**COTTON WATER USE EFFICIENCY UNDER CLIMATE CHANGE IN CÔTE D'IVOIRE**

**ABSTRACT**

The studys’ objective was to identify water use efficiency (WUE) on cotton subjected to complementary irrigation in northern Côte d'Ivoire. Therefore, a weighted rain water loss coefficient, due to run off and deep percolation, was used. A four treatments trial has been set up. These were T0 (Untreated controls), T1 (Reference control), T2 (Innovation, supplemental irrigation and agro-pharmaceuticals), T3 (Irrigation without agro-pharmaceuticals). Thus, at cotton bolls weight level, WUE, analysis showed high significant difference between treatments (p<0.01). The results were respectively 0.361±0.012; 0.227±0.012; 0.031±0.012 and 0.025±0.012 kg/m3 for T2, T1, T3 and T0. Innovation WUE was like reference control one but 14.4 times higher than untreated control value. Similarly, balls’ average weight comparison showed a high significant difference between treatments. Results were 5.4±0.0614; 4.0±0.0614; 2.9±0.0614 and 2.6±0.0614 g/boll, respectively for T0, T1, T3 and T0. Innovation was 35% higher than reference control (p<0.01), while strait irrigated plots averaged 11.5% higher than untreated control (p<0.01). Thus, it appeared that water supplementation has improved bolls average weight.

**Keywords:** *Climate change, supplementary irrigation, water use efficiency, cotton*

**I - INTRODUCTION**

Agricultural activities in sub-Saharan Africa have been strongly affected by climate variability (Pastori et *al.*, 2019; Dékoula et *al.*, 2018). In Côte d'Ivoire, recommended cotton sowing period, from 20 May to 20 June (CNRA, 2006), is increasingly being questioned. Sustainable cotton production influenced by global changes has been explored from both innovative cropping as well as conventional and organic cotton cultivation point of view (Soumare and Havard, 2017). These advanced technologies are promising in terms of soil fertility control, crop rotations, pest and water management (Soumare and Havard, 2017). however, for Ivorian cotton, yields, which had exceeded 1400 kg/ha in the early 2000s, have completely fallen (Ducroquet et *al.*, 2017). In fact, for nearly 30 years, West African climate has been subject to an unprecedented climatic variability phenomenon, which has had a significant impact on populations lives (Brou et *al.*, 2005). Thus, growing cotton, which occupied farmers for 327 334 ha in 2018 (FIRCA, 2018), is not spared. Indeed, this crop water needs, vary according not only to region, but also to agricultural season length, irrigation method, climatic environment and grown variety (CCIC, 2018). In fact, it takes between 3000 and 7000 L of water to obtain one cotton fiber kilogram (CCIC, 2018). However, compared to total global production, this water quantity amounts to approximately 1200 L per kilogram of fiber (CCIC, 2018). In fact, cotton’s share of global agricultural water consumption is about 3% (CCIC, 2018). The Regional Integrated Cotton Protection Program in Africa (PR-PICA) (2018) has noted, over years, average yields below 1,500 kg/ha of seed cotton, which is lower than promoted varieties potential. Indeed, on experimental plots, those varieties have obtained 1,826 to 1,984 kg/ha (CNRA, 2006). As example, yields for cotton campaigns 2016-2017 and 2017-2018 in Côte d’Ivoire were respectively1,260 and 1,258 kg/ha (PR-PICA, 2018). However, it’s the average yield level improvement that contributes sustainably to total production increase. Renou (2007) suggested that to improve seed cotton production, pest nuisance should be reduced by early sowing or by increasing the seeding density to obtain more bolls per hectare. On the other hand, according to Yang et al. (2014), a parabolic correlation was established between yield and planting density, with all other factors kept at their optimal level. Thus, yield followed a quadratic curve that increased with additional nitrogen input to a maximum and then decreased (Moore, 1998). This leads to believe that approaches set out by Renou (2007) concerning sowing timing and density remain intimately linked to optimization of some environmental factors which include rainfall. Indeed, Pettigrew (2010) indicated that early planting required irrigation to achieve the expected yield. In this context, yield improvement depends on a farm management system that mobilizes and controls water (Assouman et *al.*, 2016). At this level, several water sources are available to supply the crops. Indeed, according to Thivet and Blinda (2009) there is rainwater (or green water), surface water (grey water) and groundwater (blue water), mainly used for localized or sprinkler irrigation systems. Irrigation water comes from a source, such as a dam or a borehole, and is conveyed through a pipes network to farms (Bhouri et *al.*, 2015). This water supply chain shows that, between source and consumption, there is probably a water loss. Indeed, to evaluate the losses, efficacy parameters have been defined (Bhouri et *al.*, 2015). These include irrigation efficiency at plot level and efficiency of water use by the crop (Bhouri et *al.*, 2015). In fact, this practice leads, in addition to good irrigation management, to better weeds control, as well as pests (Silvie and Fok, 2016). It also helps to reduce farmers' exposure to pesticides (Silvie and Fok, 2016). In any case, irrigation implementation requires prior parameterization. Therefore, this study objective is to estimate water use efficiency under supplementary irrigation and assess its impact on cotton boll weight.

**II - METHOD OF ANALYSIS AND EQUIPMENT**

**II – 1 - Method**

**- Theoretical tools**

Water use efficiency (WUE) for a plant under irrigation regime can be calculated in relation to total input during crop cycle, taking into account rainfall (Pereira, 2005). The formula is as follows:

*EUEp =Yp /P*  (1)

*EUEir =Yi /Vi* (2)

*EUEip =Yi / (P+Vi)* (3)

 Y: crop yield (kg/ha)

 P: cumulative volume of water fallen during the crop cycle (m3/ha)

Vi: the total volume of irrigation applied during the growing season (m3/ha).

With WUE, it’s possible to evaluate plants’ water consumption process efficiency, for biomass production (Bhouri et *al.*, 2015). Rain effectiveness is also evaluated. Effective rainfall, the rainfall part that is actually used by the plant after losses deduction such as surface runoff and deep percolation (Laere, 2003; Carluer et *al.*, 2010).

The following formulas were mentioned by Laere (2003):

*Peff = 0,6 x Pavg - 10 (for Pavg< 70 mm/month)* (4)

*Peff = 0,8 x Pavg - 25 (for Pavg> 70 mm/month)* (5)

 - Peff: *effective rainfall (mm) and Pavg: averagerainfall (mm)*

-**Experimental site**

The experimental site is Nidieou, a Côte d’Ivoire north village located in cotton company IVOIRE COTON production area. It is between 9°57' and 9°59' north latitude and 6°35' and 6°38' west longitude (Figure 1).



Figure 1 : Trials site location- Nidieou (Google Map, 2019)

**II – 2 - Equipment**

**- Biological material**

In terms of biological material, seed used was the Y616C variety, lot 209, from the IVOIRE COTON ginning plant in Boundiali (Northern Côte d'Ivoire). It was produced during the 2017 campaign by cotton producers selected by the cotton company. The basic biological material was provided to IVOIRE COTON by the CNRA for propagation. That seed, which had not been delinted, was subdivided into two 10 kg parts, one of which was intended for objects that had not been chemically treated for protection.

**- Technical equipment**

Irrigation was carried out by sprinkling using a boom with 6 sprinklers of 1 m3 per hour on the line, under pressure of 2 bars. It has a flow rate of 16.67 mm per hour (Table 1). The soil is sandy loam, and the water source is a shallow borehole that can contain silt and organic matter (Laere, 2003). A well 7 m deep, and 1 m in diameter is dug at the edge of the plot located 135 m from the water reservoir built for the village.

**Table 1**: Sprinkler distribution parameters

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Model Code  | 5022 | Pressure: | 2 (bar) |  |
| Nozzle: | mm\*mm | 3.0\*1.8 | Discharge: | 1 (m3/hr) |  |
| Spacing(m) | Spacing (m) | Position | Precipitation | Uniformity |
| Between sprinklers | Between lines | spacing | Dose (mm/h) | CU | DU | SC |
| ( % ) | ( % ) | 5% |
| 6 | 10 | Square | 16,7 | 93 | 91 | 1,1 |

Coefficient of uniformity (CU%) CU>85% = Good distribution

Uniformity of Distribution (UD%) DU>75% = Good, DU<67% = not acceptable.

Programming Coefficient (SC) SC<1.2 = Good, SC>2.0 = Low

**Source:** JIC (2016)

The device allows water twice for 7 minutes 2 times a day, between 6 and 7 a.m. in the morning, and after 5 p.m. in the evening (Petersen and Gulik, 2009; Milly and Dunne, 2016). Irrigation is triggered the day after the threshold of 3 mm of rain is reached and/or after 3 days without rain. The difference between supplementary irrigation and continuous watering is that the first one consists in adding small water amounts for crops to compensate for insufficient rainfall, aiming for yields stabilizing (Laere, 2003).

Two rain gauges, 3 kilometers apart installed, one in the village and the other on the experimental plot, allowed daily readings. The Weather Radar website, downloaded on a Samsung android mobile phone, was used to obtain data on temperature, relative humidity, wind speed and atmospheric pressure. This information has been used to estimate the plants’ daily water requirements (Petersen and Gulik, 2009; Milly and Dunne, 2016). The daily evapotranspiration is 4 mm (Dekoula et *al.*, 2018). The recording of rainfall in 2017 at the experimental site helped to situate the cultivation period from June to October 2018. Sowing took place during the period from 28 to 30 May 2018. The period of the 80% useful rainy season starts from May 25 to November 3 (Dekoula et al., 2018). The formula is as follows:

$ET\_{c}=K\_{c}\*ET\_{o}$ (6)

ETC = Crop Evapotranspiration (inch or mm)

KC = Crop Coefficient

ETO = Standard Evapotranspiration (mm) (Table 2)

Data related to calculated irrigation dosage concerns the daily requirements report by phase of cotton cycle. Namely, emergence, growth, maturity and senescence. The daily dosage is 3.5 mm (maximum demand phase close to the general value of 4 mm (Dekalou et *al.*, 2018). The Kc values are 0.45, 0.75, 1.15 and 0.75 respectively for emergence, growth, maturity and senescence stages of the cotton life cycle (FAO, 2017).

**Table 2:** Indicative values of ETo (mm/day)

|  |  |
| --- | --- |
|  | Average daily temperature |
| Zone Climatique | Low (less than 15°C) | medium (15-25°C) | high (more than 25°C) |
| Desert / arid | 4-6 | 7-8 | 9-10 |
| Semi-arid | 4-5 | 6-7 | 8-9 |
| Sub-humid | 3-4 | 5-6 | 7-8 |
| Wet | 1-2 | 3-4 | 5-6 |

**Source:** FAO (2017**)**

**- Chemical Materials**

In terms of agricultural inputs, mineral fertilizer was NPKSB 15-15-15-6-1 Bulk B. Phytosanitary treatments were carried out with products authorized by the Plant Protection department of Country Agriculture Ministry. These are seed treatment, herbicides, plant growth regulator and insecticides application. It was every 10 days from the 35th day to the 115th day after cotton plant emergence, giving 8 insecticide treatments (PR-PICA, 2017).

II – 3 - Methodology

- Experimental plot

The study took place during the 2018 cotton season. It was preceded in 2017 by preliminary studies for soil sampling and analysis, rainfall surveys and water point opening. The system consisted of 300 m² (20 m x 15 m) elementary plots, divided into 4 treatments with 3 repetitions (Tables 3 and 4).

Table 3: Trials treatments

|  |  |
| --- | --- |
| Items | Labelled |
| T0 | Untreated controls (without irrigation and agro-pharmaceuticals products) |
| T1 | Reference controls (without irrigation, applications of agro-pharmaceuticals, farmers practice) |
| T2 | Innovation (Supplemental Irrigation plus Agro-pharmaceuticals) |
| T3 | Irrigation only (without agro-pharmaceuticals) |

Table 4 : Experimental plots set-up by elementary blocks

|  |  |  |
| --- | --- | --- |
| **Bloc 1** | **Bloc 3** | **Bloc 2** |
| T11 | T03 | T02 |
| T01 | T13 | T12 |
| T31 | T33 | T22 |
| T21 | T23 | T32 |

**- Sampling method**

In terms of soil analysis, systematic sampling was carried out in May 2017 on the 0.6 ha trial site, at a depth of 30 cm (Pleysier, 1991). This sample was sent to National Polytechnic Institute (ESA INP-HB in Côte d’Ivoire) pedology laboratory. Concerning the cotton plot, observations were made on a sample of 30 plants taken in groups of 5 consecutive plants per line, following the sequential method known as the "diagonal" method (Nibouche et *al.*, 2003), on each elementary plot. Part of the surveys carried out concerned boll production and yield. Bolls were collected by sampling 4 capsules on three ridges following the diagonal and weighted per plot. Seed cotton production is estimated from 3 sub-plots of 4 lines by 3 meters following the diagonal per basic plot, then convert into yield per hectare

**- Soil sample analyses and corrections**

Soil analysis led to plant nutrient needs determination by identifying soil type, pH and various mineral components. Results are recorded in Table 5. From these results, three fundamental parameters were determined. On top of soil type, volumes of water to be used and mineral fertilizers corrected. For that, determination diagram was used with recorded proportions of clay, sand and silt (Figure 2).

**- Determination of soil type**

The analytical data (Table 6) indicate, from Figure 2, that it’s a sandy loam. Soil surveys carried out by Assouman et *al.* (2016) on the Bagoué alluvial plain, revealed a soil material structured in layers composed of 20 cm of brown to light ochre silt on the surface, which rests on about 1 m of sand. There is a predominance of sand 74.3%. Physical characterization revealed that the soils studied have a predominantly sandy texture in the surface horizon and this gives them a low capacity to retain exchangeable bases (Assouman et *al.*, 2016).

 Table 5: Soil Sample Analysis Results

|  |  |  |  |
| --- | --- | --- | --- |
| Elements | Values | Elements | Values |
| Clay (%) | 12 | pHKCl | 4,7 |
| Fine loam (%) | 7 | Mg2+ (Cmol+/kg) | 0,253 |
| Coarse silt (%) | 6,65 | K+ (Cmol+/kg) | 0,074 |
| Coarse sand (%) | 52 | Densité | 1,4 |
| Fine sand (%) | 22, 35 | Na+ (Cmol+/kg) | 0,09 |
| Nitrogen (%) | 0,03 | CEC (Cmol+/kg) | 3,5 |
| Carbon (%) | 0,34 | Fe (ppm) | 76 |
| Assimilable phosphorus (ppm) | 164 | Mn (ppm) | 89 |
| Total Phosphorus (ppm) | 700 | Cu (ppm) | 0 |
| pHwater | 5,6 | Zn (ppm) | 0 |



Figure 2: Determination of soil type (silt-sandy soil)

 Source: Elharrar (2016)

Concerning the experimental plot, results (Table 6) give values close to thresholds minimum limits allowed for cotton cultivation (Kouadio et *al.*, 2018). These analyses have demonstrated need to amend fertilization recommendations (CNRA, 2006; PR-PICA, 2018). It was necessary to identify the correction factors and calculate the potential needs.

**- Mineral fertilizer dosage corrections**

In the field, fertilization considers the soil deficit and the plant needs (Elharrar, 2016). The quantities intended for the plant are multiplied by a correction factor to absorb losses related to the soil structure (Table 6). Thus, the quantities used per ha on the experimental plots T1 and T2 were 280 kg for NPKSB 15.15.15.6.1 and 65 kg for 46% urea (Tables 7).

Table 6: Experimental plot soil chemical equilibrium Characteristics

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Ratio | C/N | Mg/K | Ca/Mg | K/CEC (%) |
| Valeurs | 11,33 | 3,42 | 2,65 | 2,11 |
| Results | Normal Mineralization | Lower Limit | Below Minimum Threshold | Lower Limit |
| VSM | 9< C/N<12 | 3< Mg/K<25 | 3< Ca/Mg<5 | K/CEC≥ 2 % |

VSM= Average threshold value (Kouadio and *al.,* 2018)

Table 7: Input of main mineral fertilizers NPK

|  |  |  |  |
| --- | --- | --- | --- |
|  | Export of dry matter | Needs Identification  | Inputs for experimental plot Urée-46% (65 kg/ha) + NPKSB-15.15.15 .6.1 (280 kg/ha) |
| Nutrients | Recommended doses (Urée 50 et NPK 200 kg/ha) | Parameters1 | Correction Factor² for Full Field |
| N | 53 | Silty-sandy soil | 1,3 | 71,9 |
| P2O5 | 30 | Acidic pH, 5.6 | 1,3 | 42 |
| K20 | 30 | Silty-sandy soil | 1,4 | 42 |

**Source :1**Study data / **²**Elharrar (2016)

**- Activities execution**

The crop establishment was carried out according to procedures recommended by CNRA (2006). Indeed, the sowing took place from 28 to 29 May 2018. This period was determined by estimated start of useful rainy season (Dekoula & *al.*, 2018).

**III – RESULTS**

After environmental data, in particular rainfall, this chapter is related to statistical analyses results linked to measured parameters. This is mainly information on the components of WEU and production.

III – 1 - At trial level

- Rainfall and Water Use Efficiency

In addition to temperature (Table 8), relative humidity and wind speed (Table 9) were recorded. A total of 1033.5 mm was obtained from May to October 2018 on the experimental site, with drought period identified, mainly in June and July (Table 10). The 24.5 mm supplemental irrigation led to an upward correction in the rainfall level. Indeed, average rainfall curves in trial region and is slightly different from experimental plot one (Figure 3).

Table 8: Monthly average temperatures at the experimental site in 2018

|  |
| --- |
| Period |
| Températures (°C) | June | July | August | September | October | Average |
| Maximum | 32,73 | 31,32 | 28 | 30,38 | 33,45 | 31 |
| Minimum | 22,27 | 22,05 | 21 | 21,86 | 23,09 | 22 |
| Average | 27,5 | 26,68 | 24,5 | 26,12 | 28,27 | 27 |

Table 9: Monthly average relative humidity and wind speed on the experimental site in 2018

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Period | June | July | August | September | October | Average |
|  Relative humidity (%)  | 67,3 | 77,9 | 88,6 | 83,5 | 79,7 | 79,4 |
|  Wind speed (km/h)  | 8,5 | 7,6 | 7,8 | 5,2 | 5,2 | 6,9 |

Table 10: Rainfall and supplementary irrigation data in 2018

|  |
| --- |
| Period |
|  | May | June | July | August | September | October | Total |
| Mean rainfall zone (mm) | 65,35 | 168,7 | 143,85 | 369,25 | 220 | 29,5 | 996,7 |
| Rainfall on experimental site (mm) | 67,8 | 172 | 153,2 | 375,5 | 236 | 29 | 1033,5 |
| Supplemental irrigation (mm) | 3,5 | 7 | 14 | 0 | 0 | 0 | 24,5 |
| Number of rainy days | 5 | 11 | 11 | 17 | 8 | 2 | 54,0 |
| Number of days of irrigation | 1 | 2 | 4 | 0 | 0 | 0 | 7,0 |



Figure 3: Average monthly rainfall in the experimental area compared to total rainfall in irrigated plots

- WUE test results

Useful rainfall was obtained over cropping period, using a weighted coefficient (24%, (Carluer & *al.*, 2010)) of rainwater loss by runoff and deep percolation (Table 11). At WUE level in relation to yield, the analysis shows a highly significant difference between treatments (Table 12) (p<0.01). The results were 0.361±0.012, 0.227±0.01, 0.031±0.012 and 0.025±0.012 kg/m3, respectively for innovation, farmers practice, irrigation-only and untreated control. The innovation has a higher average but not significantly different from reference control one (Table 12). But the difference with the untreated is highly significant, Innovation EUE is 14.4 times higher than untreated one.

Table 11: Estimated Water Use Efficiencies (WUE) by Treatment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Plots | Untreated plots | Irrigated only | Reference  | Innovative  |
| Average yield (cotton seed) (Kg/ha) | 180,7 | 226,6 | 1 616,3 | 2 657,8 |
| EUEp (kg/m3)\* | 0,025 |  | 0,227 |  |
| EUEip (kg/m3)\* |  | 0,031 |  | 0,361 |
| Useful rainfall June to September (m3/ha)² | 7 119 | 7 119 | 7 119 | 7 119 |
| Rainfall June to September (m3/ha) | 9367 | 9367 | 9367 | 9367 |
| Supplementary irrigation (m3/ha) | 0 | 245 | 0 | 245 |

\*: Estimated with the formulas (2) et (4) ; **²**: Average loss by runoff and deep percolation: sandy soils (30%), silt soils (12.5%), clay-silt soils (0%) (Carluer & *al.*, 2010).

**Table 12** : WUE test results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatement | Average WUE | St.Er.  | Treatement\*Blocs (B) | Average WUE | St.Er. |
| T0 | 0,025 a | 0,012 | T0\*B1 | 0,029a | 0,016 |
| T1 | 0,227 b | 0,012 | T0\*B2 | 0,026 a | 0,016 |
| T2 | 0,361 b | 0,012 | T0\*B3 | 0,021 a | 0,016 |
| T3 | 0,031 a | 0,012 | T1\*B1 | 0,280 b | 0,016 |
|  |  |  | T1\*B2 | 0,221 b | 0,016 |
| Bloc | **Average WUE** | **St.Er.**  | T1\*B3 | 0,180 b | 0,016 |
|  |  |  | T2\*B1 | 0,346 b | 0,016 |
| Bloc1 | 0,173a | 0,010 | T2\*B2 | 0,411 b | 0,016 |
| Bloc2 | 0,172 a | 0,010 | T2\*B3 | 0,326 b | 0,016 |
| Bloc3 | 0,138 b | 0,010 | T3\*B1 | 0,036 a | 0,016 |
|  |  |  | T3\*B2 | 0,031 a | 0,016 |
|  |  |  | T3\*B3 | 0,025 a | 0,016 |

At the same time, strait irrigated treatment recorded an average WUE like untreated control one.

**III – 2 – Bolls Mean Weight**

The analysis in relation to average boll weight showed a highly significant difference between treatments (Table 13). The results were respectively 5.4±0.0614, 4.0±0.0614, 2.9±0.0614 and 2.6±0.0614 g/boll for innovation, current practice, irrigation only treatment, and untreated control. Innovation average weight is 35% higher than reference control one (p<0.01). At the same time, strait irrigated plots averaged 11.5% higher than untreated control (p<0.01). It appears that the addition of water has improved average bolls’ weight. Similarly, growers practice obtained an average of 53.8% higher than the untreated control one (p<0.01) while the innovation was 86.2% higher than the strait irrigation one (p<0.01).

**Table 13** : Average boll weight

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Traitements | Moyenne | Er. St. | Traitement\*Blocs | Moyenne | Er. St. |
| T0 | 2,6a | 0,0614 | T0\*Bloc3 | 2,2000a | 0,1063 |
| T3 | 2,9b | 0,0614 | T3\*Bloc1 | 2,3667a | 0,1063 |
| T1 | 4,0c | 0,0614 | T0\*Bloc1 | 2,8000b | 0,1063 |
| T2 | 5,4d | 0,0614 | T0\*Bloc2 | 2,8000b | 0,1063 |
|  |  |  | T3\*Bloc2 | 2,9667b | 0,1063 |
| Bloc | **Moyenne** | **Er. St.** | T1\*Bloc3 | 3,0000b | 0,1063 |
|  |  |  | T3\*Bloc3 | 3,4333c | 0,1063 |
| Bloc3 | 3,3a | 0,1488 | T2\*Bloc3 | 4,5000d | 0,1063 |
| Bloc1 | 3,9b | 0,1488 | T1\*Bloc2 | 4,5333d | 0,1063 |
| Bloc2 | 4,1b | 0,1488 | T1\*Bloc1 | 4,6000d | 0,1063 |
|  |  |  | T2\*Bloc1 | 5,8000e | 0,1063 |
|  |  |  | T2\*Bloc2 | 5,9667e | 0,1063 |

**IV - DISCUSSION**

These results demonstrate that supplemental irrigation combined with agro-pharmaceutical treatment contributes to improvement of seed cotton yield (Bednarz & *al.*, 2005; Zhi & *al.*, 2016). Thus, supplementary irrigation alone cannot allow plants to mature; however, it complements rainfall (Laere, 2003). By comparison, cotton uses almost as much water as sugarcane and less water than rice (CCIC, 2018). In fact, the use of localized irrigation (drip irrigation) saved 26.9% of water and obtained a 43.1% increase in seed cotton yield compared to standard sprinkler irrigation (Singh et al., 2010). In parallel, this innovation leads, in addition to good irrigation management, to better control of weeds, as well as pests (Silvie and Fok, 2016). In this context, supplementary irrigation is also water efficient. For example, according to Karam & *al.* (2005), maize had a water use efficiency of 1.34 to 1.88 kg/m3, while cotton, soybeans and sunflowers were 0.64, 0.54 and 0.86 kg/m3, respectively. Also, the most important information at this level is that the efficiency of water use can be significantly high if the irrigation water supply is reduced (Zwart and Bastiaanssen, 2004). In addition, WUE varies depending on the type of biomass chosen. For example, for seed cotton, Zwart and Bastiaanssen (2004) obtained values ranging from 0.4 to 0.95 kg/m3, while fiber values ranged from 0.14 to 0.33 kg/m3. The rain effectiveness is evaluated. Indeed, when temperatures are high, the fertilization of ovules is compromised, leading to the production of a reduced number of seeds per boll, a low capsular weight and therefore ultimately a loss of seed cotton yield (Pettigrew, 2008). Indeed, compared to reference control, average capsular weight is improved by supplementary irrigation, reaching 5.4g. Relatively, Amangoua & *al.*, working on 5 varieties of cotton, obtained average capsule weights ranging from 4.16 to 5.4g in Ivory Coast. Thus, under drought conditions, the drop in seed cotton yield was substantial (about 17.5%) when the level of irrigation was reduced from 100% to 70% evapotranspiration (ASABE, 2015).

In this context, sprinkler irrigation has the advantage of being able to contribute to fruiting bodies temperature reduction by 2°C, a few hours after low-frequency watering (Saadia & *al*., 1996). Also, the yield is sensitive to moisture conditions, a significant reduction in production was recorded in simulated dry land conditions (Brewer & *al*., 2016). However, for the cotton field, the estimation of water requirements is strongly correlated with yield on both arid plots and under irrigation conditions (Karam & *al.*, 2006).

Thus, supplementary irrigation provides a substantial benefit even when transgenic seeds are involved (Lakho & *al.*, 2016; FAO, 2018). Since under conditions of water stress, there is a noticeable reduction in the percentage of fiber per seed (Konan & *al.*, 2015). At this level, Singh & *al.* (2010) mentioned that the decline in cotton crop yield, under irrigation deficit, was correlated with the decrease in both bolls number per plant and average capsular weight. The need for water is so important that its scarcity over a period of the crop cycle poses a threat to the crop (Khan, 2018). Also, as mentioned by Pastori & *al.*, (2019), it becomes possible to predict that adoption of more intensive agricultural practices with sustainable irrigation methods can effectively increase the capacity to adapt to climate change impacts and other external environmental stressors.

 **V - CONCLUSION**

These results show that supplemental irrigation combined with agro-pharmaceutical treatment contributes to the improvement of cotton bolls yield. Thus, supplementary irrigation alone cannot allow plants to mature; however, it complements rainfall. Therefore, water source for irrigation becomes like cotton plant enemies, another challenge to be overcome. In short, supplementary irrigation consumes less water than continuous irrigation. In fine, harvest parity price calculation, including seeds cost, should help to better perceive the economic impact of complementary irrigation introduction in Côte d'Ivoire cotton cropping system.

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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