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Effect of Cow Dung Dose and Sowing Density on the Agronomic Performance of a Cotton Variety (*Gossypium hirsutum* l.) Grown in the Bere Region in the North-West of Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. Authors KN, NNA and KNJ designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author KYJ is the laboratory manager. All authors read and approved the final manuscript.

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ABSTRACT

The present study aims to determine the optimal dose of ox dung and the sowing density that optimize the yield of seed cotton in the region of BERE in the North-West of Côte d'Ivoire. Six fertilizer doses (T0, T1, T2, T3, T4 and T5) were tested. Among these six doses, T1, T2, T3 and T4 are composed of a mixture of ox dung and NPK mineral fertilizer, T0 is the mineral NPK fertilizer and T5 is composed only of cattle dung. These doses were tested on cotton plants through 4 seeding densities : low density (LowD : 50 cm x 80 cm with 2 plant.pocket^{-1}, either 50000 Plant.ha^{-1}), medium density 1 (Me D1: 40 cm x 80 cm with 2 plant.pocket^{-1}, either 62500 Plant.ha^{-1}), medium density 2 (Me D2 : 20 cm x 80 cm with 1 plant.pocket^{-1}, either 62500 Plant.ha^{-1}) and high density (Hi D : 30 cm x 80 cm with 2 plant.pocket^{-1}, with 83500 Plant.ha^{-1}). Observations focused on six agronomic parameters. All the organo-mineral treatments were more productive than the simple NPK and beef dung treatment. The T2 treatment (2000 kg.ha^{-1} of cow dung + 100 kg.ha^{-1} of NPK) made it possible to observe the highest values of the number of capsules per plant (14.37

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capsules), of the cottonseed mass per plant (57.02 g) and seed cotton yield (3636.23 kg.ha^{-1}). In terms of sowing density, cotton plants sown under high density (Hi D : 30cm x 80cm, or 83,500 Plant.ha^{-1}) gave a higher seed cotton yield (3950.68 kg.ha^{-1}). The medium seed cotton yield of cotton plants reached its optimum (4434.77 kg.ha^{-1}) when they were sown at high density (83500 Plant.ha^{-1}) and treated with T2 (2000 kg.ha^{-1} of cattle dung + 100 kg.ha^{-1} of NPK).

Keywords: Cotton plant; yield; density; dose; ox dung; fertilizer.

1. INTRODUCTION

The decline in yields in cotton agrarian units is recurrent in Côte d'Ivoire despite the use of mineral fertilizers [1]. As a result, the use of organic manure and in particular ox dung in the Ivorian cotton basin is no longer a matter of choice, but a necessity to increase yields and maintain soil fertility. Cotton plants treated with ox dung have been shown to produce more than those treated with NPK only [1]. Other studies maintain that dung alone does not allow the stability of yield and soil fertility. It must therefore be used in combination with mineral fertilizers [2]. The effectiveness of organo-mineral fertilizers has also been proven on soil fertility in Côte d'Ivoire by Akanza et Yoro, 2003) [3], on cotton yield in Mali by koulibaly et al. (2009) [4] and on the agronomic parameters of several other crops including cassava in Côte d'Ivoire (Konan, 2021) [5] and pineapple in Benin [6]. Despite its beneficial actions on the physical and chemical properties of the soil (Bacyé et al., 2019) [7] and on cotton yield (Dagbenonbakin et al., 2012) [8], the quantities of ox dung brought into cotton farming units are still at the discretion of producers in Côte d'Ivoire. It has also been reported that in Burkina Faso, the quantities of organic manure brought to the fields also vary from one producer to another [9]. However, Beninese experiments have reported that the optimization of seed cotton yield admits an optimal dose of ox dung. The optimal dose of fertilizer is a very important factor to take into account in any production system. Indeed, below the optimal dose, the plants are under-fed. As a result, they can show deficiencies in certain nutritive elements and consequently express poor yields. Below In addition, the determination of the optimal dose of each type of fertilizer requires knowledge of the level of influence of the sowing density. Because it has been justified that the yield of crops in the open field varies according to sowing densities [10] ; [11]. Indeed, the efficient use of soil resources depends on the number of plants present on a given surface unit. Indeed, it has been demonstrated in China that cotton fiber yield increases linearly with density up to the color of the density balance point beyond which yield decreases [12]. Studies have also shown that cotton yield varies with seeding rate when growing conditions change [13]. Also, cotton plants express their best yield when the sowing density reaches its optimum [14]. In China, Yang et al., (2014) [15] have shown that, when the sowing density reaches its equilibrium, it generates an environment favorable to cotton plants and which consequently optimizes their yield. Other studies have also shown declines in cotton lint yields linked to the reduction in sowing density in China [16]. This is why, in order to optimize seed cotton yield by ox dung in the Ivorian cotton basin, this study proposes to determine the optimal dose of ox dung and the optimal sowing density associated with this dose in the region of Côte d'Ivoire. BERE in the North-West of the Côte d'Ivoire.

2. MATERIALS AND METHODS

2.1 Study Zone

The study took place from 2019 to 2021 in the Sub-Prefecture of Tiéningboué in the BERE region in the northwest of Côte d'Ivoire. The study plot has coordinates of 8.120° North and 5.760° West. The soil that housed the study is of the Ferrisol type. It is loose and has a sandy-clay texture with an estimated chemical composition of 0.18% nitrogen, 0.005% phosphorus, 0.036% potassium, 0.55% organic matter and 0.32% organic carbon. Its pH is equal to 5.84. The annual rainfall recorded over the study period (2019, 2020 and 2021) are respectively 822 mm, 942 mm and 1124 mm. The area is under the influence of two seasons. The dry one which extends from November to the end of February, is characterized by dry and hot winds which blow from North to South. The other called rainy season starts from March to October.

2.2 Plant Material

Cotton seeds of an improved 3rd generation variety were used as planting material. This is Gouassou fus/R3 with a cycle of between 130 and 150 days of the Gossypium hirsutum cultivar. He was selected by le Centre National de Recherches Agronomiques (CNRA) of Cote d'Ivoire and popularized by la compagnie Ivoirienne pour le développement des textiles (CIDT).

2.3 Fertilizers

The main fertilizers used in this study consist of a mineral fertilizer (NPK) according to the formulation (15-15-15) and an organic fertilizer (ox dung). The chemical composiotion of the cows dung used is (N = 1.56% ; P = 0.14% ; K = 0.54%) as well as (12.26% organic carbon, 21.24% organic matter, 0.99% magnesium and 1.59% Calcium). It has a basic pH equal to 8.65.

2.4 Methods

2.4.1 Experimental Device and cultural practice

The experimental device used is a completely randomized block with 3 repetitions with 6 treatments. The plot has been demarcated over an area of 10,000 m² (1 ha). It was subdivided into 3 blocks each having an area of 3000 m² (30 m x 100 m). The distance between 2 consecutive blocks is 5 m. Within each block, 48 elementary plots have been delimited with an area of 50 m² (10 m x 5 m). They are 2 m apart from each other. On each elementary plot, 6 ridges 10 m long and 0.3 m high were made. The crests of the ridges are 0.8 m apart. The different processing operations carried out within each block are :

T0 = 200 kg.ha^{-1} of NPK ;
T1 = 1500 kg.ha^{-1} cow dung + 150 kg.ha^{-1} of NPK ;
T2 = 2000 kg.ha^{-1} of cow dung + 100 kg.ha^{-1} of NPK ;
T3 = 2500 kg.ha^{-1} cow dung + 100 kg.ha^{-1} of NPK ;
T4 = 2500 kg.ha^{-1} of cow dung + 50 kg.ha^{-1} of NPK ;
T5 = 3000 kg.ha^{-1} cow dung.

In order to better assess the effect of each of these doses, 4 sowing densities have been defined, namely:

- low density (Lw D) = 252 plant.elementary^{-1} plot (50 cm x 80 cm with 2 plant.pocket^{-1}, either 50000 plant.ha^{-1})
- Medium density 1 (Med D1) = 306 plant.elementary^{-1} plot (40 cm x 80 cm wirh 2 plants each pocket, either 62500 plant.ha^{-1})
- Medium density 2 (Med D2) = 306 plant.elementary^{-1} plot (20 cm x 80 cm with 1 plant each pocket, either 62500 plant. ha^{-1})
- High density (Hi D) = 408 plant. elementary^{-1} plot (30 cm x 80 cm with 2 plants each pocket, eithert 83500 plant. ha^{-1}).

The treatment of the elementary plots with ox dung was carried out 1 month before sowing the seeds. While the spreading of NPK occurred on the 21st day after sowing. Sowing is carried out on the same day in June. Regular weeding was carried out. The first took place 60 days after sowing and the second, at the start of boll opening (i.e. 110 days after sowing). During the cycle, 6 insecticide treatments were carried out with a rate of 14 days to fight against parasites.

2.4.2 Collection of data

Data collection began at the beginning of the opening of the capsules, i.e. 110 days after sowing. Data are collected on 90 randomly selected plants in each elementary plot. Thus, the vegetative branches, the fruiting branches and the mature capsules were counted on each of the plants chosen. The length of the main stem of these plants was measured. After all the capsules were opened (140 days after sowing), the seed cotton from each plant was harvested and weighed using an electronic scale. The method of collecting data on the parameters studied is summarized in the Table 1.

2.5 Statistical Analysis of Data

The two-factor variance analysis (FVAN 2) was used to evaluate the effects of fertilizer doses and different sowing densities on cotton agro-morphological parameters. The significance of the test was determined by comparing the probability (P) associated with the statistic to the threshold P = 0.05. When a significant difference was observed ($P < 0.05$) between the factors studied for a given parameter, multiple comparisons were carried out using the Least Significant Difference test (PPDS). This test made it possible to identify the factors that significantly induce this difference. All statistical tests were performed using R software.

Table 1. Measurement methods and parameters studied

Agro-morphological parameters	Measurement methods and sample size per elementary Plot (carried out on 90 plants)
Length of main stem: Lg MSt (cm)	Measurement of the distance between the soil surface of the terminal bud,
Number of vegetative branches : Nbr V Br	Number of all vegetative branches of each plant,
Number of fruiting branches : Nbr F Br	Number of all the fruiting branches of each plant,
Number of capsules : Nbr Ca	Number of all the mature capsules of each plant,
Mass of seed cotton : Ma S Cton (g)	Medium mass of seed cotton per plant,
Seed cotton Yield : ($kg.ha^{-1}$)	Mass of seed cotton per plant evaluated per hectare

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Comparison of different doses of fertilizers according to the agronomic parameters of the cotton plant

The analysis of the data reveals that there is a significant difference ($P < 0.05$) between the different doses applied to the parameters of the cotton plant (Table 2). The highest values of all the parameters analyzed were obtained with the T2 treatment (2000 $kg.ha^{-1}$ of ox dung + 100 $kg.ha^{-1}$ of NPK). The lowest values were observed under the T0 control (200 $kg.ha^{-1}$ of NPK). The T2 treatment increased the number of capsules by 1.21 times compared to the pure NPK mineral fertilizer control T0 (200 $kg.ha^{-1}$ of NPK) and by 1.11 times compared to the exclusive ox dung control T5 (3000 $kg.ha^{-1}$ of beef dung). The values of seed cotton mass (57.02g) and seed cotton yield (3636.23 $kg.ha^{-1}$) observed under T2 are 1.39 times those observed under T0 and 1.12 times those under T5. All organo-mineral and even organic formulations are more productive than the exclusive mineral fertilizer (T0). Treatments T1 (1500 $kg.ha^{-1}$ of ox dung + 150 $kg.ha^{-1}$ of NPK), T3 (2500 $kg.ha^{-1}$ of ox dung + 100 $kg.ha^{-1}$ of NPK) and T4 (2500 $kg.ha^{-1}$ of cattle dung + 50 $kg.ha^{-1}$ of NPK) gave statistically the same values of seed cotton yield per hectare.

For each variable, values with the same letters on the line are statistically equal. Lg MSt: length of the main stem (cm), Number V Br: number of vegetative branches per plant, Number F Br: number of fruiting branches per plant, Number ca: number of capsules per plant, Ma SCton: mass of seed cotton per plant plant (g), Yield: medium seed cotton yield per hectare ($kg.ha^{-1}$).

3.1.2 Comparison of the four sowing densities according to the agronomic parameters of the cotton plant

The averages of the agro-morphological variables were analyzed on cotton plants from 4 sowing densities (Table 3). The results showed that except for the number of vegetative branches, all the other variables were influenced by the variation in seeding density. The P values of the influenced variables are all less than 0.05 ($P < 0.05$). The number of fruiting branches, the number of bolls and the seed cotton mass per plant increased when the seeding rate decreased. The highest values of these 3 variables were obtained at low density (IIFai D). On the other hand, the lowest values of these parameters were observed at the medium density 2 (Med D2) and at the high density (For D). The highest seed cotton yield (3950.68 $kg.ha^{-1}$) was produced at high density (For D). The medium density 1 (Med D1) made it possible to observe the maximum growth of the cotton plants (120.03 cm). The development of the vegetative branches was not influenced by the variation of the density of sowing giving all identical values ($P > 0.05$).

For each variable, values with the same letters on the line are statistically equal. Lg MSt: length of the main stem (cm); Nbr Br V: number of vegetative branches per plant; Nbr Br F: number of fruiting branches per plant; Nbr ca: number of capsules per plant; Macton: seed cotton mass per plant (g); Yield: medium seed cotton yield per hectare ($kg.ha^{-1}$). Fai D: low density (50 cm x 80 cm); Med D1: medium density 1 (40 cm x 80 cm); MoyD2: medium density 2 (20 cm x 80 cm) For D: high density (30 cm x 80 cm).

Table 2. Results of the effect of fertilizer doses on the agro-morphological parameters of cotton plants

Variables	Averages (± standard deviation)						Statistics	
	T0	T1	T2	T3	T4	T5	F	P
Lg MSt	116.53± 22.10[b]	119.18±21.01[a]	118.24±19.18[a]	116.88±21.35[b]	119.65±23.89[a]	117.13±24.42[b]	7.4	<0.0001
Nbr V Br	2.38±1.09[c]	2.58±1.07[a]	2.59±1.08[a]	2.48±1.05[b]	2.44±1.12[b]	2.22±1.15[d]	33.8	<0.0001
Nbr F Br	17.02±7.81[b]	18.10±7.66[a]	18.75±7.95[a]	17.96±7.71[b]	18.09±8.23[a]	17.33±7.41[b]	13.45	<0.0001
Nbr Ca	11.86±6.41[d]	13.68±7.18[b]	14.37±7.42[a]	13.72±7.27[b]	13.82±8.56[b]	12.99±6.96[c]	31.03	<0.0001
Ma SCton	40.88±24.24[e]	54.61±29.84[b]	57.02±31.16[a]	53.96±31.85[c]	54.93±36.25[b]	50.73±30.30[d]	77.22	<0.0001
Yield	2615.77±1568.01[d]	3473.05±1877.56[b]	3636.23±2002.77[a]	3426.16±1976.70[b]	3498.12±2354.75[b]	3226.26±1937.69[c]	74.94	<0.0001

Table 3. Results of the effect of seeding density on agronomic parameters of cotton plant

Variables	Averages (± standard deviation)			For D	Statistics	
	IFaiD	Med D1	Med D2		F	P
Lg MSt	117.17±24.09[c]	120.03±23.34[a]	116.27±20.28[c]	118.27±20.19[b]	17.5	<0.0001
Nbr V Br	2.45±1.13[b]	2.43±1.04[b]	2.44±1.19[b]	2.49±1.03[b]	1.87	0.1426
Nbr F Br Br	19.73±8.40[a]	18.39±7.63[b]	16.77±7.49[c]	16.62±7.29[c]	117.7	<0.0001
Nbr Ca	15.52±8.32[a]	14.01±7.60[b]	11.96±6.59[c]	12.14±6.19[c]	175.5	<0.0001
Ma SCton	60.04±35.82[a]	54.48±31.26[b]	46.26±28.12[c]	47.31±27.05[c]	143.5	<0.0001
Yield	3002.14±1791.46[c]	3405.57±1954.34[b]	2892.01±1757.84[d]	3950.68±2259.3[a]	195.5	<0.0001

Table 4. Results of the effect of the fertilizer dose-seeding density interaction on the agronomic parameters of cotton

		Variables					
		Lg mst (cm)	**Nbr V br**	**Nbr F Br**	**Nbr Ca**	**Ma SCton (g)**	**Yield (kg.ha^{-1})**
	T0	111.99±22.38^{g}	2.27±1.16^{c}	18.13±8.38^{c}	13.24±7.519^{d}	45.36±28.66^{k}	2268.33±1433.186^{f}
	T1	118.40±22.25^{d}	2.54±1.07±^{b}	19.40±8.18^{b}	15.56±8.06^{b}	61.92±34.27^{c}	3096.20±1713.77^{e}
	T2	117.56±21.10^{e}	2.53±1.05^{b}	20.72±8.54^{a}	16.58±8.58^{a}	66.17±35.15^{a}	3308.88±1757.91^{e}
IFai D	T3	114.94±21.91^{f}	2.55±1.01^{b}	20.51±8.81^{a}	16.28±8.90^{a}	63.27±40.59^{b}	3163.88±2029.69^{e}
	T4	119.06±23.72^{d}	2.53±1.13^{b}	19.86±8.17^{b}	16.04±8.67^{a}	63.89±37.81^{b}	3194.90±1890.56^{e}
	T5	121.04±30.85^{b}	2.25±1.30^{c}	19.73±8.11^{b}	15.39±7.72^{b}	59.61±33.49^{d}	2980.64±1674.55^{f}
	T0	118.65±23.98^{d}	2.42±1.04^{c}	17.74±7.18^{d}	12.73±6.64^{e}	44.95±24.48^{j}	2809.60±1530.55^{f}
	T1	118.88±21.13^{d}	2.45±1.08^{c}	18.40±7.17^{c}	14.22±7.07^{c}	56.99±30.35^{e}	3562.38±1897.17^{d}
	T2	118.69±19.74^{d}	2.56±1.10^{b}	19.49±8.39^{b}	15.16±7.76^{b}	60.45±34.12^{c}	3778.12±2133.03^{d}
Med D1	T3	118.54±23.47^{d}	2.33±0.99^{c}	17.45±6.96^{c}	13.55±6.82^{d}	53.37±28.51^{f}	3335.64±1781.98^{e}
	T4	125.64±24.39^{a}	2.52±1.00^{b}	19.51±8.46^{b}	14.81±9.57^{c}	59.01±36.39^{d}	3688.54±2274.78^{d}
	T5	119.78±26.06^{d}	2.26±1.02^{c}	17.77±7.22^{c}	13.58±7.09^{d}	52.14±29.86^{gg}	3259.14±1866.65^{e}
	T0	114.48±19.74^{f}	2.42±1.09^{c}	15.43±7.09^{e}	10.07±4.99^{g}	34.84±19.71^{k}	2181.24±1231.70^{g}
	T1	120.57±19.27^{c}	2.75±1.10^{a}	17.84±8.236^{c}	12.96±7.40^{e}	51.40±28.09^{g}	3212.50±1755.80^{e}
	T2	116.08±17.52^{e}	2.57±1.18^{b}	17.30±7.28^{c}	12.56±5.95^{e}	48.37±24.28^{h}	3023.14±1517.58^{h}
Med D2	T3	117.91±18.93^{e}	2.51±1.11^{b}	17.75±7.35^{c}	13.15±6.57^{d}	51.38±27.73^{g}	3211.80±1733.25^{e}
	T4	115.83±24.91^{e}	2.30±1.27^{c}	16.07±7.64^{d}	11.76±7.62^{f}	46.41±34.75^{i}	2900.81±2172.16^{f}
	T5	112.75±19.69^{g}	2.11±1.27^{d}	16.25±6.99^{d}	11.27±6.13^{f}	45.16±28.66^{j}	2822.56±1791.54^{f}
	T0	120.99±21.00^{c}	2.41±1.06^{b}	16.77±8.25^{d}	11.39±5.72^{f}	38.37±21.55^{k}	3203.92±1800.09^{e}
For D	T1	118.87±21.26^{d}	2.58±1.00^{b}	16.77±6.72^{d}	12.00±5.42^{e}	48.15±23.89^{i}	4021.14±1995.55^{c}
	T2	120.63±17.91^{c}	2.72±0.96^{a}	17.48±6.96^{c}	13.18±6.42^{d}	53.11±26.72^{f}	4434.77±2231.74^{a}
	T3	116.13±20.69^{e}	2.52±1.08^{b}	16.14±6.94^{d}	11.89±5.70^{f}	47.82±26.52i	3993.31±2215.04^{d}
	T4	118.05±21.33^{d}	2.42±1.04^{b}	16.93±8.01^{d}	12.69±7.54^{e}	50.39±33.34h	4208.24±2784.26^{b}
	T5	114.93±18.02^{f}	2.27±0.98^{c}	15.60±6.58^{e}	11.71±5.96^{f}	46.02±26.60i	3842.70±2221.69^{d}
Statistics	F	9.3	4.51	4.83	3.44	3.05	2.50
	P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0010

For each variable, values with the same letters on the line are statistically equal. Lg MSt: length of the main stem (cm), Nbr V Br: number of vegetative branches per plant, Nbr F Br: number of fruiting branches per plant, Nbr ca: number of capsules per plant, Ma SCton: mass of seed cotton per plant plant (g), Yield: average seed cotton yield per hectare (kg.ha-1). LwD: low density (50 cm x 80 cm); Med D1: medium density 1 (40 cm x 80 cm); Med D2: medium density 2 (20 cm x 80 cm) HiD: high density (30 cm x 80 cm)

3.1.3 Effect of the sowing density – fertilizer dose interaction on the agronomic parameters of cotton

The joint effect of sowing density and ox dung dose was analyzed on 6 variables (Table 4). All these analyzed variables show significant differences between all the sowing density-fertilizer dose interactions ($P < 0.05$). The highest yield (4434.77 $kg.ha^{-1}$) was observed at high sowing density (For D: 30cm x 80cm, i.e. 83500 $plant.ha^{-1}$) with the T2 dose (2000 $kg.ha^{-1}$ of ox dung + 100 $kg.ha^{-1}$ of NPK). The lowest yield (2182.24 $kg.ha^{-1}$) was obtained at medium density (Avg D1: 40cm x 80cm, i.e. 62500 $plant.ha^{-1}$) with 100% NPK mineral fertilizer (T0: 100 $kg.ha^{-1}$ of NPK). The highest values for the number of fruiting branches, the number of bolls and the seed cotton mass per plant were obtained at low density (IFai D: 50cm x 80 cm, i.e. 62,500 $plant.ha^{-1}$) with the T2 dose (2,000 $kg.ha^{-1}$ of ox dung + 100 $kg.ha^{-1}$ of NPK). The lowest values of these three variables were observed at medium density 2 (med D2: 20cm x 80cm) with 100% NPK mineral fertilizer. The height growth of the cotton plants was greater at medium density 1 (Medium D1: 40cm x 80cm) with the T4 dose (2500 $kg.ha^{-1}$ of ox dung + 50 $kg.ha^{-1}$ of NPK).

3.2 Discussion

3.2.1 Effect of fertilizer doses on the agronomic parameters of cotton

The T2 treatment, which is the combination of 100 kg of NPK and 2000 kg of cow dung, made it possible to observe the highest values of cotton mass and seed cotton yield. The high values at the level of this treatment would be explained by the fact that the mineral elements contained in the mineral fertilizer NPK are intensely made available to the plants as soon as it is incorporated into the soil. Also, ox dung gradually provides plants with nutrients such as nitrogen, phosphorus and potassium. The high values at the level of the combination (2000 kg ox dung and 100 $kg.ha^{-1}$ of NPK) are also explained by the influence of ox dung on the physical and biological properties of the soil. The permanent presence of ox dung in the soil promotes biological activity and improves the organic carbon of the soil, which leads to the regulation of soil PH. It participates in the establishment of the clay-humic complex allowing the fixation of minerals. It increases the aeration of the soil, the water retention capacity allowing better development of the root system of cotton plants. The improvement of the physical and chemical properties of the soil by organic matter has been demonstrated by Nyembo et al. (2014) [17] during their work carried out in the DR Congo on the improvement of the physical and chemical properties of the soil under the combined contribution of bio-waste. They also concluded that the use of organic manures can amplify the effectiveness of mineral fertilizers on crop yield. Ox dung also provides plants with mineral elements such as calcium, magnesium, organic carbon and even organic matter. As a result, the combination of ox dung and NPK mineral fertilizer compensates for the loss of nutrients and therefore increases the yield of cotton plants. Our results are consistent with those obtained by Pouya et al. (2013) [18] carried out in Burkina Faso. These authors observed increases in seed cotton yield under fertilization with a combination of organic and mineral fertilizers in a soil fertility management study and their effects on cotton production. It should be noted that plant production is closely linked to the availability and balance between nutrients (N, P, K, Ca, Mg, etc.). A continuous and reasonable availability of these elements allows plants to express their productivity potential. But, an excess of these nutrients can lead to a drop in plant yield. This situation could explain the low seed cotton yields observed under treatments T3 and T4, the quantities of cow dung of which are greater than T2. Furthermore, the difference in seed cotton yield between treatments T1 and T2 is explained by the fact that the quantity of ox dung (1500 $kg.ha^{-1}$) contained in T1 would be insufficient to compensate for all the losses or imbalances that nutrients from the NPK mineral fertilizer associated with it. It has also been proven in Benin by Dagbenonbakin et al. (2012) [8] that the efficiency of organo-mineral manure on seed cotton yield, imposes an optimal dose to be respected. These authors tested several doses of organo-mineral manures on cotton yield in Benin. They concluded that the addition of 100 kg/ha of NPK to compost made from ox dung (2500 $kg.ha^{-1}$) made it possible to optimize seed cotton yield. The low values of seed cotton mass and seed cotton yield were obtained with the T0 treatment (200 $kg.ha^{-1}$ of NPK). This difference in yield between T0 and the treatments (T1, T2, T3 and T4) is due to the absence of dung in the T0 treatment. In fact, according to Akanza et Yoro (2003) [3], organic manure appears as a regulator and stabilizer of soil fertility. Likewise, Ouandaogo et al. (2016) [19] asserted that exclusive mineral fertilization leads to a drop in nitrogen and organic carbon levels in the soil.

They also noticed low yields of sorghum and cowpea from mineral fertilization alone compared to organo-mineral fertilizers. Also, the mineral elements such as nitrogen, phosphorus and potassium contained in the NPK mineral fertilizer are intensely made available to the plants as soon as it is incorporated into the soil. As a result, mineral nutrient losses through runoff can occur, depriving plants of minerals during periods of active need. Our results are similar to those of Koulibaly et al. (2015) [20] who observed a low yield of seed cotton treated with the exclusive mineral manure. The Control T5 treatment consisting solely of ox dung induced low values of seed cotton yield compared to the other organo-mineral treatments. These differences could be explained by the absence of mineral fertilizer (NPK). Indeed, the cow dung contained in these treatments gradually makes the mineral elements available to the cotton plants during their cycle. Indeed, it has been demonstrated in Burkina Faso that there is a certain complementarity between organic manure and mineral manure for improving soil fertility [21]. This author carried out his investigations on the influence of mineral fertilizer and mineral fertilizer combined with organic manure on the soil in Burkina Faso. Other authors like Igue et al. (2016) [22] proved the effectiveness of a combination of ox dung and mineral fertilizer on maize yield in Benin by testing several doses of this combination on maize. During their work in Burkina Faso Somda et al. (2017) [23] also reported the optimization of fonio and sorghum yields induced by organo-mineral manure and also concluded that it improves soil fertility.

3.2.2 Effect of sowing density on the agronomic parameters of cotton

Cotton plants sown at low density (lowD) expressed the highest values of the number of bolls and cotton mass per plant. These differences are due to the fact that, in low density, competitions for nutrients, water, light and space are reduced between cotton plants compared to high density. Cotton plants from low density therefore benefit from sufficient space to flourish and make efficient use of water, light and nutrients to truly express their production potential compared to those from high density. This situation explains the high production of bolls and seed cotton mass per plant under the low density compared to the high density. In high density, the optimal conditions for nutrition and development of cotton plants are reduced. The resulting consequence is the reduction in capsule production as reported by Sekloka et al. (2016) [13] during their work on two cotton plant morphotypes. However, seed cotton yield is higher in high density than in low density. This result could be explained by the fact that the number of plants per hectare for low density (lowD) is much lower than the number of plants at high density (For D). Similar studies carried out in Benin have reported that under densities varying from 41,667 plant.ha^{-1} to 62,500 plant. ha^{-1}, the best seed cotton yield is obtained at high density estimated at 62,500 plant.ha^{-1} [14]. The increase in the number of bolls and the seed cotton mass in low seeding density (IFai D) is similar to the results obtained by [11]. Indeed, these authors observed an increase in the mass and number of fruits per plant linked to the reduction in the density of okra sowing in Côte d'Ivoire. Our results corroborate with those observed in China by [15]. They showed that, when the sowing density reaches its equilibrium, it generates an environment favorable to cotton plants and which consequently optimizes their yield. Studies carried out on densities ranging from 75,000 to 105,000 plant.ha^{-1} have also highlighted reductions in cotton fiber yields linked to the reduction in sowing density in China [16]. By studying the influence of variation in sowing density in China, authors have observed that cotton fiber yield increases linearly with density up to the color of the density equilibrium point beyond which fiber yield decreases [12]. The seed cotton yield per hectare allowed us to distinguish the interaction formed by the high seeding density (For D) and the T2 treatment which gave the highest yield of seed cotton per hectare. This assume that the optimization of the average yield must take into account the need of plants for nutrients and the number of plants likely to create a microclimate favorable to their development. The variation in cotton yield as a function of the microenvironment created by the sowing density has been reported by Yang et al. (2014) [15] in China. Our observations are consistent with Amonmidé et al. (2020) [14] who showed that the efficiency of fertilizers is linked to the density of plants on the given plot. Indeed, the latter studied the productivity of cotton plants treated with mineral manure under various sowing densities. Ivorian experiments carried out on voandzou have proven that there is a threshold from which the number of plant.ha^{-1} of voandzou induces an optimal yield [10].

4. CONCLUSION

The effects of ox dung dose and seeding density were evaluated on some cotton plant agro-morphological parameters in order to determine the optimal values that optimize seed cotton yield. The seed cotton yield, the seed cotton mass and the number of bolls of the cotton plants treated with T2 (2000 kg.ha^{-1} of ox dung + 100 kg.ha^{-1} of NPK) were greater than those resulting from the other treatments. The high density (For D: 30 cm x 80 cm, i.e. 83,500 plant.ha^{-1}) made it possible to obtain the highest seed cotton yield compared to other sowing densities. The low sowing density (LwD: 50 cm x 80 cm, i.e. 50,000 plant.ha^{-1}) induced the highest values for the number of bolls and the seed cotton mass per plant. All the organo-mineral treatments were more productive than the T0 treatment (200 kg.ha^{-1} of NPK). However, the more effective use of ox dung imposes the dose T2 (2000 kg.ha^{-1} of ox dung + 100 kg.ha^{-1} of NPK) and the density For D (30cm x 80cm, i.e. 83500 plant.ha^{-1}) to hope optimize seed cotton yield up to 4434.77 kg.ha^{-1}.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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