ORIGINAL ARTICLE

Determination Crops Coefficients of Bean for Conditions of the Central Provinces in Cuba

Determinación de coeficientes del cultivo del frijol para las condiciones de las provincias centrales, Cuba

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ABSTRACT: Water needs of crops are determined by climate demand and crop type, these two parameters are interrelated through Crop Coefficient (Kc). It varies in time because of the factors that influence in the crop development. The objective of the research was to determine bean Kc under the conditions of the Cuban central provinces. The study was carried out in the Cooperative Production Basic Unit (UBPC) "Victoria II", belonging to the Agricultural Enterprise Camagüey. Center pivot machines were used on red Fersalitic soil, where samplings of soil moisture were made every five days with TDR-300. Crop evapotranspiration (ETc) was determined taking into account the irrigation made and the usable rain during the cropping period. Kc values were calculated starting from the relationship of moisture balance every five days and the results were validated. These results showed the increase in ETc during the flowering and pod formation stages with a value of 3.98 mm/day. The Kc obtained were 0.45 (Kc initial), 1.00 (Kc mid) and 0.38 (Kc end) and in their validation, a constant trend was observed in the behavior of the Kc results, while their variation in relation to the results of the research stage is maintained in a range of less than 10 %. It was concluded that Kc parameters obtained can be used for bean irrigation scheduling under the conditions of the central provinces.

***Keywords*:** Irrigation Scheduling, Efficiency, Water Needs.

RESUMEN: Las necesidades de agua de los cultivos están determinadas por la demanda climática y el tipo de cultivo, estos dos parámetros a su vez, están relacionados entre sí a través del Coeficiente de Cultivo (Kc), este coeficiente varía en el tiempo debido a los factores que influyen en el desarrollo del cultivo. El objetivo determinar los Kc del frijol en las condiciones de las provincias centrales de Cuba. El estudio se realizó en la Unidad Básica de Producción Cooperativa (UBPC) “Victoria II”, perteneciente a la Empresa Agropecuaria Camagüey, empleando tecnología de máquinas de pívot central sobre suelo Fersialítico pardo rojizo, para ello se efectuaron muestreos de humedad del suelo cada cinco días con el equipo TDR-300, se determinó la evapotranspiración del cultivo (ETc) teniendo en cuenta los riegos realizados y la lluvia aprovechable durante el periodo del cultivo, los valores de Kc fueron calculados a partir de la relación del balance de humedad cada cinco días y se validaron de los resultados. Los resultados obtenidos mostraron el incremento de la ETc durante la etapa de floración y formación de las vainas con un valor de 3,98 mm/día, los Kc obtenidos fueron 0,45 (Kc inic), 1,00 (Kc med) y 0,38 (Kc fin) y en la validación de los resultados se observó que se mantiene la tendencia en el comportamiento de los valores de Kc, en tanto la variación en relación a los resultados de la etapa investigativa se mantienen en un rango menor al 10% de variación. Se concluye que los valores de Kc obtenidos pueden emplearse para la programación del riego del frijol en las condiciones de las provincias centrales.

***Palabras clave*:** programación de riego, eficiencia, requerimientos de agua.

INTRODUCTION

The available water for crop irrigation is increasingly limited both quantitatively and qualitatively due to the accelerated growth of domestic and industrial demands, which makes the efficient use of water increasingly necessary in irrigation systems. An efficient irrigation is that one capable of keeping soil moisture within appropriate limits, which will depend on crop features, climate conditions and environment management, all of which is expressed through evapotranspiration (ET) (Bonet-Pérez *et al.*, 2010).

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The correct water for irrigation scheduling based on an adequate balance implies knowledge about water needs of the crop and water availability in the supply source. Crop water needs are determined by climatic demand and crop type, these two parameters in turn, are related to each other through the so-called Crop Coefficient (Kc) which is a value obtained by relating the crop evapotranspiration (ETc) with the reference evapotranspiration (ETo), this coefficient varies over time due to factors influencing crop development (Herrera-Puebla *et al.*, 2018).

The Kc integrates the effects of the characteristics that distinguish a reference crop, which has a uniform appearance and covers completely the soil surface. Different crops will have different Kc values and the crop features that vary during its growth will also affect the Kc value (Allen *et al.*, 2006).

In the unit under study, the main problems related to irrigation scheduling in bean cropping in the province are referred to the poor knowledge of personnel in charge of the activity, due to lack of training. It provokes an inefficient management of irrigation water of bean with electric machines of center pivot and affects the crop by not applying the irrigation standards and frequencies necessary for its normal growth and development. Because of that, it is necessary to apply an irrigation schedule that guarantees the adequate use of the areas under irrigation and satisfactory productive results.

Based on that, the objective of this work was to determine crop coefficients (Kc) of beans under the conditions of the central provinces of Cuba.

MATERIALS AND METHODS

The research was carried out during three campaigns (2019 - 2022), in areas of the Cooperative Production Basic Unit (UBPC) "Victoria II", belonging to the Agricultural Enterprise Camagüey. It is geographically located in Camagüey Municipality, at Camagüey Province in Cuba, between coordinates N (310.00-315.00) and E (403.00-408.00) in San Serapio map sheet (4680-II-A), at a scale of 1:25 000 (Figure 1).

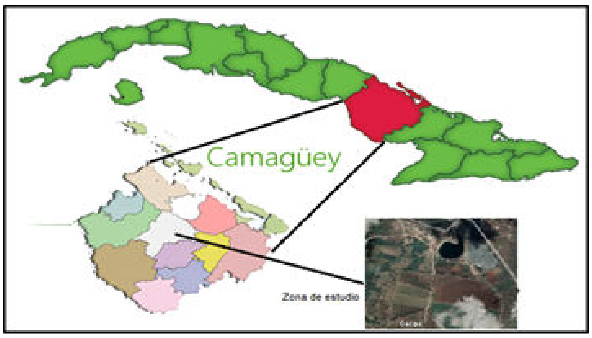

FIGURE 1. Satellite image UBPC “Victoria II” Cuba. Source: https://www.google.com.cu (2020).

The main activity of the Unit is aimed at producing crops, including roots and tubers, vegetables, fruits and grains; being beans the most representative one.

Irrigation Infrastructure

The UBPC has a total area of 403.0 ha distributed over 17 farms, of which 144.0 ha are under irrigation, including 82,0 ha with sprinkler irrigation linked to 6 semi-stationary systems (medium pressure) and 62.0 ha to irrigation with 5 center pivot machines (Rodríguez-Correa & Bonet-Pérez, 2018).

The UBPC has a supply source of surface water (Borges micro dam) for irrigation. Its main parameters occupy a total volume of 1.102 MM m^3, according to the information from the Hydraulic Exploitation Company in Camagüey (INRH-Cuba, 2018).

The irrigation system works from a main pumping station located in the reservoir, from which the water is pumped by a closed conductor to a regulating box placed at a higher point in the area and then it is distributed by gravity towards the entire irrigation network. It uses closed conductors, which feed the Pumping Stations of each of the irrigation systems installed in the unit (IIRD-Cuba, 2000).

Soils

From an updated study carried out by the Cuban Soil Research Institute IS-Cuba (2010), it was specified that there are six types of soils at the UBPC "Victoria II" (Figure 2).

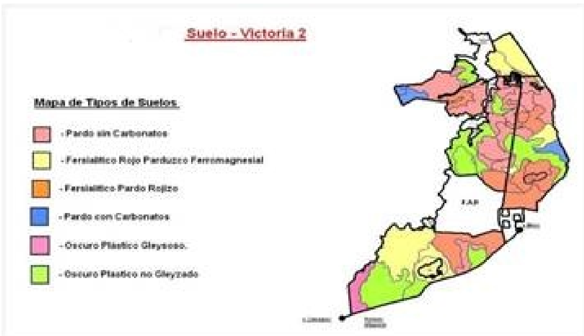

FIGURE 2. Predominant soils in the UBPC “Victoria II”. Source: Soil Research Institute IS-Cuba (2010).

Climate

The locality presents typical characteristics of tropical climate of seasonally humid equatorial savannah forests with humid summer and with a comparatively remarkable trend to continental character within the country. Plains predominate in its physical-geographical condition.

The characterization of the UBPC "Victoria II" in 2019, was based on the data offered by the meteorological station of Camagüey, Cuba (78355) CMP-Camagüey (2020), located at 21° 24' north latitude and 77º 51' west longitude, with a height of 118 m above sea level, which is the closest and most representative station for the study area (Table 1).

Characterization of the Experimental Area

The research was carried out in areas of electric center pivot machine. The predominant soil in the research area is reddish brown Fersialitic whose main characteristics are shown in Table 2.

Calculation of the Application Efficiency of the Electric Center Pivot Machine

The evaluation of the machine was carried out according to the procedure described in NC ISO 11545 (2009) and the obtained values of uniformity coefficient (Cu) and discharge efficiency (Ef) were used to determine the working regime in each of the phases of crop development.

Pivot Machine Adjustment

From the soil and the crop features, the net irrigation standards to be applied by stage of physiological development were determined, which were used for the operation of the regulation table of the pivot machine and the efficiency of application obtained during the evaluation will determine the necessary regulation for the entire crop stage.

TDR-300 Calibration

For the determination of soil moisture, the digital soil moisture sensor TDR-300 (Time Domain Reflectometer) was used (Figure 3).

The TDR-300 probe has proven to be an effective method that allows quickly and efficiently obtain volumetric moisture content readings in the soil to operate the irrigation system and keeping the level of available moisture between the upper and the lower limit of the reserve easily usable (López-Silva *et al.*, 2017).

FIGURE 3. TDR 300 soil moisture meter. Source: https://www.viaindustrial.com/pp/ (Viaindustrial, 2020).

FIGURE 4. SORTORIUS Signum 1 digital scale. Source: https://rsu.mx/producto/ Alibaba.com (2020).

Before starting the study, the TDR-300 equipment was calibrated using the gravimetric method to determine the moisture present, using a SORTORIOS Signum 1 digital scale with a weighing range of up to 35 kg and a precision of 0.1 g (Figure 4).

TABLE 1. Average values of climatic parameters

Parameter	U.M.	Half
Temperature	°C	22.2
RH	%	77
Wind speed	km/h	8.6 a 13.7
Precipitation	mm	1390.9
Insolation	Light-hours/day	7.8
Cloudiness	Eighths	4 a 5

TABLE 2. Characteristics of the predominant soil in the research area. Genetic Classification: Reddish Brown Fersialitic, Cuba

Depth (cm)	Apparent density (g/cm³)	Porosity (%)	Field capacity (% bss)	Infiltration speed (mm/h)
00 - 10	1.26	52.4	31.4	21
10- 20	1.26	52.4	30.0	21
20- 30	1.26	52.4	34.9	21

Source: Soil Research Institute. IS-Cuba (2018).

Calculation of Crop Evapotranspiration

To determine moisture of the soil to be used in the moisture balance, a control position was defined (Figure 5) occupying an area of 4 m^2; in it, soil moisture sampling was carried out every five days.

From the moisture present, the moisture reserve was calculated.

$$W = 100 \times H \times Da \times Hp \quad (1)$$

Where: W. Moisture reserve (mm); H. Depth to moisten (mm); Gives. Apparent density (mm); Moisture present (mm).

From the soil moisture balance method, the initial and final reserve moisture of the period was calculated, considering the final reserve of one period as the initial reserve of the following period:

$$Wf = Wi + R + LLa - ETc \quad (2)$$

Where: Wf. Final reserve (mm); Wi- Initial reserve (mm); R. Net irrigation standard (mm); Lla. Usable rainfall (mm); Etc. Evapotranspiration (mm).

The value of the magnitude of the rainfall that occurred was measured with a rain gauge located in the research area, performing the daily reading at the same time. The calculation of usable rainfall during the period was carried out taking into account the rainfall (Ll) and the irrigation (R) applied, as well as the ETc of the crop during the decade evaluated in the period prior to the rain.

After calculating the final Wf, the ETc of the evaluated period is determined taking into account the irrigations carried out and the usable rainfall, according to the following equation:

$$ETc = (Wi + R + LLa) - Wf \quad (3)$$

Where: ETc. Crop evapotranspiration (mm); Wi- initial moisture reserve (mm); Wf- final moisture reserve (mm); LLa- usable rainfall (mm); R- irrigation (mm).

Calculation of the Kc

During 2019-2020 and 2020-2021 campaigns, bean evapotranspiration behavior was calculated; the average results obtained are shown.

The methodology approved by the FAO for the study of crop evapotranspiration (ETc) is based on its calculation as the product of the reference evapotranspiration (ETo) and the crop coefficient (Kc) (Bonet-Pérez *et al.*, 2010).

The Kc values were calculated from the relationship of the moisture balance of the period every five days knowing the ETc and the ETo, according to the expression:

$$Kc = ETc/ETo \quad (4)$$

For this, the forecast of the behavior of the reference evapotranspiration (ETo) for the study area was obtained weekly from the Province Meteorological Center (CMP) in Camagüey, Cuba CMP-Camagüey (2020) (Figure 6).

FIGURE 5. Location of the control position.

FIGURE 6. Daily reference evapotranspiration information. Source: Centro Meteorológico Provincial de Camagüey CMP-Camagüey (2020).

The Kc values obtained were transformed into the steps described in the Penman-Monteith method (Allen *et al.*, 2006).

After performing the calculation, the Kc curve was prepared from the data obtained, determining the duration of the development stages and the value of the Kc corresponding to each one, the curve represents the changes along of their growth period.

Validation of Kc Results

The validation of the results is aimed at verifying the results obtained under production conditions, it was carried out during 2021-2022 campaign, for which the ETc values were determined from the moisture balance, with this information and the ETo values obtained from the Meteorological Center of Camagüey, Cuba CMP-Camagüey (2020), the Kc were calculated, the values obtained were compared with those calculated during the research stage.

RESULTS AND DISCUSSION

Evaluation of the Electric Center Pivot Machine

As a result of the evaluation of the electric center pivot machine, values of Uniformity Coefficient and Application Efficiency of 82 % and 75 %, respectively, were obtained. Tarjuelo (2005) considers that for this technology, the Uniformity Coefficient is adequate in the range between 85 and 90 % (Jiménez, *et al.* , 2011), for which the value obtained can be classified as acceptable. The Application Efficiency, however, is low, which is attributed to prevailing wind speed that usually behaved in the range of 2.8 to 3.5 m/s, during the operation of this irrigation system. Hence, in the development of the research, one of the aspects taken into account was to place the emitters at the same height to reduce the incidence of the wind. Referring to that, Tarjuelo (2005) indicates to reduce the height of the emitter to diminish losses due to evaporation and drag, without harm irrigation quality parameters; night irrigation also contributes to reduce these hindrances.

Pivot Machine Regulation

The results of the necessary regulation for the application of irrigation throughout the cropping stage are shown in Table 3.

TDR Calibration - 300

With the calibration of the TDR-300, values were obtained which reflect the relationship between the equipment reading and the soil moisture in the research area, as shown in Table 4.

Calculation of Crop Evapotranspiration

During the cropping cycle, there were 6 rain events with a total magnitude of 62.5 mm and 51% utilization. Figure 7 shows their distribution.

During the entire crop cycle, 16 irrigations were carried out; total moisture inputs were 263 mm. Its distribution is shown in figure 8.

The results of crop evapotranspiration (ETc) obtained from moisture balance by stages of physiological development are shown in Table 5.

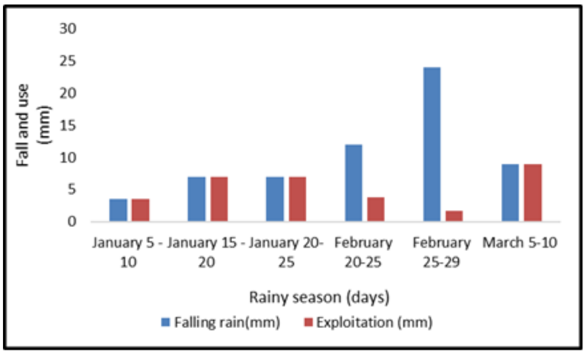

FIGURE 7. Total and usable rainfall.

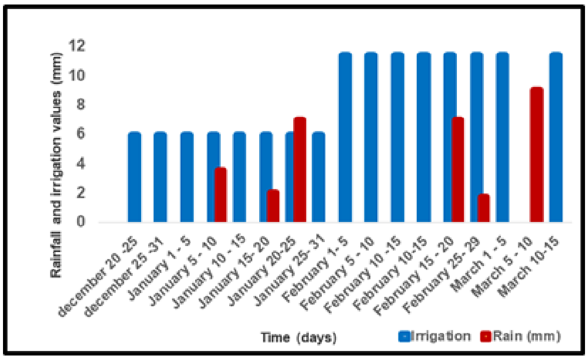

FIGURE 8. Moisture ingress

The ETc values varied at all stages of crop development, increasing as the crop grows and develops, reaching its maximum value at the time of flowering and pod formation.

The results reported by different authors coincide in stating that bean is a crop susceptible to both, excess and deficit of moisture, during its development cycle (Polón-Pérez *et al.*, 2014).

The highest consumption is observed in the flowering and pod formation stage, a result that coincides with reports from Rivera & Chaves (2019), that identify the period during the flowering stage as critical for water demand.

TABLE 3. Pivot machine regulation

Physiological development stage	Net norm (mm)	Gross norm (mm)	Regulation (%)
Sowing - Germination	5.92	10.03	25
Germination - Establishment	5.92	10.03	25
Establishment - Flowering	5.92	10.03	25
Flowering - pod formation	11.34	19.22	15
Pod formation - Harvesting	11.34	19.22	15

TABLE 4. Scale for irrigation programming based on the reading of the TDR-300

Reading TDR	CC bss (%)	Reading TDR	CC bss (%)	Reading TDR	CC bss (%)
> 75	100	67	92	54	84
75	98	65	90	49	82
72	96	62	88	45	80
69	94	60	86	< 45	< 80

TABLE 5. Crop evapotranspiration values during the experimental stage

Physiological development stage	ETc (mm/day)
Sowing - Germination	1.61
Germination - Establishment	2.43
Establishment - Flowering	2.82
Flowering - Pod formation	3.98
Pod formation - Harvest	1.86

TABLE 6. Mean values of ETo during the experimental stage

Month	ETo (mm/día)		
	1ª Ten	2ª Ten	3ª Ten
December	3.50	3.72	3.50
January	3.69	3.41	3.75
February	3.71	3.88	3.80
March	4.02	4.25	4.20

Calculation of the Kc

A summary of the ETo information received from the Camagüey Meteorological Center, Cuba CMP-Camagüey (2020), during the two campaigns of the experimental stage is shown in Table 6.

The Kc integrates the effects of the characteristics that distinguish a reference crop, which has a uniform appearance and completely covers the soil surface. Different crops will have different Kc values and the characteristics of the crop that varies during its growth will also affect the Kc value (Rodríguez-Correa *et al.*, 2022).

The factors that affect the values in the Kc are the characteristics of the crop, the development stage and the duration of the vegetative period. They will have a seasonal variation: initial phase (germination and initial growth with 10 % coverage), development phase (from the end of the initial phase and between 70 % - 80 % coverage), maturing phase (from full coverage to start maturation (leaf fall) and final phase (from the end of the previous phase to harvesting) (Rivera & Chaves, 2019).

The Penman-Monteith method recommended by Allen *et al.* (2006) for calculating the Kc, suggests the use of the graph in which the four stages are framed (Figure 9).

The values obtained were used to prepare the Kc curve (Figure 10).

The results obtained in the research were 0.45 (Kc init), 1.00 (Kc mid) and 0.38 (Kc end), which are similar to Allen *et al.* (2006), with values of 0.40; 1.15 and 0.35 and are far from those indicated by Hermoso-Veramendi (2020), which were 0.89; 0.90 and 0.57 respectively. In these last results, it is observed that the Kc values of the initial and middle stages are practically coincident, which is far from the behavior observed during the investigation stage.

The values shown in Figure 10 are in correspondence with what was proposed by Zamora-Herrera *et al.* (2014), who have pointed out that during the cropping growth period the variation of Kc expresses the changes in the vegetation and in the degree of soil covering. In the research, it was taken into account from the physiological point of view, when the plant was in the period of highest water demand. That is shown in the results obtained.

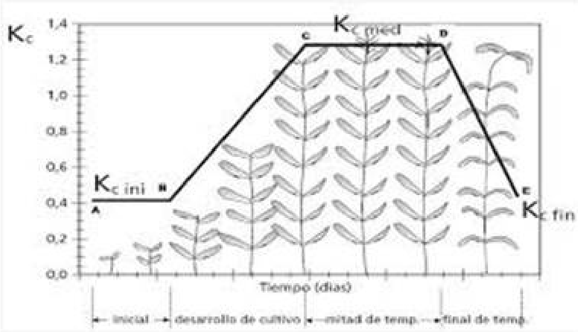

FIGURE 9. Crop Coefficient (Kc) during crop development. Source: Allen *et al.* (2006).

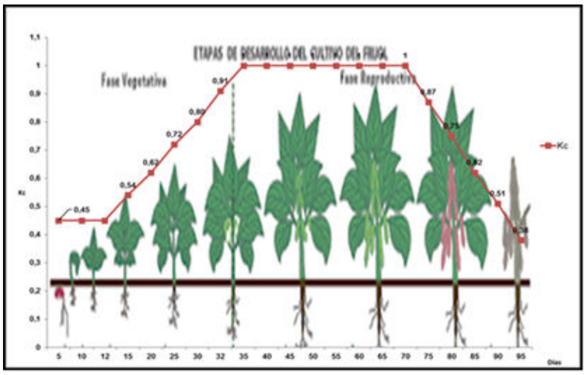

FIGURE 10. Kc curve obtained during the investigation.

Studies carried out by López-Silva *et al.* (2017), report the possibility of applying Controlled Deficit Irrigation criteria in bean cropping, taking care not to create water stress conditions in the flowering stage and pod formation, which guarantees the highest irrigation water productivity.

While ETo represents an indicator of climatic demand, the value of Kc varies mainly depending on the particular characteristics of the crop and its stage of development, affected only to a small extent depending on the climate. This allows the transfer of standard values of the crop coefficient between different geographical areas and climates (Herrera-Puebla *et al.*, 2018).

Validation of Kc

During validation, the results shown in Table 7 were obtained.

It is observed that the same trend is kept in the behavior of the Kc values, while the variation in relation to the results of the researching stage remains in a range of less than 10 % variation, which confirms the validity of the values calculated.

CONCLUSIONS

- The evapotranspiration of the crop in the experimental stage was of 3.98 mm/day and the highest demand was obtained in the phase of flowering-grain formation.
- The values of crop coefficients varied as follows: 0.45 at the initial stage, 1.00 at the middle stage and 0.38 at the end.
- The Kc values determined can be used for bean irrigation scheduling under the conditions of the central Cuban provinces.

REFERENCES

ALIBABA.COM: *Balanza digital SORTORIUS Signum 1., [en línea]*, Alibaba.com, 2020, *Disponible en:* https://rsu.mx/producto/, *[Consulta: 20 de octubre de 2020].*

ALLEN, R.G.; PEREIRA, L.S.; RAES, D.; SMITH, M.: *Evapotranspiración del cultivo: guías para la determinación de los requerimientos de agua de los cultivos*, Ed. Estudio FAO Riego y Drenaje 56, vol. 298, Roma. Italia, 2006, ISBN: 92-5-304219-2.

ONET-PÉREZ, C.; ACEA-LAHERA, I.; BROWN-MANRIQUE, O.; HERNÁNDEZ-VICTORIA, M.; DUARTE-DÍAZ, C.: "Coeficientes de cultivo para la programación del riego de la piña", *Revista Ciencias Técnicas Agropecuarias*, 19(3): 23-27, 2010, ISSN: 2071-0054, Publisher: Universidad Agraria de La Habana.

CABELLO, J.: *Determinación del coeficiente de cultivo kc para frejol Phasseolus vulgaris bajo invernadero en la granja Santa Inés, [en línea]*, Universidad Académica de Ciencias Agropecuarias, Carrera de Ingeniería Agronómica., Trabajo de titulación previo a la obtención del título de Ingeniero Agrónomo, Machala, 2015, *Disponible en:* http://repositorio.utmachala.edu.ec/bitstream/48000/3022/10/tesis.pdf, *[Consulta: 28 de febrero de 2019].*

CMP-CAMAGÜEY: *Información de evapotranspiración de referencia diaria de la zona de estudio*, Inst. Centro Meteorológico Provincial (CMP), Camagüey, Cuba, 2020.

HERMOSO-VERAMENDI, S.: "Determinación del coeficiente de cultivo (KC), para frijol (phaseolus vulgaris l.), Bajo invernadero en el centro de investigación y experimentación de Cañasbamba, 2018", mayo de 2020.

HERRERA-PUEBLA, J.; GONZÁLEZ-ROBAINA, F.; DÍAZ-PÉREZ, Y.: "Consumo de agua y coeficientes de cultivo en el sorgo de grano (Sorgum vulgare L. Monech)", *Revista Ingeniería Agrícola*, 8(3): 25-30, 2018, ISSN: 2227-8761, Publisher: Instituto de Investigaciones de Ingeniería Agrícola.

HTTPS://WWW.GOOGLE.COM.CU: *Mapa Satélite de Altagracia. Ubicación de la UBPC Victoria II. Provincia de Camagüey, [en línea]*, Camagüey, Cuba, 2020, *Disponible en:* https://www.google.com.cu, *[Consulta: 20 de octubre de 2020].*

IIRD-CUBA: *Proyecto 2253. Incremento de la efectividad de los sistemas de riego en una unidad productiva de referencia*, Inst. Instituto de Investigaciones de Riego y Drenaje (IIRD), Informe de proyecto, La Habana, Cuba, 2000.

TABLE 7. Validation results of Kc values

Stage	Days		Kc		
	A	B	A	B	C
Initial	12	10	0.45	0.50	0.90
Developing	23	20	0.45 - 1.00	0.50-0.96	0.99
Mean	38	35	1.00	0.96	1.04
Final	22	27	1.00 - 0.38	0.96-0.42	0.90
Total	**95**	**92**	**0.79**	**0.78**	**1.01**

Legend: A. Research stage. B. Validation. C. Relationship between the results obtained during the experimental stage and the validation stage.

INRH-CUBA: *Parámetros principales de la Micro presa Borges.*, Inst. Instituto Nacional de Recursos Hidráulicos (INRH), Camagüey, Cuba, 2018.

IS-CUBA: *Informe sobre la actualización de los suelos en la UBPC Victoria II para el Programa de Polígonos de Conservación de Suelos*, Inst. Instituto de Suelos (IS), Camagüey, Cuba, 2010.

IS-CUBA: *Informe de actualización de los datos de suelos del Polígono provincial de suelos en Camagüey, Cuba*, Inst. Instituto de Suelos (IS), Camagüey, Cuba, 2018.

JIMÉNEZ, E.; DOMÍNGUEZ, M.; PÉREZ, R.: "Parámetros de explotación y uniformidad de riego en la máquina de pivote central OTECH-IRRIMEC", *Revista Ingeniería Agrícola*, 1(1): 7-12, 2011, ISSN: 2227-8761, Publisher: Instituto de Investigaciones de Ingeniería Agrícola.

LÓPEZ-SILVA, M.; CARMENATES-HERNÁNDEZ, D.; MUJICA-CERVANTES, A.; PANEQUE-RONDÓN, P.: "Operación del pivote central evaluando la dinámica de humedad en el suelo con TRD", *Revista Ingeniería Agrícola*, 7(3): 11-16, 2017, ISSN: 2227-8761, Publisher: Instituto de Investigaciones de Ingeniería Agrícola.

NC ISO 11545: *Máquinas agrícolas para riego-pivotes centrales y máquinas de avance frontal equipadas con boquillas difusoras o aspersores-determinación de la uniformidad de distribución del agua*, Inst. Oficina Nacional de Normalización, La Habana, Cuba, 2009.

POLÓN-PÉREZ, R.; MIRANDA-CABALLERO, A.; RAMÍREZ-ARREBATO, M.A.; MAQUEIRA-LÓPEZ, L.A.: "Efectos del estrés de agua sobre el rendimiento de granos en la fase vegetativa en el cultivo del frijol (Phaseolus vulgaris L.)", *Revista Ciencias Técnicas Agropecuarias*, 23(4): 33-36, 2014, ISSN: 2071-0054, Publisher: Universidad Agraria de La Habana.

RIVERA, J.C.; CHAVES, C.A.: "Riego restringido en cinco cultivares de frijol (Phaseolus vulgaris L.)", *Boletín Técnico*, 17: 2019, Publisher: Universidad de Costa Rica.

RODRIGUEZ-CORREA, D.; BONET-PÉREZ, C.: "Propuesta de estrategia de extensión de buenas prácticas de riego en una unidad productiva agrícola", *Revista Ingeniería Agrícola*, 8(2): 35-40, 2018, ISSN: 2227-8761, Publisher: Instituto de Investigaciones de Ingeniería Agrícola.

RODRÍGUEZ-CORREA, D.; BONET-PÉREZ, C.; DE LA CARIDAD MOLA-FINES, B.; GUERRERO-POSADA, P.; MARTÍNEZ-DER, C.; MACHADO-CARBALLO, M.: "Estrategias de riego deficitario controlado para el cultivo del frijol", *Revista Ingeniería Agrícola*, 12(1): 54-58, 2022, ISSN: 2306-1545, Publisher: Instituto de Investigaciones de Ingeniería Agrícola.

TARJUELO, J.M.: *El riego por aspersión y su tecnología*, Ed. Mundi-Prensa, Tercera ed., Madrid, España, Centro Regional de Estudios del Agua-CREA- Universidad de Castilla-La Mancha, 2005, ISBN: 84-8476-239-4.

VIAINDUSTRIAL: *Medidor de humedad de suelo equipo TDR-300*, *[en línea]*, viaindustrial.com, 2020, *Disponible en:* https://www.viaindustrial.com/pp/.

ZAMORA-HERRERA, E.; DUARTE-DÍAZ, C.; CUN-GONZÁLEZ, R.; PÉREZ-HERNÁNDEZ, R.; LEÓN-FUNDORA, M.: "Coeficientes de cultivos (Kc) en Cuba", *Revista Ingeniería Agrícola*, 4(3): 16-22, 2014, ISSN: 2306-1545, Publisher: Instituto de Investigaciones de Ingeniería Agrícola.

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