Edição especial – VI Winotec
ISSN 1808-8546 (ONLINE) 1808-3765 (CD-ROM)

COEFICIENTES DAS CULTURAS: BASE DE DADOS PARA O NORDESTE COMO SUPORTE AO MANEJO DA IRRIGAÇÃO

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1 RESUMO

O coeficiente da cultura (Kc) é o parâmetro mais comumente utilizado para estimar a necessidade de água da cultura, mediante a estimativa da evapotranspiração (ETc). Neste contexto, objetivou-se, com o presente trabalho, desenvolver e disponibilizar um atualizado banco de dados de coeficientes das culturas (Kc's) de relevâncias agroeconômicas específicos para a região nordeste brasileira, por meio do oferecimento de informações de Kc's padronizados em uma interface acessível e passível de apropriação aos agricultores irrigantes locais, com vistas ao oferecimento de subsídios técnicos – científicos capazes de auxiliarem ao manejo racional e sustentável da agricultura irrigada regional. Para tanto, realizou-se uma abrangente e atualizada pesquisa bibliográfica sobre os coeficientes das culturas (Kc's), determinados especificamente nas condições edafoclimáticas da região nordeste brasileira e disponibilizou-se um banco de dados Kc's. Identificaram-se lacunas existentes em termos de culturas de importâncias agroeconômicas regionais nas quais as informações acerca dos Kc's não são ainda disponibilizadas e/ou encontram-se desatualizadas, sobretudo, junto às frutíferas aceroleira e goiabeira, bem como junto às espécies vegetais forrageiras, o que aponta a necessidade do desenvolvimento de pesquisas básicas e aplicadas acerca das temáticas em questão.

Palavras-chave: evapotranspiração, necessidades hídricas dos cultivos, economia de água.

Recebido em 03/12/2024 e aprovado para publicação em 12/12/2024
DOI: http://dx.doi.org/10.15809/irriga.2024v29p210-219

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CROP COEFFICIENTS: DATABASE FOR THE NORTHEAST TO SUPPORT IRRIGATION MANAGEMENT

2 ABSTRACT

The crop coefficient (Kc) is the parameter most commonly used to estimate a crop's need for water by estimating evapotranspiration (ETc). In this context, the aim of this study was to develop and make available an up-to-date database of crop coefficients (Kc's) of specific agroeconomic relevance to the northeastern region of Brazil by offering information on standardized Kc values in an accessible interface that can be appropriated by local irrigation farmers, with the goal of providing technical and scientific support capable of assisting in the rational and sustainable management of regional irrigated agriculture. To this end, a comprehensive and up-to-date bibliographical survey was carried out on crop coefficients (Kcs), which were determined specifically in the soil and climate conditions of the northeastern Brazilian region, and a Kc database was constructed. Gaps were identified in terms of crops of regional agroeconomic importance where information on Kcs is not yet available and/or is out of date, especially for the fruit trees aceroleira and guava, as well as for fodder plant species, which points to the need to develop basic and applied research on the issues in question.

Keywords: evapotranspiration, crop water requirements, saving water.

3 INTRODUCTION

The crop coefficient (Kc) is the element commonly used to estimate crop water requirements, called crop evapotranspiration (ETc), as it makes it possible to predict the irrigation depth to be applied. This method is presented in the FAO *Irrigation Manual and Drainage Paper* 56 (FAO-56) (FAO, 1998), which explicitly presents the procedures for calculating the Kc values (Han *et al.*, 2019). The Kc values of the main plant species grown under different irrigation regimes at different stages of development are recommended in the FAO-56 manual. However, although the approach to Kc's use methodology is simple to use, the differences between the values of these coefficients determined locally and the indicative values tabulated in the FAO-56 manual are often accentuated and may therefore lead to prominent errors in the process of calculating crop evapotranspiration and, consequently, water requirements throughout irrigation events (Pereira *et al*., 2015).

Although these various works present Kc values for the most diverse crops, it is clear that this information is completely dispersed in the literature, practically restricted to the academic and scientific community, as it is not always presented in accessible language, making it difficult for irrigators and extension workers to disseminate and appropriate this information.

In this context, the objective of this work was to develop and make available an updated database of crop coefficients (KCSs) for plant species of specific agroeconomic relevance for the northeast

region of Brazil by offering information on standardized Kc values via an accessible interface that can be appropriated by local irrigated farmers, with the goal of offering technical subsidies capable of assisting in the rational and sustainable management of regional irrigated agriculture.

4 MATERIALS AND METHODS

To construct a modern database of crop coefficients (Kc) for the soil and climate conditions of Northeast Brazil, documentary bibliographic research was used. To this end, bibliographic surveys were carried out in the most varied specialized publications (theses, dissertations, scientific articles, etc.) that reported results of research developed with the objective of determining crop coefficients (**KCs**) for the most diverse plant species.

The following keywords were used for the searches: crop evapotranspiration, crop coefficients, crop coefficients and irrigation Kc, in Portuguese and, preferably, in English on the ScienceDirect, Scopus and Scielo platforms. Three prior selection criteria were established for publications to be included in the database: (1) the agricultural crop must be on the list of plant species predominantly cultivated in public irrigation projects located in the Brazilian northeast region, as described by the National Water and Sanitation Agency (2021); (2) the municipality where the field experiment was carried out, focusing the search only on research carried out exclusively in municipalities belonging to one of the nine states in the northeast region; (3) delimitation of the publication period from the year 2000 onward, with a view to creating a database that is as up-to-date as possible.

From each previously selected publication, according to the established criteria, the following information was extracted and duly organized in electronic spreadsheets: (1) separation of phenological stages (number, names and durations of stages) and (2) crop coefficients by phenological stage.

The materialization of this duly systematized database took place in tables, where the plant species defined according to criterion 1 were grouped according to the definitions of the botanical classification criteria, with the objective of offering a practical tool to select the most appropriate Kc values for irrigation programming in the region.

5 RESULTS AND DISCUSSION

Tables 1, 2, 3, 4 and 5 present the results of the cultivation coefficients (KKs) recommended for the main vegetable species, i.e., oil, energy, grain, fiber and fruit, in irrigated crops in Northeast Brazil.

Table 1. Cultivation coefficients (Kc) of the main oilseed species in Northeast Brazil [1]

Culture	Phenological stages	DAT	Kc	Source	Kc (FAO-56)
Pumpkin	Establishment	0 - 13	0.42	Lima (2013) Mossoro - RN	0.50
	Vegetative	14 - 36	0.68		0.50
	Flowering and Fruiting	37 - 52	1.08		1.00
	Maturation	53 - 63	0.78		0.80
Onion	Home	0 - 20*	0.48	Oliveira *et al* . (2013) Juazeiro - BA	0.70
	Vegetative	21* - 46*	0.68		0.70
	Bulbification	47* - 74*	1.05		1.05
	Maturation	75* - 91*	1.02		1.00
Watermelon	Home	0 - 13	0.39	Ferreira *et al* . (2015) Teresina - PI	0.40
	Growth	14 - 29	0.80		1.00
	Intermediate	30 - 52	1.14		1.00
	End	53 - 63	0.59		0.75
Melon	Home	0 - 23	0.21	Miranda and Bleicher (2001) Paraipaba - CE	0.50
	Growth	24 - 42	0.71		0.50
	Intermediate	43 - 61	1.20		1.00
	End	62 - 69	0.97		0.75

DAT: days after transplantation.

Table 2. Cultivation coefficients (Kc) of the main grain species in Northeast Brazil [1]

Culture	Phenological stages	DAS	Kc	Source	Kc (FAO-56)
Rice	Emergence – tillering	0 - 26	1.10	Lima and Oliveira (2003) Miguel Alves - PI	1.05
	Tillering – floral primordium	27 - 61	1.10		1.20
	Floral primordium – flowering	62 - 90	1.10		1.20
	Flowering – milky phase	91 - 107	0.95		0.90
Cowpea	Vegetative	0 - 34	0.78	Souza, Bezerra and Theophilus (2005) Fortaleza - CE	0.5
	Flowering	35 - 50	1.27		1.05
	Filling the pods	51 - 64	1.02		1.05
	Maturation	65 - 68	0.69		0.90
Corn (grains)	Vegetative	0 - 39	0.86	Souza *et al* . (2015) Petrolina - PE	0.3
	Flowering	40 - 53	1.23		1.20
	Grain filling	54 - 74	0.97		1.20
	Maturation	75 - 111	0.52		0.60
Corn (green)	Home	0 – 16	0.50	Santos *et al* . (2014) Alagoinha - RN	0.3
	Vegetative development	17 - 37	0.64		1.15
	Flowering	38 - 65	1.12		1.15
	Physiological maturity	66 - 80	1.11		1.05
Sorghum	Home	0 – 21	0.40	Lima *et al* . (2021) Apodi - RN	0.3
	Vegetative growth	22 – 54	0.68		1.05
	Flowering	55 – 81	1.14		1.05
	Physiological maturity	82 - 95	1.10		0.55
Soy	Home	0 - 20	0.38	Bastos *et al* . (2007) Gurgueia - PI	0.4
	Growth	21 - 45	0.93		1.15
	Intermediary	46 - 70	1.04		1.15
	End	71 – 110	1.29		0.50
	Physiological maturity	110 - 120	0.80		0.50

[1] DAS: days after sowing;

Table 3. Cultivation coefficients (Kc) of the main energy species in Northeast China

Culture	Phenological stages	DAT	Kc	Source	Kc (FAO-56)
Sugarcane	Home	0 - 30	0.23	Goncalves (2010) Fortaleza - CE	0.40
	Vegetative Development	31 - 80	0.66		1.25
	Intermediate	81 - 318	1.03		1.25
	End	319 - 437	0.75		0.75

DAT: days after transplantation.

Table 4. Cultivation coefficients (Kc) of the main fibrous species in Northeast Brazil .

Culture	Phenological stages	DAT	Kc	Source	Kc (FAO-56)
Cassava	Establishment	0 - 19	0.55	(2009) Cross of Souls - BA	0.30
		20 - 39	0.56		0.30
	Vegetative	40 – 59	0.61		0.30
		60 – 79	0.74		0.30
		80 – 99	0.90		0.30
		100 - 119	0.98		0.30
		120 - 139	0.93		0.30
		140 - 159	0.86		0.30
	Tuberization	160 - 179	0.78		1.10
		180 - 199	0.72		1.10
		200 - 219	0.70		0.50
		220 - 239	0.67		0.50
		240 - 259	0.65		0.50
		260 - 279	0.61		0.50
		280 - 299	0.56		0.50
	Numbness	300 - 365	0.55		0.50

DAT: days after transplantation.

Table 5. Cultivation coefficients (Kc) of the main fruit species of Northeast Brazil [1]

Culture	Phenological stages	DAT	Kc	Source	Kc (FAO-56)
Banana	Vegetative Growth	0 - 100	0.85	Silva and Bezerra (2009) Pentecost- CE	0.50
	Flowering - Fruiting	101 - (onward)	1.00		1.00 - 1.10
Coconut	Vegetative development I	0 - 365	0.65	Miranda *et al.* (2007) Paraipaba - CE	0.70
	Vegetative development II	366 - 731	0.85		0.70
	Flowering and fruit development	732 - (onward)	1.00		0.70
Guava	Budding and vegetative growth	0 - 62	0.76	Teixeira *et al* . (2003) Petrolina - PE	0.45
	Vegetative growth and flowering	63 - 77	0.81		0.90
	Physiological fall of fruits	78 - 110	0.85		0.90
	Fruit growth	111 - 174	0.80		0.90
	Fruit ripening and harvesting	175 - 203	0.75		0.65
Mango	Vegetative growth	0 - 191	0.88	Silva *et al* . (2019) Petrolina - PE	0.70
	Flowering	192 - 227	0.84		0.70
	Fruit fall	228 - 285	0.81		0.70
	Fruit formation and maturation	286 – 345	0.73		0.70
Orange	-	0 – 145	0.30	Silva (2019) Rio Largo - AL	0.70
	-	146 – 176	0.31		0.65
	-	177 – 207	0.41		0.70
	-	208 – 238	1.28		0.70
	-	239 - 269	1.18		0.70
	-	270 - 300	1.12		0.70
	-	301 – (onward)	1.22		0.70
Grape	-	0 - 30	0.25	(2006) São Francisco River Basin	0.30
	-	31 - 61	0.50		0.85
	-	62 - 72	0.60		0.85
	-	73 - 103	0.90		0.45
	-	104 - 124	0.60		0.45
	-	125 - 150	0.90		0.45
	-	151 - 166	0.60		0.45

[1] DAT: days after transplantation.

The discrepancy between the crop coefficients (Kc) obtained in Northeast Brazil and the values recommended by FAO-56 can be explained by several interconnected factors, which reflect the environmental, agronomic and methodological particularities of the region. The Northeast Region of Brazil, characterized by a predominantly semiarid climate, presents high rainfall variability, high temperatures and significant evapotranspiration rates (Santos; Cunha; Ribeiro-Neto, 2019).

These conditions contrast with those considered in the studies that underpinned the FAO-56 coefficients, which were developed for more stable and moderate climates, often in temperate regions or regions with greater water availability. As a consequence, locally determined Kc values in Northeast China tend to diverge from international standards, highlighting the need for adjustments to meet the particularities of the region (Lorenzoni *et al*., 2019).

Furthermore, the physiological characteristics of crops growing in Northeast China influence these variations. Agricultural species such as cassava and cowpea present specific adaptations to the semiarid climate, such as greater tolerance to drought and adjustments in the phenological cycle (Silva *et al*., 2021; Vieira *et al*., 2024).

The methodology adopted to determine crop coefficients also plays a relevant role. In Northeast China, local studies often use approaches that consider real crop conditions, including direct measurements of evapotranspiration and water balance in the field. These methods allow a more accurate assessment of the interaction between crops and the environment, resulting in crop coefficients that are more aligned with regional reality.

6 CONCLUSIONS

Gaps were identified in terms of crops of regional agroeconomic importance in which information about Kcs is not yet available and/or is outdated, especially for the fruit species acerola and guava, as well as forage plant species, which points to the need for the development of basic and applied research on the themes in the Northeast Region.

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