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EFFICIENCY OF THE USE OF IRRIGATION WATER WITH SOIL MOISTURE SENSORS IN THE PRODUCTION OF THE BANANA (*Musa AAA*)

[1]Fanny Rodríguez Jarama – [2]Javier Del Cioppo - [3]Juan José Prado – [4] Kleber Medina

[1, 2,4] Universidad Agraria del Ecuador

ABSTRACT

The banana production system represents one of the main agricultural items in Ecuador and especially in the province of El Oro. Water is a limited resource that every day decreases its availability due to the inefficient use of irrigation systems, reducing the productivity of this crop. . The objectives of this research were to determine the water needs of the area, establishing irrigation schedules to measure banana production. Sensors were used to determine soil humidity through moisture retention curves at 25% of irrigation threshold and the evaporimeter tank case A to calculate total evapotranspiration. The volume of used water for the crop estimated in 12 weeks from the emission of the acorn to the harvest was quantified, consuming 1375.29 m3 / ha with the moisture retention curve and 2255.9 m3 / ha with evaporimeter tank case A As a response to the used technologies, it was determined that the treatment with soil humidity sensors is 35% more efficient (0.46 Kg / m3) than the evaporimeter tank case A (0.34 Kg / m3), However, there was a reduction in the ratio of treatment 1, which was 0.96 compared to the average ratio for the area, similar to that of treatment 2, which was 1.19.

Keywords : Programming, irrigation, sensors, sheet, water, irrometer.

RESUMEN

El sistema productivo de banano representa uno de los principales rubros agrícolas en el Ecuador y especialmente la provincia de El Oro. El agua es un recurso limitado que cada día disminuye su disponibilidad por el uso ineficiente de los sistemas de irrigación mermando la productividad de este cultivo. Los objetivos de la investigación fueron determinar las necesidades hídricas de la zona, estableciendo programaciones de riego para medir la producción del banano. Se utilizo sensores para determinar la humedad del suelo mediante curvas de retención de humedad al 25% de umbral de riego y el tanque evaporímetro caso A para calcular la evapotranspiración total. Se cuantificó el volumen de agua utilizado para el cultivo estimado en 12 semanas desde la emisión de la bellota hasta la cosecha, consumiendo 1375,29 m3/ha con la curva de retención de humedad y 2255,9 m3/ha con tanque evaporímetro caso A. Como respuesta a las tecnologías utilizadas se determinó que el tratamiento con sensores de humedad del suelo es 35% más eficiente (0,46 Kg/m3) que el tanque evaporímetro caso A (0,34 Kg/m3), sin embargo existió una reducción en el ratio del tratamiento 1 que fue de 0,96 en comparación al ratio medio de la zona, parecido al del tratamiento 2 que fue de 1,19.

Palabras claves

Programación, riego, sensores, lámina, agua**,** irrometer

1. Introduction

In the world rivers, lakes, etc. contribute to agriculture with 70% of fresh water, the demand for food in the coming years until 2050 would gradually rise to reach 70%, which would cause the demand for water is also expected to be affected. (La Organización de las Naciones Unidas para la Alimentación y la Agricultura [FAO], 2017).

The reason for life is water, a resource of great importance for the development of planet earth, which is increasingly limited, every day consumption must be more efficient and adequate of it. (Fernández, 2018). However, it is important to conserve the set between the soil and the water directly influence the crop, both its yield and quality are affected if one of these factors are not available for it. (Medina et al., 2016).

Ecuador has an approximate area of 3 136 000 ha. and 93.3 % of the area belongs to the western side whose slopes flow into the Pacific Ocean and the remaining area on the eastern side falls into the source of the Amazon River. The western area is the most important extension in the agricultural field of which the Guayas river basin contributes to irrigation with 40.4% of irrigable area, then 12.6% of irrigable area is contributed by its counterpart the Esmeraldas river which has a significance of 30% of arable land in Ecuador. (León, 2014).

In the city of Machala many banana plantations are developed that are of great socio-economic importance, this is considered a symbol crop of the area, an activity that takes place every month of the year.

Banana production is one of the agro-industries that require a frequent water supply and when limited can generate an impact on its development cycle and the technique and use of irrigation systems are influenced by the availability of water resources in each sector (FA0, 2017).

Despite its importance in the area for small, medium, and large producers, it does not have an adequate management and dosage of water use within the plantations, so it is essential to determine studies based on irrigation sheets and adequate doses of irrigation water to decree the efficiency of water use within the plantation related to the type of soil and climate of the canton.

The use of moisture sensors for irrigation scheduling, seeks as a result to obtain information on the water content in the soil and thus establish the irrigation schedules. (Ferrándiz, 2017).

The new irrigation methodologies based on the use of sensors in the research of banana cultivation, has allowed the use of a lower volume of water resources, with percentages lower than 26% of that foreseen by the methodologies used by farmers in the area. (Ritter, Machín y Regalado, 2009).

It should be noted that the usable water is the parameter of available water that is between the wilting coefficient and the field capacity, this can be easily absorbed by the roots, while the deficit allowed in irrigation management (DPM) is the percentage of water that cannot lower the permanent wilting point to avoid stress on the crop, the difference between the field capacity and deficit allowed in irrigation management for each crop is the irrigation lamina to apply, the deficit can be between 25% to 50%. (Enciso, Porter, y Périès, 2015).

Irrigation scheduling has the purpose of determining how much water to irrigate within the crops, in crops of major importance in the country, their irrigation systems have been programmed with old methods and have not been provided with technical criteria to apply a calculated irrigation lamian within the same. (Lucín, 2018).
Irrigation scheduling within a crop will be related to the Etc, which can be calculated by different techniques, either manually or by software. (Mesa, 2019).
Irrigation scheduling is directly related to each kilogram produced by the crop, water is a fundamental part of growth to achieve optimal yields. (León, Arzube, Orrala, y Drouet, 2019).

Amaya, (2015) mentions the volume of water used through the use of subfoliar irrigation in banana crops in the province of El Oro, under theoretical irrigation sheets calculated plus the use of fertigation explains that the crop was influenced by the irrigation treatments.

The advantages of using sprinkler irrigation are the water economy, the adaptation to almost any terrain providing a good daily control of the wet bulb in the soil, being a fixed system requires little maintenance and offers a high irrigation efficiency up to 90% with a low flow rate. (Salazar, 2019). The most frequent disadvantages are that their networks are often damaged by crops, requiring that the emitters are always vertical for efficient operation. (Solórzano, 2012).

The study conducted by Gabino, (2019), in the city of Machala, province of El Oro in the banana crop, evaluated the banana bunches under sprinkler irrigation, using an irrigation lamina calculated with the Penman-Moteith method with the use of biodegradable protectors and laurel infusion in the care of the bunch, analyzing the post-harvest bunch quality variables.

By using a sprinkler irrigation method with different weed control treatments on banana crops in the province of El Oro, different weights of bunches for export were recorded (Lara, 2015). Working with the banana crop under sprinkler irrigation and the application of potassium fertilization with the objective of determining an adequate dose to optimize the balance, they found that the highest yield per plant was obtained in the treatment that received the daily irrigation plus K2O, providing 6% more income in the banana box (Villaseñor et al., 2020).

Previous studies have been conducted such as, (Cardenas-Lailhacar & Dukes, 2010) indicates that even when site specific calibration can be performed to achieve maximum yield potential, most soil moisture sensors tested can be a useful tool to reduce over-irrigation, under Florida conditions, even when using factory calibrations. It was further demonstrated how soil observations measured with the Watermark sensors reasonably matched what was numerically calculated in the soil; only when the observed soil increased above -20 kPa did the observed soil not match the calculated soil, possibly due to limitations of the moisture sensor to measure soil in the wet range above -20 kPa. (Janssens et al., 2015), also (Vories & Sudduth, 2021) which intended to provide guidance on how best to use soil moisture sensor data for irrigation management, however (Salman et al., 2021) asserts that Watermark sensors should only be used when a high level of accuracy is not required, such as in farm irrigation management and, in this case, site-specific calibration is also required.

The hypothesis of this research is to defend that by using irrigation water efficiently, the amount of water needed to produce 1 kg of banana will be known. Therefore, the objectives were (a) To evaluate the efficiency of irrigation water use in the production of the banana crop (Musa cavendish AAA.). (b) Establish the irrigation scheduling by using the soil moisture curve in the banana crop in the parish of El Cambio, province of El Oro. (c) Establish the Benefit-Cost between treatments.

2 Materials and Methods

2.1. Experimental research: This study was carried out in the city of Machala, in the parish of El Cambio, precisely in the Finca Valle Verde, with the following UTM coordinates; X 616222.17, Y: 9632692. 16, in an experimental plot of 14000m2, the data of the variables of water volume (m3/Ha), fruit size (mm), bunch weight (Kg), fruit length (inches), ratio, benefit-cost ratio of the two irrigation methods were analysed. The work was experimental, where there were two treatments, one was the use of soil moisture sensors and the other was the evapotranspiration of the ETC crop through the evaporation vat and the Kc of the banana crop. For the comparison of means, the nonparametric Mann-Whitney U test for independent samples was used with a 5% probability.

Ho: Treatment 1 will not have differences with treatment 2 on the efficiency of water use in banana crop production.

Ha: Treatment 1 will have a difference with treatment 2 on the efficiency of water use in banana crop production.

2.2. To evaluate the efficiency of irrigation water, use in banana (Musa cavendish AAA.) crop production.

2.2.1. Water availability in soil. Treatment 1. For the estimation of the available moisture in the irrigated soil, watermark moisture sensors were used, which respond to the variation of the electrical resistance [ohm], which increases or decreases according to the amount of water in the soil, giving measurements in the range of 0 to 200 kilo pascals (kPa), The sensor's built-in voltage transduction module sends its voltage reading (0-5V) to the controller, with its porous polymer structure and granular matrix, where high reading accuracy is obtained in fine and medium soils (Irrometer, 1978).

For the installation of the sensors, it is necessary to: 1.-Soak the sensors in irrigation water overnight. Always place the sensors well moistened. Using a D. 7/8" iron pipe, make a hole in the soil to the desired depth. In very dense soils or of very thick texture, to practice a hole something bigger (25-30 mm) and then to fill the hollow with a mud slurry. To ensure the correct functioning of the sensor, it is essential that it fits snugly in the hole. The ideal way to create the hole is by using the installation tool. This makes a hole of larger diameter than the sensor except at the lower end where it creates a hole exactly with the diameter of the sensor. Fill the hole with water and insert the sensor until it reaches the bottom. To perform this operation, it can be pushed with a piece of PVC pipe of 20 mm. 4.-Fill the hole with a mud slurry to eliminate any air pocket. 5.-If desired, the PVC pipe can be left in the hole and glued to the sensor. The sensor wires are passed through the tube and attached to the top.

To read these sensors, they were connected to a watermark meter, which is a portable device designed to be used in the field. The digital readout shows the status of the soil moisture sensors, in centibars (cb) or kilopascals (kPa) of water tension although the electrical resistance is measured in ohms, this value represents the energy that the root system of a plant uses to draw water from the soil (Irrometer, 1978).

Once the sensor readings were taken in the field, they were interpreted using the moisture retention curve obtained by sampling undisturbed soil at a depth of 30 centimetre's, 1500 grams for each soil profile, and once obtained and identified, they were transferred to the INIAP laboratories to determine the moisture retention curve using the Richards Pot method. The moisture retention curve relates the water contained in the soil with the pressure it exerts on the soil, the information from it allows quantifying water levels and usable suction in plants (Arias, 2019), known as usable water moisture ranging from field capacity to permanent wilting point. The moisture retention curve delivered gravimetric moisture values are 33.91% for field capacity at 0.33 bar tension and 21.57% at 15 bar tension for permanent wilting point. For this research, an irrigation threshold of 25% of this usable moisture was considered, where the tension that should mark the sensors was 70 cbar for this type of soil, also known as the permissible exhaustion, once reached, irrigation was done until reaching field capacity again at a depth of 30 cm, with an irrigation lamina of 11.6 mm.

2.2.2. Evapotranspiration Evaporimeter tank class A Treatment 2.

The water needs of crops is composed of a set of processes related between the soil and the plants, giving us as a result the crop evapotranspiration (ETc) (Mendoza and Bermudez, 2015), one way to determine them is with the use of evaporimeter tank class A for irrigation scheduling which is a circular structure, which is mounted on a wooden pallet 15cm above the ground that has the following characteristics: Circular shape, diameter of 120.7cm, depth of 25cm and material galvanized iron or sheet metal (0.8 mm) (FAO, 2006) The tank is always level. Once installed, the tank is filled with water up to 5 cm below the rim and the water level should not drop to more than 7.5 cm below the rim. The water was regularly changed, weekly, to eliminate turbidity and was insulated to prevent access to animals.

The method is based on the following expressions:

$$ETc = ETo*Kc$$

Where:

ETc = Crop evapotranspiration, mm/day.

ETo = Reference evapotranspiration of a typical crop. It depends only on the climatic variables of the area, mm/day.

Kc = Crop coefficient. It depends on the crop and its stage of development.

ETo according to the tank is calculated with the following relation:

$$ETo = ET*Kp$$

Where:

ETo = Evapotranspiration of the reference crop, mm/day.

ET = Evaporation measured in the evaporimeter tank, mm/day.

Kp = Tank coefficient which depends on the minimum relative humidity, the 24-hour average wind speed and the type of cover around the tank. The tank coefficient, Kp, for the class A tank.

The ETc values were taken and calculated daily during the growth process of the banana bunch, estimating a kc set at 1.1 for all stages of the crop, whose daily irrigation demand was recorded in a data sheet obtaining a time and volume of irrigation used in the crop cycle.

2.3. Study variables.

Water volume (m3/ha): All irrigation sheets applied in mm were summed and converted into cubic meters per hectare by multiplying by 10.

Fruit caliber in millimetre's (mm): The diameter of the finger of the center of the last hand of the banana bunch was taken using a caliper or caliper foot, giving the measurement in millimeters (mm).

Weight of the bunch (Kg): The weight of the whole bunch was measured using a scale and established in kilograms (Kg).

Length of the fruit (inches): The length of the finger of the center of the last hand on the banana bunch was measured with a tape measure in inches.

Ratio = (Number of boxes)/(Number of bunches).

Benefit-cost ratio: The economic analysis will be carried out based on the yield and production costs of the treatments under study in order to obtain the Cost-Benefit ratio (C/B).

3. Results and Discussion

3.1. Water volume (m3/ha):

The variable water volume m3/ha was taken by using a data sheet daily data of irrigation sheets were recorded, obtaining weekly water volumes, adding the total volume in cubic meters per hectare for treatment 1 moisture sensors in 12 weeks was estimated at 1375.29 m3/ha, while for treatment 2 by the evaporimeter tank method case A the volume of irrigation water recorded was 2296.10m3/ha. Table 1.

Table 1. Water volume m3/Ha

Water volume m3/Ha		
Weeks	Treatment 1	Treatment 2
1	136,47	207,06
2	143,53	208,09
3	140,00	204,99
4	136,47	197,74
5	136,47	182,21
6	136,47	183,25
7	136,47	178,07
8	0,00	196,71
9	136,47	183,25
10	132,94	254,49
11	140,00	214,31
12	0	85,93
TOTAL	1375,29	2296,10

Relationship between treatment 1 and treatment 2

Rodríguez y Prado, 2020

3.2. Fruit size in millimeters (mm):

T1 with its mean of 38.42 mm is lower than the mean of T2 with 39.19 mm, obtaining a probability of <0.0001 less than 0.05 where it was observed that if there is a significant difference in the two treatments between their means, in addition these fruit diameter are suitable for export when compared with the study conducted by Gabino, (2019) in the city of Machala, province of El Oro in the cultivation of banana bunches were evaluated under sprinkler irrigation, using irrigation sheets calculated with the

Penman-Moteith method, analyzing the variable of fruit diameter of the last hand of the bunch, establishing harvest values between 38mm to 40. 33 mm.

3.3. Bunch weight (Kg):

In reference to bunch weight, the means of the bunch weights where T1 weight was 19.58 kg, which is lower than the mean of T2 with 23.84 kg, there is a significant difference in the two treatments in the use of water, in addition to being within the weights of bunches for export, This is in agreement with Lara, (2015), who demonstrates in an investigation on banana using an irrigation treatment with different weed controls in the province of El Oro, that recorded bunch weights from 17.78 kg to 21.83 kg for export.

3.4. Fruit length (inches):

For the length of the fingers of the fruit, where T1 has a mean of 8.12 inches and T2 8.75 inches having a difference in the two treatments of 0.63 inches registering within the ranges of fruit length for export in the banana zone of El Oro, noting a similarity with the research conducted by Pizarro, (2019) in the banana crop in the city of Machala applying subfoliar irrigation plus the use of rooter in banana established the length of fruit of the last hand 7.8 inches.

3.5. Ratio

The relationship between the number of boxes versus the number of bunches harvested obtained an average of 0.96 in T1 and 1.17 in T2, meaning that the bunch harvested in T1 was not enough to complete the weight of a box of bananas, while the bunch in T2 did complete a box of bananas and provided a surplus for another box, being the boxes of bananas that were processed in this research are 17.69 kilograms of export fruit.

3.6. Benefit-cost ratio

It can be seen that the costs that were used in the production of a box of banana in T1 is $ 4.15 dollars and in T2 is $ 4.20 dollars being the difference of 0.05 ctvs. of dollar per box of banana production table 2. Agreeing with the research conducted in the area of the province of El Oro in the banana crop by Guevara, (2015), who concluded that analyzing the production costs in a banana box, in the analyzed variable of benefit-cost ratio, that the income per banana box is between 0.01 to 1.50 dollars of profit, where in the present research in its variable benefit-cost ratio of the banana box is within the values established in the area of El Oro .

Table 2. Benefit/cost ratio

Total cost of production of banana box				
Cost		Description	T1	T2
Variable costs	Variable cost per cluster	Black Sigatoka	0,38	0,38
		Sheathing	0,38	0,38
		Leaf removal	0,23	0,23
		De-leafing	0,06	0,06
		Planting point	0,12	0,12
		Pests	0,02	0,02
		Nematicide	0,13	0,13
		Fertilization	0,48	0,48
		Weed control	0,11	0,11
		Other work	0,06	0,06
		Irrigation diesel	0,11	0,21
		Day's irrigation	0,23	0,34
	Variable cost per box	Harvesting	0,74	0,74
		Transportation	0,23	0,23
Fixed cost		Administrative	0,80	0,66
		Packer maintenance	0,05	0,04
Total production cost of a banana box			4,15	4,20
	Banana box price		6,04	6,04
	Benefit/cost		1,5	1,4

Total cost of banana box production, benefit/cost relationship

Rodriguez y Prado, 2020

3.7. Efficiency in water use

The relationship between banana production per treatment and the water consumed by the treatments shows that T1 has the highest efficiency with 0.46 kg/m3 and T2 has a lower efficiency of 0.34 kg/m3, which indicates that with the same cubic meter of water used, 0.46 kg and 0.34 kg of bananas are obtained, respectively.

4. Conclusions

The amount of water used in this research using the methodology of using humidity sensors is 1375.3 m3 to obtain the production of the banana bunch, while with the irrigation programming based on climatological data, 2296.1 m3 were needed to produce the same banana bunch.

In the morphological characteristics of the crop, it could be observed that with the moisture sensor method, similar responses were obtained in the growth of the bunch, compared to the evaporation vat method, where the two methods complied with adequate characteristics in the fruit obtained for export.

The problem exposed in the present research is the lack of knowledge of the efficient use of water resources for the production of banana crops, being the methodology proposed as the use of humidity sensors together with the humidity curve, to carry out the irrigation programming the most efficient, since 2.17m3 of water need to be applied to produce 1 kilogram of fruit, while with an irrigation programming based on climatic data 2.94m3 are needed to produce the same kilogram of fruit for export. However, the ratio was affected because when irrigating only when 25% of the usable moisture was consumed, the irrigation frequencies were around 4 to 5 days, different from the irrigation that was given due to the water consumption of the evaporation vat, where irrigation was given daily, so it is recommended to find the appropriate irrigation threshold so that the ratio does not decrease.

Due to what happened with the ratio there is a lower production in the first treatment, however, this treatment presents a better use of the water resource that is reflected in the lower use of external energy to move the irrigation water generating a significant saving, therefore, the benefit-cost ratio in this research was higher in the methodology of using moisture sensors, obtaining a benefit of 1.50 per box of banana produced, while with an irrigation schedule based on climatic data was lower obtaining a benefit of 1.40 dollars for the same box of banana processed.

References

1. Amaya, A.,(2015). Fertigación del cultivar banano musa sapientum en un sistema de riego por aspersión subfoliar en Arenillas El Oro. Universidad Técnica de Machala.Recuperado de http://repositorio.utmachala.edu.ec/handle/48000/175
2. Amaya, M., (2019). Uso eficiente del agua de riego mediante sondas de capacitancia fdr, en el cultivo de banano. Universidad Técnica de Machala. Recuperado de http://repositorio.utmachala.edu.ec/handle/48000/15166
3. Arias, C., (2019). Distribución espacial de las propiedades físicas y de la curva de retención de humedad en suelos con cultivo de banano. Universidad Técnica de Machala. Recuperado de http://repositorio.utmachala.edu.ec/handle/48000/175
4. Ballestero, M., Arroyo, V., y Abel, M., (2015). Inseguridad económica del agua en Latinoamérica: de la abundancia a la inseguridad. Recuperado de http://scioteca.caf.com/handle/123456789/787
5. Cardenas-Lailhacar, B., & Dukes, M. D. (2010). Precision of soil moisture sensor irrigation controllers under field conditions. *Agricultural Water Management*, *97*(5), 666–672. https://doi.org/10.1016/j.agwat.2009.12.009
6. Enciso, J., Porter, D., y Périès, X., (2015). Uso de sensores de humedad del suelo para eficientizar el riego. Recuperado de http://www.euskobaratza.eus/src/upload s/2016/02/Enciso-et-al-2008.-Uso-de-sensores-de-humedad-para-optimizar-el-riego.pdf
7. FAO., (2006). Evapotranspiración del cultivo. Recuperado de http://www.fao.org/3/a-x0490s.pdf
8. FAO., (2017). Huella de Agua de la industria Bananera. Recuperado de http://www.fao.org/3/a-i6914s.pdf.
9. Fernández, A. (2018). Evaluación de la huella hídrica del banano en la provincia de los ríos, 2018. Universidad Técnica Estatal De Quevedo. Recuperado de https://repositorio.uteq.edu.ec/bitstream/43000/3939/1/T-UTEQ-0100.pdf.
10. Ferrándiz, J., (2017). Estudio del manejo del agua de riego mediante sensores de humedad. Recuperado de http://dspace.umh.es/bitstream/11000/4187/1/TFG Ferrándiz Molina%2C José.pdf.
11. Gabino, C., (2019). Evaluación de la calidad exportable de racimos de banano tratados con protectores biodegradables e infusión de laurel rosado (nerium oleander). Universidad Técnica de Machala. Recuperado de http://repositorio.utmachal a.edu.ec/handle/48000/15166.
12. Guevara, B., (2015). Analizar los costos de producción de una caja de banano convencional de la hacienda "los tamarindos" del sitio jumón, santa rosa. Universidad técnica de Machala. Recuperado de http://repositorio.utmachala .edu.ec/bitstream/48000/2008/1/CD773_TESIS.pdf.
13. Irrometer, W., (1978a). Medidor digital watermark. Recuperado de https://www.irrometer.com/pdf/spanish/sensors/407sp-Meter-WEB.pdf
14. Irrometer, W., (1978b). Sensor de humedad del suelo watermark– modelo 200ss. Recuperado de https://www.irrometer.com/pdf/spanish/sensors/403SPWATER MARK Sensor-WEB.pdf.
15. Irrometer, W., (2017). Instrucciones para el servicio y la utilización del medidor y sensores Watermark, 4–7. Recuperado de: https://www.hidric.com/wp-content/uploads/2019/08/instrucciones-watermark.pdf
16. Janssens, P., Diels, J., Vanderborght, J., Elsen, F., Elsen, A., Deckers, T., & Vandendriessche, H. (2015). Numerical calculation of soil water potential in an irrigated "conference" pear orchard. *Agricultural Water Management*, *148*, 113–

122. https://doi.org/10.1016/j.agwat.2014.09.023
17. Lara, R., (2015). Evaluación de alternativas de manejo de malezas en banano orgánico (Musa paradisiaca l.) En la etapa de establecimiento en la provincia de El Oro cantón El Guabo. ESPE-Universidad de las Fuerzas Armadas. Recuperado de: https://repositorio.espe.edu.ec/bitstream/21000/10235/2/T-ESPE-002785.pdf
18. León, Á., (2014). Efecto de diferentes láminas de riego en el comportamiento productivo del pimiento (Capsicum annum L.) en la península de santa elena, comuna río verde. Universidad Agraria del Ecuador.
19. León, Á., Arzube, M., Orrala, N., y Drouet, A. (2019). Efecto del riego deficitario controlado en el cultivo de pimiento (Capsicum annuum L.) utilizando la tina de evaporación clase a, en río verde, Santa Elena, Ecuador. Journal of Science and Research, 5, 114–124. Recuperado de https://revistas.utb.edu.ec/index.php /sr/article/view/765/606.
20. Lucín, J., (2018). Necesidades y calendario de riego en el cultivo de plátano (Musa paradisiaca). New England Journal of Medicine. Universidad de Guayaquil. Recuperado de http://repositorio.ug.edu.ec/bitstream/redug/35447/1/Lucín Preciado Juan Eddy.pdf
21. Medina, E., Mancilla, O., Larios, M., Guevara, R., Olguín, J., y Barreto, O., (2016). Calidad del agua para riego y suelos agrícolas en Tuxcacuesco, Jalisco. Idesia, 34(6), 51–59. recuperado de https://doi.org/10.4067/S0718-3429201600500035
22. Mendoza, J., y Bermúdez, J., (2015). Diseño, implementación y evaluación de un sistema de riego por microaspersión en café (Coffea arábica L.) En la espam mfl. Escuela Superior Politécnica Agropecuaria De Manabí Manuel Félix López. Recuperado de http://repositorio.espam.edu.ec/bitstream/42000/456/1/TA50 .pdf
23. Mesa, R., (2019). Incremento de la producción de Solanum lycopersicum L. cv. Aegean en cultivo protegido mediante alternativa de manejo del riego. Universidad Central "Marta Abreu" De Las Villas.Recuperado de https://dspace.uclv.edu.cu/bitstream/handle/123456789/10866/TesisMsCRolando Mesa 2018.pdf?
24. Pizarro, G., (2019). Efectos de los enraizadores en la velocidad del retorno en banano (Musa x paradisiaca) clon Williams. Universidad técnica de Machala. Recuperado de http://repositorio.utmachala.edu.ec/handle/48000/15166
25. Ritter, A., Machín, N., y Regalado, C. M. (2009). Evaluación de estrategias para la aplicación de agua en la zona no saturada en el cultivo del plátano, IX, 1–9. Recuperado de https://www.icia.es/icia/download/suelosyriegos/p388.pdf
26. Salazar, R., (2019). Diseño de un sistema de riego por aspersión aplicado al modelo productivo de agrícola industrial sukia s.a. Instituto tecnológico de costa. Recuperado de https://repositoriotec.tec.ac.cr/bitstream/handle/2238/11285/diseno_sistema_riego_aspersion_aplicado.pdf?sequence=1&isAllowed=y
27. Salman, A. K., Aldulaimy, S. E., Mohammed, H. J., & Abed, Y. M. (2021). Performance of soil moisture sensors in gypsiferous and salt-affected soils. *Biosystems Engineering*, *209*, 200–209. https://doi.org/10.1016/j.biosystemseng.2021.07.006
28. Solórzano, A., (2012). Diseño e implementación de un sistema de riego por aspersión, en cacao (Theobroma cacao L.) en el campus de la espam-mfl. Recuperado de http://repositorio.espam.edu.ec/bitstream/42000/19/1/SolòrzanoAngulo%2CAnaJohana.pdf
29. Villaseñor, D., Noblecilla, Y., Luna, E., Molero, R., Barrezueta, S., Huarquila, W., … Garzón, J., (2020). Respuesta óptima económica de la fertilización potásica sobre variables productivas del banano (Musa spp.). Chilean Journal of Agricultural and Animal Sciences, 36(2), 161–170. Recuperado de https://doi.org/10.29393/CHJAAS36-14RODV80014
30. Vories, E., & Sudduth, K. (2021). Determining sensor-based field capacity for irrigation scheduling. *Agricultural Water Management*, *250*(March), 106860. https://doi.org/10.1016/j.agwat.2021.106860