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Efficient use of water in sweet chili pepper farming (*Capsicum spp.)* from department of Sucre, Colombia

Uso eficiente del agua en el cultivo de ají dulce (*Capsicum spp.*) en el departamento de Sucre, Colombia

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Abstract

Development and production indicators from a Sweet Chili Peper plantation (*Capsicum spp.*) were evaluated for a 200-day cycle after transplanting (DAT), under effect of four water doses (2.0; 2.6; 3,2 and 4,0 L.plant^{-1}.day^{-1}) in Corozal municipality, Sucre Department, Colombia. The experiment was carried out from August 2017 to March 2018, with a completely randomized design, with four replications. The applied water doses had an effect on all variables evaluated in the climatic conditions of the study area. Plants irrigated with highest doses registered better responses in the production variables; but use of the lowest doses exceeded productive average of crops without irrigation.
Key words: water deficit, sweet chili pepper, dry matter, water dose

Resumen

Se evaluaron los indicadores de desarrollo y producción de un cultivo de Ají Dulce (*Capsicum spp.*), para un ciclo de 200 días después del trasplante (DDT), bajo el efecto de cuatro dosis de agua (2,0; 2,6; 3,2 y 4,0 L.planta^{-1}.día^{-1}) en el municipio de Corozal, departamento de Sucre, Colombia. El experimento se llevó a cabo entre los meses de agosto de 2017 a marzo de 2018, con un diseño completamente al azar, con cuatro repeticiones. Las dosis de agua aplicadas tuvieron efecto sobre todas las variables evaluadas en las condiciones climáticas de la zona de estudio. Las plantas irrigadas con las dosis más altas registraron mejores respuestas en las variables de producción; pero el uso de las menores dosis superó el promedio productivo de cultivos sin riego.
Palabras clave: déficit hídrico, ají dulce, materia seca, dosis de agua.

1. Introduction

Sweet Chili Pepper is the most important edible nightshade for seasoning after potatoes and tomatoes. It has a nutritional value, made up of high content of vitamins A and C; which, along to a pleasant flavor, make this vegetable a valuable and essential ingredient in food preparation in many countries around the world. In Colombia, in 2007, Sweet Chili Pepper farming presented an area of 95 hectares with a production of 810 tons; with a notable rise in 2010, with 247 planted hectares and a production of 1,824 tons. In 2014, 850 hectares

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were planted with a production of 6,315.5 tons; indicating an increasing trend of planted area; thus, being necessary to improve average production, equal to 7.53 tons.ha^{-1}, through technical assistance and technologies such as use of quality seeds, fertilization and irrigation (Casseres, 1981; Medina et al., 2006; AGRONET, 2014).

To meet growing demand for Sweet Chili Pepper in Colombia, the efficient use of water strategy can be used through controlled deficit irrigation (CDI) without significant reductions in production. This is an alternative to the current water shortage in some regions of the country, since it allows water savings close to 40% with localized high-frequency irrigation.

When there are no optimal humidity limits for plants' metabolic and physiological processes, water stress is caused, affecting cell growth, photosynthetic and respiratory rates, and consequently biomass production. In this sense, one of the determining factors for agricultural development is water supply, being drip irrigation, the most efficient system to guarantee a good production, because it supplies the bulks of water required by the crop, gives security to the production in drought seasons, and fertilizer application can be done with the irrigation (Sánchez et al., 2003; Sánchez et al., 2004; Aguilera, 2005; Lambers et al., 2008; Gómez et al., 2010; González et al., 2011; Padrón et al., 2014).

This research aims to establish the minimum water requirement for profitable and competitive production of Sweet Chili Pepper (*Capsicum spp*.) in the dry season in the Sucre department in Colombia.

2. Materials and Methods

2.1. Study location

The experiment took place in the municipality of Corozal, Sucre, Colombia, located at 9°19'01" North Latitude and 75°17'36" West Longitude, at a height of 174 masl, in an environment of tropical dry forest with climatic condition averages with a temperature of 29°C, 78% relative humidity and annual precipitation between 900 and 1200 mm (Aguilera, 2012).

2.2. Setting Up of the Research

A lot with the appropriate characteristics for the crop planting and irrigation was selected. Soil sampling was performed at a depth of 0-20 cm, for the respective physical and chemical analysis to adequately establish tillage and fertilization. Water samples were taken to determine quality for agricultural use and a drip irrigation system was designed and installed. Seed beds were made *in situ* and transplanted 30 days after germination. A tensiometer was installed to each treatment to measure soil humidity.

2.3. Experimental Design

The study was developed under a completely randomized experimental design (CRD) with four treatments equivalent to consumptive uses with values of crop coefficient (Kc) of 0.50; 0.65; 0.80 and 1.00 daily applied to a Sweet Chili Pepper plantation, Topito variety (*Capsicum spp*.); by means of a drip irrigation system with four repetitions each, for a total of 16 experimental units (EU). Each EU with 85 plants, sown at 0.8 m between plants and 1.0m between rows; for a total of 1,360 plants and an area of 1,100 m^2. Data obtained was tabulated in Excel, version 2016. An analysis of variance (ANOVA) and comparison of means, according to Tukey method, were performed with a 0.05 significance using SAS software version 9.1.

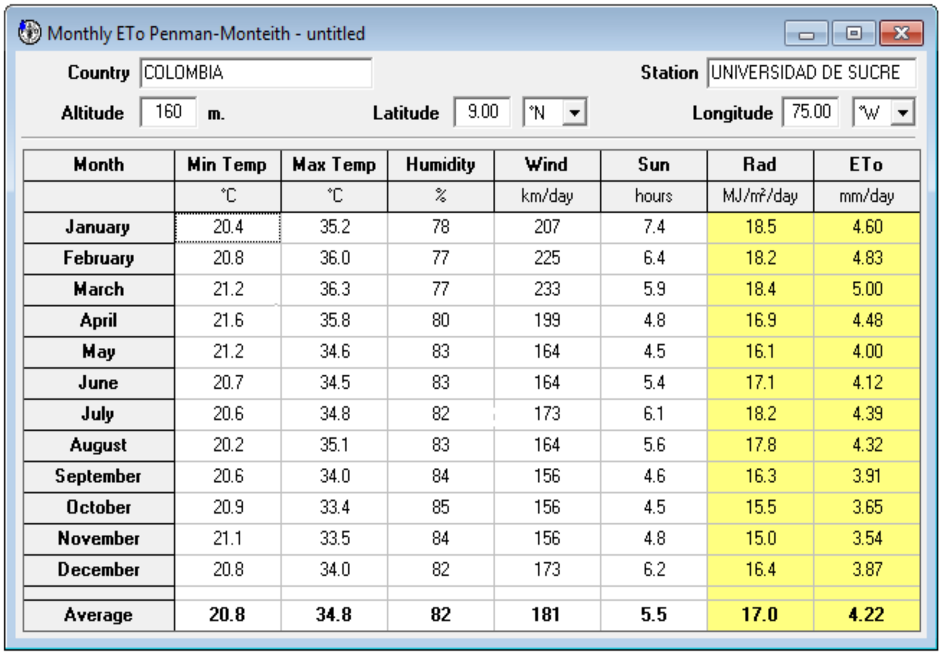
2.4. Estimation of irrigation doses

The irrigation sheet for each treatment (dose) was estimated according to the consumptive use equation (CU), which is derived from the product of the crop coefficient (Kc) and the evapotranspiration of a reference crop under optimal humidity conditions. (ETo).

$$UC = K_c * ET_o(\frac{mm}{day}) \qquad (1)$$

According to FAO (1990), Palencia et al. (2006), Da Cunha et al. (2014) and Vergara et al. (2017), ET_o was estimated using the Penman-Monteith equation because it is the most used and reliable method. The CROPWAT 8.0 free version software was used for estimating procedure with multi-year monthly average information of the study area referring to maximum and minimum temperatures (°C), relative humidity (%), wind speed (Km day^{-1}) and insolation (h) supplied by the Institute of Hydrology, Meteorology and Environmental Studies of Colombia (IDEAM, 2017). The estimated values of radiation and ETo are presented in Figure 1.

Figure 1
Estimation of radiation and ETo
using CROPWAT 8.0 FAO Software



Monthly ETo Penman-Monteith - untitled

Country COLOMBIA Station UNIVERSIDAD DE SUCRE
Altitude 160 m. Latitude 9.00 °N Longitude 75.00 °W

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	20.4	35.2	78	207	7.4	18.5	4.60
February	20.8	36.0	77	225	6.4	18.2	4.83
March	21.2	36.3	77	233	5.9	18.4	5.00
April	21.6	35.8	80	199	4.8	16.9	4.48
May	21.2	34.6	83	164	4.5	16.1	4.00
June	20.7	34.5	83	164	5.4	17.1	4.12
July	20.6	34.8	82	173	6.1	18.2	4.39
August	20.2	35.1	83	164	5.6	17.8	4.32
September	20.6	34.0	84	156	4.6	16.3	3.91
October	20.9	33.4	85	156	4.5	15.5	3.65
November	21.1	33.5	84	156	4.8	15.0	3.54
December	20.8	34.0	82	173	6.2	16.4	3.87
Average	**20.8**	**34.8**	**82**	**181**	**5.5**	**17.0**	**4.22**

Source: The Authors

Table 1 shows the treatments, corresponding to the applied irrigation doses, estimated with the maximum evapotranspiration (5 mm day^{-1}) and the proposed Kc values.

Table 1
Treatments estimated from maximum ETo

Treatments	Kc	Eto (mm.day^{-1})	CU (mm.day^{-1})	Dose (L.$plant^{-1}$.day^{-1})
T1	0,50	5,0	2,5	2,0
T2	0,65	5,0	3,3	2,6
T3	0,80	5,0	4,0	3,2
T4	1,00	5,0	5,0	4,0

Source: The Authors

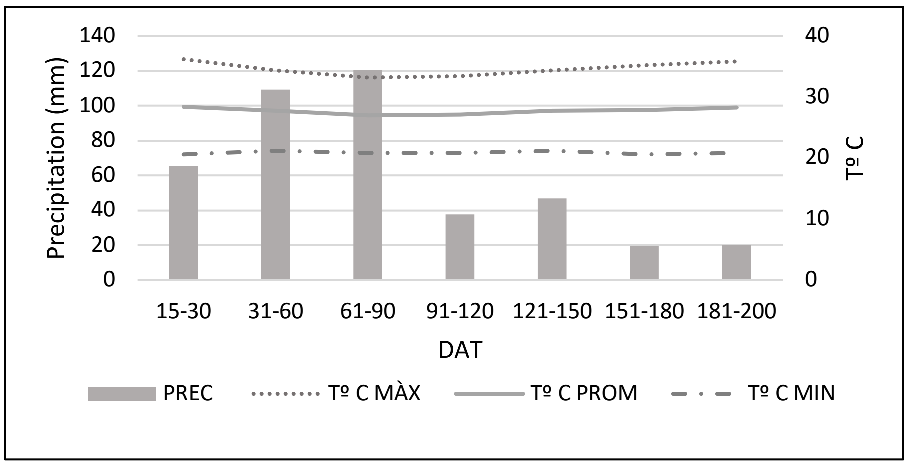
2.4. Development and production variables

Useful plants located in the center of the experimental units were selected for measuring fresh and dry leaf, stem, root and fruit biomass, through precision weighing and dehydration in ovens at 70°C for 72 hours. Variables of fresh and dry biomass of leaves, stems and roots were carried out following the methodology of Jaimez (2000), taking 6 plants per experimental unit at 30, 60, 90, 120, 160 and 190 days after transplanting (DAT). For the fruits, 9 plants were selected from the start of production to 200 DAT.

3. Results and Discussion

During the 200 days after transplanting (DAT) the crop in the study area, there was an accumulated precipitation of 472 mm, lower than that reported by Sánchez et al. (2003), who found the best water dose for development and production variables, a water requirement of 714.3 mm for a crop cycle of 160 DAT. Therefore, the Sweet Chili Pepper plants, under the meteorological conditions of the study area, would not have obtained sufficient humidity to properly carry out physiological processes. Figure 2 presents distribution of precipitation and temperatures of the test site, showing that 68.6% of the precipitation occurred in the first 75 DAT, corresponding to the crop establishment and vegetative phase; with irregular distribution, which would intensify the effects of lack of water in case of having an irrigation system. Variability of rainfall in this area in the registration period agrees with the reports of Aguilera (2005) in previous years.

Figure 2
Precipitation and temperature during development of the Sweet Chili Pepper crop after transplanting (DAT) in Corozal, Sucre



Source: The Authors

Physical and chemical properties of the soil where the test was carried out, are presented in Table 2. Considering the soil physical properties, especially its high apparent density, the soil was mechanized in such a way that it allowed water infiltration, to which a disc plow pass and two rake passes were performed. Regarding chemical component of the soil, a general fertilization was carried out on the crop with 180 $kg.ha^{-1}$ of N, 60 $kg.ha^{-1}$ of P and 160 $kg.ha^{-1}$ of K.

Table 2
Physical-chemical properties of the test soil

Property	Unit	Value	Property	Unit	Value
pH	1:1, P/V	6,48	Ca	$Cmol.kg^{-1}$	28,60
OM	%	2,01	Mg	$Cmol.kg^{-1}$	12,20
C.E.C	$Cmol.kg^{-1}$	41,40	Na	$Cmol.kg^{-1}$	0,09
Texture	-	Clayey	Cu	$mg.kg^{-1}$	0,20
Bd	$(g.cm^{-3})$	1,92	Fe	$mg.kg^{-1}$	6,00
P	$mg.kg^{-1}$	15,80	Zn	$mg.kg^{-1}$	0,50
S	$mg.kg^{-1}$	4,80	Mn	$mg.kg^{-1}$	29,60
K	$Cmol.kg^{-1}$	0,47	B	$mg.kg^{-1}$	0,20

OM: Organic M; Bd: Bulk density; CEC: Cation Exchange Capacity

Source: The Authors

3.1. Biomass Accumulation

The analysis of variance carried out indicates that there is an effect of the applied water doses on accumulation of dry matter of leaves, stems, roots and fruits of the Sweet Chili Pepper crop. According to Salisbury & Ross (2000); Azcón-Bieto & Talón, (2008) and Taiz & Zeiger, (2010); these results are because plant growth is a complex and irreversible physiological process in terms of dry matter increase as a function of time, involving cell division, expansion and differentiation, under conditions of adequate supply of water and nutrient.

At 60 DAT, there was a difference in the response of the dry matter of the leaf, root and fruit to the applied water doses; while for stem, the differentiation started from 90 DAT. The 4.0 L. plant^{-1}.dia^{-1} irrigation dose presented the best results in dry matter of leaves, stems and roots with 78.7g, 116.4g and 60.2g, respectively, while the 2.0 L.plant.day^{-1} dose irrigation obtained the lowest values. Possibly the found results are because plants with a higher dose of applied water have a better capacity for absorbing nutrients, increasing growth and therefore presenting a greater reserve of photoassimilates; which agrees with the reported by Álvarez et al. (2010) in Romero plants. On the other hand, low water content decreases photosynthesis, delays transport of nutrients and water; with the respective negative effect on production, corroborated by Prieto et al. (2010) in his research of hydric states in vine cultivation. According to the above and Tadeo (2000), importance of adequate water supply is highlighted, since it is one of the limiting factors of plant biomass production, and it has been proven that there is a direct relationship of water availability and conversion of fresh matter to dry matter.

In full agreement with Viloria et al. (1998); Núñez et al. (2005) and Baracaldo et al. (2014), it can be affirmed that production of dry matter in the aerial part of the plant is highly related to interception of photosynthetically active radiation, where as the availability of water in the soil decreases, translocation of carbohydrates increases to the root. Meanwhile, excess water causes stress to the roots, generating greater synthesis of ethylene and less supply of phytoregulators such as cytokinins and gibberellins to the stem, decreasing its longitudinal growth and biomass accumulation, affecting adsorption, nutrient transport and production. Variation of fruit dry matter depends on the dry matter from the roots. Given the existence of more roots, absorption capacity of water and nutrients, increases; raising the capacity for fruit development.

3.2. Dry Matter Trend

Table 3 shows the trend of variables of dry matter accumulation with application of 2.0; 2.6; 3,2 and 4,0 L.plant^{-1}.day^{-1} water doses, observing that the best adjustment corresponds to a quadratic polynomial model with the form $Y = Y_0 + AX + BX^2$. Results show that at 60 DAT, there are no differences between applied water doses and biomass distribution in the different plant organs; but between 90 and 160 DAT, fruits show a higher percentage of dry biomass, with the consequent decrease in leaf and root.

Table 3
Parameters of the trend regression equations of dry mass b
ehavior in Sweet Chili Pepper in Corozal, Sucre, Colombia

	LDM	SDM	RDM	FDM
Y_0	5,42	-41,20	48,34	26,70
A	9,07	55,08	-17,28	3,20
B	1,06	-4,74	3,95	0,26
R^2	0,990	0,994	0,996	0,774

LDM: leaf dry matter; SDM: Stem dry matter; RDM: root dry matter, FDM: fruit dry matter

Source: The Authors

3.2. Effect on production indicators

According to Table 4, a significant effect (P ≤ 0.05) was observed in the variables: yield of fresh fruit, number of fruits per plant (NFP) and frui dry matter (FDM); which indicates the influence in said variables of the water doses applied to the Sweet Chili Pepper crop (*Capsicum spp*.). These results coincide with the research of Sánchez et al. (2003); Quintal et al. (2012); Gunawardena & De Silva (2014) and Montes (2017), which found a significant effect when different water doses are applied to Sweet Chili Pepper plants; increasing performance with increasing water doses.

Table 4
Effect of four water doses in Sweet Chili Pepper, Topito variety (*Capcicum spp*.), on the productive indicators at 200 DDT

Variation Source	Components		
	Yield	NFP	FDM
Model	131420595,6*	25279,59500*	4676898,922*
Error	574951,8	245,95500	119.113
R^2	0,995644	0,990364	0,975164
CV	1,866453	1,932051	4,058

*: Significant Effect (according to Tukey p < 0,05); R^2: Determination Coefficient ; CV = Coefficient of variance.

Source: The Authors

Table 5 shows the productive indicators of Sweet Chili Pepper Topito variety (*Capsicum spp*.) With the application of different doses of water; noting that the highest yields, number and fruit dry mass per plant in descending order, were presented with doses of 4.0; 3.2; 2.6 and 2.0 $L.plant^{-1}.day^{-1}$. These results are because the soil is kept in adequate humidity, the absorption of water and nutrients by the root represents less energy expenditure, and thus, production increases; which agrees with the research from Sánchez et al. (2003).

Table 5
Effect of the four water doses on the production of Sweet Chili Pepper, Topito variety (Capcicum spp.), at 200 DAT

Water Dose ($L.planta^{-1}.día^{-1}$)	Production Indicators		
	Yield ($Kg.ha^{-1}$)	NFP ($Frutos.planta^{-1}$)	FDM ($Kg.ha^{-1}$)
4,0	15848,2 A	291,375 A	3238,95 A
3,2	12548,3 B	244,825 B	2569,50 B
2,6	10480,3 C	218,900 C	2269,78 C
2,0	8033,5 D	182,200 D	1742,80 D

Values with the same letter in the columns represent non-significant statistical differences.

Source: The Authors

Total average yield of Sweet Chili Pepper, Topito variety with a 4 $L.plant^{-1}.day^{-1}$ dose was 11,636 $kg.ha^{-1}$ for a 160 day crop cycle, equivalent to a 72.73 $kg.ha^{-1}.day^{-1}$ productive ratio, whereas Sánchez et al. (2003), reported for the same cycle and dose, 9,856 $kg.ha^{-1}$ with a 61.6 $kg.day^{-1}$ ratio, a value lower than that obtained in this research.

3.3. Trend of production indicators

Table 6 shows the trends of the variables: yield, number of fruits per plant (NFP) and fruit dry matter (FDM) with respect to the application of irrigation doses of 2.0; 2.6; 3.2 and 4.0 $L.plant^{-1}.day^{-1}$, which best adjustment was a linear model with form $Y = A + BX$; indicating the rise of the variables when increasing water doses applied in a growing cycle of Sweet Chili Pepper, Topito variety of 200 DAT.

Table 6
Parameters of the trend regression equations
from the behavior of production indicators

$Y = A + BX$	Yield	NFP	FDM
A	307,74	76,12	309,18
B	3096,902	42,9	581,99
R^2	0,995	0,987	0,9667

Source: The Authors

4. Conclusions

Highest yields of fresh fruits, number of fruits per plant and dry matter of fruits in the Sweet Chili Pepper plants, Topito variety, were obtained with the 4.0 $L.plant^{-1}\ day^{-1}$ dose whereas the lowest yields of fresh fruit, number of fruits per plant and dry matter of fruits in the Sweet Chili Pepper plants, Topito variety, were obtained with the dose of 2.0 $L.plant^{-1}.day^{-1}$. Nonetheless, indicators of the production variables determined with the application of water doses of 3.2 and 2.6 $L.plant^{-1}\ day^{-1}$, are higher than the national average for this crop. Therefore, the controlled deficit irrigation with applications in this range, is a good alternative of efficient water use for growers of Sweet Chili Pepper, Topito variety in the Corozal municipality in Sucre, Colombia.

As the water dose increased, the variables: dry mass of leaves, stems, roots and fruits; yield of fresh fruits; number of fruits per plant; and production of dry matter of fruits; significantly increased as well.

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