J. Agronomy & Crop Science **185**, 113—119 (2000)

ISSN 0931-2250

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Effects of Water Deficit on the Dynamics of Flowering and Fruit Production in *Capsicum chinense* Jacq in a Tropical Semiarid Region of Venezuela

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With 3 figures and 2 tables

Received November 20, 1998; accepted October 12, 1999

Abstract

The degree of crop sensitivity to water deficit, during the different developmental stages of a plant, is an important aspect to consider in tropical semiarid regions. The effect of water deficit on flowering dynamics and fruit production of sweet pepper (*Capsicum chinense*) was evaluated under several water regimes, during three consecutive years. A complete randomized block design with three replicates was employed. Flowering dynamics and fruit production were measured weekly, and water potentials were obtained twice during the experiments. For all years, flowering began at approximately 70 days after transplanting. In the most favourable year (trial 1996), there were no differences in total flower and fruit production in terms of irrigation frequency. For the other less favourable years, flowering and fruit production were significantly different between irrigation frequencies. Our results show that low water availability, prior to flowering, reduces the number of flowers produced and retards the occurrence of maximum flowering. On the other hand, a water deficit during the period between flowering and fruit development reduces final fruit production. This suggests that a water deficit during this last stage affects final yield to a greater extent.

Key words: capsicum — flowering — water stress — irrigation frequency — fruit production — tropical semiarid region

Introduction

The variability in the degree of crop sensitivity to water deficit, during the different developmental stages of a plant, has been thoroughly described in the literature. Plaut (1995) found a greater decrease in maize production (*Zea mays* L.) when the water deficit occurred during flowering and cob formation. On the other hand, Muchow (1989), working on the same crop, found a decrease in production when the deficit was produced during either vegetative or reproductive stages.

For soybean (*Glycine max* L.), most reports agree that water deficit notably diminishes production when it occurs just before or during flowering (DeBruyn et al. 1995, Choi et al. 1996). While in another legume, *Vigna radiata* L. Wilczek, lower productivity was obtained when water deficit occurred during grain formation (Ney et al. 1994). A slight decrease in tomato (*Lycopersicum esculentum* Mill.) yield was found independently of the moment of the water deficit.

Duration and severity of water deficits vary depending on climatic conditions of each location. In the case of tropical semiarid regions, the rainy season is defined by a large variability in the frequency and quantity of precipitation. This means that the degree of water deficit may change during any of the crop's phenological stages (Williams et al. 1985). In spite of the fact that many of these regions have irrigation systems, the frequency of watering decreases during the dry season due to lower water availability. Consequently, crop sowing is limited to the beginning of the rainy season. Little information exists on the relationship between the time of sowing, watering frequencies and crop productivity in tropical semiarid regions (Muchow 1989). An important aspect to consider is how the length of the periods of water deficit influences flowering dynamics and subsequent fruit production.

In this work, flowering dynamics and fruit production of sweet pepper, *Capsicum chinense* were evaluated under several water regimes. Different watering frequency treatments were applied during three consecutive years which showed different precipitation patterns in terms of quantity and moment of occurrence within the crop's developmental stages.

Materials and Methods

Three trials were carried out in the IIAP Experimental Station at San Juan de Lagunillas-ULA, Mérida State (8°31′N, 71°71′W), Venezuela, at an altitude of 1100 m.a.s.l. This is a semiarid region with a mean annual temperature of 22 °C and mean annual precipitation of 570 mm year^{-1} (data obtained from the Venezuelan Ministry of the Environmental and Renewable Natural Resources). According to USDA soil taxonomy of 1975, soils have been classified as typical Cambortid with an effective depth of 21 cm (Ochoa and Malagón 1979). The cultivar was denominated ANMB1: orange colour.

Seed sowing by hand was carried out on 30th September 1994, 29th November 1995 and 5th November 1996 in previously disinfected, completely exposed seed beds prepared with a mixture of sand and organic soil in equal amounts. Pest control and disease prevention measures were employed. For the first two trials, seedlings were transplanted to the field 69 days after sowing, and 73 days later for the last trial (8th December 1994, 7th February 1996 and 16th January 1997, respectively). Sowing distance was 40 cm between plants and 80 cm between arrays according to Suniaga (1980) and Añez and Figueredo (1993). During the initial 27 days, plants were irrigated using the furrow method (12 l m^{-2}) every two to three days. From this moment on, the different watering frequency treatments were started, maintaining the same quantity of water. Watering frequencies were at 3, 6 and 9 days in a complete randomized block design with three replicates. Just before watering, the plot soils had an available water content, determined with resistance cells, of 68–80 %, 35–45 % and 8–20 % of field capacity for 3, 6 and 9 day treatments, respectively.

Whenever there was a precipitation above 6 mm, the irrigation schedule was started again. Plants were fertilized 30 days after transplantation (DAT) with a 15–15–15 commercial NPK fertilizer equivalent to 95 kg ha^{-1} of N, P and K, then fertilized with 23 kg of N in the form of diamonium phosphate 45 and 65 days later and 200 kg of K in the form of K_2SO_4 at 65 days. Four plants were randomly marked from the central rows of each plot (12 for each treatment) and the number of open flowers were registered weekly. Fruits from plants in the central arrays, which had completely changed to an orange colour, were harvested every week and their fresh weight determined. Midday leaf water potentials (Ψ_L) were determined for each treatment (n = 3) using a pressure bomb. These measurements were carried out between 13:00 and 14:30 h, 60 and 120 DAT. Differences in production and total number of flowers were analysed by analysis of variance (ANOVA) and Duncan's test was used to compare the effect of watering frequencies.

Results

Even though the 1995 trial had the largest amount of precipitation, the rains began 40 days after flowering onset, with a frequency of 6–9 days thereafter (Fig. 1). For the 1996 trial, the period of rains began before the onset of flowering with a frequency between 3 and 6 days until the end of the trial. The 1997 trial had several days with precipitation during the period of flowering. However, within this period, there was a 50-day interval with very little rain (Fig. 1). Due to the characteristics of the three trials, we defined:a year with an uneven distribution of rains (trial 1995), which had several days with high precipitation (above 30 mm) and a total of 327 mm. Precipitation for preflowering and the flower-fruitset period were 5 and 50 mm, respectively;a year with early and evenly distributed rains (trial 1996) with a total of 314 mm throughout the 201 DAT. Precipitation for preflowering and the flower-fruitset period were 129 and 50 mm, respectively;a drier year (trial 1997), with a total precipitation of 239 mm. Precipitation for the preflowering and flower-fruitset period were 60 and 5 mm, respectively.

The irrigation supplied (12 l m^{-2}) compensated for the total potential evapotranspiration which occurs in approximately three days for this region (Mendez 1995). This means that if the crop depended only on irrigation, plants could be subjected to a slight degree of water stress with a 3-day watering frequency, increasing the degree of stress with the other watering frequencies. Minimum Ψ_L for the 3-day watering frequency was above -1.5 and -1.7 MPa at 60 and 120 DAT, respectively (Table 1).

For the 6-day frequency, minimum Ψ_L slightly decreased with the exception of a–1.9 MPa value observed at 120 DAT for the 1995 trial. Minimum Ψ_L was lowest for the 9-day watering frequency (Table 1). Variations were not noticeable at 120 days, for the 1996 trials, since rain frequency did not exceed 4–5 days.

Flowering began between 70 and 76 DAT for all trials (Fig. 2). A first maximum of flowers/plant was obtained between 83 and 93 DAT for the last two trials, while in the 1995 sowing, maximum flowering was delayed until 105 DAT. A second flowering maximum occurred a week earlier in the 1996 sowing (140 DAT) compared to the 1997 sowing (146 DAT). Approximately 55 days occurred between flowering maximums. For the 1995 sowing, a second flowering period had not appeared 160 DAT.

The number of flowers/plant decreased at lower wat-

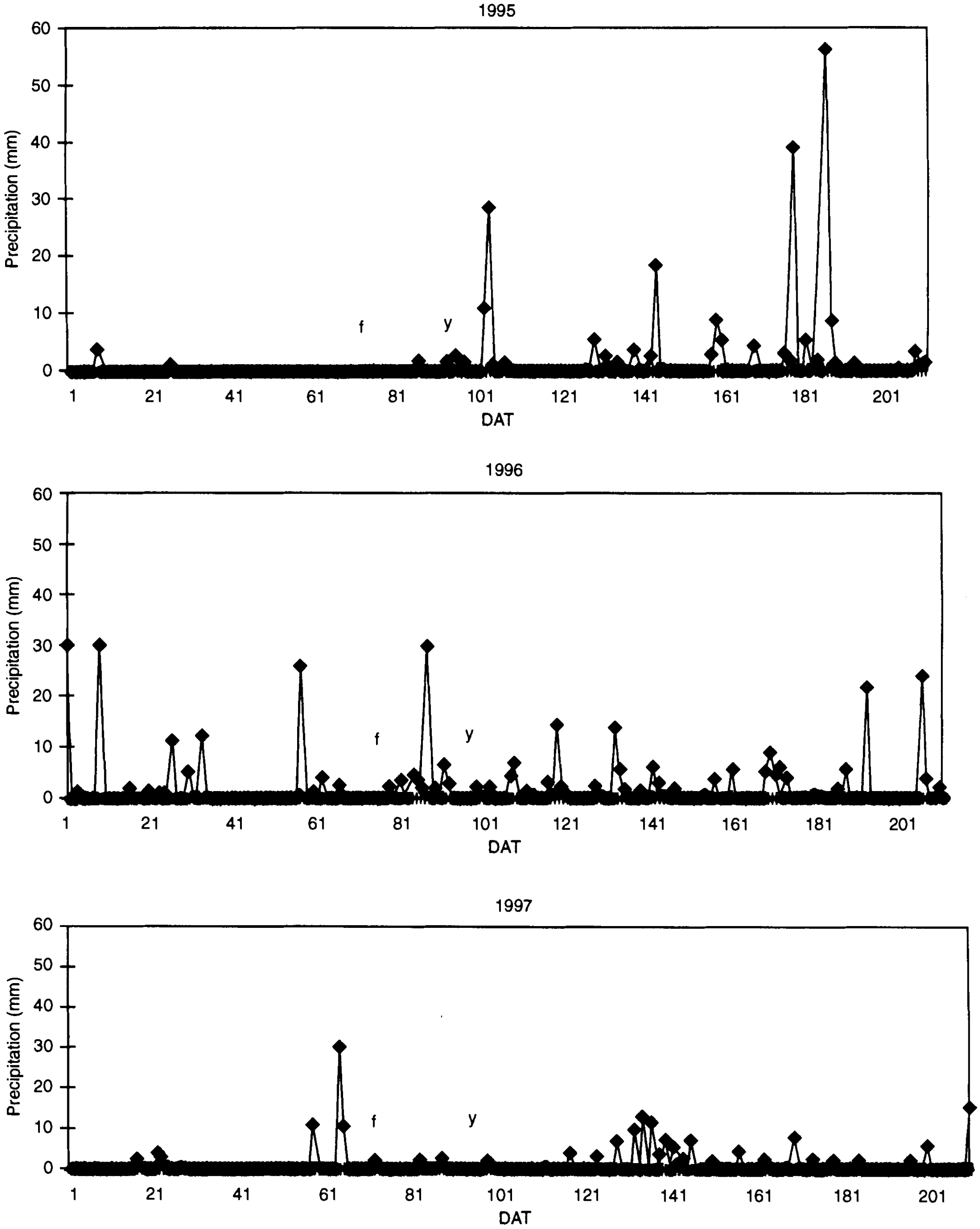

Fig. 1: Distribution of precipitation through the different crop cycles for the three sowing years. DAT (days after transplantion); f (flowering onset); y (fruit production onset)

Table 1: Leaf water potentials (MPa) at 60 and 120 DAT for *Capsicum chinense* during the three sowing years. Standard errors in parenthesis

	1995			1966			1997		
Irrigation frequency	3	6	9	3	6	9	3	6	9
60 days	−1.30	−1.44	−1.93	−1.43	−1.68	−2.06	−1.50	−1.51	−2.16
	(0.04)	(0.05)	(0.03)	(0.04)	(0.12)	(0.12)	(0.03)	(0.04)	(0.04)
120 days	−1.43	−1.95	−2.48	−1.53	−1.58	−1.74	−1.66	−1.76	−2.08
	(0.08)	(0.03)	(0.08)	(0.05)	(0.07)	(0.06)	(0.08)	(0.10)	(0.04)

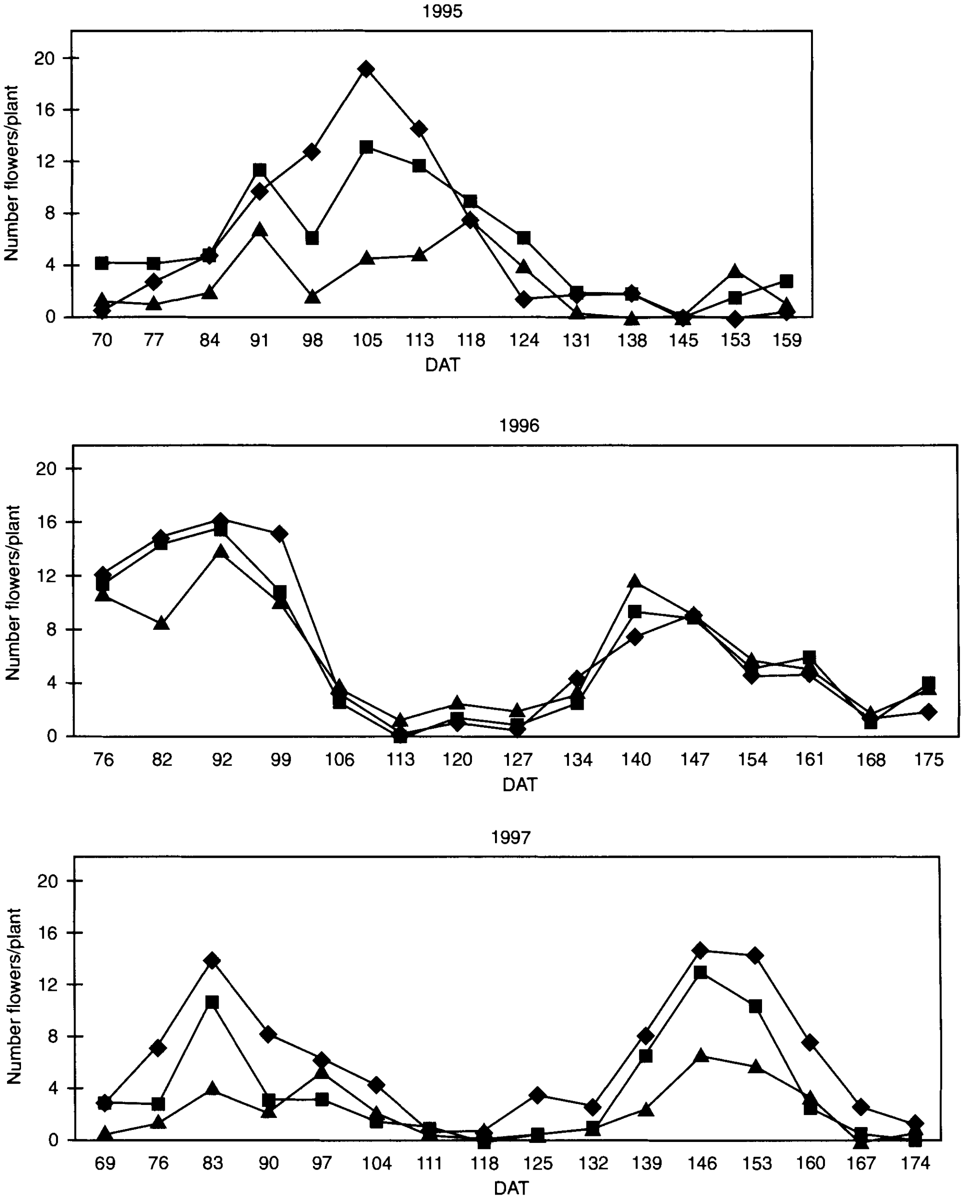

Fig. 2: Weekly flowering dynamics for the three sowing years. DAT (days after transplantion). Irrigation frequencies: (◆) 3 days (■) 6 days (▲) 9 days

ering frequencies for the 1995 and 1997 sowings (Fig. 2). This trend was more evident during flowering maximums. For these trials, the total number of flowers/plant significantly decreased (50–60 %) in the 9-day watering frequencies with respect to the 3-day frequency. For the 1996 trial, differences were less accentuated between treatments, and there were no significant differences in the total number of flowers/plant (Table 2). Under the studied conditions, mean maximum for all trials was 16 flowers/plant for the 3-day frequency.

Fruit harvest began 97 DAT Fig. 3), with maximums between 122 and 130 DAT. Similar to the flowering behaviour, the 1996 trial did not show any significant differences either in weekly production, or in total production (Table 1). For the 1995 and 1997 sowings, weekly fruit production decreased at lower watering frequencies, reaching a 70 % reduction for 9-day frequencies at maximum production. Total fruit production for the 6 and 9-day watering treatments was significantly lower in relation to the 3-day frequency for the 1995 and 1997 trials (Table 2). A delay, which occurred during flowering in the 1995 sowing, produced a lag in fruit production (Fig. 3).

Table 2: Total number of flowers per plant (TNF) and fruit yield (FY, t/ha) for *Capsicum chinense* during the three sowing years

	1995		1996		1997	
Irrigation frequency	TNF	FY	TNF	FY	TNF	FY
3 days	77.6 a	22.5 a	116.5 a	22.6 a	98.3 a	17.8 a
6 days	71.6 a	16.7 b	107.8 a	21.6 a	59.8 b	11.8 b
9 days	39.8 b	12.1 b	114.2 a	21.5 a	37.3 b	8.0 b

Means followed by different letters, within columns, are significantly different (P = 0.05) according to Duncan's Test.

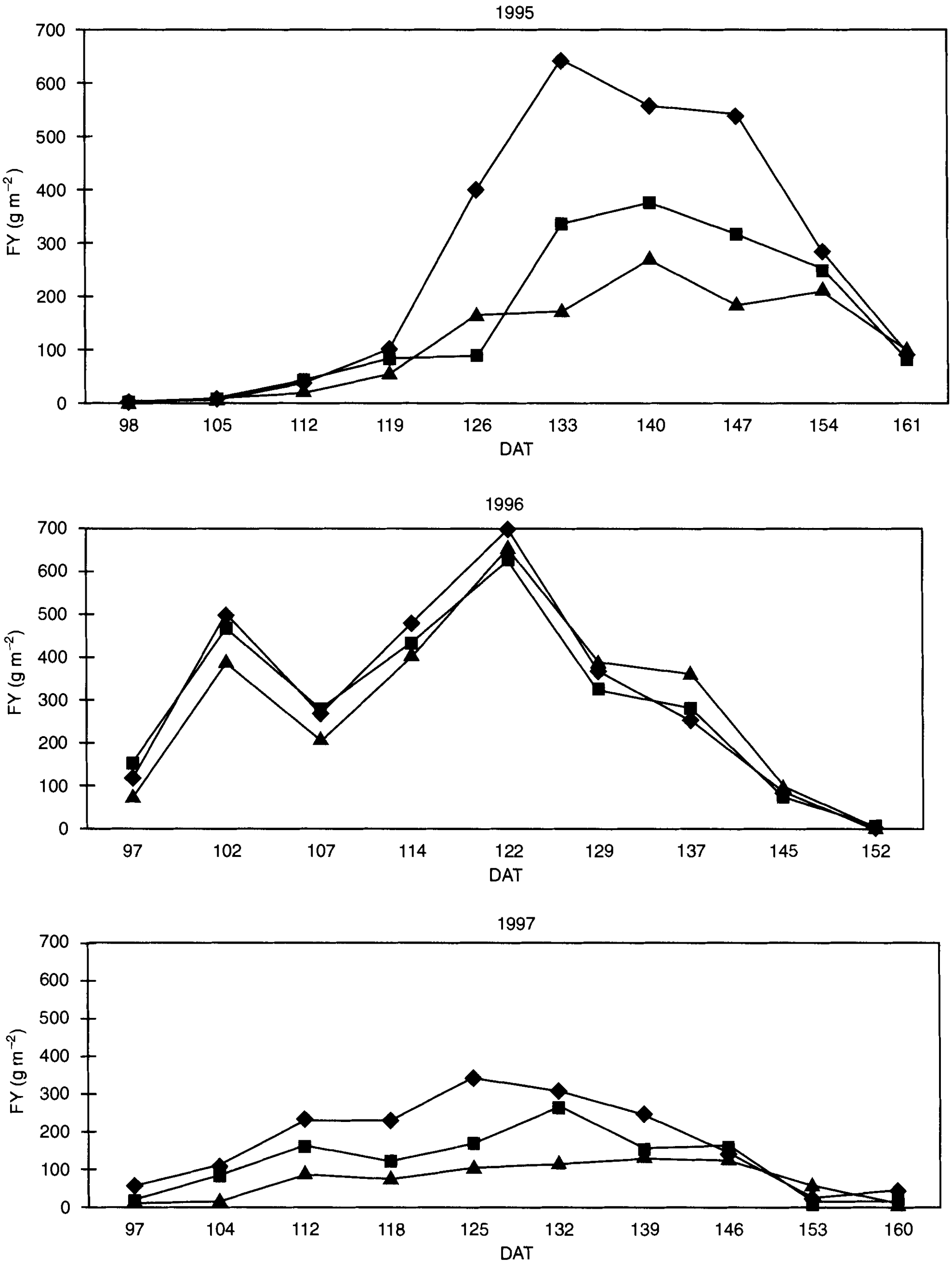

Fig. 3: Weekly fruit yield (FY) for the three sowing years. DAT (days after transplanting). Irrigation frequencies: (◆) 3 days, (■) 6 days, (▲) 9 days

Discussion

A 25-day delay in flowering maximums, in absence of precipitation as observed for the 1995 trial, occurred in spite of irrigating every 3 days. This was due to extremely low precipitation during the vegetative and initial flowering stages. Such a delay in flowering maximums was not observed in the 1996 and 1997 trials due to greater water availability during the period previous to flowering and a few weeks following the onset of flowering. The scarce precipitation between flowering and the beginning of fruit production, during the 1997 trial, resulted in lower fruit production for all irrigation treatments compared to the other years. Although the 1995 trial was greatly affected by low precipitation in terms of a delay in flowering, fruit production was less affected due to the water input through precipitation, which occurred between flowering and fruit development. A reduction in available water in this stage could result in a larger number of aborted flowers and/or a decrease in fruit size. The period previous to or during flowering have been described as one of the most susceptible stages to water deficits in several crops: *Cajanus cajan* (L.) Millsp. (Nandwal et al. 1993), *Arachis hipogaea* L. (Golakiya and Patel 1992, Golakiya 1993), *Glycine max* (De-Bruyn et al. 1995), *Vigna radiata* (Hamid et al. 1990) resulting in lower yields. However, our results suggest that, for *C. chinense*, low water availability during this period reduces the number of flowers produced and retards the occurrence of maximum flowering. On the other hand, low water availability during the period between flowering and fruit development reduces final fruit production. This means that, even though water availability is determinant during both stages, a water deficit during fruit development affects final fruit production to a greater extent.

A decrease in number of flowers and lower fruit yields due to lower water availability during the crop's cycle have been described for *Capsicum. annuum* L. (Beese et al. 1982) and *L. esculentum* (Plaut 1995, Mendez 1995). Lower production in *C. annuum*, due to lower water availability, has been associated to a reduction in leaf area (Horton et al. 1982). Lower Ψ_L in *C. chinense* due to the different watering frequencies caused stomatal closure and lower photosynthetic rates which resulted in lower fruit production (Jaimez et al. 1999). High evapotranspiration rates during dry periods in this region significantly reduce both flower production and final yields in tomato (Mendez 1995).

As a strategy for this region, transplanting of *C. chinense* should be carried out 60 days before precipitation onset, so that the rain season coincides with flowering and fruit development. These stages are critical, and water availability is essential to avoid a significant decrease in fruit production.

Zusammenfassung

Einflüsse von Wassermangel auf die Dynamik der Blüte und Fruchtproduktion bei *Capsicum chinense* in einer tropischen semiariden Region von Venezuela

Der Grad der Empfindlichkeit gegenüber Wassermangel während der unterschiedlichen Entwicklungsstadien der Pflanze ist ein bedeutender Aspekt, der unter tropischen, semiariden Bedingungen berücksichtigt werden sollte. Der Einfluss von Wassermangel auf die Blühdynamik und die Fruchtproduktion von Gemüsepaprika (*Capsicum chinense*) wurde unter verschiedenen Wasserbedingungen während drei aufeinander folgender Jahre bestimmt. Ein komplett randomisierter Blockversuch mit drei Wiederholungen wurder durchgeführt. Die Blühdynamik und Fruchtproduktion wurde wöchentlich gemessen und das Wasserpotential wurde 2mal während des Experiments bestimmt. In allen Jahren begann die Blüte etwa 70 Tage nach der Planzung. In dem günstigen Jahr (Versuch 96) wurden keine Unterschiede in der Gesamtblüte und Fruchtproduktion im Hinblick auf die Bewässerungshäufigkeit gefunden. Für die anderen, weniger günstigen Jahre fanden sich zur Blühdynamik und Fruchtproduktion signifikante unterschiedliche Ergebnisse in Abhängigkeit von der Bewässerungshäufigkeit. Unsere Ergebnisse zeigen, dass eine geringe Wasserverfügbarkeit vor der Blüte die Anzahl der Blüten reduziert und das Auftreten der Vollblüte verzögert. Auf der anderen Seite reduziert Wasserdefizit während der Periode zwischen der Blüte und der Fruchtentwicklung die endgültige Fruchtproduktion. Dies weist darauf hin, dass Wasserdefizit während der letzten Entwicklungsphase den abschließenden Ertrag in einem größeren Umfang beeinträchtigt.

Acknowledgements

This research was supported by grant FO-315–94 from the CDCHT-ULA. We are grateful to Cesar Figueredo for his technical assistance and Andrew Daymond for comments and suggestions on the manuscript.

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