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Influence of the Year and Growing Area on Maize (*Zea mays* L.) Production in the Central and North-Central Zones of Côte d'Ivoire (Departments of Bouake and Katiola)

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Abstract

Several studies conducted in recent years in Côte d'Ivoire reveal that agriculture is increasingly affected by the adverse effects of climate variability. The present study aims at evaluating the effect of the zone and the year of cultivation on the productivity of maize in the Central and North-Central zones of Cote d'Ivoire. It was carried out for two years (2020 and 2021). The experimental design used was a completely randomized block design with three replications. Observations were made on 12 agronomic parameters (plant size, internode size, collar diameter, number of leaves, number of internodes, cob insertion level, cob length, cob diameter, total kernels, cob dry weight, kernel dry weight, yield). The results showed that all agronomic traits of maize were significantly influenced by locality, except for the number of leaves. The highest values of the traits were observed in the locality of Bouaké. However, the year of cultivation did not influence the agronomic parameters of maize. This study will help to avoid yield decreases due to rainfall disturbances as a consequence of climate change.

Keywords

Climate Variability, Agronomic Parameters, Growing Area

1. Introduction

Maize is the staple food of the population. It is consumed heavily in several forms and is the staple food of the populations of northern Côte d'Ivoire. The yields obtained in farming areas of around 600 to 700 kg/ha are not only extremely low. They could decline further under the effect of fragile soils, very strong pest pressure, lack of adequate human and financial resources and, above all, increasingly frequent agro-climatological disturbances. Changes in the length of the rainy season and the intensity of rainfall are factors that affect crop production. Africa is particularly affected, especially the least developed countries, which are already very vulnerable socially and economically. The current evolution of the climate has large-scale consequences for ecosystems and causes major climatic upheavals. The current climate changes have irreversible consequences on the life of humans and the activities they carry out. Thus, agricultural activities seem to be the most vulnerable because it contributes to 32% of the growth of sub-Saharan African countries. Most of the ecosystems of the agro-ecological regions are today marked by degradation due to the high climatic variability associated with a greater frequency of extreme phenomena (droughts, floods, storms, hurricanes, temperature increase, etc.) compromising food security [1]. This high temporal, spatial and quantitative variability of rainfall makes agricultural production systems more vulnerable and is a major constraint to food self-sufficiency objectives [2]. In Côte d'Ivoire, agriculture is rainfed and seasonal, and is therefore exposed to the effects of climate variability. All regions of the country are affected by these effects, particularly the Central and North Central zones. These regions are more affected by changes in rainfall patterns, poor distribution of rainfall and strong winds [3]. According to Dekoula *et al.*, (2018) [4], the consequences of changes in the useful rainy season (beginning, end, and length) on the duration and position of the vegetation cycle are proving to be as constraining as the decline in total rainfall. Some studies have shown that yields of crops such as cowpea vary from one area to another (Kouassi *et al.*, 2018 [5], Kouamé *et al.*, 2020 [6]). However, none of them mentioned the effect of spatial variability on maize yields. The objective of the present work is to determine the effects of spatial-temporal variability on maize productivity in the Central and North Central zones. Specifically, this study aims to assess the effect of zone and crop year on agronomic parameters of maize.

2. Material and Methods

2.1. Study Environment

The experiments were conducted concurrently in Bouake and Katiola departments (**Figure 1**) over two years (2020-2021) during the rainy season (March to July). An experimental field was set up in Kongonekro, located 10 km away in Bouaké department. Bouaké, the capital of the Gbêkê region in central Côte d'Ivoire, is located at 7˚41' North latitude and 5˚02' West longitude on the main road linking Abidjan to the north. The soils are of modest fertility and very sensitive to erosion. An average rainfall of 1373 mm with very irregular rainfall was obtained with an annual temperature of 26.2˚C. The second experimental field was set up in the department of Katiola, located in the Hambol region of north-central Côte d'Ivoire. It is located between 8˚10' North latitude and 5˚4'

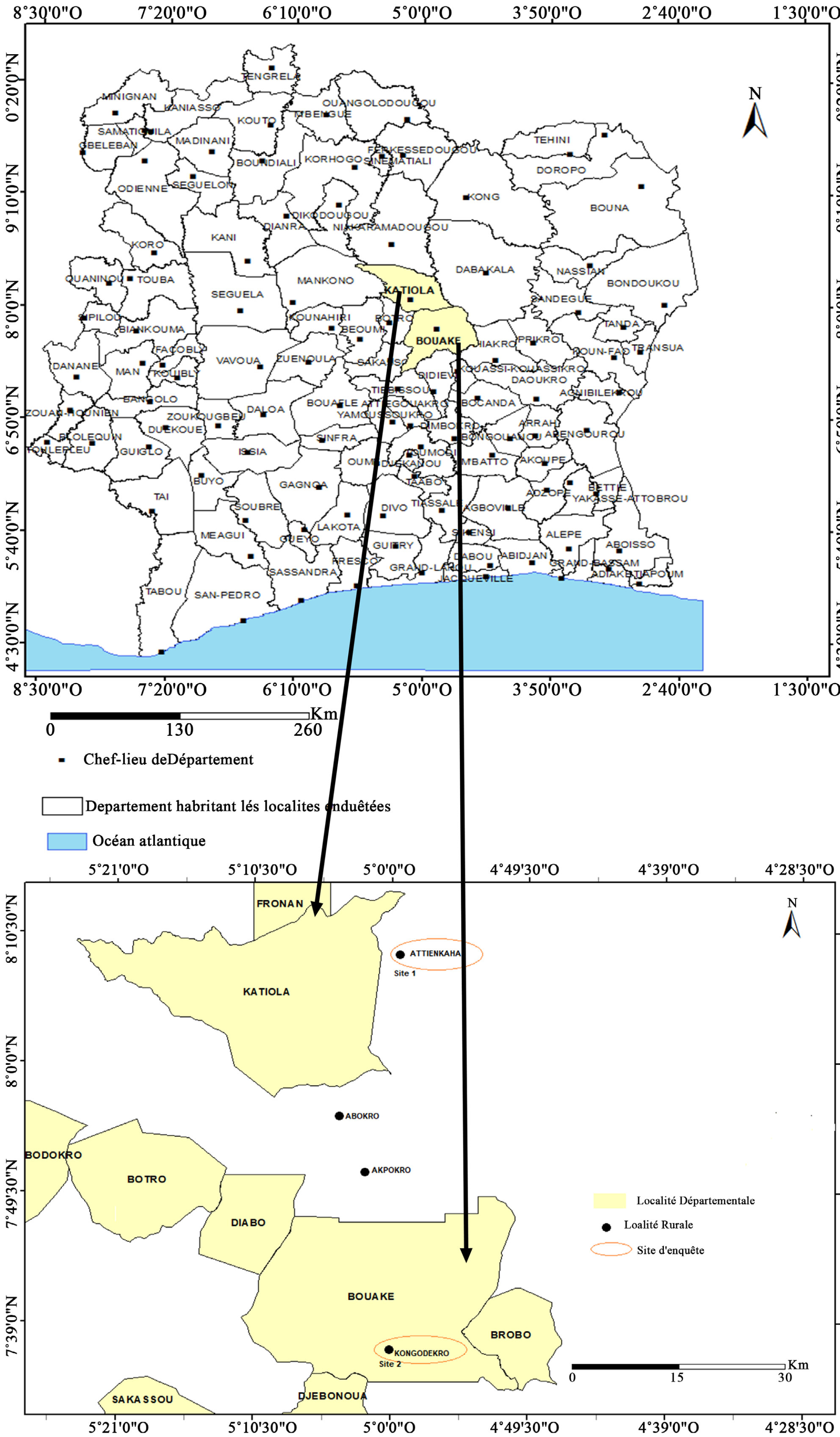

Figure 1. Location of the experimental sites of Attienkaha (Katiola) and Kongonekro (Bouaké).

West longitude and covers an area of 9420 km^2 [7]. Annual rainfall varies between 1100 mm and 1200 mm. The average temperatures recorded in this area vary between 26.45˚C and 33.67˚C. The soils are of ferralitic type dominated by clayey-sandy and gravelly textured soils [8]. The vegetation is that of pre-forest savannah.

2.2. Plant Material

The plant material consists of the improved maize variety F8128, with a long cycle (120 days) from the Bouaké National Agricultural Research Center (CNRA). The choice of this variety is justified by its organoleptic and agronomic qualities and its availability in the seed extension structures (ANADER, CNRA).

2.3. Experimental Device

The experimental set-up used is that of completely randomized blocks with three replications. A plot of 1296 m^2 (54 m × 24 m) consisting of three (3) blocks was set up. The spacing between two consecutive blocks is 3 m. Each block consists of four (4) elementary plots of 24 m^2 (6 m × 4 m) spaced at 2 m. Two factors were studied. The first factor is the locality. These were the localities of Bouaké and Katiola. These localities were chosen because they are areas of high maize production. The second factor is the crop year (2020 and 2021). The grains were sown at a rate of 3 per poquet with a spacing of 0.75m between rows and 0.40 m on row (0.75 m × 0.40 m). Organic fertilization consisting of sorghum detritus at a rate of 40 tons per hectare was applied to the different elementary plots. Two separations were carried out in order to leave the most vigorous plant. In order to avoid competition for mineral, carbon and water nutrition and parasitic pressures, four (4) weedings were carried out from the time of establishment to data collection.

2.4. Data Collection

One hundred and forty (140) days after sowing, fifty (50) plants were randomly selected and then labeled per elementary plot. The measurements concerned the growth parameters and the yield parameters. Regarding the growth parameters, the size of the plants was measured from the collar to the point of insertion of the panicle. The measurement of internode size was done on the internode located just below the point of spike insertion. Diameter at the collar was the circumference of the collar. For the number of leaves and the number of internodes a simple count of the living leaves of a plant and the internodes of each plant was made. Yield parameters were also assessed after harvest. For example, the length and diameter of the ear were measured on the largest line formed by the grains on the ear and the circumference at mid-height of the ear, respectively. The ears were stripped of their spathes and dried to constant weights followed by a count of the number of grains per ear and per plant. Dry weight of the ear, dry weight of seeds per ear and yield were determined using a TH-500 microbalance (capacity 500 g × 0.1 g). The measurements made are reported in **Table 1**.

2.5. Statistical Analysis

For each agronomic parameter studied, the means were compared taking into account locality and crop year through a two-factor analysis of variance (ANOVA 2). The significance of the test was determined by comparing the probability (P) associated with the statistic at the $\alpha = 0.05$ threshold. When a significant difference was observed between variables, the ANOVA was completed with the Smallest Significant Difference (SSD) test. The LSD allows us to see the homogeneous groups, since it locates at what level this significant difference occurs. The statistical software used in this work is STATISTICA version 7.1. The results are presented in the form of means plus or minus standard deviation.

3. Results

3.1. Comparison of the Two Localities According to the Agronomic Characteristics of Corn

The analyses performed to evaluate the effect of locality showed that all the analyzed traits were influenced by locality, except for the number of leaves (Table 2). The highest values of these traits were observed in the locality of Bouaké. Thus, the highest parameters such as grain weight (92.74 ± 67.64) and yield (3.09 ± 23.77) were observed in this locality. However, the number of leaves did not distinguish the two localities, giving statistically identical values.

3.2. Comparison of the Two Years of Cultivation According to the Agronomic Characteristics of Corn

The results showed that four of the twelve (12) traits analyzed were influenced by the crop year (Table 3). Thus, the highest values of agronomic traits were

Table 1. Methods of measuring agronomic parameters in response to year and growing area.

Agronomic parameters	Methods of measurement per elementary plot carried out for 50 plants
Plant size: PS	Measurement concerned the collar to the point of panicle insertion
Size of the Internode: SI	Measurement concerned the size of the internode
Diameter of the Collar: DC	Measurement of the diameter of the collar of each plant
Number of Leaves: NL	Number of all leaves of each plant
Number of Internodes: NI	Number of all the internodes of each plant
Level of ear Insertion: LEI	Measurement from the collar to the level of the ear insertion
Ear length: EL	Measure of the length of the ear of each plant
Diameter of the ear: DE	Measure of the diameter of the ear of each plant
Total Grains of the Ear: TGE	Total grains of the ear of each plant
Dry Weight of the Ear: DWE	Mass of the dry ear on each plant
Dry Weight of the Grains of the Ear: DWGE	Mass of the dry grains of the ear on each plant
Yield: YIED	Total dry grain mass per hectare

Table 2. Effect of locality on agronomic traits of corn.

Variables	Means (± standard deviation)		Statistics	
	BOUAKE	KATIOLA F	F	P
PS (cm)	178.81 ± 30.04^a	174.89 ± 32.41^b	22.6	<0.0001
SI (cm)	15.15 ± 2.76^a	14.46 ± 2.82^b	89.6	<0.0001
DC (cm)	6.88 ± 1.78^a	6.61 ± 2.34^b	23.42	<0.0001
NL	13.97 ± 1.12^a	13.90 ± 1.11^a	5.8	0.157
NI	14.00 ± 1.12^a	13.91 ± 1.12^b	6.8	0.0090
NEI (cm)	74.92 ± 16.97^a	71.77 ± 25.13^b	31.03	<0.0001
EL (cm)	11.70 ± 2.95^a	10.94 ± 4.90^b	50.10	<0.0001
DE (cm)	12.34 ± 2.37^a	11.98 ± 3.76^b	18.51	<0.0001
TGE	298.70 ± 103.73^a	292.86 ± 107.28^b	4.41	0.0357
DWE (g)	91.00 ± 47.69^a	87.94 ± 39.85^b	6.98	0.0082
DWGE(g)	92.74 ± 67.64a	89.40 ± 65.45^b	5.47	0.0194
YIED (t/h)	3.09 ± 23.77a	2.97 ± 19.32^b	4.49	0.0237

For each character, values with the same letters in rows are statistically equal. PS: Plant size; SI: Internode size; DC: Neck diameter; NL: Number of leaves; NI: Number of internodes; LEI: Ear insertion level; EL: Ear length; DE: Ear diameter; TGE: Total grains; DWE: Ear dry weight; DWGE: Grain dry weight; YIELD: Yield.

Table 3. Effect of crop year on agronomic traits of corn.

Variables	Means (±standard deviation)		Statistics	
	2020	2021	F	P
PS (cm)	175.60 ± 31.87^b	177.58 ± 30.40^a	5.7	0.017
SI (cm)	14.81 ± 2.83^b	14.80 ± 2.72^b	480.59	0.891
DC (cm)	6.59 ± 1.81^b	6.81 ± 2.13^a	17.62	<0.001
NL	13.94 ± 1.19^b	13.90 ± 1.02^b	1.7	0.195
NI	13.97 ± 1.20^b	13.90 ± 1.02^b	5.1	0.063
LEI (cm)	18.33 ± 0.34^b	24.37 ± 0.45^a	8.52	0.003
EL (cm)	11.29 ± 3.10^b	11.40 ± 4.88^b	1.8	0.298
DE (cm)	12.20 ± 3.17^b	12.13 ± 3.16^b	0.71	0.401
TGE	294.98 ± 109.88^a	297.51 ± 101.86^a	0.81	0.367
DWE (g)	88.47 ± 41.11^a	90.68 ± 47.08^a	3.58	0.058
DWGE(g)	68.30 ± 36.22^a	65.07 ± 35.02^b	11.73	0.006
YIED (T/ha)	2.27 ± 47.51^b	2.16 ± 39.34^b	1.24	0.005

For each character, values with the same letters in rows are statistically equal. PS: Plant size; SI: Internode size; DC: Neck diameter; NL: Number of leaves; NI: Number of internodes; LEI: Ear insertion level; EL: Ear length; DE: Ear diameter; TGE: Total grains; DWE: Ear dry weight; DWGE: Grain dry weight; YIELD: Yield.

observed in the crop year 2021. On the other hand, the highest grain dry weight (68.30 ± 36.22) and yield per hectare (2.27 ± 47.51) was recorded at the level of the year 2020. Parameters such as internode size, number of leaves, number of internodes, ear length, ear diameter, total kernels, ear dry weight and yield did not show any difference between the two crop years.

3.3. Effect of Locality-Crop Year Interaction on Agronomic Traits of Maize

Table 4 shows that there is no significant effect of the combined action of crop year and locality on any of the traits studied. Thus, the means are statistically identical.

4. Discussion

The analyses performed to evaluate the effect of locality showed that all the analyzed traits were influenced by locality, except for the number of leaves. The highest values of the traits were observed in the locality of Bouaké. Two hypotheses could explain the increase in plant productivity in Bouaké than in Katiola. These are the chemical composition of the soils and the rainfall. The chemical characteristics of the soils in the Bouaké area were significantly better than those in Katiola [8]. Indeed, these authors during a study on the diagnosis of soil

Table 4. Year-location interaction effect.

Variables	Means (±standard deviation)		Statistics		F	P
	BOUAKE		KATIOLA			
	2020	2021	2020	2021		
PS (cm)	178.06 ± 31.12[a]	179.56 ± 28.90[a]	173.15 ± 32.43[a]	175.50 ± 31.78[a]	0.3	0.6048
SI (cm)	15.20 ± 2.73[b]	15.09 ± 2.60[b]	14.42 ± 2.87[b]	14.50 ± 2.80[b]	1.6	0.2057
DC (cm)	6.81 ± 1.79[a]	6.95 ± 1.77[a]	6.37 ± 1.80[a]	6.68 ± 2.45[a]	2.54	0.1110
NL	13.97 ± 1.17[a]	13.97 ± 1.06[a]	13.90 ± 1.21[a]	13.82 ± 0.96[a]	2.2	0.1352
NI	14.00 ± 1.18[a]	13.98 ± 1.07[a]	13.94 ± 1.23[a]	13.82 ± 0.96[a]	3.0	0.0813
LEI (cm)	74.02 ± 17.73[a]	75.83 ± 16.13[a]	70.85 ± 18.80[a]	72.31 ± 30.61[a]	0.10	0.7570
EL (cm)	11.71 ± 2.99[a]	11.69 ± 2.91[a]	10.87 ± 3.15[a]	11.10 ± 6.30[a]	1.48	0.2238
DE (cm)	12.39 ± 2.44[a]	12.29 ± 2.30[a]	12.01 ± 3.75[a]	11.96 ± 3.85[a]	0.13	0.7222
TGE	297.36 ± 108.66[a]	300.4 ± 98.59[a]	292.61 ± 111.07[a]	294.87 ± 105.14[a]	0.01	0.9416
DWE (g)	89.81 ± 40.98[a]	92.19 ± 53.56[a]	87.13 ± 41.22[a]	89.10 ± 39.14[a]	0.03	0.8604
DWGE (g)	69.24 ± 36.06[a]	66.03 ± 34.17[a]	67.37 ± 36.37[a]	64.06 ± 35.87[a]	0.01	0.9574
YIED(T/ha)	2.30 ± 67.25[a]	2.20 ± 19.22[a]	2.24 ± 12.44[a]	2.13 ± 19.37[a]	0.04	0.7883

For each character, values with the same letters in rows are statistically equal. PS: Plant size; SI: Internode size, DC: Neck diameter; NL: Number of leaves; NI: Number of internodes; LEI: Ear insertion level; EL: Ear length, DE: Ear diameter, TGE: Total grains; DWE: Ear dry weight; DWGE: Grain dry weight; YIELD: Yield.

fertility in north-central Côte d'Ivoire showed that the soil of Bouaké is more fertile than that of Katiola. The presence of major exchangeable elements such as potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na) favored a good biological activity in Bouaké (C.E.C = 12.94) more than in Katiola (C.E.C = 5.98). All of these mineral elements were available to the plants because they were better dissolved. The low CEC values of the Katiola soils do not give them a high buffering capacity. This would be unfavorable for efficient mineral nutrition of maize in these areas [9]. Furthermore, a high C/N ratio in Katiola reflects low biological activity of soils in this region. This results in a concentration of poorly decomposed organic matter which would result in poor plant development in Katiola (29.10) than in Bouaké (13.82) [8]. Sorghum detritus would be different from other organic waste because it comes from alcoholic fermentation. In fact, this alcoholic fermentation and its granular aspect give it a rapid mineralization and a high content of mineral elements necessary for the harmonious development of corn plants. This would contribute to the improvement of maize yield in Bouaké.

Rainfall in the two zones showed different values during the March-July 2020-2021 growing season. The amount of rainfall during the experimental period was significantly greater in Bouake than in Katiola. Also, the late start of the rainy season in Katiola could be detrimental to the long-cycle maize variety, which will not be able to complete its cycle properly because the end of the rainy season is earlier. Our results are consistent with those of Kouamé *et al.* (2020) [6] on the variability of cowpea varieties in Côte d'Ivoire. It revealed an important diversity of the studied agronomic characters according to the zone of culture. Thus, the Daloa zone presented the lowest values for the agro-morphological characteristics. According to these authors the accumulation of reserves in the seeds depends on climatic factors [5]. They explain these results by the fact that the Soubré area being located in the South of Côte d'Ivoire has a higher rainfall than Daloa. These results show that the agro-morphological traits studied were influenced by climatic conditions. Other authors such as Hounzinme *et al.* (2020) [10] found the same results. They observed that the regression analysis between climatic parameters and maize yield showed that the variability of climatic conditions had effects on maize yields. Indeed, corn growth also varies with environmental conditions. A temperature below 15˚C can induce a slowdown in growth, thus negatively affecting yield. Therefore, there is a tolerable temperature threshold for maize productivity. Maize emerged as the most temperature-sensitive crop. Observation of rainfall and yields of rainfed crops shows that years of poor rainfall are generally followed by a decrease in yields. With a high average temperature (about 35˚C) accompanied by a decrease in rainfall, low yields are observed.

Weight and yield were not influenced by the interaction of locality and crop year. This result can be explained by the fact that the climatic parameters (temperature and rainfall) did not change significantly during the test years. Environmental factors play an important role in plant physiology [11]. The distribution of rainfall during the experimental years appears to be sufficient for the water requirements of maize [12]. Indeed, according to these authors, only water deficit negatively influences the grain yield of maize.

5. Conclusion

The overall objective of this work was to evaluate the impact of agroecological disturbances on crop productivity. The results showed that the locality significantly influenced the agronomic traits of the maize variety F8128, except for the number of leaves. The highest values of the traits were observed in the locality of Bouaké. However, the year of cultivation did not influence the yield and yield parameters. This study will make it possible to avoid yield decreases due to rainfall disturbances resulting from climate change. However, for its implementation, other agro-climatological factors such as hygrometry, temperature and other study areas need to be studied beforehand.

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Conflicts of Interest

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

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