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Original article

Water footprint estimation in soybean (*Glycine max* (L.) Merrill) cultivation

Estimación de la huella hídrica en el cultivo de la soya (*Glycine max* (L.) Merrill)

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ABSTRACT: The water footprint (WF) of a product or service is defined as the total amount of water used throughout the entire production process. Particularly in agricultural products, the largest amount of water is used for irrigation; therefore, quantifying it is crucial for raising public awareness about water use and protecting water resources. Soybeans are an important crop as a source of high-quality protein and oil. Furthermore, due to their biological nitrogen fixation capacity (BNF), they are a significant crop for reducing the application of nitrogen (N) fertilizers while maintaining high yields. To estimate the water footprint (WF) of the crop, an experiment was conducted in the Central Area of INCA (National Institute of Agricultural Science). Were planted 1.8 ha with the CIGB-CC6 cultivar at planting density of 240 000 plants per ha. The CropWat 8.0 program was used to calculate irrigation and effective rainfall requirements. The green, blue, and gray components of the WF were estimated under these irrigation and cultivation conditions. Among the main results, it was noted that the yield obtained, 1380 kg ha^{-1}, is considered relatively low, and there was a greater dependence on irrigation than on rainfall. The estimated water footprint for the soybean crop was 3.581 m^3 kg^{-1}.

Key words: Irrigation, yield, evapotranspiration, effective rain.

RESUMEN: La huella hídrica (HH) de un producto o servicio se define como, la cantidad de agua total empleada a través de todo el proceso productivo. Particularmente, en los productos del agro, la mayor cantidad de agua corresponde a la empleada mediante el riego, es por ello que su cuantificación tiene gran importancia como vía para lograr mayor conciencia social de su uso y protección de los recursos hídricos. La soya, es un cultivo importante como fuente de proteína y aceite de alta calidad. Además, por su capacidad biológica de fijación de nitrógeno (BFN), es un cultivo significativo para reducir la aplicación de fertilizantes de Nitrógeno (N) y mantener un alto rendimiento. Con el objetivo de estimar la HH del cultivo, se realizó un experimento en el Área Central del INCA y para ello se sembró un área de 1,8 ha con el cultivar CIGB-CC6 con una densidad de siembra de 240 000 plantas por ha. Para el cálculo de los requerimientos de riego y de lluvia efectiva se utilizó el programa CropWat 8.0. Se estimaron los componentes verde, azul y gris de la HH bajo estas condiciones de riego y cultivo. Entre los principales resultados se señala, que el rendimiento que se obtuvo, 1380 Kg ha^{-1} se considera relativamente bajo y existió una mayor dependencia del aporte por riego que por lluvia. La estimación de la huella hídrica para el cultivo de la soya fue de un total de 3,581 m^3 kg^{-1}.

Palabras claves: Riego, rendimiento, evapotranspiración, lluvia efectiva.

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INTRODUCTION

Currently, the planet is facing a severe environmental crisis, and within this, water occupies a special place. This resource is fundamental for the existence of life on Earth, and although it is often thought to be abundant, the reality is that only a small fraction of all water can be used for human consumption and use. Therefore, the idea that it is plentiful is considered completely mistaken (1).

Undoubtedly, water constitutes a valuable, highly demanded, and unfortunately scarce resource, which must be consciously protected. However, it is generally overexploited and used indiscriminately, turning its scarcity into a global problem (2, 3).

Agriculture is the human activity that consumes the most freshwater worldwide. It is expected that competition for water resources will continue to increase, as well as consumptive use in the agricultural sector to meet the growing food needs of the population (4).

With the aim of raising social awareness and analyzing the relationship between human consumption habits and their impact on natural resources (5), the concept of water footprint (WF) is defined as a method for evaluating the efficient use of water sources to develop better water management practices in agriculture, assessing the efficient use of this resource in agricultural production (6). This method has been applied to different crops worldwide; however, in our country, there are few results related to this topic.

Soybean, in turn, is a crop in high demand in Cuba due to its nutritional value, protein content, and high-quality oil (7). Moreover, due to its biological nitrogen fixation (BNF) capacity, it is a significant crop for reducing the application of nitrogen (N) fertilizers and maintaining high yields in crop rotation systems (8).

Despite the productive potential of soybean, it should be noted that water stress considerably reduces yield, restricts pod growth, and decreases the number and size of seeds (9). In addition, it shortens grain filling (10) and negatively affects seed quality (9). Furthermore, (11) report that it negatively influences both yield and the chemical components of leaves and seeds.

Therefore, establishing an inadequate irrigation strategy for soybean cultivation can considerably reduce yield and lead to poor use of water resources. It can also reduce grain quality by negatively affecting its chemical composition (12).

Based on the above, the objective of this study was to estimate the water footprint of soybean cultivation under field conditions at an agricultural experimental farm.

Therefore, establishing an inadequate irrigation strategy for soybean cultivation can significantly reduce yield and lead to poor use of water resources. In addition, it can reduce grain quality by negatively affecting their chemical composition (12).

MATERIALS AND METHODS

The experiment was conducted on a 110-hectare agricultural experimental farm, located at 22º58′00″N and 82°09′00″W at 130 meters above sea level, belonging to the Agricultural Services Department of the National Institute of Agricultural Sciences, situated within San José de las Lajas municipality, Mayabeque province.

To carry out the study, 1.8 ha of soybean were sown in January 2024 on a soil classified as Compacted Red Ferrallitic (13). The cultivar used was CIGB-CC6 with a planting density of 240 000 plants per hectare, and a basal fertilization of 350 kg ha^{-1} of the complete formula 12-12-17-5 was applied.

The climate in the area showed average decadal rainfall of 16 mm and a mean annual precipitation of 1.623 mm. The reference evapotranspiration (ETo) was about 1.875 mm per year. Table 1 shows the climatic data recorded during the trial period. The crop cycle lasted 85 days, and the accumulated reference evapotranspiration (ETo) over the crop period was 455 mm.

The estimation of the crop water footprint was carried out using the following procedure: For the calculation of the blue and green footprints, the CROPWAT 8.0 model (14) was employed. This software estimates crop water requirements using climatic, soil, and phenological information, and is based on the methodologies described in FAO Irrigation and Drainage Papers No. 24, 33, and 56.

Irrigation consisted of replenishing the standard crop evapotranspiration at six-day intervals. Reference evapotranspiration (ETo, mm), standard crop evapotranspiration (ETc, mm), and irrigation requirements (ETc = ETo × Kc) were obtained through the program, which was updated with a 33-year historical series of meteorological data (1990-2023) from the Tapaste Meteorological Station. This station belongs to the National Institute of Meteorology and is located approximately 1200 m from the experimental site. For the calculation of ETo and ETc, monthly average values were used.

The crop coefficients (Kc) applied were: initial Kc = 0.62, mid Kc = 1.00, and final Kc = 0.93, as proposed by FAO for the region. The irrigation system used was sprinkler irrigation, applied through a properly calibrated central pivot machine.

Table 1. Climatic data recorded in the experimental area during the trial period

Months	Minimun T	Maximun T	R. M.	Wind	Sunshine	RAD	ETo
	ºC	ºC	%	Km day^{-1}	hours	Mj m^{-2} day^{-1}	mm day^{-1}
January	16. 6	26. 5	74	379	11.0	19.3	4.00
February	16. 8	27.4	72	386	11.0	21.6	4.65
March	17. 9	28.9	67	386	12.0	25.6	5.75
April	19. 7	30.7	66	358	13.0	28.9	6.63
May	21. 7	31.4	71	304	13.0	29.5	6.55

Planting date: January 26, 2024. Final evaluation/harvest date: May 5, 2024

In CROPWAT 8.0, the Crop Water Requirements (CWR) option was selected, and four of the five modules that compose the model were defined, as follows:

1. Climate/ETo: requires input parameters such as relative humidity (%), minimum temperature (°C), maximum temperature (°C), wind speed (km day^{-1}), and sunshine hours (h). This module provides radiation data (MJ m^{-2} day^{-1}) and reference evapotranspiration (mm day^{-1}). Data can be entered daily, every 10 days, or monthly, and are completed with information provided by the meteorological station.
2. Precipitation: requires precipitation (mm) as input and provides effective precipitation (mm). Data can be entered daily, every 10 days, or monthly. As with the previous module, it is completed with information provided by the meteorological station.
3. Crop: requires parameters such as crop coefficient (Kc, dimensionless), crop stages (days), rooting depth (m), critical depletion fraction, yield response factor, and crop height. This module was complemented with FAO information for soybean.
4. Soil: requires input parameters such as total available soil moisture (mm m^{-1}), maximum precipitation infiltration rate (mm day^{-1}), maximum rooting depth (cm), initial soil moisture depletion (%), and initial available soil moisture (mm m^{-1}).
5. CWR (output module): provides ETc and effective precipitation (Pef).

The determination of the crop water footprint (WF) was carried out according to the methodology proposed by (5), through the sum of three components:

WF=WF green + WF blue + WF grey, it is commonly expressed in m^3 t^{-1} or L kg^{-1} (4).

In some studies, it also appears expressed in m^3 kg^{-1} (2).

The green component of the water footprint is calculated using the following expression:

$$WF_{green}\left(m^3\, t^{-1}\right) = \frac{Et_{green}\left(m^3\, ha^{-1}\right)}{production\left(t\, ha^{-1}\right)}$$

Where ET_{green} represents the contribution of rainfall to the crop evapotranspiration process throughout its growth cycle.

The blue component is calculated according to the following expression:

$$WF_{blue}\left(m^3\, t^{-1}\right) = \frac{Et_{blue}\left(m^3\, ha^{-1}\right)}{production\left(t\, ha^{-1}\right)}$$

Where ET_{blue} represents the contribution of irrigation water to crop evapotranspiration throughout the entire growth cycle.

The grey component of the crop water footprint is calculated according to the following expression:

$$HH_{gray}\left(m^3\, t^{-1}\right) = \frac{\frac{N_{excess}}{(C_{max} - C_{nat})}\left(m^3\, ha^{-1}\right)}{production\left(t\, ha^{-1}\right)}$$

Where N excess (kg ha^{-1}) represents the amount of nitrogen that escapes from the crop rhizosphere. A value of 0.10 was assumed, in accordance with different regulations and directives that converge on this figure for nitrogen (e.g., EU Nitrates Directive, 91/676/EEC; Resolução CONAMA No. 357, March 17, 2005). C max represents the maximum permissible nitrogen concentration in the receiving water body, with a value of 50 mg NO_3 L^{-1}, according to the Norma Obligatoria Salvadoreña de Aguas Residuales Descargadas a un Cuerpo Receptor (Mandatory Salvadoran regulation on wastewater poured into e receiving body), CONACYT NSO:13.49.01:09, 2009 (15).

C nat is the natural nitrogen concentration in the receiving water body prior to the contaminating activity, generally considered negligible in many studies (= 0).

RESULTS AND DISCUSSION

Once the indicators for yield determination were analyzed, the final result obtained for this variable was 1380 kg ha^{-1}, which can be considered relatively low when compared with the global average of 2742 kg ha^{-1} (16). However, in relation to the values reported by other countries (Table 2) (17), the results are close to those obtained in China, higher than those of India, and considerably lower than those of the United States and Brazil.

Table 2. Comparative soybean yield data with statistics from other countries

Country	Yield in t ha^{-1}
Cuba (INCA)	1.38
China	2.0
United States	3.4
India	0.9
Brazil	3.4

On the other hand, some authors reported yields ranging from 2600 to 4038 kg ha^{-1} when working with different cultivars (18). In turn, (19) obtained yields of 1850 kg ha^{-1} with the cultivar INCA Soy 24 in Brazil and indicated that in Cuba yields range between 1500 and 2000 kg ha^{-1}. Furthermore, other Cuban researchers have reported new soybean cultivars such as INCA Soy-2, with potential yields of 3.7 t ha^{-1} (20), the cultivar CUVI-02 with productive potentials between 2.9 and 3.7 t ha^{-1} (7), and (21), working with four cultivars (DT-20, DT-26, DVN-5, and DVN-6), reported yields between 2.7 and 3.5 t ha^{-1} in May sowings, results that may have been influenced by the planting season.

The success of soybean production in tropical regions is largely due to the development of highly productive varieties adapted to specific conditions (22), among them high temperatures (23). Other factors to be considered include planting density (19), fertilization, and irrigation (4).

Additional indicators evaluated, such as monthly and cumulative values of green ET and blue ET during the 85 days of the crop cycle, are presented in Tables 3 and 4. These are considered of great importance, as they directly influence the yield of the crop under study.

Table 3. Monthly values of green ET and blue ET

MONTH	ET green (mm)	ET blue (mm)
January-February (33 days)	56.5	117.6
March (31 days)	50.2	98.0
April (21 days)	85.1	78.4

In this case, the results show that during the first 60 days the contribution of irrigation to crop evapotranspiration was greater than that provided by rainfall, whereas towards the end of the cycle rainfall became the dominant source. Overall, green ET accounted for 65 % of blue ET (1022 m^3 ha^{-1}), indicating a greater dependence on irrigation than on rainfall.

Similarly, the cumulative values exhibited a response comparable to those obtained on a monthly basis (Table 4). Rainfall occurrence during the experimental period was lower than the irrigation applied; therefore, the study demonstrates that the performance of this crop up to its yield was influenced primarily by irrigation, although yields are considered low compared to the national average.

Table 4. Cumulative values of green ET and blue ET during the 85 days of the crop cycle

Crop	ET green	ET blue
Soybean	1918 m^3 ha^{-1} (Effective rainfall)	2940 m^3 ha^{-1} (15 irrigation of 19.6 mm)

The water footprint in agriculture identifies the environmental impact of crop production. Hence, the importance of this environmental indicator lies in assessing the freshwater consumption by crops. In this study, the monthly values of the green, blue, and grey water footprints of soybean are presented in Table 5.

Table 5. Monthly green, blue, grey, and total water footprints of soybean cultivation

Month	WF Green (m3 Kg^{-1})	WF blue (m3 Kg^{-1})	WF grays (m3 Kg^{-1})	WF total (m3 Kg^{-1})
January-February 33 days	0.40	0.85	0.06	1.3
March 31 days	0.34	0.70	0.06	1.1
April 21 days	0.60	0.54	0.06	1.2

The highest values of blue and total water footprints corresponded to the first 33 days after sowing, whereas the highest value of the green water footprint occurred at the end of the crop cycle (last 21 days). These results indicate that irrigation contributed more to crop evapotranspiration than rainfall during the period, although rainfall was more frequent in the final growth stage. Therefore, a possible solution to reduce water use in soybean production could be through increasing irrigation efficiency, so that losses do not exceed the crop's water requirements. Moreover, it is not necessary to use water for pollutant dilution (grey water footprint), since this component remained at low values throughout the irrigation applied during the crop cycle.

The cumulative values of green, blue, grey, and total water footprints throughout the entire crop cycle are presented in Table 6, showing that the highest cumulative value corresponded to the blue water footprint, determined by the irrigation contribution. This result is consistent with the monthly values obtained.

Table 6. Cumulative green, blue, grey, and total water footprints of soybean cultivation

Soybean cultivation Yield	WF green	WF blue	WF gray	total WF
1380 Kg ha^{-1}	1.39 m^3 Kg^{-1}	2.13 m^3 Kg^{-1}	0.061 m^3 Kg^{-1}	3.581 m^3 Kg^{-1}

The calculation of the grey water footprint was as follows:

WF gray= 42 Kg ha^{-1} * 0.10= 4.2 Kg ha^{-1}/ 50 mg L^{-1}= 4.2/0.00005=84.000 L ha^{-1} 84.000 L ha^{-1} / 1.380 Kg ha^{-1}= 61 L Kg^{-1}= 0.061 m^3 Kg^{-1}.

To assess the behavior of the soybean water footprint obtained in this study, the results were compared with international data (Table 7).

Table 7. Comparison with other international soybean results

WF Green m^3 Kg^{-1}	WF blue m^3 Kg^{-1}	WF gray m^3 Kg^{-1}	Total WF m^3 Kg^{-1}	References
1.39	2.13	0.061	3.581	Cuba (INCA)
1.547	0.282	0.162	1.993	**(24) in Brazil**
0.783	2.525		3.309	**(25) in Mexico**
			2.471	**(26) in Thailand**

The study confirmed that the total water footprint values are similar to those reported in Mexico and higher than those obtained in Brazil and Thailand. Table 8 presents a comparison with water footprint results of other economically important international crops. In this case, the soybean water footprint was much higher than that of maize (*Zea mays*), which shows a very small value, and also higher than that of cotton (*Gossypium herbaceum*), both results reported in Brazil (24).

On the other hand, soybean showed higher values than peanut (*Arachis hypogaea*) and mungbean (*Vigna radiata*), and lower values than sunflower (*Helianthus annuus*) and sesame (*Sesamum indicum*). The latter presented a ruinous total water footprint in Thailand (26).

Table 8. Comparison of total water footprint with other economically important international crops

Crops	WF. Total m³ Kg⁻¹	References
Cotton	**1.847**	**(24) Brazil**
Maize	**0.654**	
Peanut	**1.789**	**(26) Thailand**
Mungbean	**2.525**	
Sunflower	**3.936**	
Sesame	**5.718*** **	

CONCLUSIONS

- The estimation of the water footprint for soybean cultivation was a total of 3581 m^3 kg^{-1}, distributed as 1.39 m^3 kg^{-1} from rainfall, 2.13 m^3 kg^{-1} from irrigation, and 0.049 m^3 kg^{-1} to dilute the fraction of fertilizer not absorbed by the plant.
- The blue water footprint accounted for 59.4 %, indicating that the major contribution to the crop's water requirements was due to irrigation, which in this case came from groundwater sources.
- The estimated soybean water footprint is very close to the value reported by authors in Mexico (3.309 m^3 kg^{-1}) and higher than the values published in Brazil (1.993 m^3 kg^{-1}) and Thailand (2.471 m^3 kg^{-1}).
- When comparing the soybean water footprint with other internationally important crops, it was found to be higher than that of maize, peanut, cotton, and mungbean, and lower than that of sunflower and sesame.

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BIBLIOGRAPHY

1. Esquivel A, Salgado MC. Huella hídrica de producción, consumo y per cápita de México, Estados Unidos y Canadá. In: Sarmiento JF [Coord.] Nuevas territorialidades-gestión de los territorios y recursos naturales con sustentabilidad ambiental. UNAM-AMECIDER, México, 2023. pp. 585-600. ISBN 978-607-30-8314-0 (UNAM), 978-607-8632-40-4 (AMECIDER). Available from: https://ru.iiec.unam.mx:80/id/eprint/6071
2. Wang L, Yan C, Zhang W, Zhang Y. Water footprint assessment of agricultural crop productions in the dry farming region, Shanxi province, Northern China. Agronomy. 2024, 14, 546. Available from: https://doi.org/10.3390/agronomy14030546.
3. Sunitha S, Akash A U, Sheela M N, Suresh Kumar J. The water footprint of root and tuber crops. Environment, Development and Sustainability. 2024, 26(2), p: 3021-3043, February. Available from: https://doi.org/10.1007/s10668-023-02955-1
4. Egea G, Castro-Valdecantos P, Gómez-Durán E, Munuera T, Domínguez-Niño J M, Nortes P A. Impact of irrigation management decisions on the water footprint of processing tomatoes in southern Spain. Agronomy. 2024, 14, 1863. Available from: https://doi.org/10.3390/agronomy1408186310. 4.
5. Hoekstra A Y, Chapagain A K, Aldaya M M, Mekonnen M M. The water footprint assessment manual: setting the global standard. London/ Washington, DC: Earthscan, 2011.vailableat: Available from: https://waterfootprint.org/media/downloads/TheWaterFootprintAssessmentManual_2.pdf. Accessed on: Mar 20, 2018.
6. Oweis, T, Hachum, A. Water harvesting and supplemental irrigation for improved water productivity of dry farming systems in West Asia and North Africa. Agric. Water Manag. 2006, 80(1-3), 57-73. Available from: https://doi.org/10.1016/j.agwat.2005.07.004
7. González M C, Guillama R. CUVIN-22. Cultivar de soya (*Glycine max* Merril) de grano negro. Cultivos Tropicales. 2021, 42, (4), supl. 1, e02 octubre-diciembre. Available from: http://ediciones.inca.edu.cu.
8. Setubal I S, Andrade Júnior A S, Silva S P, Rodrigues A C, Bonifácio A, Silva E H, Vieira P F, Miranda R S, Cafaro La Menza N, Souza H A. Macro and micro-nutrient accumulation and partitioning in soybean affected by water and nitrogen supply plants. 2023, 12, 1898. Available from: https://doi.org/10.3390/plants12091898.
9. Wijewardana C, Reddy K R, Alsajri F A, Irby J T, Krutz J, and B Golden. Quantifying soil moisture deficit effects on soybean yield and yield component distribution patterns. Irrigation Science. 2018, 36(4-5):241-255. Available from: DOI: http://doi.org/10.1007/50027-018-0580-1
10. Brevedan R. and Egli D B. Short periods of water stress during seed filling, leaf senescence, and yield of soybean. Crop Sci. 2003, 43:2083-2088. Available from: DOI: http://doi.org/0.2135/cropsci2003.2083
11. Saad A M, Saad M, Maaty A E, El-Hadary A. Biochemical studies on some soybean cultivars under water stress conditions. Journal of Plant Production, Mansoura Univ. 2023, 14 (3):107-115. Journal homepage. Available from: www.jpp.journals.ekb.eg
12. Du Y, Zhao Q, Chen L, Yao X, Zhang W, Zhang B and Xie F. Effect of drought stress on sugar metabolism in leaves and roots of soybean seedlings. Plant Physiology and Biochemistry. 2020, 146: 1-12. Available from: DOI: http://doi.org/10.1016/j.plaphy.2019.11.003
13 Clasificación de los suelos de Cuba 2015, edit. Ediciones-INCA, Mayabeque, Cuba, 2015, p. 93, ISBN 978-959-7023-77-7.
14. Food and Agriculture Organization for the United Nations (FAO). CROPWAT 8.0 Model, FAO, Rome. Available from: http://www.fao.org/land-water/databases-and-software/cropwat/es/ (accessed on 1 September 2020).
15. Norma Obligatoria Salvadoreña de Aguas Residuales. Descargadas a un Cuerpo Receptor, CONACYT NSO:13.49.01:09, 2009. Available from: https://osartec.gob.sv

16. FAO & UN Water. Progress on level of water stress. Global status and acceleration needs for SDG Indicator 6.4.2, 2021. FAO, Rome. Available from: https://doi.org/10.4060/cb6241en.
17. Qiao M, Hong C, Jiao Y, Hou S, Gao H. Impacts of Drought on Photosynthesis in Major Food Crops and the Related Mechanisms of Plant Responses to Drought. Plants.2024, 13, 1808. Available from: https://doi.org/10.3390/plants13131808.
18. Winck J E, Sarmento L F, Foloni J S, Henning L M, Nepomuceno A L, Melo C L, Farías, J R, Neumaier N, Barbosa A, Catuchi T A, Zanon A J, Streck N A. Growth and transpiration of soybean genotypes with AtAREB1 transcription factor for tolerance to water deicit. Plant Growth Regulation. 2023. Available from: https://doi.org/10.1007/s10725-023-01101-1.
19. Yanes L A, Calero A, Valdivia W B. y Bianco L. Influencia de altas densidades de plantas en la productividad de la soya. Universidad & Ciencia, 2023, 12 (3), pp. 155-166. Available from: https://doi.org/10.5281/zenodo.11528387.
20. Mederos A. y Ortiz R. INCASoy-2, nuevo cultivar de soya (*Glycine max* L.). Cultivos Tropicales. 2021, 42, (4) pp. e08. Available from: http://ediciones.inca.edu.cu.
21. González M C, Guillama R. CUVIN-22. Cultivar de soya (*Glycine max* Merril) de grano negro. Cultivos Tropicales. 2021, 42, (4), supl. 1, e02 octubre-diciembre. Available from: http://ediciones.inca.edu.cu.
22. Roján O, Maqueira L A, Santana I, Miranda, C. A. y Núñez M. Productividad de cultivares de soya en dos épocas de siembra. Cultivos Tropicales, 2022, 43, (1), e05 enero-marzo. Available from: http://ediciones.inca.edu.cu.
23. Marrero O, Hechavarría Y, SANTOS E. Respuesta morfoagronómica en variedades de Soya en suelo Fluvisol del municipio de Cauto Cristo (Original). Redel. Revista Granmense de Desarrollo 22 Local. Cuba. 2021, 5, (2), pp. 348-358. Available from: http://revistas.unica.cu/uniciencia.
24. Staniak M, Szpunar-Krok E, Kocira A. Responses of soybean to selected abiotic stresses—photoperiod, Temperature and Water. Agriculture, 2023, 13, 146. Available from: https://doi.org/10.3390/griculture13010146.
25. Rodríguez M, Castro M, David D, Martins K, Dias C. Water Footprint of soybean, cotton, and corn crops in the western region of Bahia State. Eng Sanit Ambient.2021, 26 (5) | set/out 2021 | 971-978. Available from: https://doi.org/10.1590/s1413-41522020041.
26. López C, Exebio A A, Flores J, Juárez A. Índice de estrés hídrico (IEH) e índice de servicio del riego (ISR) en función de la huella hídrica de los cultivos en los módulos de riego en México. Ciencia Latina Revista Científica Multidisciplinar. Marzo-Abril, 2023, 7, (2): Pp.11303-113331. Available from: https://doi.org/10.37811/cl_rcm.v7i2.6214.
27. Kumban A, Usubharatana P, Phungrassami H. Water footprint of local plant-based protein in Thailand. Journal of Applied Science and Engineering, 2022, 26, (12), Pp. 1677-1688. Available from: http://dx.doi.org/10.6180/jase.202312_26(12).0001.