2.67	23.67	16.00	20.67	22.00	18.67
	TC6	1.67	1.67	1.33	1.33	5.33	12.00	19.67	14.33	13.33	18.00	10.67
NPK with wood-ash	TC1	0.33	2.33	5.00	1.67	13.00	4.33	9.67	5.33	14.00	25.67	11.33
	TC2	2.33	13.33	4.33	5.33	12.00	6.00	9.67	11.00	8.33	11.33	13.00
	TC3	1.33	1.33	2.67	1.67	1.67	2.66	1.33	11.33	16.67	21.00	16.67
	TC4	13.33	9.67	7.67	5.33	9.33	17.67	17.67	13.67	15.33	28.67	6.67
	TC6	4.00	1.67	5.55	6.70	1.67	12.33	17.33	12.67	17.33	23.67	12.67
wood-ash	TC1	15.33	2.67	2.00	1.67	7.33	19.67	25.67	19.00	19.67	21.67	8.00
	TC2	4.00	6.67	1.33	1.33	9.00	8.33	18.33	21.00	5.00	25.33	9.67
	TC3	2.67	5.67	1.67	1.00	5.67	4.33	9.00	12.67	29.33	21.00	8.00
	TC4	16.67	18.67	5.67	3.33	3.33	5.00	5.00	14.33	10.67	12.00	11.33
	TC6	7.67	11.33	3.67	11.33	8.33	8.00	16.00	18.33	16.67	21.17	14.00
Control	TC1	1.78	1.70	6.66	1.10	3.77	7.11	5.33	1.00	0.00	3.55	1.78
	TC2	10.00	4.00	4.33	1.00	3.00	4.00	11.00	11.00	13.67	8.33	3.67
	TC3	5.33	4.00	2.67	3.33	9.00	9.67	21.33	25.67	13.33	10.67	9.33
	TC4	1.30	1.04	0.67	8.90	8.90	1.33	16.67	19.00	15.00	5.00	8.33
	TC6	3.00	4.68	0.67	5.55	1.33	5.00	12.33	19.67	19.33	11.67	8.00
LSD 0.05		3.86	3.94	1.99	1.71	3.04	3.33	6.26	4.38	4.45	3.64	2.24

Comment [h38]: In the methodology this treatment combination shall be stated. But not. so how this result was recorded?

~~**Table 7a: Effects of fertilizer types on the number of cherelle wilt during off season of cacao**~~

~~Fertilizer~~	~~Weeks after treatment application~~

	0	2	4	6	8	10	12	14	16	18	20	22	24
NPK 15-15-15	2.33ab	1.33a	0.87a	1.60a	1.00a	0.27a	0.00a	0.00a	0.00a	0.00a	0.27a	0.60a	0.60a
NPK with wood-ash	1.07b	1.27a	1.00a	1.93a	0.67a	0.07a	0.27a	0.00a	0.00a	0.00a	0.13a	0.00a	0.00a
wood-ash	4.33a	4.73a	2.80a	1.27a	1.47a	0.27a	0.20a	0.00a	0.20a	0.20a	0.20a	1.20a	1.20a
Control	1.47b	1.27a	1.13a	0.93a	0.33a	0.07a	0.67a	0.67a	0.33a	0.13a	0.07a	0.40a	0.40a

Means in same column followed by same letter (s) are not significantly different at 0.05% probability

Table 7b: Effects of fertilizer types on the number of cherelle wilt during main season of cacao

Fertilizer	Weeks after treatment application										
	26	28	30	32	34	36	38	40	42	44	46
NPK 15-15-15	0.00a	0.07a	0.00b	0.20a	0.33a	0.80a	0.60a	0.80a	0.47a	0.53ab	0.40a
NPK + wood-ash	0.07a	0.00a	0.13ab	0.13a	0.07a	1.47a	0.40a	1.07a	0.80a	0.27b	0.20a
wood-ash	0.80a	0.27a	0.13ab	0.53a	0.80a	2.60a	0.80a	1.27a	0.80a	2.47a	0.53a
Control	0.53	0.27a	0.40a	0.07a	0.73a	0.40a	0.60a	0.67a	0.87a	1.27ab	1.20a

Means in same column followed by same letter (s) are not significantly different at 0.05% probability

Table 8a: Varietal effects on the number of cherelle wilt during off season of cacao

Variety	Weeks after treatment application												
	0	2	4	6	8	10	12	14	16	18	20	22	24
TC1	0.42a	1.67a	1.50a	1.75a	1.42a	0.42a	0.08a	0.00a	0.08a	0.00a	0.00a	0.00a	0.08a
TC2	2.58a	1.67a	1.25a	1.75a	1.08a	0.08a	0.25a	0.00a	0.42a	0.25a	0.00a	1.50a	0.50a
TC3	3.92a	3.33a	1.75a	0.33a	0.83a	0.08a	0.00a	0.08a	0.00a	0.00a	0.08a	0.25a	0.17a
TC4	2.17a	2.75a	1.25a	1.92a	0.92a	0.25a	0.33a	0.00a	0.08a	0.08a	0.33a	0.58a	0.17a
TC6	2.92a	1.33a	1.50a	1.42a	0.83a	0.00a	0.00a	0.00a	0.08a	0.08a	0.42a	0.42a	0.25a

Means in same column followed by same letter (s) are not significantly different at 0.05% probability

Table 8b: Varietal effects on the number of cherelle wilt during main season of cacao

Variety	Weeks after treatment application										
	26	28	30	32	34	36	38	40	42	44	46
TC1	0.08a	0.17a	0.08a	0.33a	0.17a	0.33a	0.25a	0.50a	0.00a	0.83a	0.25b
TC2	0.42a	0.00a	0.08a	0.00a	0.75a	0.75a	1.08a	1.00a	1.17a	1.17a	1.67a
TC3	0.25a	0.08a	0.25a	0.08a	0.17a	0.08a	0.08a	0.92a	0.50a	0.83a	0.00b
TC4	0.67a	0.17a	0.25a	0.17a	0.58a	3.08a	1.25a	1.25a	0.75a	1.42a	0.17b
TC6	0.33a	0.33a	0.17a	0.58a	0.75a	2.33a	0.33a	1.08a	1.25a	1.42a	0.83ab

Means in same column followed by same letter (s) are not significantly different at 0.005% probability

Interaction effects of fertilizers and varieties on the number of cherelle wilt during light and main seasons of cacao

Tables 9a and 9b represent the interaction effects of fertilizer treatments and cacao varieties on cherelle wilt. The interaction effect between fertilizer treatments and varieties on cherelle wilt showed that at 2 weeks after treatments application, the highest number of cherelle wilt was recorded under TC3 variety treated with wood-ash (9.00), followed by variety TC4 (5.67) under same treatment. After 10 weeks of treatments application, highest mean value of (9.24) cherelle wilt was recorded under TC4 variety treated with wood-ash. This same value (9.24) was also recorded as the highest at week 14 after treatment application under TC3 variety treated with NPK with wood-ash, followed by TC6 variety (8.33) treated with NPK 15-15-15. At 24 weeks after treatments application, TC1 variety recorded the highest mean number of cherelle wilt(9.71) under NPK with wood-ash concentration.

However, at 26 weeks after treatments application in main season, TC6 variety treated with NPK 15-15-15 recorded the highest number of cherelle wilt(8.90), this was followed by variety TC6 under wood-ash treatment (8.88). At 34 weeks after treatments application no cherelle wilt was recorded under TC3, TC4 and TC6 (0.00) varieties treated with combine application of NPK with wood-ash, variety TC1 (0.00) under sole application of NPK treatment. At 38 and 46 weeks after treatments application, TC3 under wood-ash treatment had the highest value of cherelle wilt(9.20 and 5.55), respectively compared to other treatments.

~~**Effects of fertilizer types on the number of pod during light and main seasons of cacao**~~

~~Tables 10a and 10b shows the results of pod development of cacao as influenced by fertilizer types. In the light and main seasons, at 10 weeks after treatment application, cocoa stands that were treated with sole application of NPK fertilizer (0.87) and control treatment (1.47) were significantly (P<0.05) different in the number of pod from cocoa stands treated with NPK fertilizer with wood-ash combination (5.47). Also, at 18 weeks after treatment application, significant (P<0.05) difference was observed between cocoa stands treated with sole application of NPK fertilizer (0.07) and combine application of NPK fertilizer with wood-ash (1.27). However, in main season, significant (P<0.05) difference was observed in the number of pod at 44 weeks after treatments application between cocoa stands treated with combine application of NPK fertilizer with wood-ash (4.40) and the control treatment (0.60). Also, at 46 weeks after treatment application, cocoa stand treated with wood-ash (7.80) was significantly different from the control treatment (2.00). Significant higher number of pods was recorded on cacao treated with sole wood-ash at 46 weeks after treatments application. The lowest number of pods was produced by cacao on the control plots (0.00) at 28 and 30 weeks after treatments application.~~

~~**Varietal effects on the number of pod during light and main seasons of cacao**~~

~~The effects of 5 varieties of cacao on the number of pod after treatments application are shown in Tables~~

~~11a and 11b. Among the varieties, TC2 had highest number of pods at 10 weeks after treatment application (7.58). However, there was no significant (P>0.05) difference in pod~~

development among the varieties in both seasons except at 10 and 12 weeks after treatment application. At 10 weeks after treatment application, variety TC2 recorded significantly higher number of pods (7.58) than other treatments. While at 12 weeks after treatment application, the number of pods (3.25) produced by variety TC3 was significantly ($P<0.05$) higher than the number of pods (0.05) recorded in variety TC2.

Interaction effects of fertilizers and varieties on the number of pod during light and main seasons of cacao

Tables 12a and 12b show the interaction effects of fertilizer treatments and cacao varieties on the number of pod during light and main season. The number of pod varies among the cacao varieties with respect to fertilizer types.

Cacao pod development was high under TC2 variety treated with wood-ash at 2,6 and 10 weeks after treatment application compare to other varieties with the same treatment and other treatments (10.00,12.33 and 12.00) respectively. Though lower than TC2 variety treated with wood-ash, TC2 variety treated with NPK with wood-ash treatment also recorded high number of pod(11.33) at 10 weeks after treatment application. At 24 weeks after treatment application, TC2 and TC3 varieties treated with wood-ash had the highest number of pod (8.33 and 8.30) respectively when compared to other treatments. At 26 and 28 weeks after treatments application during main season of the experiment, higher pods number was observed from TC3 variety treated with wood-ash (7.77 and 7.70) respectively. TC4 variety had the highest number (10.00) of pod development under wood-ash treatment, while at 34 weeks after treatments application TC1 variety under sole application of NPK treatment, NPK with wood-ash treatment and TC4 under sole application of wood-ash treatment had same mean number of pod development (8.90). However, at 46 weeks after treatments application, TC4 variety under NPK with wood-ash treatment had the highest number of pods (14.00).

Table 9a: Interaction effects of fertilizers and varieties on the number of cherelle wilt during off season of cacao

Fertilizer	Variety	Weeks after treatment application												
		0	2	4	6	8	10	12	14	16	18	20	22	24
NPK 15-15-15	TC1	4.44	1.33	1.00	2.67	2.33	0.33	6.94	5.55	0.00	1.10	1.80	2.50	9.71
	TC2	3.00	0.33	0.67	1.33	1.00	0.33	2.78	4.86	1.10	1.40	2.20	7.49	4.16
	TC3	1.55	7.22	8.14	2.22	4.77	8.30	1.25	2.80	1.10	0.10	2.80	4.72	4.16
	TC4	4.00	2.00	1.67	2.67	1.33	0.67	2.78	5.86	0.00	0.00	1.00	2.00	2.80
	TC6	4.67	3.00	1.00	1.33	0.33	4.20	2.78	8.33	0.00	2.20	0.33	1.00	2.78
NPK with wood-ash	TC1	2.22	2.78	0.33	2.00	0.67	0.33	0.33	3.93	1.70	1.70	1.80	1.94	1.11
	TC2	1.00	1.67	1.67	1.67	1.33	1.39	0.67	6.16	2.22	8.30	2.10	5.27	0.00
	TC3	1.00	1.33	0.67	0.67	6.25	2.78	8.33	9.24	1.70	0.00	2.10	1.39	1.25
	TC4	1.67	2.33	4.44	2.00	1.33	2.80	0.33	1.23	1.10	0.00	0.33	1.39	9.71
	TC6	1.67	1.00	2.33	3.33	4.20	2.80	1.39	9.22	2.20	1.10	0.33	3.05	1.40
wood-ash	TC1	1.67	3.67	2.67	2.00	2.67	1.00	4.16	2.78	0.33	1.10	1.70	1.39	0.33
	TC2	4.67	4.00	2.33	3.00	1.33	0.00	0.33	1.62	0.33	0.67	1.10	4.67	2.00
	TC3	10.33	9.00	6.00	0.67	2.67	0.33	2.78	6.20	1.70	1.10	0.33	0.67	0.67
	TC4	2.67	5.67	1.33	0.33	0.67	9.24	0.67	3.55	0.33	0.33	1.10	1.39	0.67
	TC6	4.33	1.33	1.67	0.33	1.06	4.60	2.31	4.93	5.60	5.55	0.67	0.67	1.00
Control	TC1	0.00	1.67	2.00	0.33	7.49	1.67	6.94	5.09	0.00	1.10	1.70	2.50	1.10
	TC2	1.67	0.67	0.33	1.00	0.67	0.00	2.78	6.71	1.33	0.33	2.20	1.33	1.80
	TC3	4.33	3.00	0.33	4.44	0.67	1.80	2.80	0.33	5.60	1.10	1.70	0.33	2.80
	TC4	0.33	1.00	2.00	2.67	0.33	0.33	0.33	3.08	5.55	1.10	5.60	0.33	2.80
	TC6	1.00	1.50	1.00	0.67	1.99	2.00	4.63	4.50	0.33	0.33	0.33	8.33	2.22
LSD 0.05		1.22	1.41	1.03	0.79	0.69	0.15	0.17	0.05	0.16	0.13	0.21	0.77	0.36

Comment [h39]: In the methodology this treatment combination shall be stated. But not. so how this result was recorded?

Table 9b: Interaction effects of fertilizers and varieties on the number of cherelle wilt during main season of cacao

Table

		Weeks after treatment application										
	Variety	26	28	30	32	34	36	38	40	42	44	46
NPK 15-15-15	TC1	4.40	1.11	1.10	1.10	0.00	1.00	1.85	5.60	2.20	1.10	4.44
	TC2	4.40	1.67	1.10	2.80	1.00	1.33	2.00	1.00	1.67	1.67	1.67
	TC3	2.20	2.22	5.60	0.33	1.48	3.60.	3.52	1.70	2.78	1.90	2.20
	TC4	3.30	1.02	1.10	0.00	5.60	0.33	0.33	2.00	0.33	5.00	0.33
	TC6	8.90	0.33	5.55	0.67	0.67	1.33	0.67	1.00	0.33	1.00	0.00
NPK with wood-ash	TC1	2.20	1.11	0.00	0.67	5.60	8.90	0.33	1.00	1.10	4.40	0.33
	TC2	4.40	2.22	0.33	1.10	0.33	1.00	1.00	1.33	1.33	0.67	0.33
	TC3	0.00	3.33	1.67	1.10	0.00	0.33	1.70	3.33	5.55	2.20	4.40
	TC4	0.33	2.22	0.33	5.60	0.00	6.00	0.67	2.00	0.67	0.67	0.00
	TC6	2.22	4.44	5.55	1.11	0.00	2.20	5.55	1.00	2.00	2.20	0.33
wood-ash	TC1	0.33	0.67	0.33	0.67	4.44	0.33	7.41	0.33	1.11	3.33	3.33
	TC2	1.67	0.00	1.10	1.10	0.33	1.33	5.18	1.67	0.33	2.00	1.00
	TC3	1.00	0.33	7.41	1.10	0.33	4.44	9.20	3.33	1.00	2.00	5.55
	TC4	1.00	1.57	7.41	0.67	1.33	6.00	3.33	0.33	0.67	1.67	3.33
	TC6	8.88	0.33	0.33	1.33	2.00	6.67	0.67	0.67	2.00	3.33	1.67
Control	TC1	2.20	2.22	1.11	0.00	0.67	6.70	0.67	0.67	7.80	2.22	0.67
	TC2	2.22	2.22	1.11	4.40	1.33	0.67	1.33	0.00	1.33	0.33	3.67
	TC3	2.20	1.11	1.00	3.30	0.33	4.40	0.33	0.33	1.00	1.33	2.22
	TC4	1.33	0.67	6.67	1.11	1.00	1.78	0.67	0.67	1.33	3.33	0.33
	TC6	1.33	0.67	0.33	0.33	0.33	1.33	5.18	1.67	0.67	1.33	1.33
LDS 0.05		0.39	0.15	0.15	0.28	0.37	1.49	0.64	0.76	0.51	0.80	0.39

Comment [h40]: In the methodology this treatment combination shall be stated. But not. so how this result was recorded?

Table 10a: Effects of fertilizer types on the number of pod during off season of cacao

Fertilizer	Weeks after treatment application												
	0	2	4	6	8	10	12	14	16	18	20	22	24
NPK 15-15-15	3.60a	3.87a	2.87a	2.00a	2.13a	0.87b	0.47a	0.47a	0.27a	0.07b	0.27a	0.20a	0.20b
NPK with wood-ash	3.00a	4.13a	4.67a	4.40a	3.07a	5.47a	1.60a	1.40a	1.13a	1.27a	0.87a	0.93a	1.13b
wood-ash	6.47a	6.27a	4.93a	4.60a	3.67a	3.67ab	2.40a	1.20a	1.20a	0.87ab	0.87a	0.80a	0.20b
Control	2.87a	3.60a	2.67a	2.80a	2.33a	1.47b	1.00a	1.07a	0.60a	0.13ab	0.33a	0.27a	0.20b

Means in same column followed by same letter (s) are not significantly different at 0.005% probability

Table 10b: Effects of fertilizer types on the number of pod during main season of cacao

Fertilizer	Weeks after treatment application										
	26	28	30	32	34	36	38	40	42	44	46
NPK 15-15-15	0.20a	0.07a	0.20a	0.73a	0.13a	0.27a	0.40a	4.93a	4.67a	2.13ab	5.13ab
NPK + wood-ash	0.93a	0.53a	0.13a	0.60a	0.47a	0.27a	0.40a	4.73a	4.00a	4.40a	6.67ab
wood-ash	0.87a	0.27a	1.87a	1.60a	0.13a	1.60a	1.33a	6.67a	4.93a	2.93ab	7.80a
Control	0.47a	0.00a	0.00a	0.10a	1.00a	0.40a	0.40a	3.20ab	2.07ab	0.60b	2.00b

Means in same column followed by same letter(s) are not significantly different at 0.005% probability

Table 11a: Varietal effects on the number of pod during off season of cacao

Variety	Weeks after treatment application												
	0	2	4	6	8	10	12	14	16	18	20	22	24
TC1	3.00a	4.42a	3.50a	3.25a	1.83a	1.42b	1.25ab	1.58a	0.92a	0.33a	0.42a	0.67a	0.00a
TC2	7.08a	6.83a	5.75a	5.42a	4.75a	7.58a	0.50b	1.33a	1.00a	0.08a	0.58a	0.25a	0.33a
TC3	2.83a	3.50a	3.42a	2.83a	2.75a	1.83b	3.25a	1.00a	0.50a	0.58a	0.50a	0.50a	0.83a
TC4	3.58a	4.92a	4.33a	3.75a	3.08a	1.83b	0.92ab	0.50a	0.58a	0.67a	0.58a	0.50a	0.58a
TC6	3.42a	2.67a	1.92a	2.00a	1.58a	1.67b	0.92ab	0.75a	1.00a	1.25a	0.83a	0.83a	0.42a

Means in same column followed by same letter (s) are not significantly different at 0.005% probability

Table 11b: Varietal effects on the number of pod during main season of cacao

Variety	Weeks after treatment application										
	26	28	30	32	34	36	38	40	42	44	46
TC1	0.17a	0.42a	0.17a	0.83a	0.17a	0.08a	0.17a	4.50a	1.75a	3.08a	5.00a
TC2	0.17a	0.08a	0.58a	0.75a	0.67a	0.75a	1.00a	4.92a	3.25a	2.67a	5.08a
TC3	0.67a	0.00a	0.25a	0.58a	0.17a	0.00a	0.00a	5.00a	5.25a	3.33a	4.17a
TC4	1.25a	0.17a	1.75a	2.50a	0.58a	1.00a	1.00a	5.83a	4.33a	1.00a	6.17a
TC6	0.83a	0.42a	0.00a	1.50a	0.58a	1.33a	1.00a	4.17a	3.75a	2.50a	6.58a

Means in same column followed by same letter (s) are not significantly different at 0.005% probability

Table 12a: Interaction effects of fertilizers and varieties on the number of pod during off season of cacao

Means in same column followed by same letter (s) are not significantly different at 0.05% probability

Fertilizer	Variety	Weeks after treatment application												
		0	2	4	6	8	10	12	14	16	18	20	22	24
NPK 15-15-15	TC1	1.00	3.67	2.33	2.00	1.00	0.67	0.67	0.67	1.70	0.33	1.70	0.00	1.53
	TC2	5.33	4.33	3.67	2.67	5.00	2.00	0.33	0.33	1.10	1.11	0.00	1.70	2.36
	TC3	3.33	3.33	2.00	1.67	1.67	1.00	0.67	0.67	0.33	2.20	5.55	2.22	4.44
	TC4	5.67	6.00	5.33	3.33	3.00	0.67	0.33	2.78	0.33	1.10	0.67	1.50	3.47
	TC6	2.67	2.00	1.00	0.33	4.40	1.00	0.33	0.67	0.67	3.33	0.67	1.00	1.00
NPK with wood-ash	TC1	2.33	5.00	4.00	4.33	3.67	4.00	2.33	3.00	2.00	0.67	1.33	2.00	1.53
	TC2	1.00	3.00	2.00	1.00	0.67	11.33	0.33	0.33	1.33	4.40	1.67	0.33	0.33
	TC3	3.67	4.67	5.67	4.67	1.67	2.67	1.33	1.00	6.10	0.67	0.67	2.00	3.33
	TC4	5.67	7.33	8.00	7.00	5.33	4.67	2.67	1.33	0.67	1.33	0.67	0.33	1.33
	TC6	2.33	0.67	3.67	5.00	4.00	4.67	1.33	1.33	1.67	3.67	4.44	1.33	0.67
wood-ash	TC1	8.33	8.00	6.33	4.33	2.00	0.33	1.00	1.67	1.00	0.33	0.33	0.67	6.94
	TC2	13.00	10.00	9.67	12.33	7.67	12.00	1.00	0.67	0.67	0.33	0.67	0.67	8.33
	TC3	4.00	5.33	5.67	4.00	7.67	3.33	7.67	2.33	1.67	1.67	1.33	4.40	8.30
	TC4	1.67	2.33	1.00	2.00	0.67	1.67	0.67	0.67	1.33	1.33	0.33	1.00	0.67
	TC6	5.33	5.67	2.00	0.33	0.33	1.00	1.67	0.67	1.33	0.67	1.67	1.67	1.40
Control	TC1	0.33	1.00	1.33	2.33	0.67	0.67	1.00	1.00	0.67	3.33	2.20	4.44	1.53
	TC2	9.00	7.00	7.67	5.67	5.67	5.00	0.33	4.00	2.00	0.00	0.00	0.00	0.67
	TC3	0.33	0.67	0.33	1.00	0.00	0.33	3.33	1.17	2.78	4.40	2.20	4.44	4.44
	TC4	1.33	4.00	3.00	2.67	3.33	0.33	1.10	8.88	0.00	1.10	0.67	0.67	0.33
	TC6	3.33	2.33	1.00	2.33	2.00	1.00	0.33	0.33	0.33	0.67	1.00	0.67	4.60
LSD 0.05		1.69	1.59	1.72	1.62	1.66	1.25	0.89	0.89	0.56	0.46	0.4[3	0.51	0.31

Comment [h41]: In the methodology this treatment combination shall be stated. But not. so how this result was recorded?

Table 12b: Interaction effects of fertilizers and varieties on the number of pod during main season of cacao

		Weeks after treatment application										
Fertilizer	Variety	26	28	30	32	34	36	38	40	42	44	46
NPK 15-15-15	TC1	2.78	4.10	4.30	4.44	8.90	1.70	2.50	1.67	0.33	0.33	3.00
	TC2	2.78	4.56	1.00	1.67	0.67	1.33	2.00	5.67	6.33	6.33	4.33
	TC3	1.39	1.00	5.00	0.67	1.60	1.70	3.33	4.00	4.33	2.00	3.00
	TC4	1.10	5.30	6.94	7.40	4.40	3.90	8.30	9.00	9.00	0.33	5.00
	TC6	1.00	0.33	9.30	1.33	1.80	5.55	8.05	4.33	3.33	1.67	10.33
NPK with wood-ash	TC1	0.67	0.33	0.67	8.90	8.90	4.40	0.00	8.33	3.67	9.67	10.00
	TC2	0.33	0.33	6.50	0.00	4.40	3.89	6.11	3.00	1.33	1.67	4.00
	TC3	2.67	1.20	5.80	6.70	6.70	7.20	5.00	2.33	3.67	5.00	2.00
	TC4	1.00	0.67	2.20	1.10	2.33	1.33	2.00	8.00	7.67	2.67	14.00
	TC6	1.44	1.33	1.20	1.60	0.00	2.80	5.60	2.00	3.67	3.00	3.33
wood-ash	TC1	1.11	1.33	5.60	3.33	4.67	0.33	0.67	8.00	3.00	1.67	6.67
	TC2	4.78	7.71	1.33	2.07	5.60	3.33	8.33	7.67	5.00	2.67	10.67
	TC3	7.77	7.70	1.00	2.96	1.10	8.33	4.72	6.67	10.00	4.67	6.67
	TC4	0.67	1.30	7.00	10.00	8.90	2.67	2.00	4.00	0.67	1.00	5.33
	TC6	1.67	1.89	3.89	4.67	0.00	5.00	4.00	7.00	6.00	4.67	9.67
Control	TC1	1.11	1.26	8.00	2.20	0.40	9.40	1.70	2.22	1.30	0.67	0.33
	TC2	0.33	4.56	4.30	1.33	2.00	1.67	2.00	3.33	0.33	7.80	1.33
	TC3	3.77	1.00	2.10	1.67	0.67	9.40	4.20	7.00	3.00	1.67	5.00
	TC4	3.33	1.13	1.11	1.48	4.90	2.20	3.33	2.33	2.70	8.90	3.33
	TC6	0.67	1.80	8.30	1.18	2.33	0.33	1.50	3.33	2.00	0.67	3.00
LSD 0.05		0.66	0.31	1.08	1.76	0.49	0.92	0.69	2.51	1.71	1.09	2.19

Means in same column followed by same letter (s) are not significantly different at 0.05% probability

Comment [h42]: In the methodology this treatment combination shall be stated. But not. so how this result was recorded?

Discussion

Effects of NPK fertilizer and wood-ash on the number of flower in cacao during light and main seasons.

Comment [h43]: This sub titles those constructed with this, does not represent the means of study.

Flowers development during light and main seasons were enhanced with sole application of wood-ash treatment. This was in conformity with the findings of Wiklund (2017) who reported that application of wood-ash increased flowers and pods productions of plants. Combine application of NPK with wood-ash treatment was found to enhanced flower production which was justified by the report of Boan, (2009) that the use of plant derivative ash as source of potassium (K) in place of expensive potassium fertilizer on cocoa plant increased the availability of potassium (K) and magnesium (Mg) in soil and potassium content in plant tissue for enhanced flowering and pod yield.

Higher number of cherelle was recorded during light and main seasons of the experiment on cacao stands treated with sole application of NPK fertilizer and wood-ash treatments was in line with the findings of Moyin-Jesu (2008) that NPK attributes to quicker release of major nutrients to plants. While Smolka-Danielowska (2022) reported that wood-ash contains basic elements such as Al, Si, P, Na, K, Mg, Ca and Fe. The findings was also supported by the Akanbi *et al*., (2014) who reported that oil palm bunch ash contains high nutrient elements such as Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), and Magnesium (Mg)for enhanced growth and development in crops.

NPK with wood-ash treatment significantly increased the number of pods at 10 and 18 weeks after treatment application compare to other treatments and the control during the light season of the experiment. This was in conformity with the study of Goudsmit*et al*. (2023), who described the effects of fertilizer treatments on cacao pod development and pod nutrient content.According to Bote (2016) and El-Motaium*et al*. (2019), seasonal difference in pod development could be attributed to seasonal growth in vegetation and tendency for treatments assimilation.

Comment [h44]: Very poor discussion without any relative author.

CONCLUSION

wood-ash contains beneficial nutrients or properties that positively influenced flower growth. The rate of floral development during the light and the main seasons was significantly influenced by the application of wood-ash. A synergistic impact from the application of wood-ash and NPK treatment also increased flower development during the main season. But at 46 weeks after the application of the treatments, it had a more pronounced effect compared to other treatments. The combination of NPK with wood-ash treatment had a positive influence on flower development especially on the TC6 variety at 4 weeks following treatment application. On the other hand, the TC3 variety flower development during the light and main season at weeks 6, 12, 14, 16, 28, 30, 34, 36, 40, 42, and 44 after treatment application were significantly improved by the single application of wood-ash treatment.

When compared to the control treatment, the use of NPK fertilizer and wood-ash treatments improved cherelle development during the light and main season at 10 and 14 weeks after treatment application. The main season cherelle development was positively impacted by the combine application of NPK fertilizer and wood-ash treatment, producing noticeable higher

number of cherellees than the control treatment. The application of sole and combined NPK and wood-ash had favorable effects on cherelle development in the cacao stands and improved the growth and performance of the varieties during light and main season as shown by the significantly higher number of cherelles recorded on these varieties across the weeks compared to the control treatment.

The combination of NPK and wood-ash fertilizer treatment had a positive effect on pod development during the light and main seasons of the experiment specifically at 10 and 18 weeks following treatment application. At 44 weeks after treatment application, combined application of NPK and wood-ash treatment had a favourable effect on pod development during the main season. At 46 weeks following treatment application, the sole application of wood-ash treatment had a favourable effect on pod development during the main season. It can be concluded that both combination of NPK with wood-ash and the sole application of wood-ash treatment had a positive effect on pod development during both seasons of the experiment. These treatments potentially enhanced the development and performance of the selected varieties.

RECOMMENDATIONS

Based on the findings from the study, flower, cherelle and pod developmental rate were significantly improved with the application of NPK, NPK with wood-ash and wood-ash treatments. These fertilizer treatments are therefore recommended for enhanced performance, development and yield of TC1, TC2, TC3, TC4 and TC6 varieties during light and main seasons. For optimum canopy development and enhanced assimilate production, utilization and storage in term of pod yield, application of NPK and wood-ash combinations is required in cacao production.

Comment [h45]: Out of scientific writing

Ethical approval and consent to participate: The research does not involve the use of animal nor human and therefore requires no ethical approval

Consent for publication: This is to affirm that all author approved the submission of the manuscript for publication.

Availability of Data: The data used for the write up of the manuscript is from a personal research work

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Comment [h46]:

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