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Response of the Maize Variety EV87-28 to a Fertilization Strategy Involving Indorama Granular Urea on Ferralsol in the Central Ivory Coast

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Abstract

In Côte d'Ivoire, the decline in soil fertility strongly impacts the productivity of maize (*Zea mays* L.) on heavily leached ferralitic soil. In this study, the general objective was therefore to improve the productivity of maize EV87-28 on the Ferralsols in pre-forested areas during different cropping seasons. Eight (8) micro-plots were set up according to a total randomization device with three repetitions. Two factors were studied: nitrogen fertilizer modalities (main factor) and crop season (secondary factor). Growth, flowering and yield parameters were measured and analyzed. The results showed that there was no interaction between the nitrogen fertilizer factor and the cropping season factor. In addition, this study showed the short rainy season had the most positive impact on growth, flowering and yield parameters than the long rainy season. The results also showed that the different nitrogen fertilizer modalities had no statistically different effects on growth, flowering and yield parameters. However, quantitative differences were reported, highlighting one nitrogen fertilizer modality, which is the combination of urea granule + farm manure (75% urea indorama granules and 25% farm manure). The combination of urea granule + farm manure (75% urea indorama granules and 25% farm manure) had the best effect on corn grain yield. So, the combination of urea (75%) and manure (25%), that resulted in yield gain, could be recommended for corn fertilization during the small rainy season.

Keywords

Indorama Granular Urea, Ferralsol, Cultural Seasons, Maize, Ivory Coast

1. Introduction

Maize (*Zea mays* L.) is an important food resource in tropical and subtropical regions. It draws its success from the richness of its seeds in starch, vitamin K and trace elements, then the absence of gluten [1] [2].

In Côte d'Ivoire, maize farming appears to be a true culture of income and diversification of the farmer's sources of income. Domestic production increased from 840,000 tonnes in 2013 to 1,025,000 tonnes in 2017, making maize the second most widely grown cereal in Côte d'Ivoire [3]. Maize is grown throughout the country with a predominance of production in the northern half of the country, which provides 60% of production [4]. This cereal is the main raw material for the manufacture of livestock feed in Côte d'Ivoire with the development of pig and poultry farming and holds a significant share of the population's diet [4] [5].

Despite growing demand, maize production remains at 2.11 t/ha [3] [4]. This low yield relative to demand is due to soil nutrient depletion [6] [7], low fertilizer use [8], use of traditional, unprofitable varieties [9], and inadequate post-harvest conservation [10] [11].

Thus, the increase in domestic production is subject to the increase in arable land. However, high land pressure in large areas of food production this extensive agriculture is no longer possible [6].

Therefore, integrated management of soil fertility through the combination of synthetic fertilizers and exogenous organic matter is the most appropriate way to increase maize yields [6] [12] [13] [14].

Indeed, nitrogen considered to be the most limiting nutrient in corn influences all phases of corn development and production [10] [13] [14]. The lack of nitrogen can cause a decrease in yield, while an excess represents a risk of contamination of air and water, in addition to incurring unnecessary costs [15]. Thus, the nature of nitrogen fertilizer is paramount, because the phenomenon of denitrification and volatilization facilitates the loss of nitrogen mineral manure in the environment, especially in rainy periods [5] [15]. In addition, knowledge of the cultivation of soil is essential for the application of nitrogen fertilizers. In Côte d'Ivoire, the soil of the Ferrasol type, heavily degraded and leached over crops, is the most affected by the cultivation of maize in the pre-forest zone [6] [12]. Degraded, compacted soil with a steep slope or other features that reduce water infiltration will be more conducive to nitrogen losses from erosion or runoff [16] [17]. Thus, the nature and modalities of applications of nitrogen fertilizer, brought to a soil, are a good way to control this form of loss and maximize corn grain yields.

Also, corn farming in Côte d'Ivoire, is very demanding in water, with a critical period that extends from flowering to grain filling [10] [18]. Thus, the risk of water deficit, which is combined with soil poverty in nitrate, is very marked for maize cultivation according to the growing season in Côte d'Ivoire [18]. According to the reference [19], nitrogen fertilization and climatic conditions (rainfall and temperature) are the two dominant factors in maize production and yield.

Thus, the present study carried out on ferralsol in the pre-forest zone aims to evaluate the influence of different doses of nitrogen fertilizers on the growth and productivity of the maize variety EV87-28 (*Zea mays* L.) according to the production season.

2. Materials and Methods

2.1. Expérimental Site

This study was conducted at the Food Crops Research Station (SRCV) of the National Center for Agricultural Research (CNRA) of Bouake. This station is located in the Guinean savannah, in central Côte d'Ivoire at 7˚46' north latitude, 5˚06' west longitude and 375 m altitude [12]. The climate is humid tropical with a four-season rainfall regime, including a large dry season (November to February), a large rainy season (March to June), a small dry season (July to August) and a small rainy season (September to October). The average annual rainfall is 1200 mm with an average temperature of 25.73˚C [20] [21] (**Figure 1**).

2.2. Soil Analysis

A sample of strongly desaturated ferrallitic soil was taken between 0 and 20 cm deep. The analyzes performed were particle size [22], soil pH, organic carbon [23] [24], total nitrogen [25], Olsen's assimilable phosphorus [26], exchangeable bases, cation exchange capacity [27], exchange aluminum [28], free iron [29] and phosphorus saturation rate (PSD) by method [30].

2.3. Experimental Set-Up and Implementation of Experimentation

The experiment was carried out from April to July 2017 and from August to November 2018. At each period the experimental device was a completely randomized random device with three (3) repetitions. Two factors were studied: nitrogen fertilizer (main factor) and crop season (secondary factor). The nitrogen fertilizer factor consists of eight (8) treatments or modalities: T0: Control (Zero fertilizer application).

1) T1: Reference control (200 kg/ha NPK (15-15-15) + 50 kg/ha urea).

2) T2: Recommended dose of NPK (100% N Indorama Urea Granule).

3) T3: Recommended dose of NPK (100% N through prilled urea).

4) T4: Full dose of PK + 75% N through Indorama Granular Urea + 25% N through FYM.

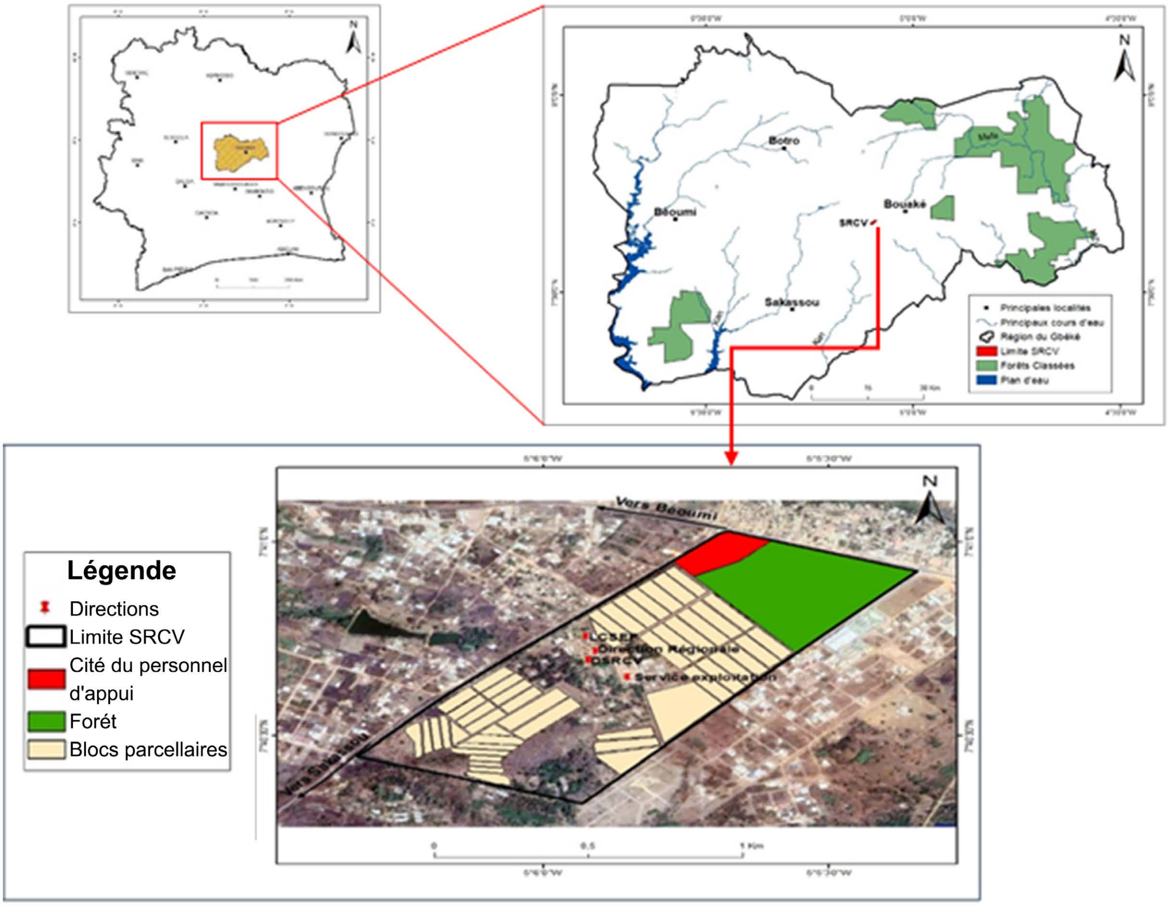

Figure 1. Location of study site.

5) T5: Full dose of P&K + 75% N through prilled Urea + 25% N through FYM.

6) T6: Full dose of P&K + 75% N through Indorama Granular Urea.

7) T7: Full dose of P&K + 75% N through Prilled Urea (FYM: Farm manure).

The planting season factor consists of two (2) modalities: small rainy season and large rainy season.

Each elementary plot measures 150 m^2 (15 m 10 m) with a spacing of 0.5 m and 1 m between repetitions. A background fertilizer (NPK 15-15-15) was applied to 200 kg/ha after tillage. Three (3) maize seeds were sown per pan, then 40 days after sowing, 100 kg/ha of urea were brought.

Weeding was carried out 15 days apart from the 30th day after sunrise.

2.4. Plant Material

The variety of maize used in the study is EV87-28. This cultivar has a maturity cycle of 90 to 100 days and a potential yield of 7 to 9 $t \cdot ha^{-1}$.

2.5. Data Collection

Observations focused on vegetative parameters and yield parameters. The vegetative parameters observed the male and female flowering time, the height of the plant the level of insertion, the number of plants harvested, the length of the ears, the weight of the dry matter, the moisture content of the seeds, 100 grain weight and corn yield gain. Grain yield was calculated by reducing grain weights to 14% moisture. The formula for determining yield and yield gain is:

$$\text{yield} = \frac{\text{Field\_Seed\_Weight\_}(\text{kg})}{\text{Elementary\_Parcel\_Area\_}(\text{m}^2)} \times 10000 . \tag{1}$$

$$\text{yield\_gain} = \frac{\text{Benchmark\_yield} - \text{Treatement\_yield}}{\text{Benchmark\_yield}} \times 100 \tag{2}$$

The yield of each nitrogen fertilizer modality was estimated in tonnes per hectare (t/ha). The yield gain for each nitrogen fertilizer method was evaluated as a percentage (%) compared with the reference treatment.

2.6. Statistical Analysis

Data were collected on different vegetation parameters and yield, and were analyzed for variance (ANOVA) to determine the effect of treatments. The significance threshold was set at 0.05. The Tukey post hoc test was performed from the agricultural package determine significant levels when a difference was observed at the set threshold. The graphs estimating quantitative differences and yield gain were made using the ggplot2 package. All analyzes and graphical representations were performed using R software version 4.3.1.

3. Results

3.1. Description and Physicochemical Characteristics of Test Sites Soils

The 2017 and 2018 experiments take place on Ferralsol soil, whose slope is estimated to be low. Soil is described as highly desaturated and highly leached ferrallitic soil according to the International Soil Reference and Information Center (ISRIC) and the Food and Agriculture Organization of the United Nations (FAO) (1998). The surface horizon (0 - 20 cm), is clay-sandy and sandy-clay respectively for the experimental site of 2017 and 2018, with regard to their granulometric compositions (**Table 1**). With a low acidic pH H_2O, excellent at the 2018 experimental site and acceptable at the 2017 experimental site, both study sites have low levels of organic carbon-C and total nitrogen-N. But their C/Nt ratios suggest rapid mineralization and therefore strong biological activity especially at the level of the first 20 centimeters of the soil (**Table 1**). The potassium (K), exchangeable calcium (Ca) and magnesium content of the two study sites indicate an imbalance of exchangeable soil bases. In addition, the soil cation exchange capacity (CEC) of the 2018 experimental site is almost three times that of 2017. The content of assimilable phosphorus remains relatively low for both soils. However, the 2017 experimental site is significantly higher than in 2018. No aluminum toxicity was noted (Al: CEC = 25.5%).

Table 1. Physical, physico-chemical and chemical composition of experimental site soils.

Features	Values	
	Experimental site 2017	Experimental site 2018
Clay ($g \cdot kg^{-1}$)	29.1	21.2
Silt ($g \cdot kg^{-1}$)	10.6	12.5
Sand ($g \cdot kg^{-1}$)	60.4	66.3
pH H_2O	5.1	6.2
pH KCl	4.2	5.3
Organic carbon - C ($g \cdot kg^{-1}$)	1.22	1.60
Total nitrogen - N ($g \cdot kg^{-1}$)	0.9	1.14
C/N	1.32	1.40
N-NO_3^-	15.80	3.56
N-NH_4^+	5.81	7.45
CEC ($cmol \cdot kg^{-1}$)	3.57	9.17
P.ass ($mg \cdot kg^{-1}$)	32.96	18.39
Ca ($cmol \cdot kg^{-1}$)	1.84	5.85
Mg ($cmol \cdot kg^{-1}$)	0.75	1.19
K ($cmol \cdot kg^{-1}$)	0.37	0.35
Exchangeable Al	0.58	0.08

Nt: Total nitrogen; P. ass: Assimilable phosphorus; C: Total carbon; NH_4^+: ammonium ion; N-NO_3^-: nitrate ion; CEC: Cation exchange capability; Ca^{2+}: calcium ion; Mg^{2+}: magnesium ion; K^+: potassium ion; Al: Aluminum.

3.2. Climatic Conditions of the Test Periods and Phenology of the Culture

The tests were carried out during the big and small rainy season where the rainfall heights reached respectively 80 mm (in June) and 127 mm (in August). Temperatures remained high during the various vegetative phases. During the major rainy season (Figure 2(a)), temperatures ranged from 24˚C to 29˚C and during the small season (Figure 2(b)) from 22˚C to 28˚C. The emergence of young plants, conditioned by a minimum of precipitation, occurred before one week. The blooms appeared about a month and a half after the emergence of plants, because with an irregular rainfall (in height) but almost present along the crop, no water deficit could be recorded. If some rainfall was decisive to reach flowering, as for production, it seems independent of the height of the rains. Indeed, for about a month and a half between flowering and harvest, rainfall behaved differently in both trials. During the rainy season, significant amounts of rain were recorded between 15 and 27 June (up to more than 120 mm). While for the small season, the daily rainfall recorded between flowering and harvest remained low (less than 5 mm).

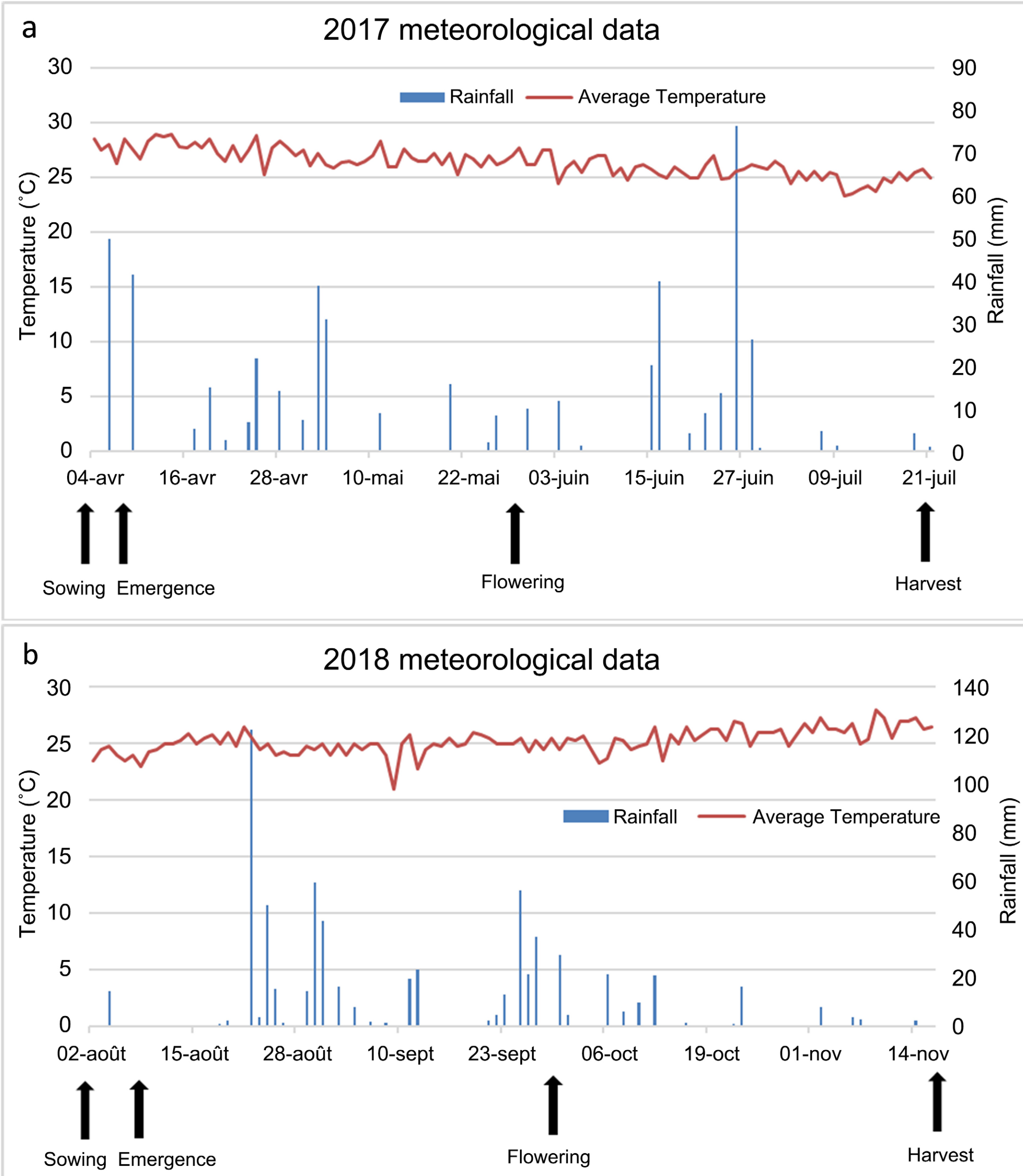

Figure 2. Daily temperature and rainfall data of experimental site during the growing season of 2017 (a) and 2018 (b).

3.3. Combined Effects of Crop Seasons and Different Fertilizer Treatments on Maize Agronomic Parameters

For all parameters assessed, there was no interaction between treatments and cropping seasons as indicated by the probability values (p) of Table 2. Indeed, the probabilities obtained were not significant. They were all above 0.05.

3.4. Distinct Effects of Different Fertilizers and Growing Seasons on Corn Flowering

From Table 3, we see that male flowering and female flowering of corn did not

Table 2. Combined effects of growing seasons and fertilizer treatments on corn agronomic parameters.

Settings	DDL	Fisher's F	p
LON EPIS	7	1.5163	0.197237
FLOM	7	0.0667	0.9995
FLOF	7	0.5635	0.7797
HP	7	1.0581	0.4121
INS EPIS	7	0.4788	0.8427
PL RE	7	0.232	0.9744
EPIS RE	7	0.6863	0.6827
MAT SEC_KG	7	0.3309	0.934
HUM	7	1.5285	0.1932
P100 GRM	7	1.7798	0.1259
Yield	7	0.8299	0.5704

Legend: LON_EPIS: Length of ears; FLOM: Male flowering; FLOF: Female flowering; HP: Plant height; INS_EPIS: Insertion of ears; PL_RE: Harvested plants; EPIS_RE: Ears harvested; MAT_SEC_KG: Dry matter; HUM (%): Humidity rate; P100_GRM: Weight of 100 grains.

Table 3. Distinct effects of different fertilizers and cropping seasons on corn flowering.

Setting	Treatments	Crop seasons
	p	
FLOM	0.775	<0.0001
FLOF	0.583	<0.0001

Legend: FLOM: Male flowering; FLOF: Female flowering.

vary statistically under the effect of different nitrogen treatments. However, the 2017 growing season (April-July) and the 2018 growing season (August-November) had a statistically different impact on these two parameters. Indeed, the averages for male flowering were 56.79 in the 2017 growing season and 55.75 in the 2018 growing season. For female flowering, the average values were 61.33 in the 2017 growing season from 60.37 to the 2018 growing season. The 2017 growing season (April-July), which corresponds to the long rainy season, made it possible to obtain abundant male and female flowering compared to that of 2018 corresponding to the short rainy season. This growing season had a positive influence on corn flowering parameters.

3.5. Distinct Effects of Different Fertilizer Treatments and Growing Seasons on Corn Growth Parameters

The fertilizers tested did not have a significant effect on growth parameters. However, a highly significant statistical difference was observed for the two growing seasons combined (**Table 4**). Indeed, the values of the length of the ears were 14.33 for the 2017 growing season (April-July) and 13.59 for the 2018 growing season (August-November). Those of the insertion of the ears were 70.08 for the 2017 growing season and 69.45 for the 2018 growing season. While, those of plant height were 122.87 for the 2017 growing season and of 206.75 in the 2018 growing season. The 2017 growing season (long rainy season) made it possible to obtain a great length of ears and an insertion of ears. While the 2018 growing season (short rainy season) obtained the tallest plant heights. The long rainy season therefore favored better growth and insertion of ears and with regard to the short rainy season, strong growth in height.

It is true that the different doses of fertilizer did not have statistically different effects on growth parameters. However, quantitative differences revealed variation (**Figures 3-5**). For ear length, the treatment Full dose of P&K + 75% N through prilled Urea + 25% N through FYM gave the greatest quantity. It was followed by the Full dose of P&K + 75% N through Indorama Granular Urea treatment (**Figure 3**). For the ear insertion parameter, the best quantity was obtained from the fertilizer Full dose of P&K + 75% N through Indorama Granular Urea + 25% N through FYM. It was followed by the fertilizer Full dose of P&K + 75% N through Indorama Granular Urea (**Figure 4**). The plants with the highest heights were obtained from fertilizer "200 kg/ha of NPK (15-15-15) + 50 kg/ha urea". The other nitrogen treatments were obtained relatively identical plant heights and, above all, significantly lower plant heights than the reference treatment "200 kg/ha of NPK (15-15-15) + 50 kg/ha urea" (**Figure 5**).

3.6. Distinct Effects of Different Fertilizer Treatments and Growing Seasons on Corn Yield Parameters

A highly significant statistical difference was observed for the two growing seasons taken together (**Table 5**). Indeed, the highest number of plants harvested was obtained during the 2018 growing season (August-November) with an average of 346.29 plants harvested, and the lowest average was obtained during the 2017 growing season (April-July) with an average of 231.63. Regarding the number of ears harvested, the highest values were obtained during the 2018 growing season (August-November) with an average of 275.42, the lowest value

Table 4. Significant effect of different fertilizers and rainy season on growth parameters.

Setting	Treatment	Sowing season
	P	
INS_EPIS	0.181	<0.0001
LON_EPIS	0.484	<0.0001
HP	0.9327	<0.0001

Legend: INS_EPIS: Insertion of ears; LON_EPIS: Length of harvested ears HP: Height of plants.

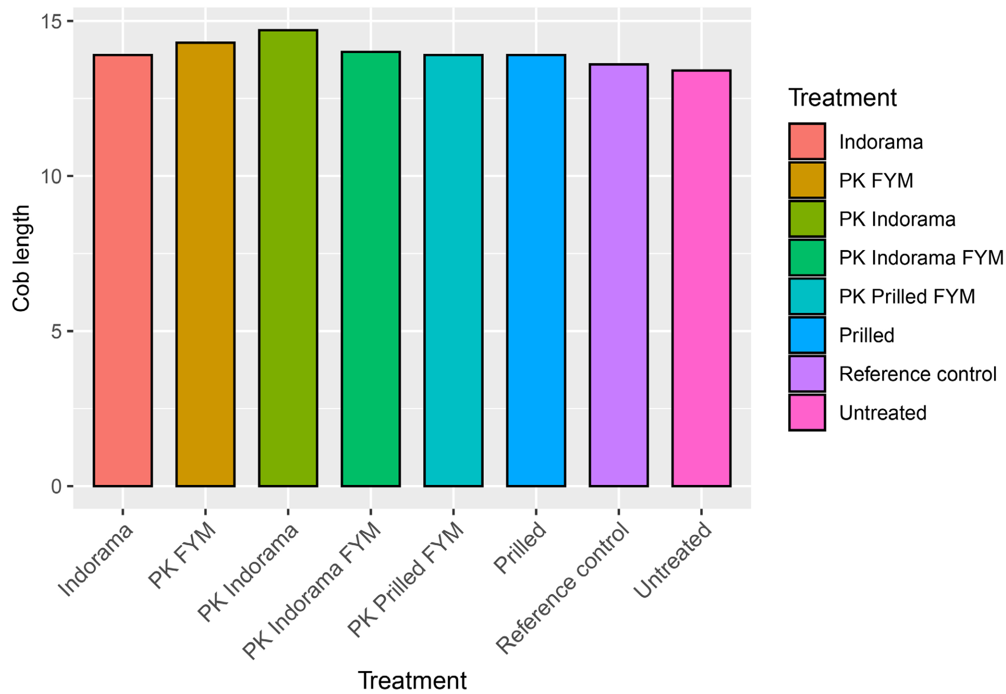

Figure 3. Average ear length values according to different fertilizer treatments. Legend: Indorama = Treatment 2; PK_FYM = Treatment 7; PK_Indorama = Treatment 6; PK_Indorama_FYM = Treatment 4; PK_Prilled FYM = Treatment 5; Prilled = Treatment 3; Reference control = Processing 1; Untreated = Treatment 0.

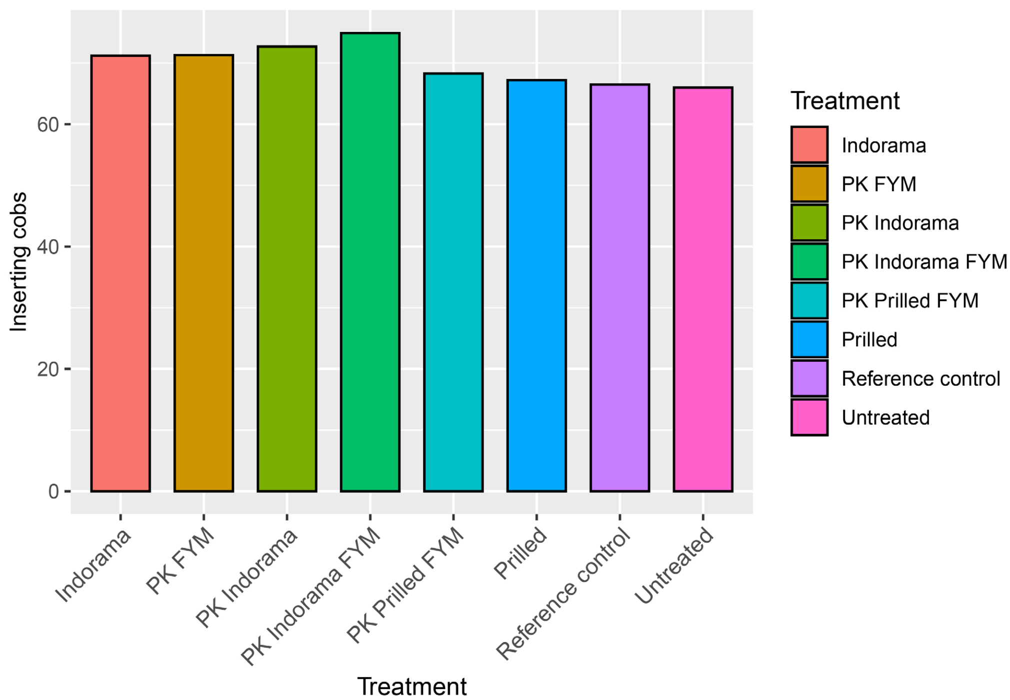

Figure 4. Average values for ear insertion according to different fertilizer treatments. Legend: Indorama = Treatment 2; PK_FYM = Treatment 7; PK_Indorama = Treatment 6; PK_Indorama_FYM = Treatment 4; PK_Prilled FYM = Treatment 5; Prilled = Treatment 3; Reference control = Processing 1; Untreated = Treatment 0.

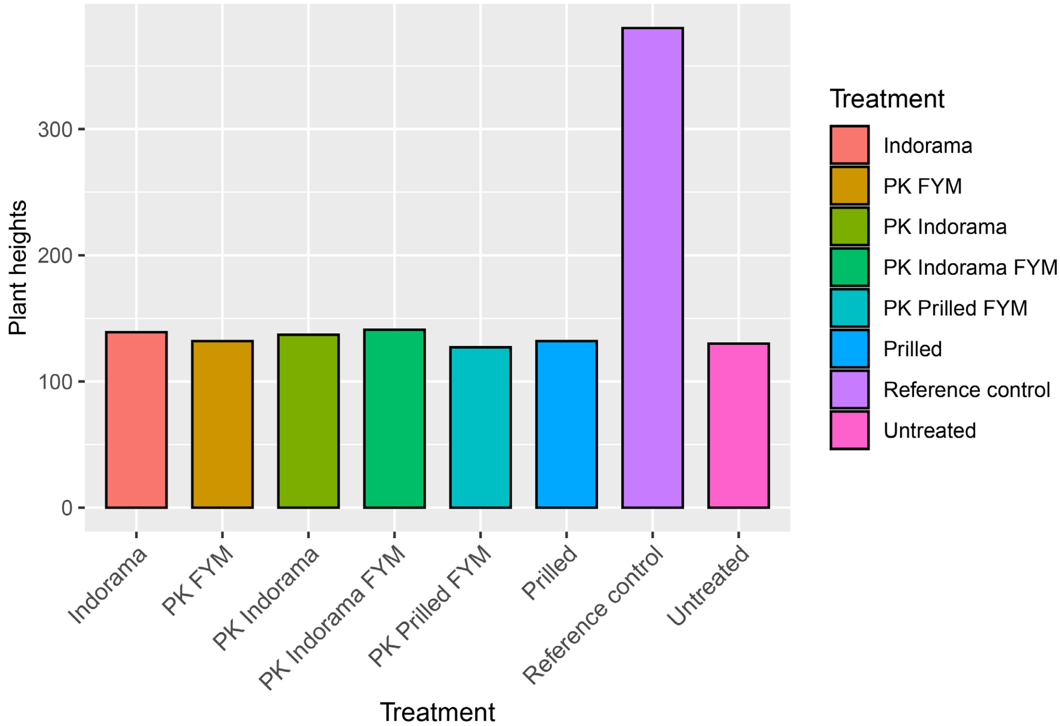

Figure 5. Average values of the height of corn plants following the different fertilizer treatments. Legend: Indorama = Treatment 2; PK_FYM = Treatment 7; PK_Indorama = Treatment 6; PK_Indorama_FYM = Treatment 4; PK_Prilled FYM = Treatment 5; Prilled = Treatment 3; Reference control = Processing 1; Untreated = Treatment 0.

Table 5. Distinct effects of different fertilizer treatments and cropping seasons on maize yield parameters.

Setting	Treatment	Sowing season
	p	
PL_RE	0.968	<0.0001
EPIS_RE	0.974	<0.0001
MAT_SEC_KG	0.77	<0.0001
P100_GRM	0.99	<0.0001
HUM	0.9783	<0.0001

was observed during the 2017 growing season with an average 142. The dry matter value varied from 17.63 to the 2018 growing season and 26.63 for the 2017 growing season. The measured humidity rate showed a high humidity rate during the 2018 growing season with a value of 15.95% compared to a value of 8.60% observed during the 2017 growing season. The weight of 100 seeds parameter was high during the 2018 growing season (short rainy season) with an average of 29.04 compared to 17.12 during the 2017 growing season (long rainy season). The short rainy season therefore made it possible to obtain the highest yield estimation parameters (**Table 5**).

The doses of fertilizers tested did not reveal any statistical difference for the yield estimation parameters (**Table 5**). However, quantitative differences revealed variation (**Figures 6-10**). For the number of plants harvested, the fertilizer composed of Full dose of P&K + 75% N through prilled Urea + 25% N through FYM gave the highest number of plants. It was followed by 100% N through Indorama Granule Urea (**Figure 6**). For the harvested ears, the fertilizer composed of Full dose of P&K + 75% N through prilled Urea + 25% N through FYM, gave the highest number of ears. It was followed by 100% N through Indorama Granule Urea and 200 kg/ha of NPK (15-15-15) + 50 kg/ha urea (**Figure 7**). For the humidity level, the two fertilizers that emerged are: Full dose of P&K + 75% N through Indorama Granular Urea and Full dose of P&K + 75% N through prilled Urea + 25% N through FYM (**Figure 8**). For dry matter, the fertilizer composed of Full dose of P&K + 75% N through prilled Urea + 25% N through FYM gave the highest dry matter. It was followed by the fertilizer Full dose of P&K + 75% N through Prilled Urea and 100% N through prilled urea (**Figure 9**). For the weight of 100 seeds, three fertilizers were found to be better than the others. These were Full dose of P&K + 75% N through prilled Urea + 25% N through FYM, Full dose of P&K + 75% N through Indorama Granular Urea and Full dose of P&K + 75% N through Prilled Urea (**Figure 10**).

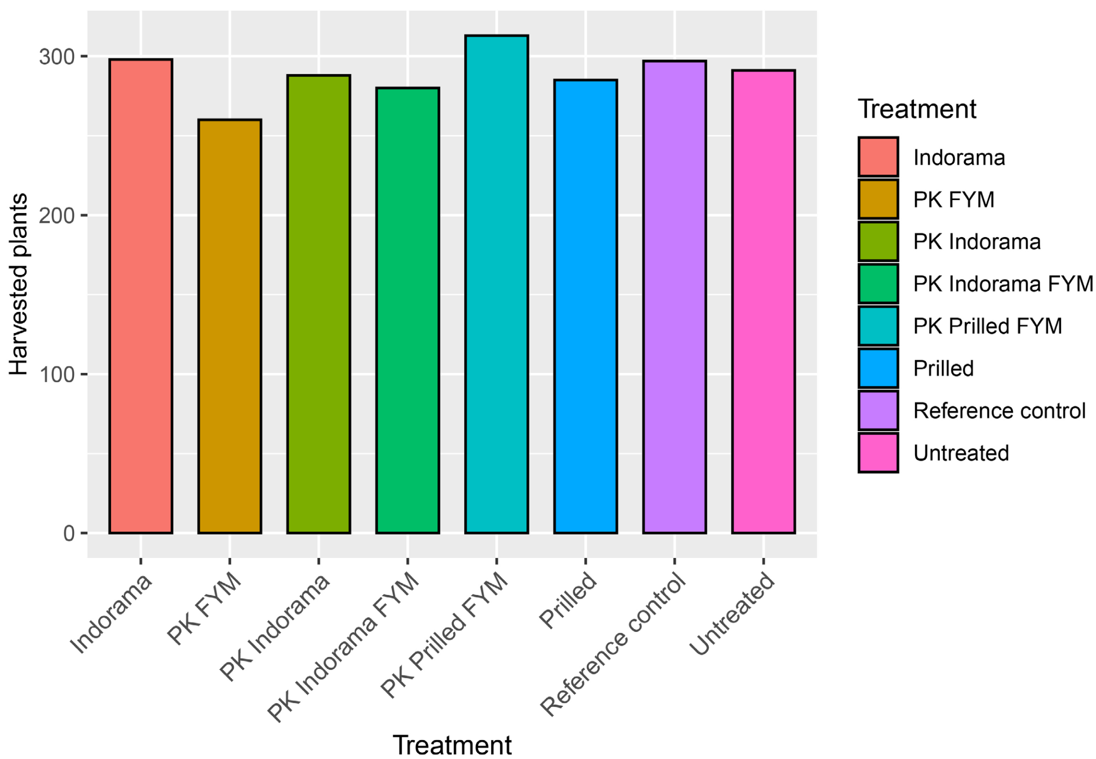

Figure 6. Average values of the harvested plants of maize material according to the different fertilizer treatments. Legend: Indorama = Treatment 2; PK_FYM = Treatment 7; PK_Indorama = Treatment 6; PK_Indorama_FYM = Treatment 4; PK_Prilled FYM = Treatment 5; Prilled = Treatment 3; Reference control = Processing 1; Untreated = Treatment 0.

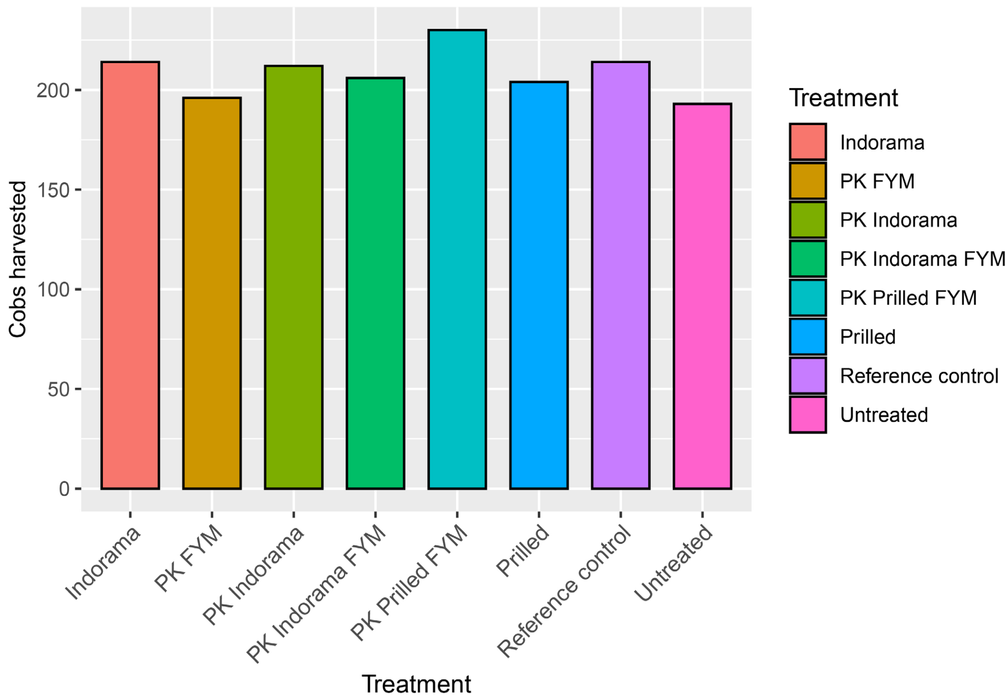

Figure 7. Average values of the harvested cobs of maize material following the different fertilizer treatments. Legend: Indorama = Treatment 2; PK_FYM = Treatment 7; PK_Indorama = Treatment 6; PK_Indorama_FYM = Treatment 4; PK_Prilled FYM = Treatment 5; Prilled = Treatment 3; Reference control = Processing 1; Untreated = Treatment 0.

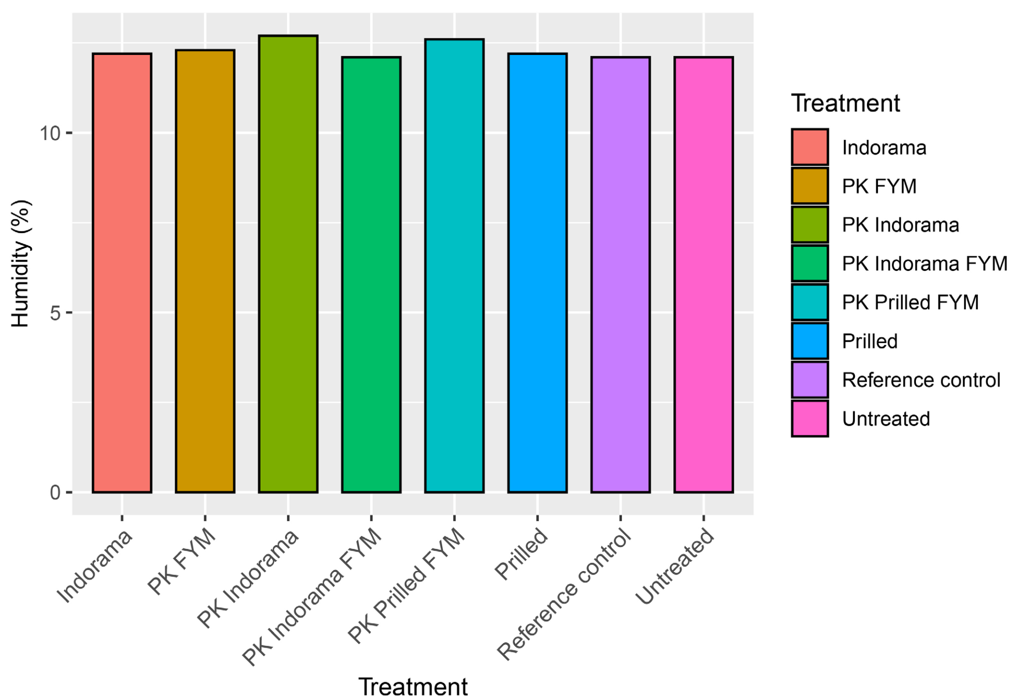

Figure 8. Average values of corn moisture content following the different fertilizer treatments. Legend: Indorama = Treatment 2; PK_FYM = Treatment 7; PK_Indorama = Treatment 6; PK_Indorama_FYM = Treatment 4; PK_Prilled FYM = Treatment 5; Prilled = Treatment 3; Reference control = Processing 1; Untreated = Treatment 0.

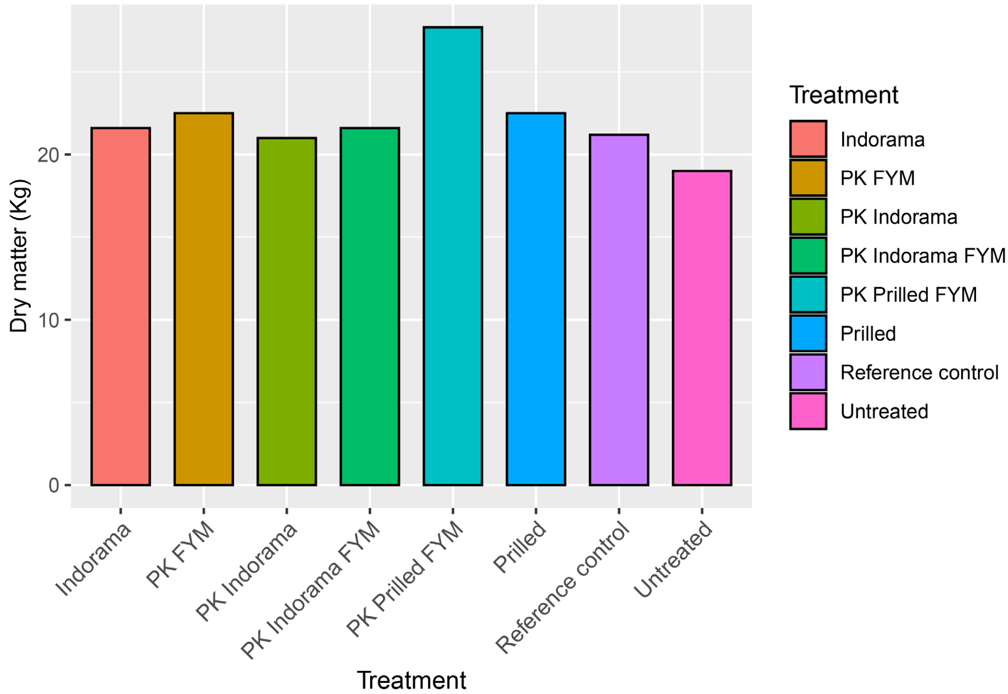

Figure 9. Average values of dried matter according to the different fertilizer treatments. Legend: Indorama = Treatment 2; PK_FYM = Treatment 7; PK_Indorama = Treatment 6; PK_Indorama_FYM = Treatment 4; PK_Prilled FYM = Treatment 5; Prilled = Treatment 3; Reference control = Processing 1; Untreated = Treatment 0.

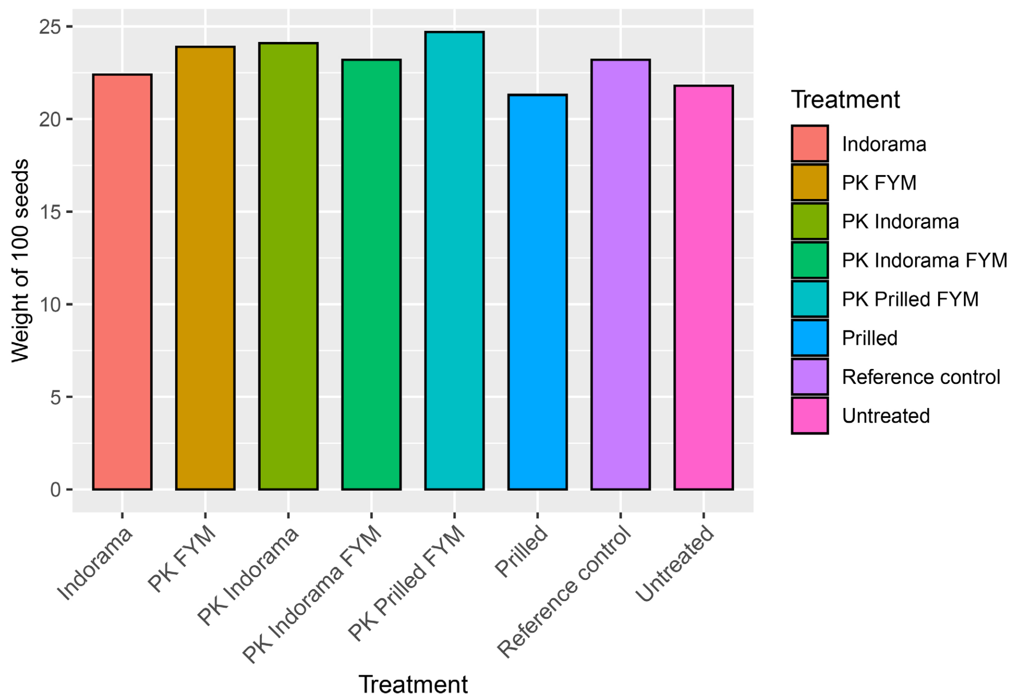

Figure 10. Average values of 100 maize grains according to the different fertilizer treatments. Legend: Indorama = Treatment 2; PK_FYM = Treatment 7; PK_Indorama = Treatment 6; PK_Indorama_FYM = Treatment 4; PK_Prilled FYM = Treatment 5; Prilled = Treatment 3; Reference control = Processing 1; Untreated = Treatment 0.

3.7. Distinct Effects of Different Fertilizer Treatments and Growing Seasons on Corn Yield

The different doses of fertilizers evaluated have no statistical difference. However, the analysis of quantitative differences (**Figure 11**) showed that the fertilizers Full dose of P&K + 75% N through prilled Urea + 25% N through FYM and Full dose of P&K + 75% N through Indorama Granular Urea resulted in a better yield. The 2018 growing season (August-November), corresponding to the short rainy season, had a better effect on the yield estimation parameters.

3.8. Highlighting the Effects of Fertilizer Treatments on Corn Agronomic Parameters

The principal component analysis carried out made it possible to determine the effect of fertilizers on the parameters evaluated. The axes having an eigenvalue greater than or equal to 1 were selected for the analysis of the results. Thus, the first three axes were retained. Axis 1 expressed 40.2783043% of the information variability and axis 2, 29.572761% of the information variability. The cumulative percentages of these two axes were greater than 50%. These two axes were therefore retained for the spatialization of the data.

Graphical representation of data (**Figure 12**) from these two axes highlighted three groups. The first group included the fertilizer Full dose of P&K + 75% N through prilled Urea + 25% N through F. This fertilizer was oriented to the positive side of axis 1. It had a positive effect on the variables harvested ears, material dryness, yield, weight of 100 seeds and humidity. These parameters were positively correlated with each other. It allowed the improvement of yield parameters

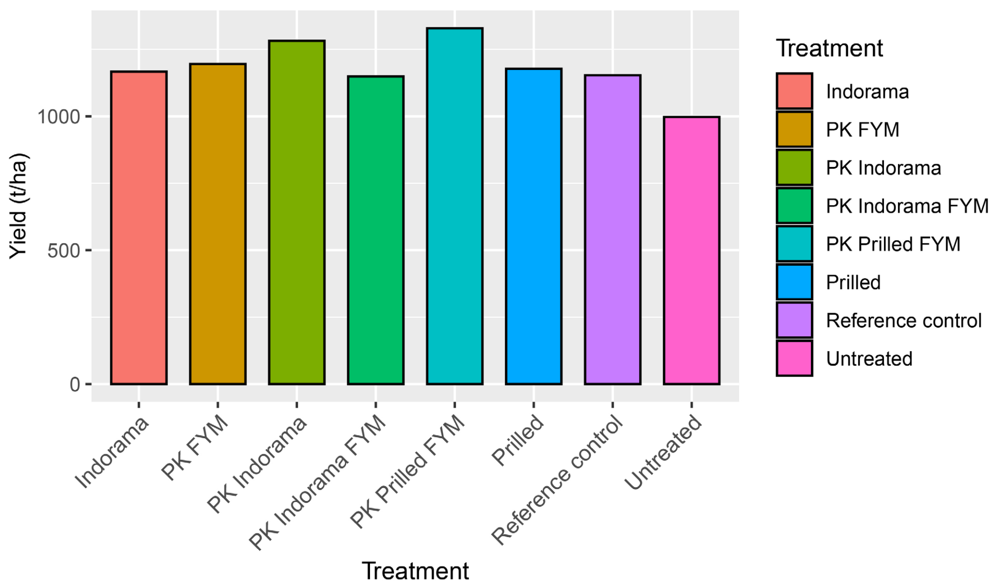

Figure 11. Average maize grain yields for different fertilizer treatments. Legend: Indorama = Treatment 2; PK_FYM = Treatment 7; PK_Indorama = Treatment 6; PK_Indorama_FYM = Treatment 4; PK_Prilled FYM = Treatment 5; Prilled = Treatment 3; Reference control = Processing 1; Untreated = Treatment 0.

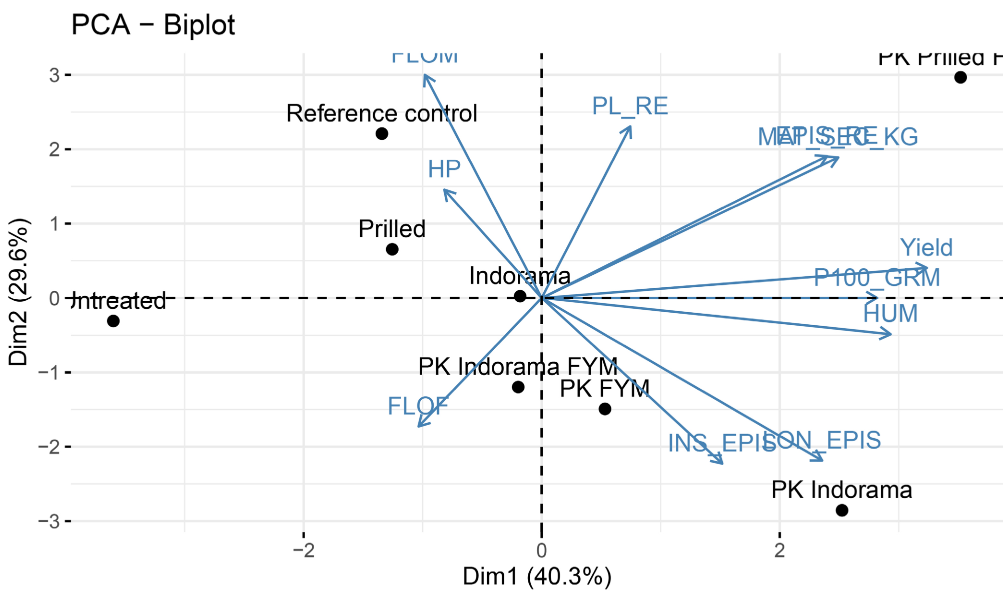

Figure 12. Correlation and dispersion of fertilizer treatments with maize agronomic data along the two main PCA axes. Legend: Indorama = Treatment 2; PK_FYM = Treatment 7; PK_Indorama = Treatment 6; PK_Indorama_FYM = Treatment 4; PK_Prilled FYM = Treatment 5; Prilled = Treatment 3; Reference control = Processing 1; Untreated = Treatment 0; LON_EPIS: Length of ears; FLOM: Male flowering; FLOF: Female flowering; HP: Plant height; INS_EPIS: Insertion of ears; PL_RE: Harvested plants; EPIS_RE: Ears harvested; MAT_SEC_KG: Dry matter; HUM (%): Humidity rate; P100_GRM: Weight of 100 grains.

as well as yield. On axis two, two groups were formed. The first group included the fertilizer 200 kg/ha of NPK (15-15-15) + 50 kg/ha urea. It had a positive effect on male flowering and harvested plants. The second group obtained from axis 2 was composed of the fertilizer Full dose of P&K + 75% N through Indorama Granular Urea. It had a positive effect on ear lengths and ear insertions.

3.9. Average Gain in Yield Obtained for the Different Fertilizer Treatments

The comparison in average gain of the different fertilizer treatments shows that without fertilizer application, a loss of gain is observed within the plots having received no fertilizer application (Figure 13). Two types of formulations made it possible to obtain a high yield gain. These were Full dose of P&K + 75% N through prilled Urea + 25% N through FYM and Full dose of P&K + 75% N through Indorama Granular Urea.

However, the formulation of Full dose of P&K + 75% N through prilled Urea + 25% N through FYM allows for better gain. Indeed, the results of the quantitative difference and the PCA confirm the effectiveness of this fertilizer.

4. Discussion

The results show us that the 2018 growing season (August-November), corresponding to the short rainy season, had a positive and better effect on growth,

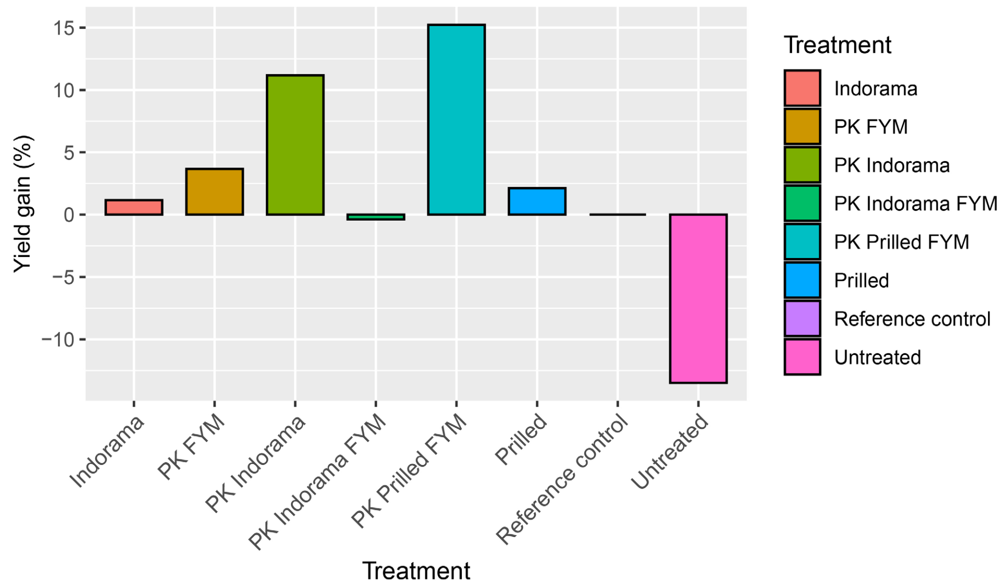

Figure 13. Average values of yield gains following the different fertilizer treatments. Legend: Indorama = Treatment 2; PK_FYM = Treatment 7; PK_Indorama = Treatment 6; PK_Indorama_FYM = Treatment 4; PK_Prilled FYM = Treatment 5; Prilled = Treatment 3; Reference control = Processing 1; Untreated = Treatment 0.

flowering and yield parameters, than the 2017 growing season (April-July), which corresponds to the long rainy season. These results could certainly be explained by the chronology of rainfall. The 2018 growing season (short rainy season) could promote better assimilation of fertilizer treatments. Corn would more easily assimilate these fertilizers during the short rainy season, which would have led to this quantitative difference. Indeed, it has been observed that sowing at the start of the growing season, with minimal rain in the first week after sowing, promotes emergence. Then, abundant and regular rainfall after emergence induces the rapid development of corn plants, flowering and therefore fruiting. The scarcity of rain at the end of the season does not seem to be harmful, because the plant will have stored enough water to complete the maturation of the corn ears (the harvest), approximately four months after sowing, and finally the temperature located between 20˚C and 30˚C, was ideal for cultivation. The maize plants were probably in a permanent state of water stress during the long rainy season, which had a negative impact on maize yields. These observations seem to contradict those of [31], where rainfall does not seem to significantly affect corn yield. On the other hand, seems to confirm that of [19] [32] [33], where climatic factors, including temperature and rainfall, had a significant effect on corn yield. This contradiction between these works is explained by [18] [21] [34] [35], whose conclusion from their work was that knowledge of the rainfall regime alone is not enough to explain the agricultural yields of corn, because a low yield can as well result from deficit or excess water conditions, also depending on nutrient levels.

The results showed that there was no interaction between the nitrogen fertilizer factor and the cropping season factor. The results also showed that the different nitrogen fertilizer modalities had no statistically different effects on growth, flowering and yield parameters. However, principal component analysis and quantitative differences highlighted the beneficial effect of three fertilizers on corn growth and grain yield, including Full dose of P&K + 75% N through prilled Urea + 25% N through FYM , Full dose of P&K + 75% N through Indorama Granular Urea and the reference treatment "200 kg/ha of NPK (15-15-15) + 50 kg/ha urea". Thus, the treatment "Full dose of P&K + 75% N through prilled Urea + 25% N through FYM" positively influenced the yield parameters. Indeed, the nitrogen supply, in this configuration, obtained the highest values of the yield parameters as indicated by the differences in quantities determined in the 2018 growing season (August-November). The regularity of the rain during this growing season would also have contributed to making the nitrogen supplied from the fertilizer Full dose of P&K + 75% N through prilled Urea + 25% N through FYM more accessible. These results are corroborated by the work of [15] [36] [37], where NPK + manure combinations give increases in corn crop yields. This observation could be explained by the rapid and large supply of nitrogen from urea granules, which are stabilized by the organic matter of farm manure, which slows down volatilization and limits nitrogen leaching, with the addition of the supply of organic nitrogen [5] [16] [37] [38].

The application of nitrogen from the formulation "Full dose of P&K + 75% N through Indorama Granular Urea" in rainy period, obtained the highest ear insertion and ear length. It seems that in rainy periods, the application of nitrogen in the form of granules, particularly indorama urea granules, leads to exaggerated vegetative growth. This observation can be explained by an excess supply of nitrogen to plants from fertilizers in the form of granules, which lengthen the vegetative phase as confirmed by the work of [13] [14], where the excess of nitrogen leads to exaggerated vegetative growth and delayed maturity. It seems that under the effect of rain, urea granules release a large quantity of nitrates, which negatively influences the development of corn plants. This trend of certain inorganic fertilizers is corroborated by the references [5] [17] [19] [21].

The addition of fertilizer, composed of 200 kg/ha of NPK (15-15-15) + 50 kg/ha urea, led to better flowering of male flowers. This abundance of male flowers was observed during the main rainy season. The composition of this fertilizer seems more effective on male flowering compared to female flowering. This observation can be explained by a rapid and excessive release of nitrogen to plants, due to the instability of urea and high rainfall. Indeed, excess nitrogen lengthens the vegetative phase as confirmed by the work of [12] [14], where this excess leads to exaggerated vegetative growth and a delay in maturity or an absence of flowering, particularly during female flowering. However, its yield encourages us, like [20] [21] [32] [39], to believe that the timely addition of mineral nitrogen fertilizers would be a very efficient way to improve the yield of corn and ensure its economic profitability.

5. Conclusion

The general objective was to evaluate the production of corn cultivated on ferralsol with the addition of different doses of nitrogen fertilizers in the two rainy seasons of the pre-forest zone of Côte d'Ivoire. The results showed us that the short season had a positive and better effect than the long rainy season on the agronomic parameters of corn, however the chronology of water supply according to the corn cultivation cycle seems to be the aspect most important. They also showed that the different applications of nitrogen obtained the same effect during the long rainy season and the short rainy season. On the other hand, the nitrogen supply at 75% N through prilled Urea + combined with 25% N manure stood out by improving most of the agronomic parameters studied compared to the controls. According to our results, the combination of urea granules + farm manure would be the best form of nitrogen application during rainy periods. The application of nitrogen from the formulation Full dose of P&K + 75% N through Indorama Granular Urea is promising and should be explored depending on the time of application to the corn crop. But at what stage of maize growth will it be most effective in a rainy period? And how often will it be applied to the corn plant?

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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