International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2021; 4(2): 55-61
Received: 16-05-2021
Accepted: 19-06-2021

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Comparative effects of two mineral fertilizers and three organic manures on the agro-morphological characteristics of a variety of sorghum (*Sorghum bicolor* L.), cultivated in commune of Korhogo, Northern Côte d'Ivoire

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Abstract
The yield of sorghum grains, despite its importance in feeding the populations of northern Côte d'Ivoire, is still very low. This study was initiated with the objective of contributing to the improvement of sorghum production by evaluating the effects of different types of mineral and organic fertilizers in improving the growth and yield characteristics of the said crop. The study was conducted in the municipality of Korhogo, following a Fisher block device, comprising 7 treatments and 4 repetitions. The 7 treatments studied included three types of mineral fertilizers (Yara Mila Actyva type and two NPK types, with surface and micro-dose applications), three types of organic fertilizers (cow, rabbit and chicken droppings) and the control without fertilizer. The results, obtained, showed that the growth and yield characteristics were improved by the NPK types and the poultry and rabbit droppings brought in. These two types of fertilizers, with average productions of ears, varying between 1.6 and 2.5 ears per plant gave the best productions. Organic fertilizer, based on cow bursa, and the control did not significantly improve the production of sorghum. In a context where the high price of mineral fertilizers is very often a brake on the intensification of crops, this study constitutes a contribution to fertilization through the use of organic fertilizers and adapted to the socio-economic conditions of the region, knowing the low income of farmers.

Keywords: *Sorghum bicolor*, production, mineral fertilization, organic fertilization, Côte d'Ivoire

Introduction

Agriculture is the main economic activity of Côte d'Ivoire. It is a sector that employs 60% of the working population, accounts for more than half of GDP and contributes nearly 70% of the country's total exports [1]. A wide variety of crops is grown and cereals occupy a prominent place in this sector. However, cereal production, which should cover the needs of the population, is, in general, in deficit, and population growth is not accompanied by that of agricultural production, which keeps the country in almost permanent food insecurity, especially in the northern part of the country.

Sorghum is one of the most cultivated cereals in the world and the most important for the millions of people living in the semi-arid and arid tropical regions of Africa [2]. Grain production, as well as, the areas devoted to its cultivation place sorghum in 5th place in the world of cereals, far behind the three most important (wheat, rice and maize). In Africa, it occupies the second place, with a production representing half that of maize (89 million tons) or 5% of the world production [3].

In Côte d'Ivoire, sorghum is mainly grown in the northern regions, beyond the 8th degree of north latitude. With an average annual production of about 40,000 tons, sorghum is the fourth cereal after rice, maize and millet, in terms of production and consumption [4]. It is used in the manufacture of traditional dishes and beer and in animal feed. Domestic production does not cover domestic demand. Meeting requirements requires an annual import of approximately 10,000 tons of sorghum grains [4].

Despite a high yield potential, sorghum cultivation is characterized by low productivity, linked to physical and socio-economic constraints hindering its production.

One of these major constraints is undoubtedly soil degradation, which has a direct impact on production and yield. It should be noted that most soils in the north of Côte d'Ivoire, dominated by ferruginous soils and ferralsols, have a low original fertility [5]: low level of organic matter and exchangeable base [6]. In addition, this fertility decreases enormously with the clearing and cultivation of these soils [7; 8; 5]. The causes of this accelerated soil degradation are due to the very nature of the soils, most of which have kaolinite as the dominant type of clay; climatic conditions characterized by aggressive rains, high winds and temperatures and crop systems that deplete soils, thus creating favorable conditions for the action of climatic factors [9; 10]. Faced with this major constraint, especially, for a crop that has great nutrient needs, such as sorghum, fertilization has been proposed by research.

Mineral fertilizers are known for their immediate and beneficial effects on yields. However, the majority of producers do not have access to it [11], given the high prices and the lack of appropriate technologies for the application of mineral fertilizers, with the consequent low rate of mineral fertilization [12, 13]. Many studies have looked at the importance of using mineral fertilizers [14, 15, 16, 17, 18]. The latter have the advantage of an availability, for the plant, of mineral elements, the fastest, thus promoting better production and high productivity [14]. However, their exclusive use leads in the long run to a decrease in organic matter, acidification of soils, desaturation of the exchange complex, an increase in aluminum toxicity, so many factors capable of reducing yield.

In view of this fact, [19] and [20] suggested the use of organic manure. However, the release of the elements by the organic amendment is gradual and slow [21, 22]. Organic manures have very beneficial effects on the physico-chemical and biological properties of the soil and play a very important role in mineral fertilization [23, 24].

Organic matter is an important source of nutrients for plants [25]. The use of organic fertilizers is therefore a key factor in the modernization of agriculture in developing countries.

The general objective of this study is to evaluate the behavior of a variety of sorghum vis-à-vis two mineral fertilizers and three types of organic fertilizers. The objectives pursued by this research are the determination of the type chemical and / or organic fertilizer, the most suitable for the cultivation of sorghum, allowing a better reaction of the variety studied.

Material and methods

Study environment

The study was conducted in the commune of Korhogo, located in north of Côte d'Ivoire, whose geographical coordinates are 9° 26' north longitude and 5° 38' west latitude. The climate of the area, of Sudanese type, is characterized by an alternation of two seasons. A large dry season, from October to May, precedes the rainy season, marked by two rainfall peaks, one in June and the other in September. The area is also characterized by average temperatures varying between 24 and 33 °C and an average monthly humidity of 20%. The annual rainfall is between 1100 and 1600 mm and the duration of insolation is 2600 hours per year.

The soil is of tropical ferruginous type, formed on granite who's leaching more or less intense, has reduced its fertility. The relief is, generally, flat and dotted in places with inselbergs [26].

Plant material

The plant material, used, was an improved variety of sorghum (*Sorghum bicolo*r L. Moench), called Sariasso 14. This variety is characterized by agronomic potential, with a high yield, which is estimated at about 5 tons per hectare per year, under the best growing conditions. The wearing of this variety is erected, and the height of the plant reaches 2 meters. The average length of its cycle is about 90 to 115 days. Its seeds have oval shape and white and semi-vitreous color. The shape of the cob is cylindrical, it is 0.5-0.70 m long. This variety is the most cultivated in the Korhogo region.

Fertilization products

The fertilization products consisted of three different types of organic fertilizers and two mineral fertilizers. These are:

- A mineral fertilizer, called "Yara Mila Actyva" or (YMA), existing in granulated form and composition NPK 23-10-5 + 3S + 2MgO + 0.3 Zn;
- A mineral fertilizer, called NPK, of formula 23-10-5 + 3S + 2MgO + 0.3 Zn, existing in granulated form;
- an organic fertilizer, composed of cow purse;
- An organic fertilizer, consisting of chicken droppings;
- An organic fertilizer, consisting of rabbit droppings.

Methods

Experimental device and treatments and their application

The experimental device consisted of Fischer blocks, completely randomized, comprising 7 treatments and 4 repetitions (blocks). The study consisted of 28 elementary plots. Each elemental plot consisted of 20 sorghum plants, transplanted on 4 lines of 5 poquets, according to the respective spacing's of 0.80 m x 0.50 m. The elementary plots and blocks were separated by a distance of 1 m and 1 m respectively.

The 7 treatments studied are as follows:

- T1: control without fertilizer input;
- T2: organic fertilizer, with cow exchange;
- T3: organic fertilizer, with rabbit droppings;
- T4: organic fertilizer, consisting of chicken droppings;
- T5: mineral fertilizer Yara Mila Actyva or YMA;
- T6: mineral fertilizer type N-P-K, by spreading on the surface on the ridges;
- T7: mineral fertilizer type N-P-K, with application in micro-dose per poquet.

These different treatments were applied during the vegetative phase of sorghum. The period of application and the doses used depend on the type of fertilizer.

Poultry droppings (chicken) were given at a dose of 400 g per poquet or per plant, or 8 kg per elemental plot. Thus, 32 kg of chicken droppings were needed to cover the entire study plot.

The treatment, consisting of rabbit droppings, was applied at a dose of 400 g per poquet, or 8 kg per elemental plot.

The cow bursa was applied at a dose of 400 g per poquet, for a total of 8 kg per elementary plot. Organic fertilizers were applied, to plowing, before sowing, in crown around each poquet.

Mineral fertilizer Yara Mila Actyva (T3) was buried at a depth of 2 cm and 5 cm around each plant. The first application was made, with a dose of 15 g/plant, on the 20th day after sowing (JAS) and the second was carried out on the 37th JAS, at a dose of 30 g/plant.

The mineral fertilizer NPK, formulation 15-15-15 + 6S + 1B, was applied on the surface to the ridges. The fertilizer was fractionated and applied after sowing. The first application was made, with a dose of 30 g/plant, the 20th JAS and the second was carried out the 40th JAS, at a dose of 15 g/plant.

The mineral fertilizer NPK, formulation 15-15-15 + 6S + 1B, was applied by micro dose to the poquet, in crown around each plant, 5 cm from the plant and 2 cm deep. Two applications, at different doses, were carried out during the vegetative phase. The first application, with a dose of 30 g/plant, was carried out on the 20th JAS and the second took place on the 40th JAS, with a dose of 15 g/plant.

Measured parameters

Various morphological and yield parameters were measured per elementary plot during the study. The vegetative phase was determined by the time between the emergence and flowering dates. As for the reproductive phase, it was evaluated by the time between the flowering dates and the maturity of the ears. The height of each plant was assessed by measuring its size, from the crown to the last newly opened leaf (arrow). The number of leaves, emitted per plant, was obtained by counting all the leaves formed. The number of tillers, emitted per plant, was obtained by counting all the tillers formed. The number of ears, emitted per plant, was obtained by counting all the ears formed.

Data processing and analysis

The data, collected and recorded using the Excel spreadsheet, were subjected to an analysis of variance using XLSTAT version 7.5 software. The significance level of the differences between the means was estimated using the Newman Keuls test, at the 5% threshold, for the classification of the means into homogeneous groups.

Results

Effect of different types of fertilizers applied on morphological parameters

During the study, the duration of the vegetative phase and the duration of the reproductive phase were measured (Table 1). The analysis of variance applied to these two parameters showed differences between the means obtained with the different treatments applied. With regard to the durations of the two phases, three homogeneous groups were formed according to the Newman Keuls test. In terms of the duration of the vegetative phase, the first group is formed by the T4 treatment (hen droppings) which had the smallest duration (119.7 days). As for the third group, with the longest duration, is constituted by the average of treatment 1 (control). Its value is 132.2 days. The other five treatments (T2, T3, T5, T6 and T7), with averages ranging from 122.7 to 125.7 days, constituted the second homogeneous group.As for the duration of the reproductive phase, the first group, with an average of 15.7 days, is formed by the T1 treatment of which its duration was the smallest. T4 treatment, with an average of 28.2 days, was the third group with the longest duration. The third group, with intermediate averages, was formed by treatments (T2, T3, T5, T6 and T7). These averages ranged from 22.2 to 25.2 days.

Table 1: Duration of the vegetative and reproductive phases of plants according to treatments

Treatment	Vegetative phase duration (Days)	Reproductive phase duration (Days)
T1	132.2 c	15.7 a
T2	124.0 b	24.0 b
T3	122.7 b	25.2 b
T4	119.7 a	28.2 c
T5	123.2 b	25.2 b
T6	125.7 b	22.2 b
T7	124.2 b	23.7 b

The affected means of the same letter, in the same column, are not significantly different at the 5% threshold, according to Newman Keuls' test.

The height of corn plants was measured in this study from the 21st JAS to the 133rd JAS (Table 2). The different measurement dates were the 21st, 35th 49th, 63rd, 77th, 91st, 105th, 119th and 133rd JAS. The analysis of variance applied to the different results obtained, since the 21st to the 133rd JAS, revealed significant differences between the averages recorded with all the treatments applied. In the 21st and 35th JAS, the T4 treatment (chicken droppings), with values of 20.5 and 40 cm respectively, produced the great height which is statistically different from those of the other treatments (T1, T2, T3, T5, T6 and T7). As for the results obtained at the 133rd JAS, the Newman Keuls test made it possible to form two (2) homogeneous groups. The first group consists of the averages of the treatments T3 (rabbit droppings) and T4 (chicken droppings), with respective values of 460 and 470 cm high, were statistically the highest. The second group, with statistically smaller values, consisted of treatment averages (T1, T2, T5, T6 and T7). These values ranged from 380 (Control) to 420 cm (T6 and T7) high.

Table 2: Summary of plant heights by treatment

Treatment	Plants Heights (cm)								
	Day after sowing (JAS)								
	21	35	49	63	77	91	105	119	133
T1	14.0 b	20.0 c	25.0 c	30.0 c	60.0 c	100.0 c	150.0 c	300.0b	380.0 b
T2	15.0 b	30.0 b	35.0ab	40.0ab	90.0 ab	200.0 ab	200.0 b	335.0 ab	385.0 b
T3	15.0 b	30.0 b	50.0ab	70.0ab	100.0ab	150.0 ab	250.0 a	350.0 ab	460.0 a
T4	20.5 a	40.0 a	60.5 a	90.0 a	130.0 a	200.0 a	260.0 a	400.0 a	470.0 a
T5	15.0 b	30.0 b	35.0ab	45.0ab	95.0 ab	200.0 ab	200.0 b	335.0 ab	390.0 b
T6	15.0 b	30.0 b	38.0ab	48.0ab	90.0 ab	140.0 ab	200.0 b	330.0 ab	420.0 b
T7	15.0 b	28.0 b	40.0ab	50.0 b	98.0 ab	150.0 ab	200.0 b	350.0 ab	420.0 b

The affected means of the same letter, in the same column, are not significantly different at the 5% threshold, according to Newman Keuls' test.

The total number of tillers formed per poquet were also studied during the study (Table 3). This parameter was counted on different dates during the vegetative phase, namely the 21st, 35th, 49th, 63rd, 77th, 91st, 105th, 119th and 133rd JAS. During the 21st, 63rd, 77th, 91st, 105th, 119th and 133rd, JAS, the analysis of variance did not reveal any significant difference between the means obtained with the different treatments applied. These values varied between 3 (T1 and T2) and 3.3 tillers (T4) per poquet, at the 21st JAS. As for the values obtained in the 133rd, they varied from 1.7 tillers (T6) to 2.8 tillers (T4) per poquet.

In the 35th and 49th JAS, the analysis of variance revealed differences between the means recorded with all treatments. At the 35th JAS, the treatment (T4), with a value of 4 tillers per poquet, produced the highest number of tillers which is statistically different of those of the other treatments whose values varied between 3 tillers (T1 and T2) and 4 tillers (T4) per poquet. As for the results of the 49th JAS, the Newman Keuls test allowed the formation of two homogeneous groups. The first group, with averages of 4 tillers and 3.7 tillers per poquet, respectively, was formed by the values of the T4 (chicken droppings) and T5 (NPK applied to the surface of the ridge) treatments. These treatments produced statistically the highest averages. The second group, with values varying between 2.6 tillers (T3) and 3 tillers (T1 and T7) per poquet, consists of the averages of the treatments T1, T2, T3, T6 and T7, having produced the smallest number of tillers per poquet.

Table 3: Summary of the number of tillers per plant poquet according to treatments

Treatments	Tillers number per poquet								
	Day after sowing (JAS)								
	21	35	49	63	77	91	105	119	133
T1	3.0 a	3.0 b	3.0 b	3.0 a	3.0 a	2.7 a	2.8 a	2.2 a	2.2 a
T2	3.0 a	3.0 b	2.9 b	2.8 a	3.0 a	2.7 a	2.5 a	2.2 a	2.4 a
T3	3.1 a	3.3. b	2.6 b	2.3 a	2.3 a	2.3 a	2.2 a	2.2 a	2.0 a
T4	3.3 a	4.0 a	4.0 a	3.0 a	3.0 a	2.7 a	2.8 a	2.6 a	2.8 a
T5	3.0 a	3.2 b	3.7 a	3.5 a	3.0 a	3.1 a	2.8 a	2.6 a	2.6 a
T6	3.0 a	3.1 b	2.7 b	2.6 a	2.3 a	2.5 a	2.5 a	1.7 a	1.7 a
T7	3.0 a	3.1 b	3.0 b	2.8 a	3.0 a	3.1 a	2.8 a	2.6 a	2.6 a

The affected means of the same letter, in the same column, are not significantly different at the 5% threshold, according to Newman Keuls' test.

The total number of leaves, produced by each poquet, was measured during the experiment. Leaf counting was done during different periods during the vegetative phase of the sorghum plants, namely the 21st, 35th, 49th, 63rd, 77th, 91st, 105th, 119th and 133rd JAS (Table 4). The analysis of variance, applied to the results obtained on the 21st JAS, did not reveal any difference between the means produced by the treatments studied. The values obtained ranged from 12 leaves (T1) to 12.5 leaves (T3, T4 and T6) per poquet.

From the 35th to the 133rd JAS, the analysis of variance revealed differences between the averages recorded with the different treatments applied. The results, obtained during the measurements of the 35th JAS, showed that the highest numbers of leaves produced were obtained with the T2, T3, T4, T5 and T7 treatments. Their averages ranged from 19 leaves (T2) to 25.5 leaves (T4) per poquet. As for the results recorded during the measurements of the 133rd JAS, the statistically highest averages were obtained with the T3, T4, T5 and T7 treatments, with values varying between 34 leaves (T3 and T5) and 40 leaves (T4) per poquet. The values, statistically the lowest, were produced by the T1, T2 and T6 treatments. These averages ranged from 25.3 leaves (T1) to 27.2 leaves (T2).

Table 4: Summary of the total number of leaves per poquet according to treatments

Treatments	Leaves total number per poquet								
	Day after showing (JAS)								
	21	35	49	63	77	91	105	119	133
T1	12.0 a	15.0 b	18.5 b	19.0 b	22.3 b	23.0 b	25.0 b	25.0 b	25.3 b
T2	12.3 a	19.0 ab	21.2 b	23.0 b	24.0 b	22.0 b	25.0 b	27.0 b	27.2 b
T3	12.5 a	20.0 ab	25.0 a	26.0 a	27.0 a	29.0 ab	30.0 a	31.0 a	34.0 ab
T4	12.5 a	25.5 a	28 0 a	2.9 a	31.0 a	34.0 a	38.0 a	38.0 a	40.0 a
T5	12.3 a	20.0 ab	25.0 a	26.2 a	27.5 a	28.2 ab	29.5 a	30.0 a	34.0 ab
T6	12.5 a	16.3 b	20.0 b	20.5 b	22.5 b	24.0 b	25.9 b	24.1 b	25.7 b
T7	12.3 a	19.2 ab	20.1 b	24.2 a	26.0 ab	29.0 ab	31.5 ab	33.0 ab	34.2 ab

The affected means of the same letter, in the same column, are not significantly different at the 5% threshold, according to Newman Keuls' test.

Effect of different types of fertilizers applied on production parameters

The number of cob produced per poquet and per treatment was evaluated during the study to investigate the influence of different types of fertilizers on sorghum productivity. This parameter was evaluated during two different periods of the plant production phase (Table 5), namely the 119th and 133rd JAS.

The analysis of variance, applied to the results during these two measurement periods, revealed significant differences between the means obtained with the different treatments applied. At the 119th JAS, the classification, according to Newman Keuls, made it possible to have two homogeneous groups. The first group, with statistically higher values, was formed by the averages of the treatments T4 (chicken droppings), T5 (mineral fertilizer Yara), T6 (NPK applied to the surface of the ridge) and T7 (NPK per micro dose). The values, obtained, varied from 0.9 to 1 ear per poquet. The second group was formed by the averages of the treatments T1 (control), T2 (cow bursa) and T3 (rabbit droppings), with values varying between 0.3 and 0.5 ears per poquet.

As for the 133rd JAS, the Newman Keuls test made it possible to have two homogeneous groups. The first, having higher averages, was constituted by the values of the treatments T3, T4, T5, T6 and T7. These treatments allowed to have values varying between 1.6 (T3) and 2.5 (T4) ears per poquet. The second group, with statistically lower values, consisted of the averages of the T1, T2 and T3 treatments. These values ranged from 1 (T1) to 1.6 ears (T3) per poquet.

Table 5: Summary number of ears per poquets according to treatments

Treatments	Eras number per poquet								
	Day after sowing (JAS)								
	21	35	49	63	77	91	105	119	133
T1								0.3 b	1.0 b
T2								0.5 b	1.3 b
T3								0.5 b	1.6 ab
T4								1.0 a	2.5 a
T5								0.9 a	2.2 a
T6								0.9 a	2.3 a
T7								0.9 a	2.3 a

The affected means of the same letter, in the same column, are not significantly different at the 5% threshold, according to Newman Keuls' test.

Discussion

The study showed the ability of mineral and organic fertilizers in improving the growth, fruiting and yield parameters of sorghum, on a ferruginous soil of Korhogo. These results are similar to those obtained in other regions of sub-Saharan Africa, notably by [27] on maize in Nigeria and by [28] on the same crop in Cameroon, showing that the general trend in the evolution of tested soil properties and yield was upwards compared to control treatment, through mineral and organic fertilization.

In this experiment, the results highlighted an improvement in production parameters, with the contribution of different types of fertilizers. It appears, therefore, that the site of the study best values fertilizers according to the initial chemical composition of the soil [29, 30]. Mineral and organic manures had a significant influence on the growth and development of the vegetative apparatus of sorghum seedlings.

In general, the study, carried out on the comparison of the effects of fertilizers on the production of above-ground biomass by sorghum plants, shows that the control without fertilizer and organic fertilizer, with cow exchange, give the lowest yields. Soil poverty and this type of organic fertilizer could be the main reason. These results reflect the need for mineral fertilization and organic fertilizers, easily decomposable and richer, to obtain good yields on these types of soils. Nutrients N, P and K are said to play important roles in plant development and growth. The inadequacy or absence of these elements causes decreases in yields. Among the mineral elements, nitrogen would influence plant growth more. Nitrogen is the main stimulus for plant growth [31]**.** In addition, the application of chemical and organic fertilizers, which provide nutrients, such as nitrogen, significantly increases the production of above-ground biomass of sorghum [32].

The expediency of the use of mineral fertilizers is revealed here, in the fact that almost all agronomic parameters have increasing values with the application of fertilizers. The beneficial effects of chemical fertilization through agriculture have been demonstrated by many authors [33, 34]. Mineral fertilizers have greater agronomic efficiency because their mineral elements are available and easily absorbed by crops.

The addition of mineral fertilizers significantly increases pollen production [15]. This improved the rate of fertilization of flowers. Mineral fertilizer, judiciously used, makes it possible to increase crop yields in large proportions. As such, it is a determining factor in agricultural yields [18].

Regarding the contribution of mineral fertilizers, [35] found that they increase the yield of crops by 40 to 100% on the soils of Kalongo and Civu, in the Democratic Republic of Congo. These results are consistent with our results, as there has been an increase in yield, with mineral fertilizer treatments compared to the non-fertilizer control.

Several authors have found similar results showing, thus, the importance of mineral fertilizer in increasing the number and weight of ears [36, 37, 14]. This confirms the claims of [38] that increasing the number of cobs leads to increased yield since yield is the sum of individual weights of each cob. Thus, many studies have looked at the need for the use of mineral fertilizers [14, 15, 16, 17, 18]. They have the advantage of availability, for the plant, of mineral elements the fastest, thus promoting better production and good productivity [14].

The study also showed that all growth characteristics and the yield were significantly improved by the organic fertilizers brought compared to the control without fertilizer.

Organic fertilizers based on rabbit droppings and chicken droppings had a much greater influence on the production of sorghum plants in the field, compared to the control treatment without fertilizers and organic fertilizer based on cow bursa, namely the improvement of the number of ears per plant. This is explained by the amount of mineral elements made available to the plants. Indeed, organic fertilizers are an important source of mineral elements. The improvement of cereal yields through the application of chicken manure has already been reported by several studies [39, 40, 41, 42]. It has been shown that a supply of 5t/ha of chicken manure has doubled the yield of millet. It was pointed out that the contribution of manure plays a very important role in nutrient recycling, soil fertility, and improving agricultural production.

By neutralizing low soil acidity and providing nutrients to plants, chicken or rabbit manure improves mineral nutrition, resulting in increased crop yields [43, 44]. These results confirm the easy mineralization of chicken and rabbit manure and its richness in mineral elements for plant nutrition.

Nutrients in organic fertilizers increase crop yields [45] by improving the physical, chemical and biological properties of the soil [46, 47] reported that applications of composted organic fertilizers, as a source of nutrients, have affected corn grain yield, indicating that the fertilizer value of these fertilizers has been comparable to that of mineral fertilizers.

The addition of organic fertilizers accelerates microbial biomass activity and improves the availability of organic matter to soil microorganisms [48]. The use of organic amendments lies in the fact that they play an important role on various soil properties [49]**.**

Indeed, [19] showed that the rate of decomposition of organic matter and the increase in yields were closely related to the synchronization between the release of nutrients and their assimilation by the plant. Faced with this fact, [19] and [20] suggested the use of organic fertilizers, such as, fertilizing crops. However, the release of elements by organic matter is gradual and slow [22], sometimes annual plants do not even benefit at the right time [21]. In addition, their use requires large quantities, which limits the use of organic fertilizers in annual crops.

The control treatment without fertilizers and the organic fertilizer based on cow bursa had, in general, markedly small effects on the improvement of all the production parameters measured. These effects are, therefore, not comparable to those obtained with mineral fertilizers and other types of organic fertilizers. The low production of the control soils can be attributed to the characteristic values of the soils in the region, marked by their poverty in mineral elements. The lack of fertilizer inputs and the lack of mineral elements are accompanied by a loss of organic matter and nutrients, soil acidification, a reduction in biomass and microbial activity **[50].**

Organic fertilizer based on cow exchange did not have a much clearer influence on the growth and production of sorghum seedlings in the field, compared to mineral treatments and organic fertilizers, i.e. the improvement of all measured performance characteristics. This is due to the slow mineralization of the cow exchange, its low nutrient content and the quantities of mineral elements made available to the plants. Indeed, the cow exchange would mineralize slowly. Since the sorghum cycle is very short, the cow exchange has not yet reached the maximum stage of mineralization that would make available to the plants mineral elements to improve their productivity. The slow mineralization of the cow exchange, the low mineral content available to the plants and the short production cycle of sorghum would explain the slight improvement in the production of sorghum by this organic fertilizer provided compared to mineral treatments.

The results, thus obtained, showed the importance of organic fertilization (chicken and rabbit droppings) and mineral fertilization (NPK) for the cultivation of sorghum, through an improvement of growth and production parameters, on the soils of the Korhogo region. If mineral fertilizer is not applied, for the cultivation of sorghum, organic fertilizers (chicken and rabbit droppings) could be used because of their efficiency on yield.

Conclusion

The study found that mineral fertilizers (NPK and Yara Mila Actyva) had the highest effects in improving the growth and production of do sorghum plants. The inputs of organic fertilizers, namely, chicken and rabbit droppings, also improved all the performance characteristics measured compared to the control without fertilizer and cow droppings.

The study, which compares the effects of mineral and organic fertilizers in sorghum cultivation, contributes to the understanding of the importance of organic fertilization, which is a value to be sought as an alternative to mineral fertilizers whose high price has often been decried by small producers. Such a study becomes unavoidable in the particular growing conditions of climate change, drastically influencing the yield of crops.

In the current context of poverty and continued degradation of land fertility, the adoption of less costly fertility regenerative techniques is essential. The poverty of the soil in organic matter is the major constraint of agricultural production in Côte d'Ivoire, and, more particularly, in the Korhogo region where the annual rainfall rarely exceeds 1200 mm of water.

The results of the present study, which have shown the improvement of production characteristics and yield by mineral fertilizers and organic fertilizers, recommend that it be continued in all agro ecological zones of sorghum cultivation, with a view to making the necessary adjustments to popularized fertilizers, to avoid the use of mineral fertilizers.

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