Article

Dates of transplantation and productivity of habanero pepper with drip irrigation

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Abstract

The effect of the date of transplant on the production of habanero pepper and the efficient use of irrigation water (UEA) was quantified and the profitability of the production was determined under drip irrigation and plastic cover conditions. The work was carried out in the municipality of Huimanguillo, Tabasco in a Fluvisol eutric soil. The Orange variety was used in five transplant dates: 1) September 17, 2014, 2) September 30, 2014, 3) December 23, 2014, 4) January 10, 2015 and 5) February 12, 2015. Four validation plots were established in the PV-2016 cycle. The transplant was performed 45 days after emergence of the seedlings in trays, with a density of 13 400 plants ha^{-1}. The irrigation was applied based on crop evapotranspiration ($ETc=ET_0$ Kc) where the reference evapotranspiration (ET_0) was estimated with the “A” type evaporimeter tank. The following culture coefficients (Kc) were used: 0.4, 0.8 and 0.7 in the initial, intermediate and final stages of crop development, respectively. It is concluded that the dates of transplantation from September 17 to February 12 have a similar effect on fruit yield except for the date of January 10, affected by *Phytophthora capsici*. As for the UEA, the date of transplantation of September 30 increased 16.5% with respect to February 12 and 33.7% with respect to January 10. The yield of the crop was higher on the dates of December and February, obtaining a cost benefit ratio of 3.1 and 3.5, respectively.

Keywords: *Capsicum chinense*, *Phytophthora capsici*, efficient use of water, irrigation sheet.

Reception date: December 2017
Acceptance date: January 2018

Introduction

Agricultural production requires the continuous improvement of irrigation practices and fundamental changes in the application of irrigation water saving methods. Drip irrigation in horticultural crops is the simplest and most efficient method of supplying water and fertilizers in the root zone of plants.

Habanero peppers in southeastern Mexico are cultivated in rainy season conditions, residual humidity and drip irrigation. Among the main problems that occur in the cultivation of habanero pepper are the damages caused by the whitefly (*Bemisia tabaci*) and the white mite (*Polyphagotarsonemus latus*), which significantly reduce the yield of the crop. The date of transplantation affects the growth and development of green pepper crops (Hamma *et al*., 2012), in the infestation and control of pests and diseases (Sujay and Giraddi, 2014) and in the commercialization of the products for the market regional and national and as a consequence in the production of the crop and in the efficient use of irrigation water. Hamma *et al*. (2012) found significant differences in dates of transplant from August to October in sweet pepper fruit yield in two continuous years of evaluation.

The efficient use of water (UEA) is expressed as the yield of green fruit per unit volume or per unit of evapotranspiration (UEA_{ET}). The UEA in agricultural crops is usually based on the water sheet applied, therefore, it can be expressed in kg m^{-3}.

Most studies on the effect of irrigation on the yield of green pepper and on the efficient use of irrigation water are limited to subhumid or arid climatic zones. Several researchers have shown that under conditions of water stress or water deficit treatments, the yield of green pepper and the UEA is reduced (González-Dugo *et al*., 2007; Sezen *et al*., 2014; Cosic *et al*., 2015), compared to treatments without water stress. However, Ashrafuzzaman *et al*. (2011) showed that with plastic cover and water deficit the highest UEA (3.5 kg m^{-3}) was obtained and was significantly better than in bare soil and irrigation treatment based on crop evapotranspiration (3.1 kg m^{-3}) and treatment with water stress (2.3 kg $m^{-3)}$.

Sezen *et al*. (2006) studied the effect of the leaf and frequency of irrigation in the UEA and on the yield of chili pepper (*C. annuum* L.). The maximum yield was 33.14 to 35.3 t ha^{-1} with a cultivation coefficient (Kc)= 1. The results indicated that the UEA values decreased with the increase of the irrigation intervals, however, lower Kc values decreased the total yield and fruits of lower quality were obtained. The aforementioned authors suggest that in the initial stage, the Kc values are less than 1 in order to save water. Yildirim *et al*. (2012) concluded that pepper pepper cultivation should be irrigated at 7-day intervals from planting to 40-50 days after transplanting. From this date, it should be reduced to 4 days, since during the periods of flowering and formation of fruits of chili are more sensitive to deficit or water stress.

Nagaz *et al*. (2012) found lower values of water productivity in the cultivation of pepper (*Capsicum annuum* L.), between 2.31 and 5.49 kg m^{-3}, which varied according to irrigation sheets applied with different irrigation deficit equivalents of 394 at 750 mm. Karam *et al*. (2009) concluded that by drip irrigation with 80% of the ETc, higher fruit yields (31.9 t ha^{-1}) were obtained in the pepper crop (*C. annum* L.) and greater optimization of the UEA from a 427 mm irrigation blade in a dry climate.

It has been shown that drip irrigation increases UEA, providing the right conditions for optimal plant development and increased productivity. However, beyond the effective control of the volume applied to irrigation, it is essential to adopt mechanisms that promote greater efficiency in the use of water, such as water retention capacity in the soil, increased infiltration and reduction of evaporation and surface runoff. The reduction of water loss through evaporation can be achieved through the implementation of plastic covers, or with organic material of vegetable origin (Coelho *et al*., 2013). Paul *et al*. (2013) found that the system of drip irrigation without plastic cover increases the yield of chili peppers (*C. annum* L.) 28% with respect to surface irrigation. However, the same authors conclude that only the plastic cover increases the yield by 13% in the absence of drip irrigation.

The plastic mulch system is a viable alternative to increase the production of habanero pepper in tropical conditions, López-López *et al*. (2015), concluded that the combination of plastic cover and drip irrigation demonstrated its effectiveness both in terms of UEA and profitability. The application of irrigation sheets based on the evapotranspiration of the crop and the application of plastic cover along with the transplant date of January 30, the yield of habanero pepper 25.2% was increased and the water productivity 29.7% compared to the treatment without plastic padding and by 57.5% compared to the date of transplant February 15.

Irrigation and sowing date in habanero pepper are important, despite high rainfall for six to eight months of the year, in the southeast of Mexico requires supplementary irrigation to meet the needs of crop evapotranspiration, mainly in the months of February, March, April and May where rainfall is insufficient to maintain the water balance. The objectives of the present study were: i) to quantify the effect of the dates of transplant on the yield of habanero pepper, the efficient use of water with drip irrigation and plastic cover; ii) to determine the profitability and economic viability of the product in the regional market of the southeast of Mexico.

Materials and methods

Study area

The experiment was conducted in the town of Villa Flores 2nd section, municipality of Huimanguillo, Tabasco, during the autumn-winter cycle 2014-2015 and spring-summer 2015, located geographically at 17° 51’ 04” north latitude and 93° 23’ 47” west longitude and an altitude of 30 m. The validation was carried out from February to July 2016 in four towns belonging to the municipality of Huimanguillo, Tabasco: Ejidos Ostitan, The Porvenir, Paredón 2$^{nd.}$ section and Francisco J. Santa María. located geographically between 17° 36.23’ to 17° 45.37’ north latitude and 93° 27.15’ to 93° 31.22’ west longitude and an altitude between 45 and 60 m. The climate of the region is humid warm, the annual average precipitation is of 2 200 mm and presents two maximum periods of rain with a decrease interval in July and August.

Physical and chemical characteristics of the soil

The soil in which the experiment was conducted is classified as Fluvisol eutric with loamy clay texture, slightly acidic pH of 6.4, low content of organic matter (1.2%), medium in ammonium (10.6 cmol kg^{-1}), medium in phosphorus (15.2 mg kg^{-1}) and deficient in potassium (0.5 mg kg^{-1}), high in exchangeable calcium (16 mg kg^{-1}) but low cation exchange capacity. Based on the texture of the soil, at the depth of 0 to 20 cm, the apparent density (Da), field capacity (CC) and permanent wilting point (PMP) are 1.35 g cm^{-3}, 36 and 18%, respectively. In the validation stage, the physical and chemical characteristics of the soils that were used are presented in Table 1. The soils where the validation plots were established are frank to clayey texture, with acidic pH (Fco. J. Santa María common) up to slightly alkaline (Paredón $2^{nd.}$ Section common) from medium to high organic matter content, low in available phosphorus, high in calcium, potassium and magnesium content, except Fco. J. Santa María common.

Table 1. Physical-chemical properties of the soils of four localities of Huimanguillo, Tabasco used for the validation of habanero pepper production with drip irrigation Spring-Summer cycle, 2016.

Parameters	Units	Ej. El Porvenir $1^{ra.}$ Section	Ej. Paredón $2^{da.}$ Section	Ej. Fco. J. Santa María	Ej. Ostitán
Granulometry	--	Clay	Loam	Sandy-Loam	Loam
Clay	(%)	45	15	9	24
Slime	(%)	10	45	23	47
Sand	(%)	45	40	68	29
Electrical conductivity	µS cm^{-1} a 25 °C	< 70	116	71.7	< 70
pH	Extract 1/2.5	6.72	7.42	4.89	6.12
Organic matter	(%)	4.82	2.34	8.16	2.5
Nitrogen Dumas	mg kg^{-1}	2.98	1.54	3.23	1.62
Active limestone	(%) $CaCO_3$	< 0.5	0.8	< 0.5	< 0.5
Phosphorus available Olsen	mg kg^{-1}	5.46	< 1.37	4.21	12.9
Calcium available	meq 100 g^{-1}	22.9	15	0.32	14.6
Magnesium available	meq 100 g^{-1}	6.01	2.97	0.32	4.52
Potassium available	meq 100 g^{-1}	0.42	0.27	0.15	0.38
Sodium available	meq 100 g^{-1}	0.41	0.3	0.36	0.28
Iron (DTPA)	mg kg^{-1}	87.3	52.4	54.3	151
Manganese (DPTA)	mg kg^{-1}	16.8	14.4	3.52	28.2
Copper (DPTA)	mg kg^{-1}	2.8	4.15	0.75	5.13
Zinc (DPTA)	mg kg^{-1}	1.4	0.89	< 0.4	1.49
Ratio C/N		9.37	8.81	14.6	8.96

Production of seedlings in trays and density of plantation

The variety used was Orange (Geneseeds Company). The sowings were carried out from July to December 2014 in trays of 200 cavities. The substrate used for germination was peat moss plus vermiculite (1:1). Once the seeds were germinated on the sixth day, the seedlings were exposed to solar radiation in the nursery to avoid elongation of the stem. The seedlings were irrigated with a nutrient solution based on 13-40-13 (acafos violet) diluted 50% and applied by sprinkling and mono ammonium phosphate (12-61-00) by submersion of the trays before transplantation.

Land preparation, installation of irrigation tape and plastic cover

The preparation of the land consisted of a fallow with three steps of harrow. The sowing beds were made with a rim of two discs for the installation of the irrigation tape and the plastic cover in manual form. Once the seed beds were built and the irrigation tape was installed, the silver and black plastic cover with a width of 1.2 m was installed manually, for a 0.6 m bed, 2.3 mm caliber, with partial perforation, diameter of 6 cm and 50 cm between spacing.

Transplant

The transplant was performed 45 days after the emergence in the trays, the characteristics of the seedlings at the time of transplant were 0.1 m in height, 2 mm in diameter of the stem and six to eight true expanded leaves. The arrangement of the plantation in the field was 1.5 m between rows and 0.5 m between plants, for a population density of 13 400 plants per hectare.

Drip irrigation

The irrigation sheets were applied according to crop evapotranspiration (*ETc*), where the reference evapotranspiration (ET_0) was obtained by the "A" type evaporimeter tank method from equation 1.

$$ET_0 = Ev\ K_t \quad 1)$$

Where: *Ev* is the daily evaporation obtained in the tank of a meteorological station located in the Huimanguillo Experimental Field, K_t is the assumed tank coefficient equal to 0.8 (Doorenbos and Kasam 1986, Allen *et al*., 2006). The crop coefficients (K_c) used for habanero pepper with plastic cover were: 0.4, 0.8 and 0.7 in the initial, intermediate and final stages, respectively. With the K_c crop evapotranspiration (ET_C) was estimated according to equation (2).

$$ET_c = ET_0\ K_c \quad 2)$$

The uniformity efficiency (EU) of the drip irrigation obtained by the hydraulic evaluation by the Chistiansen method, varied between 81 to 88%. The nominal characteristics are: internal diameter of 16 mm, caliber 6 thousand (0.15 mm), flow of 1.02 L h^{-1}, space between emitters of 0.2 m, and pressure of 8 PSI (55.2 kPa).

Fertigation

The basic fertilization consisted in the application of 100 Kg of diammonium phosphate (DAP) equivalent to 18 kg of nitrogen and 46 kg of phosphorus before the transplant. The fertilization formula applied in the fertigation was 200-150-180, distributed according to the phenological stage of the crop (initial, intermediate and final). The sources of soluble fertilizers were: 8-24-00 liquid, nitrogen, phosphorus and potassium, respectively, monoammonium phosphate (12-61-00), potassium nitrate (13-00-46), calcium nitrate (13- 00-00-17), and 20% phosphoric acid. The frequency of application of fertigation was twice a week using a Venturi injector.

Control of pests and diseases

The control of pests and diseases was done by corn trap crops (*Zea mays* L.) planted on the lateral edges of the land and applications of insecticides based on cypermethrin and methamidophos at doses of 0.5 and L ha^{-1}, respectively. The white mite (*P. latus*) was treated with spirodiclofen (envidor® 240 SC) and abamectin (hortimec 1.8 and agriver 1.8% CE) in a dose of 18 g of ia. L^{-1} water (0.5 L ha^{-1}). The whitefly (*B. tabaci*) was combated by the rotation of insecticides based on imidacloprid (confidor) in doses of 0.5 L ha^{-1}, dinotefuran (venom 20 SG) at a rate of 0.5 kg ha^{-1}; pyriprosyfen (knack, 103 g L^{-1}), at a rate of 250 mL ha^{-1}, spiromesifen (oberon® 240 SC) and spirotetramat (movento® 150 g of ia.) at a rate of 0.5 L ha^{-1}. Organic products based on argemonin, berberine and ricinin were applied, such as biodie and neem extracts (nimicide 80) in a dose of L ha^{-1}, every 15 days during the harvest period.

The prevention of diseases was carried out with mixtures of carbendazin at the rate of 1 cc plus 2 cc of Propamocarb hydrochloride per liter of water. For the prevention of fungal and bacterial diseases, copper oxychloride plus terramycins (oxytetracyclines) were used. All chemical products were applied by spray with backpack pump in the doses recommended by the manufacturers. For the wilt of the plant caused by *Phytophthora capsici* Leonian, metalaxyl plus chlorothalonil (Ridomil Gold® Bravo SC) was applied in a dose of L ha^{-1} (40 + 400 g of ia. L^{-1}).

Harvest

The cuts were made when the fruits presented the crop indexes characteristic of the crop: intense green coloration and hard texture. The number of cuts was from seven to 15, which depended on the dates of transplant.

Treatments and experimental design

The treatments applied were five transplant dates: September 17 and 30 and December 23, 2014, January 10 and February 12, 2015. The treatments were analyzed in a completely randomized design, where five sub-samples taken at the same time were obtained. random in the experimental site by date of sowing, which consisted of three rows of five m in length (15 m^2), where the yield of green fruit per cut and the total was recorded. The experimental area by date of transplant was planted on an average surface of 4 500 m^2 to complete an area of 22 500 m^2.

Measured variables

The data of precipitation, evaporation and temperatures were obtained from the climatological station of the Experimental Field Huimanguillo. The yield of green fruit was obtained from the cuts made during the crop cycle; the direct expenses plus investment expenses and net income were obtained based on the average sale price of the product at the time of harvest. The efficient use of irrigation water (UEA) was defined as the yield of green fruit (Rf) obtained per unit volume of irrigation water (Vt) applied in kg m^{-3} applied from the transplant to the last cut or harvest, not included the precipitation occurred during the crop cycle.

$$UEA = \frac{Rf}{Vt} \quad 3)$$

The "watermark" probes to measure the matrix potential, whose measurement range is 0 to -200 kPa, were installed at the depths of 0.1 and 0.3 m in each treatment.

Statistical and economic analysis

Analysis of variance was made for green fruit yield and efficient use of irrigation water through the Statistical Analysis Systems program (SAS, 2009). The mean comparison of the treatments was performed with the Duncan test (α= 0.05). The economic analysis was carried out using the income analysis method for annual crops (Gittinger, 1985), projected at 10 years, considering an annual interest rate of 3.2%.

Validation stage

The validation work was carried out in four locations in the municipality of Huimanguillo, Tabasco: 1) Ostitan common; 2) The Porvenir common; 3) Paredon 2nd. section common; and 4) Francisco J. Santa Maria common, soils are classified as Fluvisol eutric. The Orange variety was used in transplant dates from February 15 to February 26, 2016, in an area of 0.5 hectare for each locality. The production technology (variety, plastic cover, irrigation sheets, fertirrigation and control of weeds, pests and diseases) was similar to that used in the experiment.

Results and discussion

Effect of transplant date on fruit yield and efficient use of irrigation water

In the Table 2 shows the irrigation sheet (mm), the precipitation in mm, the duration of the crop in days after the transplant and the number of cuts made per transplant date. It is observed (Table 2) that there are differences of these variables due to the effect of the transplant date, where the dates of the month of September show a cultivation duration of 207 to 220 days and therefore the number of cuts was increased (15) . The precipitation during the cycle of the crop was greater (between 1 456.2 to 1 557 mm) but due to the longer duration of the crop, the irrigation sheets increased from 240 to 252 mm. On the other hand, the dates of transplant from December to February, the duration of the crop was much lower (135 to 185 days) with rainfall between 425.9 to 835.6 mm, obtaining 7 to 12 cuts with irrigation sheets applied from 228 to 313 mm.

Table 2. Irrigation sheet, precipitation, duration of the crop and number of cuts by date of transplant.

Treatment	Watering foil (mm)	Precipitation (mm)	Duration of the crop (ddt)	Number of cuts
September 17th/14	252	1557	220	15
September 30th/14	240	1456.2	207	15
December 23th/14	313	835.6	185	12
January 10th/15	228	425.9	135	7
February 12th/15	277.5	561.9	149	11

ddt= days after transplant.

These irrigation sheets tend to increase because in these transplant dates, the crop cycle coincides with the driest months of the year (February to May) and the increase in temperatures increases the population of *B. tabaci*, which they reduce the yield and the quality of the habanero pepper fruit (López *et al*., 2015). It should be noted that during the stage of flowering and fruit development for the transplant dates of the month of December to February an extraordinary event occurred (April 27, 2015) with temperatures of 40 °C and evaporation of 10.9 mm (Figure 1), and also gusts of wind of 40.7 km h^{-1} (CONAGUA, 2015). This caused fall of flowers and small fruits in the crop, resulting in reduction of fruit yields in three intermediate cuts.

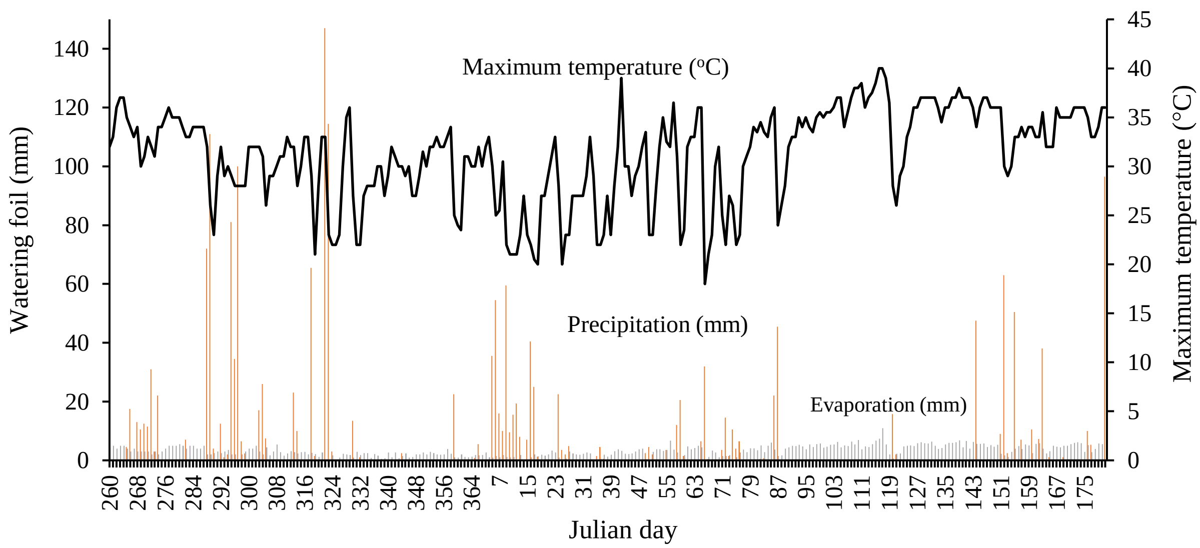

Figure 1. Precipitation in mm, evaporation in mm and maximum temperature (°C) recorded during the habanero pepper cycle in different dates of transplant.

The applied irrigation sheets varied between 1.5 to 6 mm per day, based on the calculation of the crop evapotranspiration and the plastic cover crop coefficients, used in the study, increased the efficient use of irrigation water on the dates of transplant of the month of September and as a consequence there was a water saving of approximately 18% compared to the crop coefficients proposed by Allen *et al*. (2006) for the cultivation of green pepper: 0.6 in the initial stage, 1.15 in the intermediate stage and 0.8 in the final stage.

The analysis of variances showed that transplant dates had a significant effect on fruit yield and water efficiency ($p \leq 0.05$). The comparison test of means by Duncan ($\alpha = 0.05$) indicates that the yield of fruits and the UEA, showed the highest values in the transplant dates of September 17 (19.1 t ha^{-1} and 7.6 kg m^{-3}) and September 30 (19.5 t ha^{-1} and 8.1 kg m^{-3}), from December 23 (18.9 t ha^{-1} and 6 t ha^{-1}) and from February 12 (18.8 t ha^{-1} and 6.8 kg m^{-3}), which were statistically equal to each other and significantly higher than the date of January 10, 2015 with yield of 12.3 t ha^{-1} and UEA of 5.4 kg m^{-3} (Table 3).

Table 3. Cumulative fruit yield and efficiency in the use of irrigation water for the transplant dates used in the cultivation of habanero pepper with drip irrigation and plastic cover.

Date of transplant	Fruit yield (kg ha^{-1})	Efficient use of irrigation water (kg m^{-3})
September 17th/14	19 160 a	7.603 ab[z]
September 30th/14	19 527.5 a	8.136 a
December 23th/14	18 863 ab	6.026 ab
January 10th/15	12 292 b	5.391 b
February 12th/15	18 857 a b	6.795 ab
Mean	17 855.3	6.828
Standard deviation	4 404.7	1.654

[z]= Values with the same letter within the column are the same according to Duncan ($p \leq 0.05$).

The low yield of the crop and UEA on the date of January 10 was because the crop was damaged by the wilt of the plant caused by the fungus *Phytophthora capsici* Leonian, reducing the duration of the crop in 135 days and obtaining only seven cuts. Sezen *et al*. (2014) reported that this disease affects the production of green chilies and found that *Fusarium* spp. has a relationship with water stress in red chilies, in treatments with greater water stress the incidence of these fungal diseases is higher. In this regard, López-López *et al*. (2015) reported that on transplant dates of January 30 and February 15, under conditions of drip irrigation and plastic cover, the yields and the UEA were similar.

Based on the green fruit yields obtained in the five treatments and the volume of irrigation water applied per unit area, the highest values of efficient water use were 7.6 kg m^{-3} for the date of September 17, 2014 and 8.1 kg m^{-3} for the date of September 30, 2014. The efficient use of irrigation water for the transplant date of January 10, 2015 obtained the lowest value of 5.39 kg m^{-3}; however, it was statistically equal to the dates of September 17, December 23, 2014 and February 12, 2015. Sezen *et al*. (2006) found in *C. annuum* maximum values of UEA of irrigation of 7.7 kg m^{-3} with 50% of ET_0 and minimum of 4.8 kg m^{-3} with 100% of ET_0. Hence the importance of applying irrigation sheets based on crop evapotranspiration to maximize yield and increase chili quality.

In the Figure 2 shows the effect of irrigation and precipitation on the matric potential at the depth of 0.15 and 0.3 m of the soil for the transplant date of February 12, in the layer of 0.15 m, the moisture tension varied from 0 to -50 kPa during the crop cycle, while in the 0.3 m layer, the moisture tension varied between 0 to -45 kPa. Soil moisture stress values indicate that the irrigation sheets applied to the crop and the rainfall that occurred, covered the water needs of the crop, without presenting symptoms of water stress, although there are values lower than field capacity (< -33 kPa) , these did not cause the plants to make a greater effort to absorb the water through their roots.

The soil matrix potential in the other transplant dates was very similar to the one presented in Figure 2, therefore it is confirmed that watermark humidity sensors provide accurate data in relatively humid soils under dynamic conditions of frequent wetting cycles and dried and in dry soil conditions (< -30 kPa). The measurements of the matric potential in the first 0.3 m of depth are a good indicator of the availability of water in the soil, and a useful tool for irrigation monitoring in the cultivation of habanero pepper.

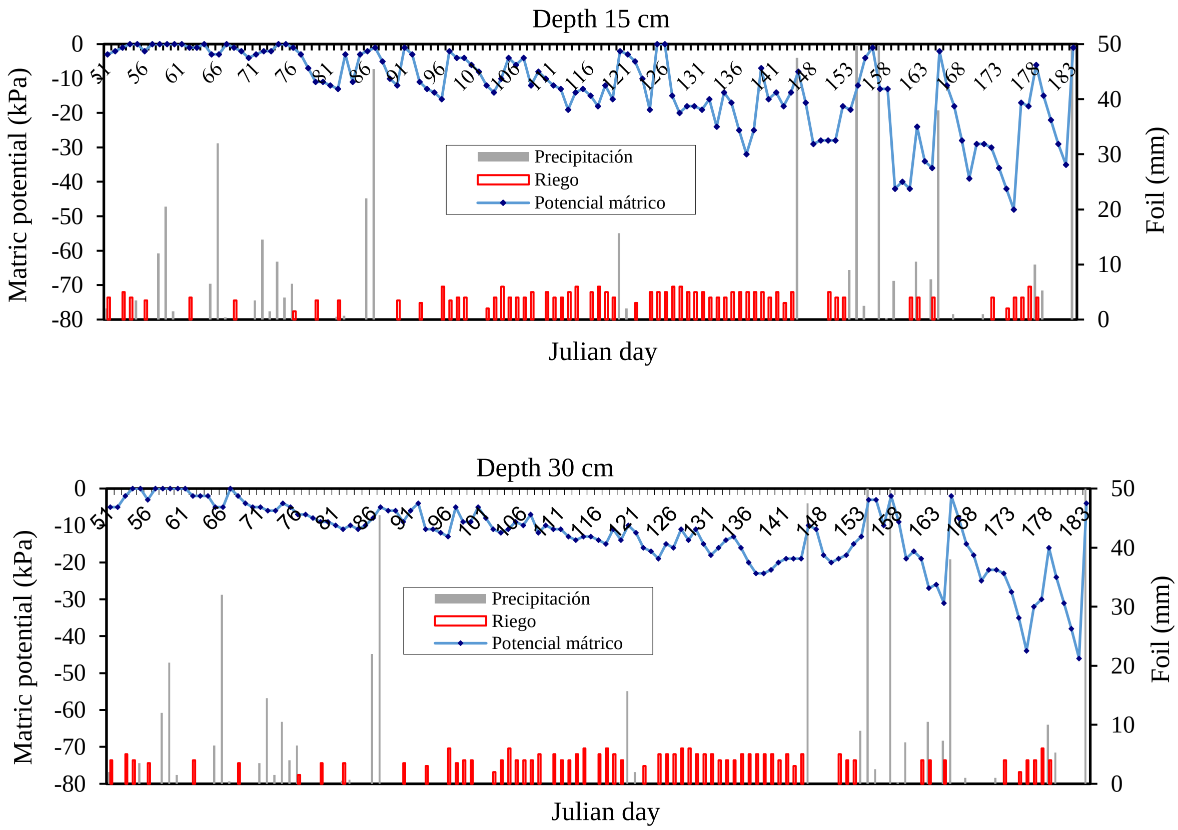

Figure 2. Effect of the irrigation sheet and precipitation on the matric potential of the soil for the transplant date of February 12 (Julian day = 43) at the depth of 0.15 and 0.3 m in the cultivation of habanero pepper with drip irrigation and plastic cover.

Economic analysis

The profitability analysis of the habanero pepper production system with drip irrigation and plastic cover, based on different transplant dates, is presented in Table 3. The direct costs of the crop were $82 950.00 per hectare, plus investment expenses of $35 000.00. The direct costs of the crop correspond to the practices carried out from the preparation of the land, production of seedlings in trays, fertirrigation, control of pests and diseases, until the harvest. The investment expenses consist in the construction of a deep well of 0.102 m in diameter and 18 m of depth, plus the acquisition of the drip irrigation system. The price of the fruit in the field was considered based on the supply and demand of the product in the regional market.

The economic analysis indicated that the crop presents a profitability from the first year, if an average yield of 19.3 t ha^{-1} and an average field price of \$15 00 kg^{-1} is considered. The cash flow is positive from the first year and the most attractive financial efficiency indicators are obtained, such as the net present value (VPN), the internal rate of return (TIR) and the cost benefit ratio (BC). The benefit-cost ratio varied mainly because of the average field price of the green fruit in the market. For the transplant dates of December 23 and February 12, the highest financial indicators were obtained, because the average price was \$24.75 kg^{-1} and \$28.3 kg^{-1}, respectively, with a minimum of \$15.00 kg^{-1} and a maximum of \$42.00 kg^{-1}.

For the September transplant dates, the lowest financial indicators were obtained: cost benefit ratio between 2.6 to 2.8, considering average prices of \$14.9 kg^{-1}. In this regard, López *et al*. (2015) found transplant dates of January 30, 2013 and February 15, 2013 differences in the benefit-cost ratio of 3.3 and 1.6, respectively, where the fruit yield on the transplant date of February 15 was mainly affected by white fly (*B. tabaci*). Paul *et al*. (2013) found in *C. annum* an increase of 54% of the cost benefit ratio of 2.4 with drip irrigation system and without plastic cover.

The profitability of habanero pepper was higher when it was transplanted in the month of February and December, since it reaches average prices in the field of \$ 28.30 kg^{-1} and \$ 24.75 kg^{-1} of green fruit, respectively. However, the yields may be more affected by the whitefly and the irrigation requirements are higher than the September transplant dates, which decreases the UEA. The results obtained in real terms are presented in Table 4.

Table 4. Profitability analysis of habanero pepper culture with drip irrigation and plastic cover in five dates of transplants.

Concept	Date of transplant				
	17-09-14	30-09-14	23-12-14	10-01-15	12-02-15
Internal rate of return (TIR)%	130.1	134.4	251.7	87.7	321.9
Net present value (VPN)	434 333.4	451 933.3	611 618.1	213 321.9	692 795.4
Cost benefit ratio (RBC)	2.476	2.523	3.123	2.02	3.516
VAN from the benefits	1 029 106	1 048 818	1 184 163	696 037	1 243 556
VAN from the costs	415 703	415 703	379 200	345 167	353 675

If the value of the production per m3 of water applied is considered, in terms of the VPN, the values vary from \$93.5 m^{-3} with the transplant date of January 10 to \$195.4 m^{-3} for the transplant date of the 23 from December. Fan *et al*. (2014) obtained for irrigation *C. annum* UEA of 3.01 kg m^{-3} and a production value per m^3 of water of \$5.7 m^{-3} (0.31 dollars m^{-3}). The results show the profitability of habanero pepper cultivation with drip irrigation systems, obtaining higher production values per unit volume of water applied.

Validation of the transplant date for the month of February

Table 5 shows the results of the validation, irrigation sheets, fruit yield and the efficient use of irrigation water. The duration of the crop was 145 to 155 days with rainfall between 518 and 546 mm. Although the duration of the crop is shortened by the high temperatures that occur on this date of transplant and by the damage caused by *B. tabaci*, the irrigation sheets are increased from 255 to 276 mm, these varied between 1.5 to 5.5 mm per day, based on the calculation of crop evapotranspiration and crop coefficients with plastic cover, used in the study. It should be noted that during the initial stage and flowering temperatures higher than 40 °C occurred with gusts of winds over 40 km h^{-1} (CONAGUA, 2016), causing flower fall in the crop, affecting fruit yields. The yield of fruits varied between 15.5 to 18.1 t ha^{-1} and the UEA was of 5.5 to 6.6 kg^{-3} with an average yield of 16.5 t ha^{-1} and average UEA of 6.1 kg m^{-3}. However, the average cost benefit ratio was 2.4, considering that the average price of the product was $25.00 kg^{-1}.

Table 5. Validation of the transplant date for the month of February for the production of habanero pepper with drip irrigation in four locations in the municipality of Huimanguillo, Tabasco.

Location	Duration of the crop (ddt)	Total watering sheet (mm)	Fruit yield (kg ha^{-1})	Efficient use of water (kg m^{-3})
Ej. Ostitán	150	270	15 502	5.74
Ej. El Porvenir	155	276	17 800	6.45
Ej. Paredón 2^da.^ sección	145	265	14 750	5.56
Ej. Fco. J. Sta. María	150	275	18 160	6.6
Promedio	150	271.5	16 553	6.09

ddt= days after the transplant.

Conclusions

The effect of transplant dates from September 17 to February 12 on the yield of habanero pepper fruit was similar except for the date of January 10 that was affected by the disease *Phytophthora capsici*. Regarding the efficient use of drip irrigation water with plastic cover, the transplant date of September 30 increased 16.5% with respect to February 12 and 33.7% with respect to January 10. The yield of the crop was higher on the dates of December and February, obtaining a cost benefit ratio of 3.1 and 3.5, respectively.

The validation plots with transplant dates for the month of February and the application of irrigation sheets based on crop evapotranspiration, showed that obtaining an average yield of 16.5 t ha^{-1} and a UEA of 6.1 kg m^{-3} is enough to achieve an attractive profitability for producers in the South-Southeast region of Mexico.

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