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Influence of Ash from Oil Mill Boiler Emptying on Oil Palm Bunches Production

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Abstract

The use of organic fertilizers is less expensive and advantageous for both the development of the plant and the sanitation of the environment. This is why this investigation aims to promote the ash from emptying of oil mill boilers as a source of organic fertilization in the production of palm bunches. To do this, different doses of oil mill boiler emptying ash were tested on oil palms in production. The results showed that the oil palms responded favorably regardless of the dose of oil mill boiler emptying ash. Thus, the comparison of the different doses Tv1 (1 kg), Tv2 (1.5 kg), Tv3 (2 kg), Tv4 (3 kg), Tv5 (4 kg), Tv6 (5 kg) and Tv7 (7 kg) showed that the high doses led to an increase in the weight of the bunches. Better still, the Tv6 treatment at a dose of 5 kg/tree proved to be optimal for good production of palm bunches with a gain of 73.9% compared to the treatment without oil mill boiler emptying ash (absolute control).

Keywords

Ash, Bunch, Incinerated Oil Palm Bunch Roundups, Oil Palm, Côte d'Ivoire

1. Introduction

The oil palm (*Elaeis guineensis* Jacq.) is an oilseed plant of African origin (Gulf of Guinea). Its cultivation began in the 20th century in Southeast Asia [1]. This crop developed in Africa between the First and Second World Wars [2]. It, therefore, occupies a very important place in the Ivorian economy with a turnover of just over 500 billion CFA francs in 2018 and represented 3.13% of Ivorian GDP [3]. Thus, Côte d'Ivoire plans to increase its production to 800,000 tons by 2025 [4]. This ambitious program must be based mainly on respect for technical routes and the provision of high-performance plant material and fertilizers adapted to the environment for producers.

Declining soil fertility is a constraint on agricultural productivity in Côte d'Ivoire [5]. For oil palm cultivation production, potassium deficiency is the main one on ferralitic soils in West Africa and more specifically in Côte d'Ivoire [6]. Thus, potassium is the essential element for good production of palm bunches [7] and appears to be the first factor limiting oil palm bunch yields.

In addition, to obtain good yields, oil palm, grown on generally very altered tropical soils, requires fairly large quantities of fertilizers. One of the solutions for improving soils, compensating for nutrient losses and nutritional deficiencies observed in production systems is the enrichment of soils with organic matter using organic waste products in the form of amendments or fertilizers [8] [9].

Solid waste (condensates, oil palm bunch roundups, fibers, shells and broken almonds) is largely stored or incinerated (reduction to ash) without any special provision and thus clogs up the oil mills. This inappropriate waste management practice from oil palm exploitation residues leads to a net loss of nutrients for agricultural soils since this waste is no longer returned to the palm groves. Indeed, various research studies have highlighted the strong potential of oil palm residues as a source of nutrients and organic matter to improve soil fertility [10].

The use of ash as fertilizer can improve soil properties by increasing soil pH, particle density, porosity, and water-holding capacity [11] [12]. Their concentration varies depending on the biomass and the combustion method used [13]. Some studies have evaluated the fertilization capacity of biomass ash [14]. Others have suggested that ash could partially replace expensive synthetic fertilizers [14].

This study, therefore, aims to enhance the ash from the oil mill boiler emptying as a source of organic fertilization in order to improve the production of oil palm bunches. Specifically, it involves performing the granulometric analysis of the oil mill boiler emptying ash and determining the optimal dose of this ash for improving the production of oil palm bunches.

2. Materials and Methods

2.1. Study Site

The study was conducted at the CNRA experimental station of La Mé, located in the South-East of Côte d'Ivoire, 24 km from Abidjan. The geographical coordinates of this station are 05˚26' North latitude and 03˚50' West longitude. The climate is humid subtropical, with distinct seasons. It also has characteristics of the Attiéan climate on the coastal edge. The soil, derived from tertiary sands, is ferralitic and highly desaturated and low in potassium [15]. It is deep, sandy on the surface and does not contain coarse elements. The clay present in this soil is mainly kaolinite and has a low exchange capacity.

2.2. Plant Material

The plant material used consisted of ten (10) year-old oil palms. These palms come from the C1001F seed category selected and popularized by the CNRA. This seed category used since 1995 comes from the second cycle of reciprocal recurrent selection [6]. It has a production potential of 25 tons of bunches/ha/year, an oil content of 26% and an industrial extraction rate of between 22 and 23% [6]. It is also characterized by early productivity in bunches, strong resistance to *fusarium* and an economic exploitation period of approximately 30 years. It is currently popularized in the Ivorian oil palm growing areas for the creation of all plantations in Côte d'Ivoire.

2.3. Fertilization Equipment

The fertilization equipment consists of potassium chloride (KCl), an oil mill boiler emptying ash, and incinerated oil palm bunch roundups of ash. The ash from the oil mill boiler emptying is ash from the combustion of oil palm bunches harvesting residues to fuel the oil mill engine. These residues are composed of oil palm seed fibers and seeds without their pulp. This emptying will serve as a test while the KCl and the ash from the incineration of oil palm bunch roundups will serve as a control.

2.4. Experimental Device

Different quantities of oil mill boiler emptying ash, KCl dose recommended by Kouamé *et al.* [6] (2 kg/oil palm) and quantity of incinerated oil palm bunch roundups ash recommended by Uribe and Bernal [16] (2 kg/oil palm), constituted the different treatments (**Table 1**). The experimental design was in completely randomized Fisher blocks of ten (10) treatments in three (3) repetitions, or thirty (30) micro-plots. Each micro-plot was composed of four (4) trees.

Table 1. Different treatments applied to oil palms.

Treatments	Designations
Ta	Without organic or mineral fertilization (Absolute control)
Tr1	Potassium chloride [2 kg per tree (Relative control 1)]
Tr2	Incinerated oil palm bunch roundups ash [2 kg per tree (Relative control 2)]
Tv1	Oil mill boiler emptying ash (1 kg per tree)
Tv2	Oil mill boiler emptying ash (1.5 kg per tree)
Tv3	Oil mill boiler emptying ash (2 kg per tree)
Tv4	Oil mill boiler emptying ash (3 kg per tree)
Tv5	Oil mill boiler emptying ash (4 kg per tree)
Tv6	Oil mill boiler emptying ash (5 kg per tree)
Tv7	Oil mill boiler emptying ash (7 kg per tree)

Ta: Absolute control; **Tr:** Relative control; **Tv:** Oil mill boiler emptying ash.

2.5. Spreading Fertilizers

In order to better appreciate the influence of fertilizers on the production of palm bunches, a ten (10) year old palm grove which had not benefited from fertilizer for more than five (5) years was chosen to set up the test. Before spreading the fertilizers, circles with a radius of 2 m were first made around the feet of the oil palm trees. Regardless of the nature of the fertilizer, the different quantities to be spread were measured using templates. These different quantities of fertilizers were spread on the surface of the circles, starting from 1 m from the feet of the oil palm trees. To do this, gloves were used to avoid any bodily contact with these fertilizers.

The spreading of fertilizers was carried out during the short rainy season, particularly in September 2024. The trial monitoring, in order to determine the influence of fertilizers on agronomic parameters, particularly the weight of the bunches, lasted eight (8) months from September.

2.6. Granulometric Parameters of Oil Mill Boiler Emptying Ash

The particle size analysis represents the mass distribution of particle sizes of the ash from oil mill boiler emptying compared to those of the ash from incinerated oil palm bunch roundups. To do this, 1 kg of each of these ashes (oil mill boiler emptying and incinerated oil palm bunch roundups) was sampled and individually sieved using a laboratory sieve at the amplitude of 3.0 for five (5) minutes. The mass of each fraction collected according to the mesh dimensions of the sieves constituting the sieve device was determined by weighing. At each mesh dimension of the sieves, the masses of the fractions collected were compared with each other, according to their nature (oil mill boiler emptying and incinerated oil palm bunch roundups).

2.7. Agronomic Parameters

The measurements were carried out on all the useful trees. The data concerned the number and weight of the bunches harvested per treatment. The harvest of the oil palm bunches was carried out every fifteen (15) days using a sickle. At each harvest, the number of bunches harvested per treatment was determined by counting. By treatment, the weights of the bunches harvested including detached seeds were determined by weighing. The number of bunches (NB) and the total weight of the bunches (TWB) made it possible to determine the average weight of the bunches (PMR) by treatment according to the following formula:

$$\mathbf{AWB} = \frac{\mathbf{TWB}}{\mathbf{NB}}$$

AWB: average weight of bunches; **TWB:** total bunches weight; **NB:** number of bunches.

2.8. Statistical Analysis

The collected data was processed using SAS software version 9.4. Normality verification tests were performed to perform parametric statistical tests. As normality was respected, the studied variants were compared by a fixed-factor analysis of variance. Comparisons of means were made at the $p = 0.05$ threshold using the Student Newman-Keul test.

3. Results and Discussion

3.1. Granulometric Analysis of Incinerated Oil Palm Bunch Roundups and Oil Mill Boiler Emptying Ash

The coarse elements were composed of particles that could not pass the 1 mm mesh. The analysis of Table 2 reveals that the ash from the oil mill boiler emptying was more composed of coarse elements (46%) than the ash from the incineration of oil palm bunch roundups (26%). Conversely, the content of fine elements in the oil mill boiler emptying ash (54%) was lower, compared to that of the incinerated oil palm bunch roundups ash (74%). This concentration of fine elements in the oil mill boiler emptying ash would affect its capacity to be dissolved to be available to the oil palm through root absorption. Therefore, it would not be surprising to observe that the Tr2 treatment (fertilization with 2 kg of incinerated oil palm bunch roundups ash per tree) and those based on high doses of oil mill boiler emptying ash express comparable effects, due to their abundance in fine elements. Similar results were observed by Miserque and Pirard [17] who emphasized that the coarse element content of fertilizers influences their qualities.

Table 2. Contents of incinerated oil palm bunch roundups and ash from emptying of oil mill boiler in coarse and fine elements.

Fertilizer components	Mesh size	Refusal of oil mill boiler emptying ash	Refusal of incinerated oil palm bunch roundups ash
Coarse elements	2 mm	28%	12%
	1 mm	18%	14%
	Total	**46%**	**26%**
Fine elements	500 µm	32%	54%
	250 µm	18%	18%
	150 µm	4%	2%
	Total	**54%**	**74%**

3.2. Number of Oil Palm Bunches according to Different Treatments

Although the concentration of the oil mill boiler emptying ash in fine elements would affect its ability to be dissolved to be available to oil palm through root absorption, the analysis of Table 3 shows that there is no significant difference between the numbers of oil palm bunches regardless of the treatment applied to the trees ($p > 0.05$). However, a high variability was observed between treatments (Table 3). This independence of the number of bunches is linked to the short duration of the test. Indeed, in oil palm, the influence of the application of fertilizer on the number of oil palm bunches is perceptible 24 months later [18].

Table 3. Number of oil palm bunches according to the different treatments.

Treatments	NB
Ta	1.65 ± 0.9[a]
Tr1	1.88 ± 0.95[a]
Tr2	2.05 ± 1.45[a]
Tv1	1.78 ± 1.35[a]
Tv2	1.68 ± 1.12[a]
Tv3	1.64 ± 0.98[a]
Tv4	1.81 ± 0.91[a]
Tv5	1.98 ± 1.46[a]
Tv6	2.21 ± 1.9[a]
Tv7	2.02 ±1.87[a]
F	0.090
p	0.529

In each column, the mean values assigned the same letter are not significantly different (Newman-Keuls test at 5%). **NB:** number of bunches; **Ta:** absolute control; **Tr:** relative control; **Tv:** oil mill boiler emptying treatment.

3.3. Total Weight and Average Weight of Oil Palm Bunches according to Different Treatments

Unlike the number of bunches, the different treatments significantly influenced the production of oil palm (p = 0.0003) (**Table 4**). The analysis of this table shows an increase in the production of bunches with the oil mill boiler emptying dose. This was not the case for the coefficients of variability which varied independently of the treatments. The treatment without fertilizer (**Ta**: absolute control) showed the lowest oil palm bunch production values (Total weight: 19.58 ± 14.45 kg; Average bunches weight: 11.26 ± 1.15 kg/bunch). These values were statistically identical to those obtained with the chemical fertilizer KCl (Total weight: 20.98 ± 12.84 kg; Average bunches weight: 11.71 ± 0.75 kg/bunch) and the oil mill boiler emptying ash at the lowest dose (Total weight: 21.17 ± 12.68 kg; Average bunches weight: 12.78 ± 0.49 kg/bunch). On the other hand, the **Tv7** treatment with the highest dose of oil mill boiler emptying generated the highest oil palm bunch production values (Total weight: 35.17 ± 27.64 kg; Average bunches weight: 16.08 ± 0.91 kg/bunch). In terms of total bunch weight, this value displayed by the **Tv7** treatment was statistically identical to those presented by the **Tr2** (27.47 ± 17.06 kg), **Tv3** (24.14 ± 15.43 kg), **Tv4** (25.75 ± 18.58 kg), **Tv5** (29.08 ± 22.02 kg) and **Tv6** (34.05 ± 27.51 kg) treatments.

Furthermore, treatments based on oil mill boiler emptying ash, whatever their doses, caused production gains compared to the chemical treatment recommended by Kouamé *et al.* [6] [**Tr1**: 2 kg of KCl per tree, (relative control 1)] and to the treatment without fertilizer (Ta: absolute control) (**Table 5**). These results attest that oil mill boiler emptying ash contains more nutrients for the production of oil palm bunches than chemical products do. It would, therefore, be advantageous to favor the use of oil mill boiler emptying ash over that of chemical fertilizers, in particular KCl, the purchase cost of which continues to increase.

Table 4. Total weight and average weight of oil palm bunches according to different treatments.

Treatments	TWB (kg)	AWB (kg/bunch)
Ta	19.58 ± 14.45c	11.26 ± 1.15d
Tr1	20.98 ± 12.84c	11.71 ± 0.75d
Tr2	27.47 ± 17.06ab	15.22 ± 1.13ab
Tv1	21.17 ± 12.68c	12.78 ± 0.49cd
Tv2	22.52 ± 17.18b	13.05 ± 1.31cd
Tv3	24.14 ± 15.43ab	13.15 ± 1.11cd
Tv4	25.75 ± 18.58ab	14.51 ± 0.45bc
Tv5	29.08 ± 22.02ab	14.86 ± 0.27bc
Tv6	34.05 ± 27.51a	15.92 ± 0.74a
Tv7	35.17±27.64a	16.08± 0.91a
F	13.16	13.16
p	0.0001	0.0001

In each column, the mean values assigned the same letter are not significantly different (Newman-Keuls test at 5%). **Ta:** absolute control; **Tr:** relative control; **Tv:** oil mill boiler emptying treatment; **AWB:** average weight of bunches; **TWB:** total bunches weight.

Table 5. Oil palm bunch production gains by treatment and compared to different controls.

Treatments	TWB (kg)	Gain compared to Ta (%)	Gain compared to Tr1 (%)	Gain compared to Tr2 (%)
Ta	19.58	-	−6.7	−28.7
Tr1	20.98	7.2	-	−23.6
Tr2	27.47	40.3	30.9	-
Tv1	21.17	8.1	0.9	−22.9
Tv2	22.52	15.0	7.3	−18.0
Tv3	24.14	23.3	15.1	−12.1
Tv4	25.75	31.5	22.7	−6.3
Tv5	29.08	48.5	38.6	5.9
Tv6	34.05	73.9	62.3	24.0
Tv7	35.17	79.6	67.6	28.0

Ta: absolute control; **Tr:** relative control; **Tv:** oil mill boiler emptying treatment; **TWB:** total bunches weight.

Similarly, only treatments **Tv5**, **Tv6**, **Tv7**, at doses greater than or equal to 4 kg of oil mill boiler emptying ash, generated production gains compared to fertilization based on incinerated oil palm bunch roundups ash (relative control 2) as recommended by Uribe and Bernal [16] (2 kg per tree). These results highlight the value from which the use of oil mill boiler emptying ash is better expressed, compared to the use of incinerated oil palm roundups ash recommended by Uribe and Bernal [16].

According to Goh [18], only production in terms of total weight of bunches (TWB), and by extension the average weight of bunches (AWB), is observable in the short time. This could justify the discrimination between treatments with respect to the production of oil palm bunches. This discrimination based on production in terms of weight is explained by the fact that the inflorescences and immature bunches present on the oil palms during the trial absorbed the necessary minerals from the fertilizers for the proper functioning of their metabolism until their maturity.

The analysis of the mineral contents recorded in **Table 6** shows that the different ashes used in the experiments are distinguished by their very high potassium content followed by that of magnesium. The improvement in the production parameters (TWB and AWB) observed during the experiment could be due to the fact that the oil mill boiler emptying is rich in potassium since, according to Caliman *et al.* [19], fertilization for the production of oil palm bunches is dominated by potassium. This assertion could be confirmed by the fact that oil mill boiler emptying ash treatments, whatever their doses, expressed gains compared to chemical treatment (**Tr1**: 2 kg KCl per tree) and to treatment without fertilizer. This potassium privilege in favor of oil palm production has been confirmed by previous studies conducted in Cameroon by Rafflegeau [20] and in Southeast Asia by Jamaluddin *et al.* [21]. The work of Ballo [22] also showed that potassium fertilizers increase the yield of oil palm bunches by 35% on ferralitic soils of southeastern Côte d'Ivoire. However, the production gains expressed by oil mill boiler emptying ash treatments compared to the 2 kg KCl/tree recommended by Kouamé *et al.* [6] could be due to the content of the oil mill boiler emptying ash with other fertilizing elements, especially magnesium which is important in the production of palm regimes [1].

Table 6. Main mineral contents of ash.

Mineral elements	Mineral element contents (% d.m)	
	Oil mill boiler emptying ash	Incinerated oil palm bunch roundups ash
N	0.86	0.81
P	1.41	2.32
K	21.72	26.00
Ca	5.27	7.23
Mg	18.14	20.14

N: nitrogen; **P:** phosphorus; **K:** potassium; **Ca:** calcium; **Mg:** magnesium; **d.m:** dry matter.

Furthermore, the comparison of the different doses of oil mill boiler emptying ash showed that high doses led to an increase in bunch weight. This increase in the dose of oil mill boiler emptying ash could be an excellent indicator of its positive effect on oil palm bunch production. Thus, only treatments with doses greater than or equal to 4 kg of oil mill boiler emptying ash generated gains compared to fertilization based on 2 kg of ash from incinerated oil palm bunch roundups recommended by Uribe and Bernal [16]. This highlights the importance of determining an optimal dose of oil mill boiler emptying ash adapted to the different ages of oil palm, taking into account the increasingly unfavorable pedoclimatic context. In the present study, the dose of treatment Tv6 (5 kg of oil mill boiler emptying ash per tree) was found to be optimal since its increase from 5 to 7 kg of oil mill boiler emptying ash per tree (Tv7) certainly increased the average weight of bunches but this increase did not generate a statistically significant difference.

4. Conclusion

According to the present investigation, it should be noted that the physical state of the oil mill boiler emptying ash has an influence on its dissolution and mineralization capacity. For the production of oil palm bunches, with the exception of the number of bunches, the oil palms reacted favorably to this production regardless of the dose of the oil mill boiler emptying ash provided, thus increasing the total and average weight of the oil palm bunches. However, the comparison of the different doses of this ash showed that the high doses led to an increase in the weight of the bunches. In addition, this oil mill boiler emptying ash at a dose of 5 kg per tree proved to be optimal for good production of oil palm bunches with a gain of 73.9% compared to the control without oil mill boiler emptying ash.

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Conflicts of Interest

The authors declare that there is no conflict of interest.

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