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# EVALUATION OF THE EFFECTIVENESS OF THE CONTRIBUTION OF AGRICULTURAL LIME AND NATURAL PHOSPHATE OF TILEMSI (PNT) ON THE PRODUCTION OF COTTON AND CORN IN THE PRODUCTION SYSTEM OF FARMS IN THE MALI-SOUTH ZONE

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## ABSTRACT

In the south of the Sahara, the cultivation of land leads to a rapid decrease in nutrients and the appearance of deficiencies in nitrogen, phosphorus, magnesium, calcium, and other elements. The major constraint of production in this area on agricultural soils is the low level of soil fertility. The objective of this study was to evaluate the effects of different amendment formulas on cotton and maize yields as well as their financial returns in order to propose a recommendable formula. To achieve this objective, the experimental set-up used was a dispersed series of five treatments of 3125 m² per school field in 6 villages in the circles of Sikasso, Koutiala and Bougouni, with each village constituting a replication. Four formulations were tested in addition to the farmer's practice, namely (i) agricultural lime (300 Kg/ha) combined with 300 Kg/ha of TNP, (ii) agricultural lime (500 Kg/ha) combined with 500 Kg/ha of TNP, (iii) agricultural lime at a dose of 300 Kg/ha and agricultural lime at a dose of 500 Kg/ha. Analysis of the results shows that the effect of the amendments varies according to the site (soil acidity level). The best marginal rates of return were recorded in Sikasso with T5 (665%), which is well above the recodable minimum (50-100%), followed by T2 (195%) at the same site. The T4 treatment remains the optimal treatment in Koutiala because it has the lowest recommendation rate (52%) compared to the farmer's practice. We also noted that all treatments in Bougouni were dominated by the farmer's practice. With respect to the evaluation of after-effects, treatments T4 and T3 remain the satisfactory treatments in Bougouni, while in Sikasso it is T4 and T2 provided the best after-effects.

**Keywords:** Agricultural Lime, Natural Phosphate Of Tilemsi (Pnt) And Production Of Cotton.

## 1. INTRODUCTION

South of the Sahara, the cultivation of land leads to a rapid decrease in nutrients and the appearance of deficiencies in nitrogen, phosphorus, magnesium, calcium and other various elements (Yoni et al., 2005). The major constraint to production in this zone on agricultural soils is the low level of fertility of these soils (Saïdou et al., 2009). Magnesium, calcium and phosphorus deficiency is widely considered to be the major constraint to agricultural production in low-input farming systems in Mali (Kouyaté et al., 2020). They constitute the limiting factors of soil production without which the application of other mineral elements (NPK and urea) will not lead to a significant increase in crop yield. Thus, the increase in yields and agricultural productivity in the southern Sahara requires the contribution of phosphorus (P), Calcium (Ca) and magnesium (Mg) for the correction of soil pH and to maintain the level. constant soil fertility.

The soils of this zone have a medium to coarse texture, sandy loam (LS) to fine sandy loam (SL), quite poor in clay. These soils are easy to work with good water infiltration, plants have easy access to water. The pH is a good indicator of the physico-chemical atmosphere of a soil and its value varies from 0 to 14, values below 7 indicate an acid environment, those above 7 correspond to a basic character. The water pH as opposed to that measured in a KCl-based suspension for plants in the southern Sahara are below the major threshold which is to be considered 5.5; the value for which the presence of exchangeable aluminum leads to risks of aluminum toxicity for many crops such as corn, sorghum, rice, tobacco, cotton.

Several studies have been conducted to evaluate the impact of the combination of natural phosphate of Tilemsi (PNT) with organic matter in order to improve the phosphate nutrition of crops. The results of these studies showed positive effects of this combination on the agronomic efficiency of natural phosphates characterized by their low reactivity (FAO, 2004; Gholizadeh et al., 2009).

The combination of PNT and ammonium sulphate improves the dissolution of PNT and the release of P (Fageria et al. 2010). According to Kouyaté et al. (2020) ammonium sulphate beyond supplying a significant amount of nitrogen (N) and sulfur (S), acidifies the soil thus creating a favorable environment for the dissolution of PNT. Fageria et al., 2010 and Serme et al., 2015 claimed that soil pH decreases linearly with the application of N by ammonium sulfate and urea. According to Kouyaté et al. (2020) the magnitude of the pH drop is greater with ammonium sulphate than with urea. If the impact of the association of PNT with acidifying fertilizers such as (NH4) 2SO4 and KCl as well as the dose of PNT which increases its solubility and significantly improves its agronomic efficiency in a characterized ecosystem by erratic rainfall in terms of quantity and distribution in the Sahelian zone of Mali have been assessed by Kouyaté et al. (2020), there is a very urgent need to evaluate the effect and aftereffect of dolomite lime alone and in combination with NTP on cotton and maize production in the cotton zone of Mali. The objective of this study is to evaluate the effects of different amendment formulas on the yields of cotton and maize as well as their financial profitability in order to propose a recommendable formula.

## 2.MATERIAL AND METHOD

### plant material

For the evaluation of the effect, the variety used is BRS 293 R2 cotton with a cycle of 120 to 150 days and a station yield of 3 t/ha,

For the after effect, the variety used is Sotubaka maize with a cycle of 120 days and a station yield of 5 t/ha.

Chemical composition of fertilizers and amendments used

Complex- Cotton N.P.K.S.B (14N-18P-18K-6S-1B) = 150 kg/ha,

Urea 46% N = 50kg/ha

N.P.K Cereal Complex (17N-17P-17K)
Phytosanitary products (insecticides)
Agricultural lime from CCM-SA (31% Cao, 20% MgO and 6% SiO2)
The natural phosphate of Tilemsi (PNT)
Organic manure (OM)

**Experimental apparatus**

The experimental device used was a scattered series of five treatments with an area of 3125 m² per field school in 6 villages in the circles of Sikasso, Koutiala and Bougouni. Each village constitutes a repetition.

Plot dimensions:

- Elementary plot (P E): 25 m x 25 m or 625 m²;
- Distance between plots is 0.50 m;

 Treatments

The treatments adopted are as follows:

T1 = control (farmer practice) + 5T/ha of OF with popularized dose of mineral fertilizer;

T2 = 300 Kg/ha of agricultural lime (CCM) + 300 Kg/ha of PNT + 5T/ha of OF + dose of mineral fertilizer;

T3 = 500 Kg/ha of agricultural lime (CCM) + 500 Kg/ha of PNT + 5T/ha of OF + popularized dose of mineral fertilizer.

T4 = 300 Kg/ha of agricultural lime (CCM) + 5T/ha of OF + popularized dose of mineral fertilizer;

T5 = 500 Kg/ha of agricultural lime (CCM) + 5T/ha of OF + popularized dose of fertilizer.

Sowing: cotton at spacings of 0.80 m x 0.30 m and corn at spacings of 0.75 x 0.50 m

The dose of mineral manure popularized for cotton is 150 Kg/ha of cotton complex and 50 Kg/ha of urea,

The dose of popularized mineral manure for maize is 100 kg/ha of cereal complex and 150 kg/ha of urea for maize.

**Measurement and observation of cotton tests**

The measurements and observations related to the following parameters: the density, the number of capsules, the average capsule weight and the yield. The density of plants at harvest was determined from counting the number of plants, the number of capsules over 100m² in each elementary plot. The number of plants on the 100m² of each 10m x 10m square was extrapolated per hectare to obtain the density of plants per hectare and the number of capsules per hectare. The average capsule weight was evaluated from the weight of 100 weighed capsules. The yield was evaluated from the plot production of each treatment.

**Calculation of income, expenses and gross margins of cotton tests**

The economic analysis was based on the partial budget approach. Fixed cost elements were not taken into account because they were assumed to be the same for the different treatments (cereal complex, urea, organic manure, labour, other production costs). The additional cost elements were calculated on the basis of the additional inputs made according to the treatments. These inputs include agricultural lime and PNT. The additional cost of each input was considered to be the quantity of the input multiplied by its acquisition price. The variable costs per treatment are therefore the sum of the costs of the various inputs used. The gross value of production was calculated on the basis of the average yield obtained by the selling price of seed cotton at 275 FCFA per kilogram. All calculation values for costs and margins have been estimated per hectare. The gross margin was obtained by subtracting from the gross production value the variable costs induced by each treatment. The marginal rate of return (MRR) was calculated by comparing the increase in variable costs resulting from switching from one option to a more expensive one with the corresponding increase in gross margin. The marginal rate of return is by definition the ratio of the marginal gross margin to the marginal variable costs expressed as a percentage.

**Maize Test Measurements and Observations**

The density of plants at washing and harvesting was determined from counting the number of plants and the number of pockets in each elementary plot. The number of plants on the 625 m² of each elementary plot was extrapolated per hectare to obtain the density of plants per hectare and the same for the number of pockets per hectare. The number of missing pockets was determined by counting the empty pockets at the level of each elementary plot and was extrapolated per hectare to obtain the number of empty pockets per hectare. The grain yield was evaluated from the plot production of each treatment.

**Data analysis**

The analysis of variance followed by the comparison of the means according to the Newman and Keuls test was used for processing the agronomic data using the STATA software (version 15). Treatment effects were considered significant when the probability $p<0.05$.

The economic data collected was entered and analyzed using SPSS and Excel software. The results related to the mean, sum, standard deviation, frequency, etc.

The variable production costs (CV) were calculated with the formula:

$$CV = \sum_{i}^{n} Q_i PU_i$$

With Q: the quantity of input i; PU: the unit price corresponding to input i and n: the number of inputs used in the production of the speculation considered (cotton and maize).

Profitability indicators such as gross product and gross margin were assessed.

The gross product in value (PBV): PBV = Yield * PU.

Gross margin (MB): MB = PBV – CV.

The rate of return: TR = MB/CV

## 3.RESULTS

Evaluation of the effect of amendments on cotton yield indicators

At the level of T1, Kléla recorded the best average density of plants/ha followed by Koutiala and the lowest was observed in Faragouaran. The highest average number of bolls/ha was observed in Koutiala followed by Kléla. The best average capsule weight (kg) was recorded in

Faragouaran, Zantiébougou, Kléla and Kignan followed by Molobala and Koutiala recorded the lowest average capsule weight (Table 1).

At the level of T2, Zantiébougou comes first in terms of average density of plants/ha followed by Kléla and Koutiala in last position with the lowest density (Table 1). This low density has a negative impact on yield. The average number of capsules/ha is higher respectively in Zantiébougou, Kléla, and Koutiala. However Molobala recorded the lowest density per hectare.

In terms of average capsular weight in kg, a similar trend to T1 was observed for T2 (Table 16).

At the level of T3, the best density of plants per hectare was observed in Kléla followed by Koutiala and Kignan recorded the lowest density (Table 1). Zantiébougou recorded the average number of bolls/ha followed by Koutiala and Kléla respectively. As for the average capsular weight in kg, a similar trend was observed for the three treatments (T1, T2 and T 3). These different parameters play a major role in determining yields.

**Table 1: Performance indicators for the different treatments**

| Circle | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| **Density of plants per hectare** | | | | | |
| Bougouni | 32880±14595 | 45360±17310 | 42240±18328 | 44880±11201 | 28920±28680 |
| Koutiala | 42 250±19 304 | 32 400±1 697 | 49 000±9 899 | 44 350±1 626 | 37 700±16 546 |
| Sikasso | 53038±5427 | 34965±0 | 43225±7814 | 44425±13188 | 64125±0 |
| **Number of capsules per hectare** | | | | | |
| Bougouni | 195376±259401 | 347280±163936 | 283840±3168 | 279120±226387 | 263640±311070 |
| Koutiala | 219 050±304268 | 199 850±233982 | 248 500±315794 | 245 100±310986 | 182 650±225214 |
| Sikasso | 284 213±199987 | 465 075±0 | 236 650±167372 | 222 388±207872 | 433 350±0 |
| **Average capsule weight** | | | | | |
| Bougouni | 3,5±0 | 3,5±0 | 3,5±0 | 3,5±0 | 3,5±0 |
| Koutiala | 3,2±0 | 3,2±0 | 3,2±0 | 3,2±0 | 3,2±0 |
| Sikasso | 3,5±0 | 3,5±0 | 3,5±0 | 3,5±0 | 3,5±0 |

**Assessment of the effect of amendments on yield**

The analysis of variance (ANOVA) shows there is no significant difference between the treatments in Bougouni. On the other hand, T 3 gives the best performance followed by T1 and T2. A contrary trend was observed in Koutiala. In this site, the analysis of variance shows a significant difference between T3 and T1. However, it did not show any significant difference between T2 and T3. Unlike the first two sites (Bougouni and Koutiala), T1 and T3 differ significantly in Sikasso (Table 2)

**Table 2: Average yield (kg/ha) of seed cotton in demonstration tests**

| Site | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| Bougouni | 1720 [a] ±640 | 1904 [a] ±573 | 1400 [a] ±979 | 1456 [a] ±792 | 1672 [a] ±1089 |
| Koutiala | 768 [a] ±973 | 840from±911 | 884b ±984 | 548 [from±1171] | 640 [b] ±792 |
| Sikasso | 1088 [a] ±679 | 976 [b] ±1030 | 1032 [b] ±1041 | 1000 [b±532] | 1552 [b] ±1097 |

Note: The figures in the same row affected by the same letter indicate that there is no significant difference between the yields of the said treatments at the 5% significance level.

**Evaluation of the economic profitability of the amendments**

The analysis of the different cropping systems shows that the best yields were obtained with the T3 treatment (500 kg ha-1 of lime + 500 kg ha-1 of PNT + 500 kg ha-1 of OF). However, the highest gross margin was obtained with treatment T1 (Control) in Bougouni followed by T3 (500 kg ha-1 of lime + 500 kg ha-1 of PNT + 500 kg ha-1 of OF). By comparing the increase in variable costs caused by switching from one option to another more expensive one with the corresponding increase in the gross margin, the results of the analysis indicate that the treatments T2, T3 of the two blocks are options dominated in Bougouni. In Koutiala, treatments T2, T3 and T5 are the dominated options. On the other hand, in Sikasso, the dominated treatments are T3 and T4. A treatment is said to be “dominated” when there is at least one option offering a higher gross margin (or profit) for lower or equal charges. In Bougouni, there is no optimal treatment because all amendment treatments were dominated treatments. In Koutiala, the T4 treatment remains the optimal treatment because it has the best marginal rate of return. On the other hand, in Sikasso it is the T5 treatment which obtains the best marginal rate of return and therefore appears to be the most satisfactory treatment.

**Table 3: Economic evaluation of the effect of the amendments**

| Sites | Trait. | Rdt (kg/ha) | PU (FCFA/kg) | PBV, (FCFA/ha) | CCM costs (FCFA/ha) | NWP costs, (CFAF/ha) | CV, (FCFA/ha) | MB, (FCFA/ha) | Dominated treatment (D) |
|---|---|---|---|---|---|---|---|---|---|
| Bougouni | T1 | 1 720 | 275 | 473 000 | - | - | 0 | 473 000 | |
| | T2 | 1 688 | 275 | 464 200 | 21000 | 10 800,00 | 31 800,00 | 432 400 | D |
| | T3 | 1 904 | 275 | 523 600 | 35000 | 18000 | 53 000,00 | 470 600 | D |
| | T4 | 1 400 | 275 | 385 000 | 21000 | - | 21 000,00 | 364 000 | D |
| | T5 | 1 672 | 275 | 459 800 | 35000 | | 35 000,00 | 424 800 | D |
| Koutiala | T1 | 768 | 275 | 211 200 | - | - | 0 | 211 200 | |
| | T2 | 700 | 275 | 192 500 | 21000 | 10 800,00 | 31 800,00 | 160 700 | D |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | T3 | 840 | 275 | 231 000 | 35000 | 18000 | 53 000,00 | 178 000 | D |
| | T4 | 884 | 275 | 243 100 | 21000 | - | 21 000,00 | 222 100 | |
| | T5 | 640 | 275 | 176 000 | 35000 | | 35 000,00 | 141 000 | D |
| Sikasso | T1 | 1 088 | 275 | 299 200 | - | - | 0 | 299 200 | |
| | T2 | 1 456 | 275 | 400 400 | 21000 | 10 800,00 | 31 800,00 | 368 600 | |
| | T3 | 976 | 275 | 268 400 | 35000 | 18000 | 53 000,00 | 215 400 | D |
| | T4 | 1 032 | 275 | 283 800 | 21000 | - | 21 000,00 | 262 800 | D |
| | T5 | 1 552 | 275 | 426 800 | 35000 | | 35 000,00 | 391 800 | |

**Table 4: Marginal Rates of Return on Recommendable Options**

| Sites | Treatments | Charges variables, (FCFA/ha) | Marginal variable costs, (CFA francs/ha) | Gross margin, (FCFA/ha) | Gross marginal margin, (FCFA/ha) | Marginal rate of return, MRR (%) |
|---|---|---|---|---|---|---|
| Koutiala | T4 | 21 000 | 21 000 | 222 100,00 | 10 900 | 52% |
| | T1 | 0 | | 211 200,00 | | |
| Sikasso | T5 | 35 000 | 3 200 | 391 800,00 | 21 280 | 665% |
| | T2 | 31 800 | 31 800 | 368 600,00 | 62 040 | 195% |
| | T1 | 0 | | 299 200,00 | | |

**Assessment of the rear effects of amendments on maize yield indicators**

In Bougouni, the T1 treatment recorded the highest number of pockets per hectare followed by Q3 with 27,032 pockets/ha and 25,464 pockets/ha respectively. The lowest number was observed in Q4 with 23,680 pockets/ha due to bird attacks at the time of germination. In Koutiala, Q5 recorded the highest number with 35,664 poquets/ha followed by Q3 with 32,916 poquets/ha. The number of pockets per hectare remains low in Siksso especially in Natoumana for all treatments compared to other production areas where the test on the one hand is on a soil (low glacis) with water stagnation during heavy rains and on the other hand has been the subject of bird attacks causing a lot of reseeding. Maize is a crop that is very sensitive to excess water and/or water deficit, lack of manure and weeds. The number of missing pockets varies by site and area. It is low in Bougouni and Koutiala for all treatments and high in Sikasso. In Bougouni, the treatment T5, recorded the highest density with 32,916 plants per hectare. It is followed by Q1 with 31,528 plants per hectare. The lowest density was observed at the T3 treatment level with 27,400 plants per hectare. The best test densities are recorded in Koutiala. Control T1

remains the densest treatment in plants with more than 41,000 plants per hectare. This is because the sowing periods in this area did not experience pockets of drought after sowing.
In Sikasso, the density of plants per hectare remains low compared to the other sites of the project as announced above. However, T4 treatment recorded the best density with 34,736 plants per hectare followed by T1 with 26,600 plants per hectare.

**Table 5: Corn Performance Indicators**

| Circle | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| **Number of pockets per hectare** | | | | | |
| Bougouni | 27032±147 | 25240±2387 | 25464±464 | 23680±181 | 23688±3089 |
| Koutiala | 25736±11461 | 25448±1346 | 32916±752 | 32560±7128 | 35664±6132 |
| Sikasso | 17552±1946 | 17632±2625 | 20544±3643 | 22296±3473 | 20592±2987 |
| **Number of missing pockets per hectare** | | | | | |
| Bougouni | 8592±7399 | 5472±1222 | 11632±10476 | 6336±3349 | 7336±2659 |
| Koutiala | 912±317 | 2584±260 | 2248±1120 | 2072±622 | 2184±1188 |
| Sikasso | 7384±1075 | 7728±1561 | 8552±5148 | 4496±2919 | 6976±204 |
| **Number of seedlings per hectare** | | | | | |
| Bougouni | 31528±8972 | 30248±3405 | 27400±3202 | 29376±11812 | 31848±12230 |
| Koutiala | 41288±4740 | 36648±5261 | 36568±3134 | 37424±882 | 39432±1459 |
| Sikasso | 26600±8044 | 24688±3960 | 24688±12671 | 34736±18192 | 25248±6924 |

***Assessment of the after-effects of amendments on maize yield***

Analysis of variance (ANOVA) shows that in Bougouni T5 differs significantly from other treatments (Table 6). On the other hand, Q3 gave the best grain yield with 2,993 Kg/ha of corn followed by T2 with 2,847 (Table 9). The same trend was observed in Koutiala. However, in this site, analysis of variance showed a significant difference between T2 and T3 treatments. Thus, a significant difference was observed between T4 and T5 and other previous treatments. Unlike the sites (Bougouni and Koutiala), T4 and T5 differ significantly from other Sikasso treatments.

**Table 6: Average maize yield (Kg/ha) from demonstration tests**

| Circle | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| Bougouni | 2 694a±415 | 2 847a±179 | 2 993a±363 | 2 512a±385 | 2 459b±414 |
| Koutiala | 2 472a±690 | 2 008a±283 | 2 088b±690 | 1 552c±724 | 1 648c±860 |
| Sikasso | 1 608b±1165 | 1 984b±1312 | 1 856b±1154 | 2 096ac±1561 | 1. 680ac±1154 |

Note: The figures in the same line affected by the same letter indicate that there is no significant difference between the yields of said treatments at the 5% significance level.

**Assessment of the economic profitability of the back-up effect of amendments on maize**

The analysis of the different cropping systems shows that the best maize yields were obtained with the T3 treatment (500 kg ha-1 of lime + 500 kg ha-1 of NWP + 500 kg ha-1 of FO) in Bougouni followed by T2 (300 kg ha-1 of lime + 300 kg ha-1 of PNT + 500 kg ha-1 of FO). In Koutiala, the T1 treatment recorded the best yield. However, in Sikasso, the best treatments were T2 and T4.

**Table 7: Economic evaluation of the backlash of amendments**

| Circle | Treatments | Maize yield, (kg/ha) | Unit selling price maize, (FCFA/kg) | Gross product obtained, (CFA francs/ha) |
|---|---|---|---|---|
| Bougouni | T1 | 2694 | 125 | 336 687,50 |
| | T2 | 2847 | 125 | 355 812,50 |
| | T3 | **2993** | **125** | **374 125,00** |
| | T4 | **2512** | **125** | **314 000,00** |
| | T5 | 2459 | 125 | 307 375,00 |
| Koutiala | T1 | **2472** | **125** | **309 000,00** |
| | T2 | 2008 | 125 | 251 000,00 |
| | T3 | 2088 | 125 | 261 000,00 |
| | T4 | 1552 | 125 | 194 000,00 |
| | T5 | **1648** | **125** | **206 000,00** |
| Sikasso | T1 | 1608 | 125 | 201 000,00 |
| | T2 | **1984** | **125** | **248 000,00** |
| | T3 | 1856 | 125 | 232 000,00 |
| | T4 | **2096** | **125** | **262 000,00** |
| | T5 | 1680 | 125 | 210 000,00 |

## 4. DISCUSSION

The soils in the cotton zone of Mali are slightly poor in general according to the chosen indicators and their tolerance thresholds. The soils are weakly acidic to neutral in the Bougouni area (pH: 6.44 to 6.71), mostly acidic in Dialé (pH: 5.06 to 5.16) and weakly acidic to neutral in the Wattorosso site. both in Koutiala (Dembélé et al 2019). The same author confirms that in Sikasso, the soils have an optimum acid pH (pH: 5.29 to 5.93). A similar study was carried out by Dembélé et al, (2017) in the Mali-south zone who reported that the overall condition of the soils in this production zone is poor where the pH varies between 4.7 and 6.1) . The majority of soils are also poor in organic matter, below the critical threshold of 6 g per kg of soil and 58% are deficient in assimilable phosphorus, are below the critical threshold of 7 mg/kg (Dembélé et al 2019) . For example, according to Kanté et al (2005) only 6% of the land receives organic manure in the Mali-south zone. Analysis of soil samples made by Dembélé et al (2019) in this area showed that macro-nutrients such as nitrogen, phosphorus and potassium are below critical levels. These results had been reported by Dembélé et al. (2017) who also found that the macronutrients (nitrogen, phosphorus and potassium) were below critical levels respectively 0.03%, 2.22 to 5.5 mg/kg and 0.01 to 0.07 cmol. Additional inputs of well-decomposed organic matter would help improve the fertility of these soils. The addition of agricultural lime and natural phosphate from Tilemsi (PNT) improves the physico-chemical properties of soils and actively contributes to correcting soil pH. The analysis of the different formulas of lime and lime amendment combined with PNT on cotton yields showed through the analysis of variance that there is a significant difference between T1 and T3 in Koutiala. This difference can be explained by the contribution of lime and PNT received by this treatment. Kouyaté et al., (2020) had reported that the supply of fertilizers can have a significant effect on exchangeable calcium during two years of study with high values for plots having received PNT. According to the same author, the release of basic ions such as Ca2+ and Mg2+ from the dissolution of lime and natural phosphate from Tilemsi contributes to significantly increase the rate of exchangeable calcium in plots with the amendments. Compared to Bougouni and Sikasso, Koutiala recorded the lowest yield of seed cotton. This can be explained by the poor distribution and variability of rainfall in the project sites. The Koutiala tests were installed late due to the late onset of the rains. The yields of the Bougouni and Sikasso tests greatly exceed the average (1000 kg/ha) of cotton yield in the CMDT zone. Regarding the economic evaluation of the tests, in Bougouni, there is no optimal treatment because all the amendment treatments were dominated treatments. In Koutiala, the T4 treatment remains the optimal treatment because it has the best marginal rate of return. On the other hand, in Sikasso it is the T5 treatment which obtains the best marginal rate of return and therefore appears to be the most satisfactory treatment. The economic evaluation of the effects of amendments on maize production varies according to the production system. In Koutiala, the T1 treatment recorded the best yield. This is explained by the fact that the T1 plot had benefited from the after-effects of the AGRA project amendment tests in the past years and from the influence of the presence of a termite mound. In Bougouni the best yield obtained was 2,993 ± 3,63 kg/ha for T3 against respectively 2,472 ± 690 kg/ha for T1 and 2,096 ± 1,561 for T2 in Koutiala and Sikasso. In general, maize yields in this study vary from 1608±1165 kg/ha to 2993±363 kg/ha. These yields are within the range of those reported (1,336 to 4,552 kg/ha) by Doumbia et al. (2,020) at the agronomic research station of Sikasso (Farako). However, our maize yields are higher than those reported (1,516 kg/ha) by Chianu et al. (2012) in the Sahel and are close to those reported (2,296 kg/ha) by Traore and Birhanu (2019) in the M'Pèssoba technology park in Koutiala.

## 5. CONCLUSION

At the level of the tests, the analysis of variance shows a significant difference between T1 and T3 of the Koutiala site. This difference can be explained by the contribution of the amendments, because the T3 received more amendments than the T1 (control). Compared to Bougouni and Sikasso, Koutiala recorded the lowest seed cotton yield. This can be explained by the poor distribution and variability of rainfall in the project sites. The Koutiala tests were installed late due to the late onset of the rains. The yields of the Bougouni and Sikasso tests greatly exceed the average (1000 kg/ha) of cotton yield in the CMDT zone.

With regard to the economic evaluation of the effect of the amendments of the tests, in Bougouni, there is no optimal treatment because all the amendment treatments were dominated treatments. In Koutiala, the T4 treatment remains the optimal treatment because it has the best marginal rate of return. On the other hand, in Sikasso it is the T5 treatment which obtains the best marginal rate of return and therefore appears to be the most satisfactory treatment.

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