Journal of Applied Biosciences 166: 17270 – 17279
ISSN 1997-5902

Influence of supplemental irrigation on the growth and yield parameters of the soybean crop (*Glycine max*) in the small rainy season in the coastal plain of Togo

*** Alfassassi AROUNA (1, 2), Adjiwanou ATIGLO-GBENOU (1, 2), Anani OGOU (3), Dong-da KALINESSO (1)**

(1) Department of Rural Engineering and Agricultural Machinery / Higher School of Agronomy / University of Lomé, 01 BP 1515 Lomé 01 - Togo

(2) Agricultural Mechanization and Process Engineering Research Team (ERMAP), University of Lomé - Togo

(3) Food and Agriculture Organization of the United Nations – FAO-Togo

Corresponding author email: arounafazaz@yahoo.fr

Submitted on 19th August 2021. Published online at www.m.elewa.org/journals/ on 31st October 2021
https://doi.org/10.35759/JABs.166.10

ABSTRACT

Subject description: In the West African coastal zone where there are two rainy seasons, it is possible to produce a second cycle of soybeans in the short rainy season thanks to supplementary irrigation in order to increase the income of producers.

Objective: Determine the water deficit threshold for soybean supplemental irrigation during the short rainy season in South -Togo.

Methodology and results: A test on the declining doses of supplemental irrigation of the soybean crop was carried out at the agronomic experimentation station of Lomé using an experimental device in Fisher blocks. Observations focused on growth and yield parameters of the soybean crop. The results obtained showed, compared to rainfed cultivation that supplemental irrigation influenced the parameters studied. The supplemental supply of 100% and 80% of the water requirements induced good plant growth and better soybean yields compared to the treatments without irrigation and the supplementary inputs of 60% and 70% of the water requirements. The yields under the "100% and 80% water requirements" treatments, respectively 2.60 t.ha^{-1} and 2.20 t.ha^{-1}, were statistically identical and represent double the yield under the treatment. "Without supplemental irrigation" (1.13 t.ha^{-1}).

Conclusion and application of results: Supplementary irrigation of 80% of soybean crop needs would save 20% of water resources. These results allow to carry out two cycles of soybean production during a crop year.

Keywords: supplemental irrigation; water deficit; growth and yield parameters; soy; South Togo.

Effet de l'irrigation de complément sous la culture du soja (*Glycine max*) en petite saison des pluies dans la région Maritime du Togo

RESUME

Description de sujet : Dans la zone côtière ouest africaine où l'on dispose de deux saisons de pluies, il est possible de produire un second cycle de soja en petite saison de pluies grâce à l'irrigation de complément en vue d'accroitre le revenu des producteurs.

Objectif : Déterminer le seuil du déficit hydrique en irrigation d'appoint du soja en petite saison pluvieuse dans le Sud –Togo.

Méthodologie et résultats : Un essai sur les doses dégressives d'irrigation de complément de la culture de soja a été réalisé à la station d'expérimentations agronomiques de Lomé suivant un dispositif expérimental en blocs de Fisher. Les observations ont porté sur les paramètres de croissance et de rendement et l'analyse statistique des données a été réalisée à l'aide du logiciel GenStat Discovery Edition 4.

Les résultats obtenus ont montré, par rapport à la culture pluviale, que l'irrigation d'appoint a influencé les paramètres étudiés. L'apport en appoint de 100% et 80% de besoins hydrique a induit une bonne croissance de plants et de meilleurs rendements en graines de soja comparativement aux traitements sans irrigation et aux apports en appoint de 60% et 70% de besoins hydriques. Les rendements sous les traitements « apport de 100% et 80% de besoins hydriques », respectivement de 2,60 $t.ha^{-1}$ et 2,20 $t.ha^{-1}$, sont statistiquement identiques et représentent le double du rendement sous le traitement « sans irrigation de complément » (1,13 $t.ha^{-1}$).

Conclusion et application des résultats : L'irrigation d'appoint de 80% des besoins de la culture de soja permettrait d'économiser 20% des ressources en eau. Ces résultats permettent d'effectuer deux cycles de production du soja au cours d'une campagne agricole.

Mots clés : irrigation de complément ; déficit hydrique ; paramètres de croissance et de rendement ; soja ; Sud-Togo.

INTRODUCTION

Globally, soybean production is the fastest growing because of its essential role in the food supply through its high protein content and energy value (WWF, 2014). In Togo, the acceleration of its production only intervened in 2008 following the difficulties encountered by the cotton sector leading to the conversion of areas previously covered by cotton into soybean fields (MCPSP / SMOCIR, 2013; Kpotchou, 2020) . It is identified as an opportunity for the diversification of agricultural exports likely to reach a large number of poor farmers (MCPSP / SMOCIR, 2013). The soybean sector has the qualities required to contribute to poverty reduction, improving household nutrition and strengthening the sustainability of farms and its consumption is popular with city dwellers (MCPSP / SMOCIR, 2013; Kpotchou, 2020). There are many advantages to growing soybeans, including low fertilizer requirements; little water requirement; reduction of striga pressure on cereals in crop rotations integrating soybeans; nitrogen enrichment of the soil; use of tops for small livestock (Javaheri & Baudoin, 2001, Dugué, 2010). However, as for all crops in Togo, soybean production, overall, is faced with enormous constraints, including the lack of water control. This leads to a high variability of the expected income to the subjection to a variable rainfall and to the limitation of investments in rain-fed agriculture (HLPE, 2015). This situation, reinforced by climate change, is reflected in a reduction in the length of the rainy season and consequently the reduction in rainfall in the Maritime region estimated at 800 mm per year, suitable for soybean cultivation (Kouamé *et al.*, 2007; Adéwi *et al.*, 2010; HLPE, 2015). Although soybean cultivation is part of rainfed agricultural systems, its integration into irrigated systems requires prior studies. Reliable irrigation increases and stabilizes incomes and builds resilience to the livelihoods of large numbers of smallholders. In addition, several studies carried out have shown that water stress has a bad influence on growth, development, yields, and the high protein content of soybeans (Blanchet *et al.*, 1977; Vidal *et al.*, 1981; Doto *et al.*, 2013;). The work carried out by Doto *et al*. (2013) in South Benin, Similar pedoclimatic conditions in South Togo focused on estimating the water consumption of soybean cultivation according to the phenological phases in order to propose an irrigation regime for efficient water management in soybean cultivation. However, no work has been done to determine the tolerant threshold for water stress that can guarantee the growth, seed yield and efficient water management of irrigated soybean cultivation in the short rainy season in the South. Togo. It is in this capacity that this study was undertaken.

MATERIAL AND METHODS

Study site: The test was conducted at the Lomé Agricultural Experimentation Station (SEAL) of the Higher School of Agronomy of the University of Lomé (ESA / UL), located at the Lomé university campus for geographical coordinates 6 ° 10 '33"N; 1 ° 12'38"E (Figure 1). The Climate is of type Guinean comprising four seasons (long rainy season; short dry season; short rainy season and long dry season) with an annual rainfall of between 800 mm and 1,200 mm, variable from one locality to another and average temperatures between 24 ° C and 32 ° C (Badameli & Dubreuil, 2015). The soil is ferralitic, with a sandy clay texture, locally called “bar land” (Worou, 2002). The annual height of rainfall recorded at the SEAL meteorological park during the test was 509.4 mm, or about half of the average annual rainfall generally recorded in the Maritime region. The work was carried out between September and December 2018, a short rainy season with a seasonal height of recorded rainfall of 50 mm. In addition, rain-fed soybean production covering the period from April to July in the study area (Tchabana *et al.*, 2020), the short rainy season would be a second potential period of production under supplemental irrigation in the southern region of Togo.

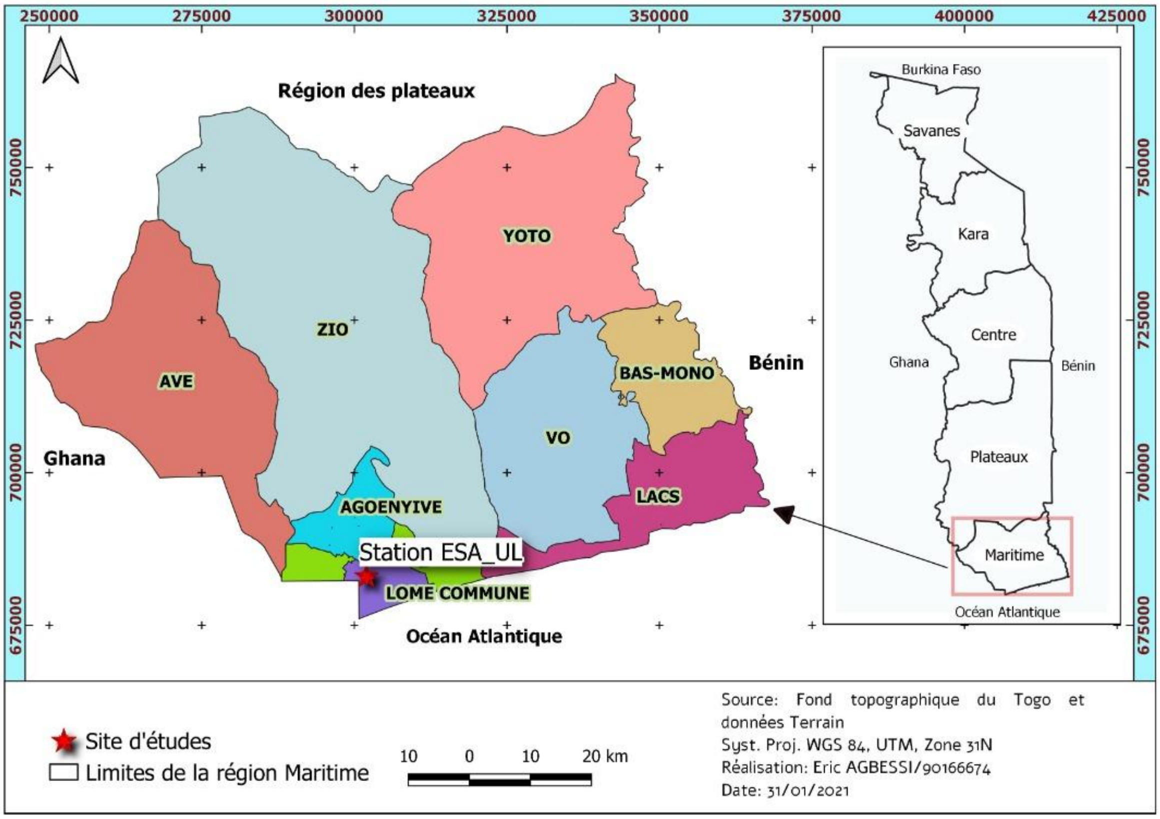


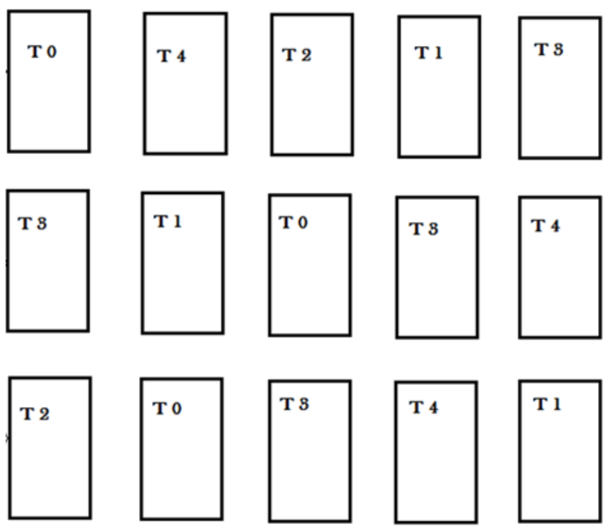
Figure 1: Experimentation site

Plant material: The plant material used is the improved soybean variety (*Glycine max*) TGX1485-1D. It is a variety with a cycle duration (sowing to maturity) of 90 to 100 days. The seed format is large oval, the potential yield is 4 t.ha-1 with an average yield obtained of 2.4 t.ha-1, growth is determined, without dehiscence of the pods, the habit is erect, resistance to diseases, insects and weeds is good, good technological suitability in oil, milk and cheese (Tchabana *et al.* , 2020),. Previous crops tested were tomato followed by maize to reduce pest pressure at soil level (Doto *et al.*, 2013).

Technical material: The set of tools used to carry out this work is composed as follows: a cutter-cutter for clearing, a daba for making the boards, a hoe for weeding, a tape measure for taking the different dimensions, a 0.1g Camry precision scale for weighing and a 10 liter graduated watering can for irrigation.

Establishment of culture: After clearing and making planks followed by watering. The flat and row sowing was carried out the next day at a depth of approximately 3 cm following a cropping pattern of 40 cm × 20 cm at the rate of 3 seeds per pocket, i.e. a density of 375,000 plants / ha (Kouamé *et al.,* 2007). The thinning was carried out 12 days after sowing (DAS) in order to remove less vigorous plants and maintain the number of plants per pocket at two. Periodic maintenance focused on mechanical weeding through weekly weeding in order to loosen the soil. Plots subject to irrigation were watered manually using a graduated watering can at a frequency of once every four (04) days against a frequency of once every 5 to 6 days recommended by Doto *et al*. (2013) with a view to minimizing the high risk of reducing the Easily Usable Reserve (RFU). The quantities of water brought to the crops vary according to the research protocol. The brown coloured pods were harvested between 7 a.m. and 8 a.m. to prevent them from bursting by cutting the plants to keep the roots in the soil so that it could benefit from the fixed nitrogen (FAO, 2013). After harvest, the cut twigs were dried for five (05) days on a concrete drying area, and then gently threshed with a stick so as not to break the seeds (McWilliams *et al.*, 1999; Kouamé *et al.*, 2007). The threshing product was then winnowed and then cleared of non-conforming grains, plant debris and stones by sorting (FAO, 2013).

Experimental design: The test was conducted using a full single-factor random block arrangement (irrigation) with three replicates. The blocks were separated from each other by 1 m wide aisles and each repetition consisted of five 3.6 m2 (3 mx 1.2 m) boards spaced 40 cm apart from each other, each corresponding to a dose of 'irrigation. The different doses of supplemental irrigation each correspond to a treatment (Figure 2).



T0: control without irrigation;

T1: additional supply of 2.6 mm corresponding to 100% water supplement;

T2: additional supply of 2.1 mm corresponding to 80% water supplement;

T3: additional supply of 1.8mm corresponding to 70% water supplement;

T4: additional supply of 1.6 mm corresponding to 60% water supplement.

Figure 2: Experimental apparatus

Data gathering: The data collected focused on the height of the plants on the 14th, 45th and 60th DAS, the leaf area, the number of pods / plant, the number of seeds / pod, the weight of 1000 seeds and the grain yield. The pruning of the plants was made from the base of the plant to the top (Figure 3) plants sampled at random at different locations in each experimental unit at the rate of thirteen (13) plants per central row, plants located at the edge not being considered (Doto *et al.*, 2013).

The soybean yield was determined after weighing by the following formula:

$$\mathrm{Rdt} = \frac{\mathrm{p} * \mathrm{d}}{1000}$$

with Yd : Yield in t.ha-1; p: Productivity (mass of seeds per plant) in kg; d: Stocking density (Number of plants per ha)

The leaf area was evaluated using the formula of Dagba (1974):

$$\log \mathrm{S} = -0{,}4108 + 0{,}8814 * \log \mathrm{L} + 1{,}1573 * \log \mathrm{l}$$

with S: leaf area in cm2; L = leaflet length (cm) and 1 = leaflet width (cm)

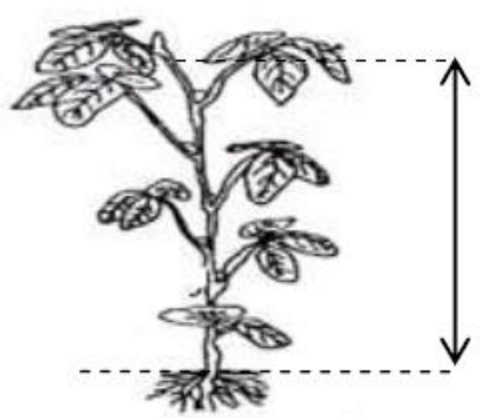


Figure 3: Measurement of plant height (Doto *et al.*, 2013)

Assessment of water needs, processing and statistical analysis of data: Crop water requirements were estimated from FAO's CROPWAT 8.0 AND CLIMWAT 2.0 for CROPWAT 8.0 software based on the water balance. The data collected was processed in an Excel spreadsheet and the analysis of variance was used for the comparison of the means of the soybean growth and yield parameters. The results obtained were statistically analysed by the GenStat Discovery Edition 4 software and then discriminated using the Student-Newman-Keuls test at a threshold of 5%.

RESULTS

The work consisted in determining the tolerant threshold of water stress under the supplementary irrigation crop of soybeans during the short rainy season in South Togo. The improved variety TGX1485-1D was the subject of this experiment and the decreasing irrigation doses were added. The observation parameters were the height of the plants, the leaf area, the number of pods / plant, the number of seeds / pod, the yield of soybeans, the mass of 1000 seeds. The results obtained differ from each other depending on the irrigation doses provided.

Amount of water received by soybean plants: During the test, the amount of water supplied by precipitation and irrigation varies according to the treatments. For the T0 treatment where no additional quantity of water was added, the quantity of water received by the plant amounts to 50 mm, corresponding to the quantity of rain recorded during this period. On the other hand, in addition to the amount of rain that fell during the test, the various irrigation doses were added according to the research protocol at the rate of twenty-four waterings for the entire period of the cycle (Table 1).

Table 1: Cumulative Water Height Received by Crops

Treatments	Irrigation water height (mm)	Cumulative height of water received by crops (mm)
T0 (without irrigation)	0	50
T1 (2.6 mm)	62.4	112.4
T2 (2.1 mm)	50.4	100.4
T3 (1.8 mm)	43.2	93.2
T4 (1.6 mm)	38.4	88.4

Influence of supplemental irrigation on the vegetative parameters of soybean plants: Already at the 14th and 45th DAS, the treatments responded differently to the cumulative quantity of water received. The plants which received, in addition, at least 70% of the water requirements of the soybean crop had a relatively faster vertical growth than the plants under the T3 (supplemental supply of 60% of water requirements) and T0 (without supplemental irrigation). On the other hand, at the end of vegetative growth, only soybean plants under T1 treatment (supplemental supply of 100% of water requirements) gave higher plant heights exceeding 60 cm. These heights are in the range of 0.6-1.5 m, in accordance with agronomic data for soybeans (Bernard, 1997). Unlike plant height, the difference in leaf area between plants under T1 treatments, Table 2).

Table 2: Vegetative parameters of soybean

Treatments	Plant height (cm)			Leaf area (cm2)
	14 DAS	45 DAS	60 DAS	
T0 (0.0 mm = without irrigation)	9.67 ± 0.58 b	33.00 ± 2.65 b	35.67 ± 1.53 d	42.03 ± 0.89 b
T4 (1.6mm = 60%)	9.94 ± 0.92 b	31.61 ± 17.99 b	48.33 ± 0.58 c	56.47 ± 12.34 ab
T3 (1.8mm = 70%)	10.67 ± 0.58 ab	48.67 ± 0.58 ab	50.67 ± 1.16 c	65.91 ± 7.38 a
T2 (2.1 mm = 80%)	11.67 ± 0.58 a	52.67 ± 1.15 a	58.67 ± 1.53 b	70.85 ± 4.74 a
T1 (2.6 mm = 100%)	12.0 ± 0.00 a	54.33 ± 1.53 a	65.33 ± 2.08 a	69.11 ± 9.36 a

* The means of a column, followed by the same letter do not differ significantly at the 5% level (Student-Newman-Keuls test); DAS : days after sowing

Influence of supplemental irrigation on the yield parameters of soybean plants: The most affected yield parameters are the number of pods / plant where the difference is statistically significant for all treatments (Table 3). The results obtained are similar to those of Vidal et al. (1981) and Sage & Durant (1999) who found that among the parameters of seed yield, it is the number of pods, which is more sensitive to drought, unlike the weight of 1000 seeds and the number of seeds per pod, which are quantitatively less affected.

Table 3: Soybean Yield Parameters

Treatments	**Pods / plant**	**Seeds / pod**	**Average yield (t.ha-1)**	**1000 grain mass (g)**
T0 (0.0 mm = without irrigation)	73.33 ± 3.51 e	2.43 ± 0.06 b	1.13 ± 0.12 c	119.43 ± 7.43 b
T4 (1.6mm = 60%)	89.67 ± 7.64 d	2.57 ± 0.12 b	1.63 ± 0.23 b	118.33 ± 2.97 b
T3 (1.8mm = 70%)	118.00 ± 6.25 c	2.67 ± 0.15 b	1.83 ± 0.21 b	122.23 ± 6.37 ab
T2 (2.1 mm = 80%)	184.67 ± 9.07 b	2.93 ± 0.12 a	2.20 ± 0.00 ab	132.00 ± 4.39 a
T1 (2.6 mm = 100%)	202.00 ± 8.89 a	3.10 ± 0.20 a	2.60 ± 0.50 a	132.87 ± 3.67 a

* The means of a column, followed by the same letter do not differ significantly at the 5% level (Student-Newman-Keuls test)

Efficiency of water use by soybean cultivation: The cumulative amount of water is used differently depending on the treatment. Only the supplemental irrigation dose of 100% of the additional needs gives better water productivity compared to the control (Table 4).

Table 4: Water Use Efficiency in Soybean Cultivation

Treatments	**Efficiency of the use of the cumulative amount of water by the cultivation of soybeans (**kg.mm-1.ha-1)	**Efficiency of irrigation water use by soybean cultivation (**kg.mm-1.ha-1)
T0 (without irrigation)	22.6	-
T4 (1.6 mm)	18.4	13.0
T3 (1.8 mm)	19.6	16.2
T2 (2.1 mm)	21.9	21.2
T1 (2.6 mm)	23.1	23.6

DISCUSSION

The quantities of water received vary between 50 mm for the T0 treatment (without irrigation) and 112.4 mm for the T1 treatment (supplementation of 100% of water needs). Thus, the soybean plants under the T1 and T2 treatments (supplementation of 80% of water requirements) which received a quantity of water greater than or equal to 100 mm would have a good response to water and consequently, higher yields (Sage & Durant, 1999). However, Javaheri & Baudoin (2001) estimate that soybean is a plant which is less demanding in water than corn and the water requirements are between 30 to 50 mm at least for the whole production cycle. Supplementary irrigation significantly improves plant height growth and leaf area, hence seed yield. The good response of crops under supplemental irrigation corroborates with the results of Doto *et al*. (2013) who found a significant difference at the 5% threshold for the heights of irrigated and non-irrigated soybean plants. However, for a rational management of water resources, supplying 70% of water requirements would help save 30% of irrigation water, since this dose makes it possible to obtain similar heights for supplying 100% of water. The leaf areas observed on the plants under the T0 treatment corroborate with the results of Vidal *et al*. (1981) who found that the deficient water regime causes a reduction in leaf area after 15 days. This proves that the leaf surface is the vegetative parameter most affected by the water deficit with the consequence of a growth retardation of the soybean plant (Vidal *et al.*, 1981). The significant influence of supplemental irrigation on soybean growth factors shows that the supply of additional water according to the physiological phases would be an alternative to increase yields and improve the quality of seeds from one season to another. (Doto *et al.*, 2013).

The soybean yields obtained are also strongly influenced by the additional water supply. This finding confirms the results of previous work, which showed the strong influence on yields of the reduction in water consumption (Blanchet *et al.*, 1977; Haskett *et al.*, 2000; Dogan *et al.*, 2007; Doto *et al.*, 2013; Radhouane *et al.*, 2014). In addition, the soybean yields under the T1 (100% intake) and T2 (80% intake) treatments, which are statistically identical, are double the soybean yields under the T0 treatment (without irrigation). These results obtained are similar to those of Doto *et al.* (2013) who found that grain yields at 9.5% moisture content for irrigated crops were double the soybean yields under non-irrigated plots. This is explained by the fact that up to 3 weeks before harvest, watering is efficient and late irrigation allows high yields thanks to well-filled grains and good protein richness (Sage & Durant, 1999). Thus, it is necessary to ensure a good water supply to the crop by irrigation to obtain a high soybean yield (Doto *et al.*, 2013). Regarding the productivity of irrigation water, it can be seen that the efficiency of the use of irrigation water by soybean cultivation is an increasing function of the irrigation dose. The results obtained are much higher than 3 kg.mm-1.ha-1, the water productivity of soybeans obtained by Doto *et al*. (2013).

CONCLUSION AND APPLICATION OF RESULTS

Supplemental irrigation under soybean cultivation has a strong influence on vegetative and soybean yield parameters. Among the vegetative parameters, the leaf surface was more impacted as well as the height of the plants at the end of vertical growth. Regarding the yield parameters, the number of pods / plant was more influenced by the water deficit followed by the soybean yield. The number of seeds per pod would probably be more related to the genetic characteristics of the variety. In view of the results obtained, it is necessary to guarantee a good water supply to the crop by irrigation to obtain a high soybean yield. Water productivity is better as water needs are 100% met. However, for a rational management of water resources, it would be wise to reduce additional water inputs by 20% since the difference between soybean yields under T1 and T2 treatments is not statistically significant.

BIBLIOGRAPHICAL REFERENCES

Badameli A. and Dubreuil V, 2015. Diagnosis of climate change in Togo through the evolution of temperature between 1961 and 2010. Proceedings of the XXVIIIth Symposium of the International Association of Climatology, July 2015, Liège, Belgium . pp. 421-426. (halshs-01176808, version 1).

Blanchet R. and Chone E, 1979. Soybean. Bull. Tech. Inf. No. 338/339, 211-222.

Dagba E, 1974. Trial to determine the leaf surface area of cowpea (Vigna unguiculata (L.) Walp). ORSTOM, 20p.

Dogan E, Kirnak H, Copur O, 2007. Deficit irrigations during soybean reproductive stages and CROPGRO-soybean simulations under semi-arid climatic conditions. Field Crop Research Journal, 103, 154-159. DOI: 10.1016 / j.fcr.2007.05.009.

https://doi.org/10.1016/j.fcr.2007.05.009

Doto CV, Ahamidé B, Agbossou KE, 2013. Evaluation of water consumption and yield of soybean crops (Glycine maxGlycine max (L.) Merr.) On ferralitic soil in South Benin. Bulletin of Agronomic Research of Benin (BRAB) Number 74 - December 2013, pp. 36-47; BRAB online on the websitehttp://www.slire.net, ISSN on paper (on hard copy): 1025-2355 and ISSN online (on line): 1840-7099.

Dugué P, 2010. Environmental assessment study and the development of sustainable production systems within the framework of food production support projects (Benin, Togo, Ghana). FARM food projects, 135 pages.

FAO / TECA, 2013. Good Soybean Production Practices. Technical sheet, 4 pages.

HLPE, 2015. Water, a stake for world food security. Report of the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome 2015, 151 pages.

Javaheri F. and Baudoin JP, 2001. Oil crops: Soya bean: 809-828. In: Crop production in Tropical Africa. Ed. By R. Raemaeker, DGCI (Directorate General for International Cooperation), Brussels, Belgium.

Haskett JD, Pachepsky YA, Acock B, 2000. Effect of climate and atmospheric change on soybean water stress: a study of Iowa, Ecological Modeling, 135 (2-3), 265-277. doi.org/10.1016/S0304-3800(00)00369-0.
https://doi.org/10.1016/S0304-3800(00)00369-0

Kouame C, N'Gbesso M, Adako M, Tahouo O, 2007. Growing soybeans well in Côte d'Ivoire. Technical sheet, 4 p. Directorate of research programs and development support -Direction of innovations and information systems CNRA, 01 BP 1740 Abidjan 01, Ivory Coast.

Kpotchou K, 2020. Soybean consumption and health in urban areas in Togo. Space, Territories, Societies and Health Review, 3 (5), 13-24. [Online] 2020, posted June 30, 2020, consulted on 2020-07-05 09:07:08, URL:https://www.retssa-ci.com/index.php?page=detail&k=93.

MCPSP / SMOCIR (Ministry of Trade and the Promotion of the Private Sector / Secretariat for the Implementation of the Reinforced Integrated Framework), 2013. Productive and Commercial Capacity Building Project for the Soybean Sector in Togo, EIF Category 2 Project , 92 p.

McWilliams DA, Berglund DR, Endres GJ, 1999. Soybean growth and management quick guide, A-1174. North Dakota State U., U. of Minnesota.

N'Zoue A, Kouame C, Mondeil F, N'Gbesso M, 2003. Agro-morphological analysis of two soybean lines (Glycine maxGlycine max L. MERR). African Agronomy 15 (3): 93-104

Radhouane L, Aissa N, Romdhane L, 2014. Effects of water stress applied to different stages of seed development in an indigenous ecotype of grain sorghum (Sorghum bicolor). Journal of Applied Biosciences 74: 6149-6156.,http://dx.doi.org/10.4314/jab.v74i1.6
https://doi.org/10.4314/jab.v74i1.6

Tchabana B, Boyoda BTK, Lombo Y, Kpemoua KE, Bonfoh B, 2020. Producing soybeans well by applying good cultural practices in Togo. Technical sheet, ITRA, 8 pages.

Sage R. and Durant O, 1999. The technique of organic soybean cultivation. Technical sheet, TECHN'ITAB cereals, 4p.

Vidal A, Arnaudo D, Arnoux M, Blayac H, Claparede L, Meynie S, 1981. Drought resistance of soybean I. - Influence of a water deficit on growth and production. Agronomie, EDP Sciences, 1981, 1 (4), pp. 295-302.

Worou, SK, 2002. Dominant soils of Togo - correlation with the World Baseline. Fourteenth meeting of the West and Central African Sub-Committee on Soil Correlation for Land Development, Abomey-Benin, 09-13 October, FAO, 98: 105-120.

WWF, 2014. The growth of soy: Impacts and solutions. WWF International, Gland, Switzerland. Report, 82 pages.