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Research Paper

Effect of rainfall on growth parameters and yield of four varieties of maize (*Zea Mays*), grown in Korhogo Commune, northern Cote d'Ivoire

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Abstract. Maize stands out as one of the largest and most cultivated cereals in the Korhogo region of northern Côte d'Ivoire. This activity is potentially dependent on climate, which is increasingly subject to variations and decreases in rainfall. The study focused on the analysis of the influence of rainfall on the growth parameters and yield of four maize varieties grown in northern Côte d'Ivoire. Study was conducted at experimental site of Saint Camille, located in commune of Korhogo. The experimental device consisted of Fisher block, completely randomized and comprised 4 blocks and 4 varieties (Benin 7, Benin 13, Ferké and Komsaya), compared to four different planting dates. Growth and performance parameters were measured. The results showed that over the 3 years (2015 to 2017) of data, rainfall as a whole indicated a weaker trend in northern Côte d'Ivoire, with an annual average of 1060 mm of water. The average annual rain number ranged from 54 to 68 days. Ferké and Komsaya, with average yields of 3.01 t/ha and 2.86 t/ha at first seeding and 1.02 t/ha and 1.07 t/ha at the fourth seedlings, were the most productive during different planting periods. These two varieties were the most adapted to climatic conditions of the north of country and are the best to be recommended to maize producers in the region, especially for late planting.

Keywords: Agronomic characteristics, Côte d'Ivoire, seedling, varieties, *Zea mays*.

INTRODUCTION

In Côte d'Ivoire, the agricultural sector contributes a large part to Gross Domestic Product (GDP). This sector employs about two-thirds of the labour force (Amusa and Iken, 2004). In agricultural field, maize stands out as one of the most important and cultivated cereals in Côte d'Ivoire and above all, in the northern part of the country (Achiri *et al*., 2017). Maize is grown for human consumption, feed production and the brewing industry (Abu *et al*., 2011). Maize is now well integrated into diversified crop systems (Gathala *et al*., 2017). Its demand is increasing day by day as various food products, livestock fodder, poultry feed and industry raw matter are required (*Shiferaw et al.,* 2011; Valbuena *et al.*, 2012; Gathala *et al.*, 2017).

Maize production has doubled over the past 40 years due to increased yields resulting from the use of improved varieties, as well as increased inputs of fertilizers, water and pesticides (Evenson and Gollin, 2003). Maize, along with rice and wheat, provides at least 30% of food calories to more than 4.5 billion people in 94 developing countries (FAO, 2016). Its grains can be used for human consumption in a variety of ways, such as corn flour and french fries. Grains have a high nutritional value. They contain approximately 66.2% starch, 11.1% protein, 7.12% oil, 1.5% minerals and is still a source of vitamin B (Yapi *et al*., 2017). In Côte d'Ivoire, almost 80% of agricultural production is provided by rainfed agriculture (MINAGRI, 2007; Noufé, 2012; Noufé *et al*., 2015). As a result, this agriculture is impacted by climate variations, particularly those related to rainfall. Agriculture is an economic activity that is highly dependent on weather conditions, such as: rain, air temperature and solar radiation, and therefore to climate change. Climate change, characterized by the resurgence of extreme events, such as droughts and floods, rising temperatures, increased variability in rainfall and agricultural season characteristics (GIEC, 2007), poses a major threat to the environment and global agricultural development, and especially to Africa. The absence, inadequacy, excess or misallocation of the rains results in sudden rainfall variations (droughts or floods) that have a profound impact on people's lives in general and farmers, in particular (Morel, 1991; Toukon, 2001).

Yield and its components are strongly influenced by environmental factors (Blum, 1988). In addition, the more limiting the factors of water supply and soil fertility, the greater the spatial and interannual variability of varietal responses because, under these conditions, genetic variance and heritability of related traits yields are even lower than in a favourable environment (Monneuveux and Depigny-This, 1995; Fukai and Cooper, 1995). Maize is a water-intensive plant, while its cultivation is, essentially, rain-fed. When its life cycle reaches 120 days, it requires a quantity of water of about 600 mm (Sylvain *et al*., 2005). Finding solutions to the negative consequences of climate change on rainfed agriculture remains a major concern for all agricultural stakeholders. For example, research is increasingly moving towards the development of genotypes adapted to climatic constraints or at least the substitution of unsuitable crops (Ouédraogo *et al*., 2010).

Since drought is the main stress that affects the majority of maize acreage annually, growers should focus their choice on drought-tolerant hybrids. Based on the assumption that rainfall recessions are causing lower yields and insufficient food products in northern Côte d'Ivoire, this study aims to analyse the climate regime and its influences on food production four varieties of maize, grown in the commune of Korhogo.

MATERIALS AND METHODS

Study locality

The study was conducted at saint Camille experimental site in Korhogo commune, in northern Côte d'Ivoire. The geographic coordinates are 9-26' north longitude and 5-38' west latitude. The climate of the area, Sudanese type, is characterized by an alternation of two seasons. A large dry season, from October to May, precedes the rainy season, marked by two rainfall peaks, one in June and the other in September. The area is also characterized by average temperatures ranging from 24 to 33 degrees Celsius and an average monthly humidity of 20%. The annual rainfall is between 900 and 1600 mm and the duration of sunstroke is 2600 hours per year. The relief is generally flat and dotted in places with inselbergs (Koffie and Yéo, 2016).

Maize varieties

The plant material, used, consisted of four varieties of maize of various origins. These include:

- two improved varieties Benin 7 (B7) and Benin 13 (B13). They are native to Benin and were acquired from an agronomic research centre;
- the improved Komsaya variety, obtained from a seed company in the city of Korhogo;
- a local variety called Ferké, acquired from farmers in the locality of Korhogo.

These different varieties are the most commonly grown in northern Côte d'Ivoire. They generally produce an average of two ears per foot. The average length of their cycle is about 90 days.

Experimental design and treatments and their application

The experimental device consisted of Fischer blocks, completely randomized, comprising 4 treatments and 4 varieties (Benin 7, Benin 13, Ferké and Komsaya). The study included 16 elementary plots. Each elemental plot consisted of 32 maize plants, transplanted over 4 lines of 8 poquets, according to the 0.40 m × 0.75 m spreads. The elementary plots and blocks were, respectively, separated by a distance of 1 m and 1 m. The area of one elemental plot was 10 m^2 (3.2 m × 3 m), corresponding to 160 m^2 as the total surface area of the test plot.

These varieties were sown on four different dates, from the beginning to the end of the rainy season. Seeding dates were:

- the first planting was carried out on June 24, 2016, corresponding to the beginning of the rainy season;
- the second took place on July 15, 2016, corresponding to the full rainy season;
- the third was held on August 5, 2016, representing the third half of the rainy season:
- the last one took place on August 29, 2016, agreeing at the end of the rainy season.

Each planting date consisted of 4 treatments (varieties) and 4 repetitions (blocks), representing, thus, an entire test plot and independently of the other planting dates.

During the experiment, the Yara Mila Actyva mineral fertilizer was buried at a depth of 2 cm and 5 cm radius, around each maize plant. The first application was made,

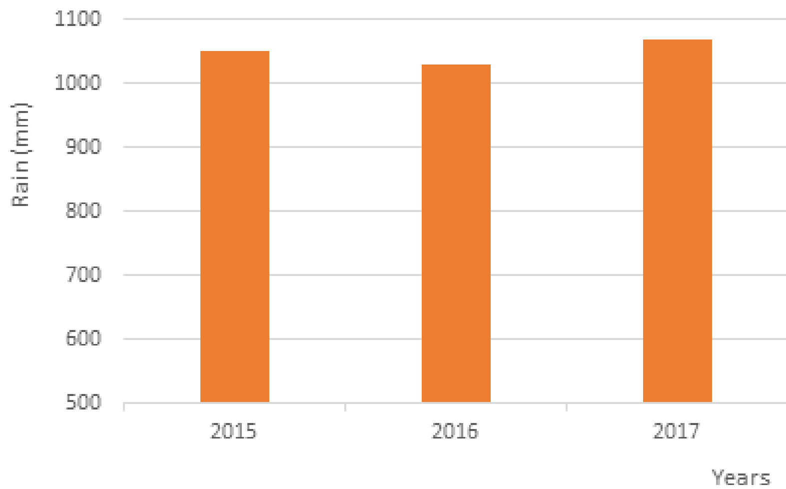

Figure 1. Changes in annual rainfall in Korhogo commune from 2015 to 2017.

with a dose of 15 g/plant, on the 15th day after sowing (DAS) and the second was done on the 30th DAS, at the dose of 30 g/plant.

Measured parameters

Rainfall data were recorded over three years, in the study location, to track its influence on maize growth and production. These data concerned the number of rainy days and the annual rainfall heights given.

Various other agronomic parameters were measured during our study, by elementary plot. The height of each plant was assessed by measuring its size, from the collar to the last newly opened leaf (arrow). The diameter at the collar was obtained by measuring the circumference of the collar of each plant. The number of leaves per plant was obtained by counting all the leaves formed. The number of ears per plant was determined by counting all the ears formed by each foot. The dry weight of each ear was obtained by weighing each ear after removal of the spathes. The weight of the grains per ear was determined by weighing all the grains carried by each ear. Yield (Y/ha) was determined from the following relationship:

$$Y = NE * WE * D$$, with

Y: yield in ton/ha; NE: Number of ears per plant; WE: Weight of each ear in kg; D: Planting density with a standard of 100,000 plants/ha.

Data processing and analysis

The data, collected and subjected to a variance analysis using the XLSTAT version 7.5 software. The level of significance of the differences between the averages was estimated using Duncan's test at the 5% threshold.

RESULTS

Evolution of rainfall in the study area

Rainfall data recorded in the study location showed high interannual variability (Figure 1). Over the 3 years, rainfall as a whole indicated not significant in northern Côte d'Ivoire, with annual averages of less than 1100 mm of water.

Annual rainfall at the Saint Camille experimental site fluctuated from 1050 to 1070 mm over the observation period, with an average of 1060 mm of water per year. It is, in general, a weakly watered region.

The total numbers of rainy days per year were also recorded at the study site (Figure 2). Over the period 2015 to 2017, the number of annual rainy days remained very low, varying between 54 to 68 days over the observation period. The largest number was obtained in 2015, with 68 days of rain. The rains that fell in the town were spread over about 2 months of the year. These total numbers of rainy days were low over the 3 years of observation.

The monthly distribution of rainfall in the north of the country is bimodal, characterized by a rainy and dry season (Figure 3). The rainy season covers the months of May to October and the dry season starts from November to April. The wettest months are August and September, which account for about 60% of the total annual amount of rain that has fallen.

Effects of rainfall on growth parameters

Average plant height of different maize varieties after the 4 planting dates were assessed (Table 1). The variance analysis reveals differences between the averages obtained with the four varieties, except during sowing 3, the averages of which do not differ between them.

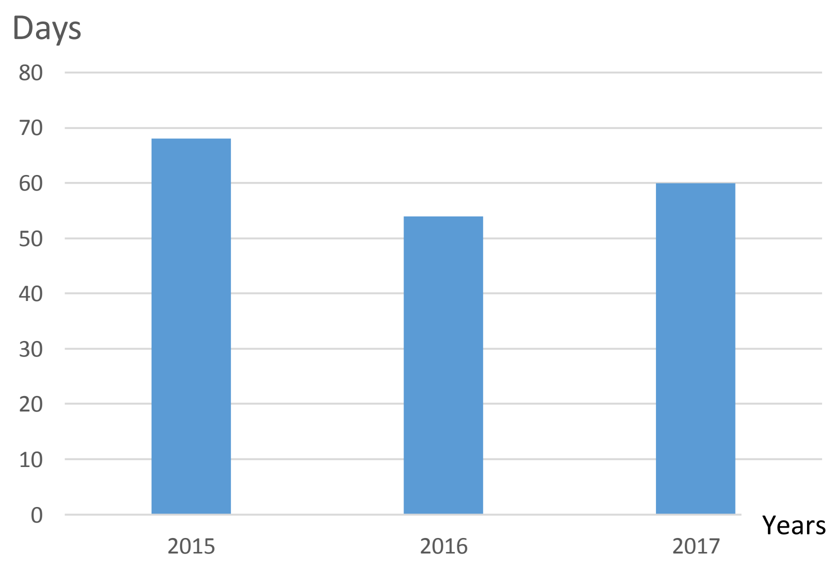

Figure 2. Changes in the total number of rainy days in Korhogo commune during the period 2015 to 2017.

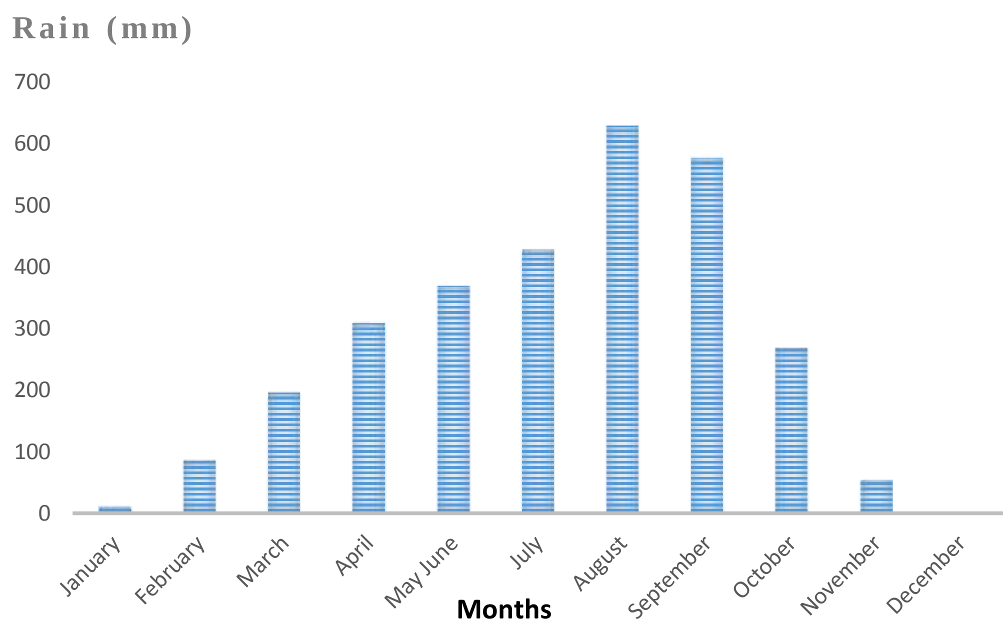

Figure 3. Changes in monthly rainfall in Korhogo commune from 2015 to 2017.

During sowing 1 (July seeding), according to Newman Keuls' test, the highest averages were obtained with the varieties Benin 13 (B13) and Benin 7 (B7), with heights of 140 and 150.5 cm, respectively. The lowest averages (120.1 and 116 cm) were recorded with the Ferké and Komsaya varieties, respectively.

For the plants obtained during the second planting, the height averages ranged from 125.9 to 162.1 cm. These averages were lower with the Benin 7 variety (125.9 cm) and higher with the other varieties (Benin 13 (147.2 cm), Komsaya and Ferké (162.1 cm)).

At the third seedling level, the variance analysis did not reveal any significant difference between the averages of the different varieties. These averages ranged from 115.8 cm (B13) to 124.4 cm (Ferké).

During sowing 4, the results of the variance analysis showed significant difference between the averages obtained with the 4 varieties. The results show the formation of three homogeneous groups, according to Newman Keuls' test. The second group, whose average was intermediate, consists of the benin 7 (127.3 cm) and Komsaya (117.6 cm) varieties.The first group, with a

Table 1. Average plant height as influenced by planting dates.

Treatments	Plant height (cm)			
	Sowing 1	Sowing 2	Sowing 3	Sowing 4
Bénin 13 (B13)	140.0^{ab}	147.2^{a}	115.8^{a}	100.0^{c}
Bénin 7 (B7)	150.5^{a}	125.9^{b}	118.2^{a}	127.3^{b}
Ferké (Fer)	120.1^{bc}	162.1^{a}	124.4^{a}	145.8^{a}
Komsaya (Kom)	116.0^{c}	147.3^{a}	118.3^{a}	117.6^{b}

The averages followed by the same letter in the same column are not significantly different, according to Newman Keuls' test

Table 2. Average collar diameter as affected by seedlings dates.

Treatments	Plants collar diameter (mm)			
	Sowing 1	Sowing 2	Sowing 3	Sowing 4
Bénin 13 (B13)	14.85^{b}	14.49^{b}	13.04^{c}	10.31^{c}
Bénin 7 (B7)	17.12^{a}	14.68^{b}	15.68^{ab}	13.62^{b}
Ferké (Fer)	17.14^{a}	17.27^{a}	14.69^{bc}	16.61^{a}
Komsaya (Kom)	13.97^{b}	17.26^{a}	16.87^{a}	12.33b^{c}

The averages followed by the same letter in the same column are not significantly different, according to Newman Keuls' test

Table 3. Average number of leaves as affected by sowing dates.

Treatments	Number of leaves			
	Sowing 1	Sowing 2	Sowing 3	Sowing 4
Bénin 13 (B13)	9.7^{b}	9.5^{b}	9.1^{c}	7.5^{c}
Bénin 7 (B7)	10.1^{ab}	10.4^{a}	10.8^{ab}	10.2^{b}
Ferké (Fer)	10.8^{a}	10.7^{a}	10.4^{b}	11.3^{a}
Komsaya (Kom)	10.5^{a}	10.9^{a}	11.3^{a}	10.6^{ab}

The averages followed by the same letter in the same column are not significantly different, according to Newman Keuls' test

value of 145.8 cm, is formed by the averages recorded with the Ferké variety. These values were the highest. The third group consists of the B13 variety, with an average value of 100 cm. This value was clearly the lowest.

The average collar diameters, for all varietiesas as affected by different seedlings dates are presented in Table 2. It is observed differences between all treatments except between B7 and Fer at sowing 1 and Fer and Kom at Sowing 2, was not siginficantly affected.

After sowing 1, the highest values of plant collar diameter were (17.14 and 17.12 mm) for Fer and B12, respectively. Meanwhile, the lowest values were (13.97 and 14.85 mm) for B13 and Kom, respectively.

After the second seedling, the resulting corn plants produced diameters at the collar ranging from 14.49 to 17.27 mm. These averages were significantly higher, with the Ferké (17.27 mm) and Komsaya (17.26 mm) varieties. As for the Benin 7 and 13 varieties, the recorded values have the lowest, with values of 14.68 and 14.49 mm, respectively.

The third seedling produced plants with diameters at the collar ranging from 13.04 to 16.87 mm. The Komsaya variety, with an average of 16.87 mm, recorded the highest value. Benin 7 and Ferké, with averages of 15.68 and 14.69 mm respectively, were intermediate to the other varieties. As for the Benin 13 variety, the averages produced were significantly the lowest, with a value of 13.04 mm.

After sowing 4, the highest values of collar diameter (17.27 and 17.26 mm) were obtained with Ferké and Komsaya cultivar, respectively. Meanwhile the lowest values (14.68 and 14.49 mm) were obtained with Benin 7and 13 repectively.

As for the results of the number of leaves issued (Table 3), the variance analysis reveals differences between the averages obtained with the four varieties and at the 4 seeding periods. The number of leaves produced by the plants from the first seedling ranged from 10 leaves (Benin 13) to 11 leaves (Ferké). The highest number of

Table 4. Yield performance summary based on planting dates.

Treatments	Yield (T/ha)			
	Sowing 1	Sowing 2	Sowing 3	Sowing 4
Bénin 13 (B13)	1.69[b]	1.04[b]	0.54[c]	0.43[c]
Bénin 7 (B7)	2.23[ab]	0.99[b]	0.59[c]	0.61[b]
Ferké (Fer)	3.01[a]	2.24[a]	2.19[a]	1.02[a]
Komsaya (Kom)	2.86[ab]	2.32[a]	1.93[b]	1.07[a]

The averages followed by the same letter in the same column are not significantly different, according to Newman Keuls' test.

leaves was issued with the Ferké, Komsaya and Benin 7 varieties.

The results from the second seedlings reveal there is no significant differences between Benin 7, Ferké and Komsaya which had the highest values. Meanwhile the lowest one were obtained with Benin 13

The corn plants of the 4 varieties, from the third seedlings, produced a varied number of leaves whose averages ranged from 9.1 leaves (Benin 13) to 11.3 leaves (Komsaya). The Benin 13 variety recorded the lowest average number of leaves issued.

As for seedlings 4, the numbers of leaves produced by the Ferké and Komsaya varieties were significantly higher, with averages of 11.3 and 10.6 leaves, respectively. The Benin 13 variety, with an average of 7.5 leaves, recorded the lowest value.

Effects of rainfall on yied performance

Average yields obtained with the four maize varieties, after application of the different planting periods were measured. The data show that both of varities and sowing dates have asignificant effect on yiled. Also, yiled decrease with increasing sowing dates (Table 4). The production of different varieties of maize was influenced by the seeding periods.

Average yields of the four varieties, obtained with the first seeding, ranged from 1.69 t/ha (Benin 13) to 3.01 t/ha (Ferké). The average recorded with the Benin 13 variety was increased by 56.1% to obtain the average produced by the Ferké variety.

As for the production of the second seedlings, the averages obtained were divided into two homogeneous groups, according to Newman Keuls' test. The second group, with significantly low averages, consists of the averages of the Benin 7 and 13 varieties, with values of 0.99 and 1.04 t/ha respectively. The first group is formed by the averages obtained with the Komsaya and Ferké varieties, having recorded the highest averages. These values were 2.24 t/ha for Ferké and 2.32 t/ha for the Komsaya variety.

At the seedling level 3, three homogeneous groups are formed. The first group is formed by the averages obtained with the Ferké variety, with a value of 2.19 t/ha. This value was significantly the highest. The second group, with an average of 1.93 t/ha, was the Komsaya variety. The third group, with the lowest averages, consists of the values obtained with the Benin 13 and Benin 7 varieties, with averages of 0.54 and 0.59 t/ha respectively.

For seedling 4, Ferké and Komsaya, with averages of 1.02 and 1.07 t/ha respectively, were significantly the most productive. The lowest yield was recorded with the Benin 13 variety, with an average of 0.43 t/ha.

DISCUSSION

In recent years, rainfall has generally declined in West Africa, and in northern Côte d'Ivoire in particular. This observation has already been raised by authors such as Buisson (1989) and Yao (1989). The decrease in rainfall is due to the combined action of man and nature (Yao, 1989). The overuse of forests and woods, combined with natural phenomena, has contributed to a significant reduction in rainfall. Seasonal bushfires, anarchic deforestation without sufficient reforestation, and extensive slash-and-burn agriculture in northern Côte d'Ivoire contribute to the decline in rainfall (Tanina *et al*., 2011).

According to Péné and Assa (2003), decline in rainfall can be explained by climate deregulation due to adverse influence of certain environmental factors on the intertropical front migration mechanism. The different positions of this front determines climate in West Africa, in particular, in Côte d'Ivoire. The number of days of clearly low rainfall recorded in the locality explains the low rainfall obtained in Korhogo.

According to this paper maize cycle life is 4 months (120 days) and sowing dates from July to October also, rain happened in the same period so there is no problem, also, as the researcher said it depend on available soil water depletion (Sylvain *et al*., 2005).

The analysis was based, on the determinants of intertropical precipitation (Ogouwalé, 2006). It is based on annual precipitation values for the period 2015-2017. The evolution of annual precipitation over this period follows a very low trend curve. Over the period 2015 - 2017, they had an average annual change of 1060 mm of rainfall heights. This drop in rainfall, however, has disrupted the agricultural activities of the population: drought increases the vulnerability of soils and crops (Tabet-Aoul and Bessaoud, 2009); intra- and inter-seasonal variability in rainfall.

The impacts of climate change are seriously affecting the environment, natural resources and the populations that depend on them, in particular, the poorest and most vulnerable communities (GIEC, 2001; IPCC, 2001). Water resources are a necessity for life, especially for agriculture (CdP-18, 2012). The use of varieties, adapted to the northern region, will allow farmers to be less vulnerable to drought, shorter rainy periods or, more generally, greater rainfall variability.

Drought is widely recognized as the number one factor limiting global agricultural maize production (Passioura, 1996). Good management of the water resource is therefore an economic and ecological necessity (Boyer, 1996). In Africa, where rainfed cultivation is overwhelmingly majority, drought is a permanent constraint on agricultural production (Ceccarelli and Grando, 1996).

Since drought is the main stress that affects the majority of maize acreage annually, producers should choose drought-tolerant hybrids for all fields exposed to this problem. These products must also provide competitive performance in situations where soil moisture conditions range from adequate to excellent.

In our study, Ferké and Komsaya produced the highest yields during the different planting periods (beginning, full and late rainfall seasons). These varieties may be recommended to corn producers in the Korhogo region for early and late planting. As for the imported varieties, Benin 7 and Benin 13, they are only usable for early seeding (early rainy season).

However, a comparison sheds light on the hierarchy of traits whose genetic variability must be sought during selection. The accumulation of biomass, the rate of growth of organs, vegetative and reproductive, must thus remain the most effective, and general, breeding targets for improving productivity, i.e. even when water deficit (Welcker, 2012).

Drought tolerance or resistance characteristics are complex and may not be easily identifiable. However, corn grain yield in the absence of moisture is the best indicator of drought tolerance. Other known traits contribute to drought tolerance, including: a well-structured root system, resistance to insects and diseases, strong characteristics for the appearance of bristles, and stable yield in various environments.

According to Turner *et al.* (2001), three main types of responses allow the plant to avoid or, more accurately, delay the dehydration of its tissues. The first group of characters is related to the efficiency of the extraction of water from the soil by the roots. The ability of roots to exploit soil water supplies under stress is a particularly effective response in seed production (Passioura, 1977).

The second type of response is by regulating the opening closing of the stomata

It conditions trade between CO_2 and H_2O, and therefore crop growth and productivity (Turner, 1997). The third is the osmotic adjustment that plants make in response to water deficit (Turner, 1986). When leaf water potential decreases, turgescence potential and stomatic conductance are maintained through an intracellular accumulation of solutes allowed by this mechanism. The relevance of the characters corresponding to these responses for selection can be discussed for each of the three defined forms of avoidance. These three are most commonly used by the set to adapt to water stress conditions.

CONCLUSION

At the end of this study, it can be remembered that rainfall has a major influence on crop productivity in northern Côte d'Ivoire. To remedy this situation, high-yielding varieties adapted to low rainfall situations must be sought in order to proceed with late planting. The Ferké and Komsaya varieties were the most productive during the different planting periods (early, full and late in the rainy season). These two varieties are therefore the most adapted to the climatic conditions of the commune of Korhogo and could be recommended to maize producers in the said region.

The succession of surplus and deficit months and with low annual rainfall lead to a local representation of climatic variations and the adoption of new modes in the exercise of maize production activities among populations. The production and profitability of this crop remain set dependent on rainfall. In a storm-fed environment, changes in rainfall patterns cause disruptions that have a profound impact on farmers' lives. In the face of uncertainty, farmers must therefore develop various adaptation strategies resulting in the choice of varieties adapted to the growing areas, the development of new technical routes, the intensification and diversification of cultures.

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