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EFFECTS OF MINERAL AND ORGANIC FERTILIZATION ON THE PHENOLOGY AND YIELD OF COWPEAS (*VIGNA UNGUICULATA* L.), GROWN IN KORHOGO REGION OF NORTHERN CÔTE D'IVOIRE

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ABSTRACT

The yield of cowpeas, despite the crop's importance in the diet of the populations of northern Côte d'Ivoire, remains very low. This study was initiated with the aim of contributing to the improvement of the production of cowpeas 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, including 4 treatments and 4 replications. The 4 treatments studied included a mineral fertilizer (NPK), two types of organic fertilizer (rabbit and chicken droppings) and the fertilizer-free control. The results showed that the growth and yield characteristics were improved by added NPK and poultry and rabbit droppings. These two types of fertilizers, with average pod productions of 1073.20 kg/ha (NPK), 933.25 kg/ha (chicken droppings) and 910.50 kg/ha (rabbit droppings), gave the best productions. The control, with 426 kg/ha, did not significantly improve the production of cowpeas. In the context where the high price of mineral fertilizers is, very often, a limitation 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, bearing in mind the low income of farmers.

Keywords: *Vigna unguiculata*, yield, mineral fertilization, organic fertilization, Côte d'Ivoire

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1. INTRODUCTION

Côte d'Ivoire is an, essentially, agricultural country whose state of natural resources is highly prone to climatic hazards [1]. The rural sector plays a key role in the country's socio-economic development, with 60 per cent of the working population and about half of GDP. It forms the basis of people's food and nutrition security and contributes more than 60% to the incomes of agricultural households [2]. A wide variety of crops is grown and cereals occupy a prominent place in this sector. Cereals (millet, sorghum, maize, rice) are the main crop production in Côte d'Ivoire [3]. However, cereal production, which should cover the needs of the population, is, in general, in deficit, and population growth is not accompanied by that agricultural production, this keeps the country in an almost permanent food insecurity, especially in the northern part of the country. In addition to cereal crops, legumes such as cowpeas are also cultivated. Cowpeas is one of the world's leading food legumes. It is a vital crop during lean seasons [4]. Moreover, it is an important source of foreign exchange.

The cowpeas is the most cultivated legume in Côte d'Ivoire after groundnuts. It is mainly grown in savannah regions for its seeds consumed as a pulse. Young pods and leaves can also be eaten as fresh vegetables. Cowpeas (*Vigna unguiculata*) is a food legume whose leaves and seeds are the most important source of plant protein in both human and animal food [5]. It is a tropical herbaceous legume. Its cultivation has considerable economic, nutritional and agronomic benefits. Economically, the cowpeas is a source of foreign exchange for producing countries. The seeds of cowpeas fuel economic exchanges at the regional and sub-regional levels.

See the size of indent, world production of cowpeas is estimated at 4.2 million tons of dry seeds, 64% of which are made in Africa. The area cultivated annually in the world is estimated at 12.5 million hectares of which about 9.8 million hectares are realized in West Africa, making this region the first producer and consumer of cowpeas.

In addition, the cowpeas occupy nowadays an important place in agronomy because it can be used as a culture of association or rotation and is able to fix atmospheric nitrogen. In such systems, it is a source of nitrogen for cereal crops, especially in areas with low soil fertility [6]. The importance of this crop therefore encourages producers to reserve a considerable share of the agricultural holding for it.

Despite a high yield potential, the cultivation of cowpeas 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 northern of Côte d'Ivoire, dominated by ferruginous soils and *Ferralsols*, have a low original fertility [7]: low exchangeable organic matter and base matter [8]. In addition, this fertility decreases enormously with the clearing and cultivation of these soils. In

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addition, due to strong demographic pressure, long-term fallow land is less practiced [9]. Export without nutrient replacement contributes to land degradation [10]. Fertilization is therefore essential for maintaining the level of soil productivity.

[11] defined fertilization as a set of agricultural techniques using fertilizers. This is a necessary practice to maintain or improve soil fertility and provide the nutrients needed for cultivation [12]. According to [10], fertilization of nutrient-depleted soils, combined with best cultivation practices and favorable plant growing conditions, increases plant productivity [13; 14] and producer income [15]. The materials used can be organic or mineral [12].

The work of [16] has shown that the cowpeas, despite its ability to fix atmospheric nitrogen, also needs additional manure as a growth stimulator at start-up. [17] showed that the use of mineral or organic fertilizers on cowpeas significantly improves its resistance to water stress and increases its seed yield. It is in this perspective of sustainable intensification of the production of cowpeas that the present work is inscribed: The overall objective of this study was to evaluate the behavior of a variety of cowpeas opposite mineral fertilizers and organic fertilizers and to promote different types of fertilization that can improve its productivity.

2. MATERIAL AND METHODS

2.1. Study environment

The study was conducted in the community 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 the Sudanese type, is characterized by an alternation of two seasons. A great 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 under more or less intense leaching, and has reduced its fertility. The relief is, generally, flat and dotted in places with inselbergs [18].

2.2. Plant material

The plant material, used in our trial, consists of the seeds of cowpeas (*Vigna unguiculata*) of improved variety (Diamond). This variety has, as, characteristics: semi-erect port, white two-tone flower, maximum length of pods (25 cm), cycle 95% maturity (61 to 64 days), rainfed cultivation, seed yield (750 to 1200 kg/ha in a controlled environment and under satisfactory conditions), red two-colored seeds, resistant to bacterial canker, thrips, striga. This variety is the most cultivated in the Korhogo region.

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2.3. Fertilization products

The fertilization products consisted of two different types of organic fertilizers and one mineral fertilizer. These were:

- a mineral fertilizer, called NPK, of formula 23-10-5+3S+2MgO+0.3 Zn, existing in granular form;

- an organic fertilizer, consisting of chicken droppings;

- an organic fertilizer, composed of rabbit droppings.

2.4. Methods

2.4.1 Experimental design and treatments and their application

The experimental design consisted of Fischer blocks, completely randomized, comprising 4 treatments and 4 repetitions (blocks). The study included 16 elementary plots. Each elementary plot consisted of 16 cowpeas seedlings, transplanted on 4 lines of 4 poquets, according to the respective spacing's of 0.40 m x 0.50 m. The elementary plots and blocks were separated by a distance of 1 m and 1 m respectively.

The 4 treatments studied were as follows:

- T1: control without fertilizer input;

- T2: mineral fertilizer type N-P-K, with application in micro-dose per poquet;

- T3: organic fertilizer, consisting of chicken droppings;

- T4: organic fertilizer, with rabbit droppings.

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

Poultry (chicken) droppings were provided at a dose of 400 g per poquet or plant, or 6.4 kg per elemental plot. Thus, 102.4 kg of chicken droppings were required to cover the entire study plot.

The treatment, consisting of rabbit droppings, was applied at a dose of 400 g per poquet, or 6.4 kg per elemental plot.

The mineral fertilizer NPK, formulation 23-10-5+3S+2MgO+0.3 Zn, was buried at a depth of 2 cm and 5 cm around each plant. The fertilizer was fractionated and applied after sowing. The first application was made, with a dose of 30 g per plant, on the 20th day after sowing (DAS) and the second was carried out on the 40th DAS, at the dose of 15 g per plant.

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2.4.2. Measured parameters

Various morphological and yield parameters were measured per elementary plot during the study.

The height of each plant was assessed by measuring its size, from the collar to the last newly opened leaf. The number of leaves, emitted per plant, was obtained by counting all the leaves formed. The number of twigs, emitted per plant, was obtained by counting all the branches formed. The diameter at the collar was obtained by measuring the circumference of the collar of each plant. The surface of the leaves was determined by measuring the diameter of the crown formed by the leaves on either side of the main stem. The biomass of the leaves was obtained by weighing the leaves, after drying in the oven at a temperature of 80º C for a period of 24 hours.

The number of pods per plant was obtained by counting all the pods produced by each plant of cowpeas. The number of seeds per pod was obtained by counting all seeds contained in each pod. Yield (tons/ha) was determined from the following relationship:

R = NG * PG * D, with

R: yield in tons/ha

NG: the total number of pods per plant;

PG: Weight of each pod in grams (g):

D: Planting density with a standard of 80,000 plants/ha.

2.4.3. Data processing and analysis

The data, collected and recorded using the Excel spreadsheet, was subjected to 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.

3. RESULTS

3.1. Effect of different types of fertilizers on morphological parameters

During the study, growth parameters, i.e. plant height, collar diameter, number of twigs and leaves, leaf area and leaf biomass were measured. The analysis of variance applied to these parameters showed differences between the means obtained with the different treatments applied. With regard to the height of the plants, the diameter at the collar and the number of branches, two homogeneous groups were formed according to Newman Keuls test (Table 1).

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At the level of these three measured parameters, the first homogeneous group was constituted by the means recorded with the T2 (NPK) and T3 (Chicken droppings) treatments. These treatments produced the highest averages. These averages were, for T2, 63.2 cm, 25 twigs and 27.5 cm, and for T3, 62 cm, 23 twigs and 26.3 cm, respectively, for the height of the plants, the number of branches and the diameter at the collar.

As for the second group, with the lowest values, was formed with the averages of the T1 (control) and T4 (rabbit droppings) treatments. These values were, for the height of the plants, 55.2 cm for T4 and 48.3 cm for T1. For the collar diameter, the averages of 20.5 cm and 22.3 cm were recorded with the T4 and T1 treatments.

Table 1: Summary of treatment effects on plant height, twig count and collar diameter

Treatments	Plants height (cm)	Number of twigs	Collar diameter (cm)
T1 (Control)	48.3 [b]	15 [b]	20.5 [b]
T2 (NPK)	63.2 [a]	25 [a]	27.5 [a]
T3 (Chicken droppings)	62 [a]	23 [a]	26.3 [a]
T4 (Rabbit droppings)	55.2 [b]	18 [b]	22.5 [b]

Means followed by the same letter, in the same column, are not significantly different at the 5% threshold, according to Newman Keuls' test.

The number of leaves produced, leaf area and leaf biomass were also measured during this study. The analysis of variance, applied to these parameters, shows differences between the means obtained with all the treatments applied (Table 2). The Newman Keuls test made it possible to classify these averages, obtained at the level of these three parameters, into three homogeneous groups. The first group, with the highest values, was the mean of T2 treatment (NPK), at the level of these three parameters. This T2 treatment therefore produced 111 leaves, a leaf area of 56.7 cm^2 and a leaf biomass of 91.3%.

The second group was formed by the averages produced by the T3 (chicken droppings) and T4 (rabbit droppings) treatments, with values of 86 and 80 leaves produced, 46.1 and 41.8 cm^2 of leaf area and 80.1 and 74.4% of leaf biomass, respectively.

The T1 (Control) treatment, with averages of 58 leaves, 39 cm^2 of leaf area and 69.7% of leaf biomass, constituted the third group and these values were the lowest.

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Table 2: Summary of the effects of all treatments applied on leaves number, leaf area and leaf biomass

Treatments	Number of leaves	Leaf area (cm^2)	Leaf biomass (%)
T1 (Control)	58 ^{c}	39 ^{c}	69.7 ^{c}
T2 (NPK)	111 ^{a}	56.7 ^{a}	91.3 ^{a}
T3 (Chicken droppings)	86 ^{b}	46.1 ^{b}	80.1 ^{b}
T4 (Rabbit droppings)	80 ^{b}	41.8 ^{b}	74.4 ^{b}

Means followed by the same letter, in the same column, are not significantly different at the 5% threshold, according to Newman Keuls' test.

3.2. Effects of different fertilizers applied on production parameters

The number of pods produced by each cowpeas plant was counted on the 45th and 62nd day after sowing (DAS) during the experiment (Table 3). The analysis of variance, applied to the results obtained on the 45th JAS, did not reveal any difference between the means produced by the treatments studied. The values obtained varied between one pods (T1) and 1.33 pods (T2). In the 62nd, the analysis of variance revealed differences between the averages recorded with the different treatments applied. The results, obtained, showed that the number of pods produced, the highest, were obtained with the T2 treatment, with an average of 3.82 pods per plant of cowpeas, forming the first homogeneous group. The second group consists of the averages of the T3 and T4 treatments, with values of 3.15 and 3.00 pods per plant respectively. The third group, with a value of 2.15 pods per plant, was formed by the average of the T1 (Control) treatment. This treatment produced the lowest average.

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Table 3: Effects of applied treatments on the number of pods produced per plant

Treatments	45th DAS	62nd DAS
T1(Control)	1.00 a	2.15 c
T2 (NPK)	1.33 a	3.82 a
T3 (Chicken droppings)	1.32 a	3.15 b
T4 (Rabbit droppings)	1.05 a	3.00 b

Means followed by the same letter, in the same column, are not significantly different at the 5% threshold, according to Newman Keuls' test.

The number of seeds per pod and the yield of the cowpeas were studied. The analysis of variance, applied to the results of these two parameters, showed differences between the means obtained with all treatments (Table 4). It appears from the analysis of this table that the classification, according to the Newman-Keuls test, allowed the formation of three homogeneous groups at the level of these two parameters studied. The first group, with the highest averages, was the value obtained with the T2 treatment. This average was 13.50 seeds per pod and a yield of 1073.20 kg/ha. As for the second group, with intermediate values, was formed by the averages of the T3 and T4 treatments. These values were 12.23 seeds per pod (T3) and 12.10 pods (T4) and 933.25 kg/ha (T3) and 910.50 kg/ha. With regard to the third group, with the lowest mean, is constituted by the value obtained with the T1 treatment (control). This treatment produced an average of 11.66 seeds per pod and a yield of 426.00 kg/ha.

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Table 4: Effects of applied treatments on the number of seeds per pod and the yield of the cowpeas

Treatments	Seeds/pod	Yield (kg/ha)
T1(Control)	11.66 [c]	426.00 [c]
T2 (NPK)	13.50 [a]	1073.20 [a]
T3 (Chicken droppings)	12.23 [b]	933.25 [b]
T4 (Rabbit droppings)	12.10 [b]	910.50 [b]

Means followed by the same letter, in the same column, are not significantly different at the 5% threshold, according to Newman Keuls' test.

4. DISCUSSION

The study showed the ability of mineral and organic fertilizers in improving the parameters of growth, fruiting and yield of cowpeas, on ferruginous soils of the Korhogo region. The increase in growth and yield characteristics, observed, is due to the improvement of the nutritional status of the soil by the various fertilizer inputs. [19] showed that most soils with low inherent fertility respond positively to different fertility improvement practices. This improvement has led to good plant nutrition, hence the increase in yields.

In this study, the results highlighted an improvement in production parameters, with the contribution of different types of fertilizers. It appears, therefore, that the study site best values fertilizers according to the initial chemical composition of the soil [20]. Mineral and organic manure had a significant influence on the growth and production of cowpeas.

In general, the study, made on the comparison of the effects of mineral and organic fertilizers on the production of cowpeas, shows that the control without fertilizer, gives the lowest yield. Low soil fertility could be the mean reason. These results reflect the need for mineral fertilization or organic fertilizers, to obtain good yields on these types of soils. In similar study elsewhere, the application of chemical and organic fertilizers, which provide nutrients, such as nitrogen, significantly increased the production of above-ground sorghum biomass [21]. The opportunity 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 that has produced the highest effects.

A mineral fertilizer refers to any material of synthetic origin that is added to a soil to provide one or more nutrients essential for plant growth [22]. Continuous cultivation without fertilizer application leads to lower yields due to soil depletion of nutrients [23]. The use of a chemical

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fertilizer may therefore be necessary to quickly provide plants with the nutrients they need [24]. Thus, nitrogen (N), phosphorus (P) and potassium (K) can be provided by fertilizer without forgetting other essential elements such as calcium (Ca), magnesium (Mg), sulfur (S), boron (B), etc. The performance of mineral fertilizers would be related to the concentration of nutrients, readily available and provided in micro-doses, at the level of root systems, which would improve accessibility and efficiency of use [25] and reduce losses. According to [26], [27], [28] and [29], the performance of mineral fertilizers in microdose is explained by the fact that the location of fertilizers in the surface horizon colonized by the roots of the plants generates their proliferation and growth; this allows plants to better capture nutrients and water. The results in the present work are consistent with those obtained by [30], [31], and [32]. Indeed, these authors had come to the conclusion that the difference between mineral and organic fertilizers was statically significant. Similarly, recent studies have shown similar results with millet on sandy soils in Niger [33; 34; 13], as well as with cowpeas and *Sorghum* in Mali [35] and Burkina Faso [36]. Mineral fertilizers have the advantage of the availability of mineral elements to the plant as quickly as possible, thus promoting better production and productivity [37].

The current study also showed that all growth characteristics and yield were significantly improved by the organic fertilizers provided compared to the control without fertilizers. Organic fertilizers based on rabbit droppings and chicken droppings had a much clearer influence on the production of cowpeas plants in the field, compared to the control treatment without fertilizer, namely the improvement in the number and weight of pods per plant.

Organic manure has very beneficial effects on the physico-chemical and biological properties of the soil. The use of manure and compost helps maintain the level of organic matter in the soil. Once spread on a field, compost provides nutrients and increases the level of organic matter in the soil [24]. The contribution of manure plays a very important role in nutrient recycling, soil fertility and the improvement of agricultural production [9]. In addition to major nutrients, organic fertilizers are rich in many substances known to have a favorable impact on soil biological life [38]. Nutrients in organic fertilizers increase crop yields [39] by improving the physical, chemical and biological properties of the soil [40].

The work of [16] proved that organic manure inputs have an influence on the seed and top yields of cowpeas, as well as on their ability to fix atmospheric nitrogen at the nodule level. [17] indicate that the application of compost increases seed yield. As for [41], better production of above-ground biomass is observed with the application of organic manure.

In the present case, the lower productivity of organic treatments compared with or in comparison of mineral treatments would be due to a low release of nutrients by composts that was weakly mineralized in the first year. Indeed, compost is valued in the long term. A positive and significant

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effect, in general, is observed the following year. The work of [16] shows that the effects of organic manure on crop yields are more pronounced in the second year. In addition, the slow evolution of compost is explained by the fact that 30% of nitrogen is released in the first year; 25% in the 2nd year and 15% in the 3rd year [42].

Since the process of nutrient release by organic fertilizers is slow, the use of mineral manure is essential to compensate for the needs of the plant at specific times of its growth [41; 22]. Nutrients in organic fertilizers increase crop yields [38] by improving the physical, chemical and biological properties of the soil [39].

The work of [16] proves that organic manure inputs have an influence on the seed and top yields of cowpeas, as well as on their ability to fix atmospheric nitrogen at the nodule level. [17] indicate that the application of compost increases seed yield. According to [40], better production of above-ground biomass is observed with the application of organic manure. In addition, their use requires large quantities, which limits the use of organic fertilizers in annual crops.

The fertilizer-free control treatment generally had a markedly small effect on the improvement of all measured production parameters. These effects are therefore not comparable to those obtained with mineral and organic fertilizers. The low production of control soils can be attributed to the characteristic values of the region's soils, marked by their poverty in mineral elements. Lack of fertilizer inputs and mineral nutrients are accompanied by loss of organic matter and nutrients, soil acidification, reduced biomass and microbial activity [43]. The non-significance of the control effect would be due to a low release of nutrients.

The results, thus obtained, showed the importance of organic fertilization (chicken and rabbit droppings) and mineral fertilization (NPK) for the cultivation of cowpeas, through an improvement in the parameters of growth and production, on the soils of the Korhogo region. Failing to apply the mineral fertilizer, for the cultivation of cowpeas, organic fertilizers (chicken droppings or rabbit droppings) could be used because of their effectiveness on yield improvement.

5. CONCLUSION

At the end of the study, it appears that mineral fertilizer (NPK) had the highest effects in improving the growth and production of cowpeas plants. The inputs of organic fertilizers, namely chicken and rabbit droppings, also improved all the yield characteristics measured compared to the control without fertilizer.

The study, relating to the comparison of the effects of mineral and organic fertilizers in cowpeas cultivation, contributes to the understanding of the importance of organic fertilization, which is a value to be sought, in replacement of mineral fertilizers whose high cost has often been decried by

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small producers. Such a study becomes unavoidable in the particular growing conditions of climate change, drastically influencing crop yields.

In the current context of poverty and continuous degradation of soil fertility, the adoption of less expensive fertility regenerative techniques is essential to avoid the excessive use of mineral fertilizers in cowpeas cultivation.

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