"ELEPHANT'S FOOT", A PLANT DISORDER IN HYDROPONIC GREENHOUSE SWEET PEPPER

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Abstract. **Sweet pepper (*Capsicum annuum* L.) is currently the vegetable crop with the largest acreage under protected agriculture in Florida. The growing system for pepper is characterized by the use of soilless media and frequent irrigation with a complete nutrient solution. A physiological plant disorder not known to occur in soil-grown plants was observed in two hydroponic greenhouse crops at Gainesville, FL. The stem became swollen below the cotyledons node level, where longitudinal cracks developed on the epidermis. Rotting occurred in these wounds and reached the internal stem vessels. Adventitious roots abscised leading to a major reduction of water absorption. The affected plants wilted suddenly with no diagnosable pathogenic disease. In other countries (*i.e.* Spain and Canada), where greenhouse sweet pepper has been grown in soilless media, the disorder has been termed "Elephant's Foot", based on a description of the stem appearance. Locating irrigation emitters close to the stem may be directly related to a cause for this disorder. Moving the emitter gradually away from the stem base partially helped to alleviate the problem. In Spain and Canada the "Elephant's Foot" disorder is avoided by transplanting a young seedling up to the cotyledonary level into a rockwool block. The block is later placed over a soilless media bag or rockwool slab. The irrigation emitter is moved from the top to the base of the block once the roots grow into the container media. Factors other than emitter location, such as irrigation and fertilization frequency, and/or the use of certain soilless media *per se* might also lead to the development of "Elephant's Foot". Additional research related to these factors is presently being conducted to determine the cause and solution for the disorder. More information and knowledge about the factors that cause the "Elephant's Foot" disorder will help avoid this problem.**

Introduction

Greenhouse production of colored sweet pepper (*Capsicum annuum* L.) is a new and expanding industry in Florida. With approximately 12 hectares, sweet pepper is currently the crop with the largest acreage under protected agriculture in this state. Crops are grown in a hydroponic system: in soilless media (perlite), where a complete nutrient solution is used to feed the plants with each irrigation. Plants are usually pruned to two main stems, which are vertically trellised on a "V" shape system (Ministry of Agriculture, Fisheries and Food, Province of British Columbia, 1996; Resh, 1996). Two hydroponic greenhouse sweet pepper crops - Fall 1998, and Spring 1999 - grown at The Horticultural Research Unit of the University of Florida, Gainesville,

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exhibited a sudden plant wilt with no diagnosable pathogenic disease (Figure 1). The physiological disorder that may end with a total wilting and the eventual death of the pepper plant is described in this report.

Materials and Methods

Thirty-eight days-old sweet pepper seedlings (“HA3378”and “HA3367”, red fruits at maturity, from Hazera Seeds Ltd., Haifa, Israel, and “Kelvin”, yellow fruit at maturity, from De Ruiter Seeds Inc., Bergschenhoek, Holland) were transplanted to the cotyledonary node depth on 17 October 1998 and 17 January 1999 in polyethylene bags filled with perlite (Aerosoil, Chemrock Inc., Jacksonville, FL). The greenhouse was a single-bay type of 9 x 30 x 4 m (width x length x height) (Atlas Greenhouse Systems Inc., Alapaha, GA), double polyethylene film, with side curtains and wing system on the roof ventilation, with a North South orientation. Each plant was irrigated on a time clock controller basis with a complete nutrient solution developed for greenhouse hydroponic tomato (Hochmuth, 1991). Emitters (Chapin Watermatics Inc., Watertown, N.Y.) were located 3 cm from the base of the stem and had a discharge flow of 150 $ml.min^{-1}$.

Results and Discussion

The symptoms of plant wilting were observed 39 days after transplanting (25 November 1998) in the fall crop, and 52 days after transplanting (10 March 1999) in the spring crop. At this moment, the first fruits that set (2^{nd} node after the crown flower) were 3-4 cm in diameter. When the plants started to wilt, in both seasons, they being irrigated seven times a day, each receiving 1 liter of solution per day. The nutrient solution had the following concentration ($mg.l^{-1}$) of NO_3^--N: 148, P: 58, K: 157, Ca: 212, Mg: 64, Na: 12, pH 6.2, and electrical conductivity 1.9 $dS.m^{-1}$ (Analytical Research Laboratory, Inst. Food Agric. Sci. Soil and Water Science Department, University of Florida). The drainage through the bottom of the bags was 15 to 25 % of the irrigated solution volume. The nutrient concentration ($mg.l^{-1}$) of the drained solution was NO_3^--N: 117, P: 41, K: 104, Ca: 206, Mg: 71, Na: 28, and pH and electrical conductivity of this solution were 6.8 and 1.8 $dS.m^{-1}$, respectively.

Before wilting started in the perlite-grown plants of both, the spring and fall crops, the plants developed a swelling of the stem diameter below the cotyledons node level. In this region, the stem diameter increased 15-20 % as compared to plants that did not exhibit the symptoms. Accompanying the swelling at the base of the stem, longitudinal cracks and wounds also appeared at the base of the plant (Figure 2 and 3). Some, but not all, of these basal cracks seemed to have occurred from an expansion of the epidermis apertures where adventitious roots normally emerged. Roots inside the soilless media were white, and in apparent healthy condition. Rotting started to occur in the wounds and reached the internal stem vessels. Adventitious roots, which emerged below the cotyledonary node, abscised, creating a major reduction in water absorption. This resulted in an immediate wilting of the plant, especially when periods of high temperatures created a high demand for water in the plant. In both seasons the disorder occurred when temperatures inside the greenhouse reached 30^oC during the day and of 15^oC during night (minimum temperature was maintained with a greenhouse propane heating system). The affected plants wilted temporarily during the afternoon, although they appeared turgid early in the morning and late in the evening. Wilted plants randomly appeared throughout the greenhouse. Some plants became swollen on the base of the stem but did not wilt or die. The severity of the disorder varied among cultivars. Red bell pepper “HA3367” (Hazera Seeds Ltd.) and yellow pepper cv. “Kelvin” (De Ruiter Seeds Inc.) were less susceptible to this disorder than red bell pepper “HA3378” (Hazera Seeds Ltd.). The disorder was not observed on red bell pepper cv. “Robusta” (De Ruiter Seeds Inc.) in a summer crop also grown in perlite bags (Jovicich *et al*., 1999).

The same plant disorder with the same characteristics has been found in other countries including Spain (A. Hernandez, Murcia, personal communication) and Canada (S. Khosla, Ontario, personal communication), in greenhouse sweet pepper crops grown in soilless media. In Spain, the disorder has been termed "Elephant's Foot", based on a description of the stem appearance (A. Hernandez, Murcia personal communication).

High humidity in the substrate, or injecting nutrient solution close to the base of the stem appeared to be related with this disorder. As in woody plants, development of hypertrophied lenticels can occur at the basal stem swelling, as this is a morphological adaptation of plants for survival under deprived oxygen-depleted conditions (Kozlowski, 1997). The increased stem diameter and a loss of epidermis extensibility could have initiated the wounds on the basal stem. Salt accumulation on the stem due to the frequent irrigation could also contribute to the epidermal wounds and stem swelling. When a solution from the perlite around the stem was measured for electrical conductivity it was 1 $dS.m^{-1}$, and emitters were 3 cm from the base of the stem. After the first wilting symptoms were observed in the spring crop (10 March 1999), irrigation emitters were moved 12 cm from the stem base. By doing this, both the perlite at the surface of the pot and the base of the plant stem region were kept dry, and further plant wilting was reduced. Epidermal wounds and cracks dried, and there was no increase in the number of wilted plants. When the disorder was observed at the beginning of March, moving the emitter from the stem base led to a reduced water uptake by the plants and to the development of blossom-end rot on the fruits. The practice of moving the emitter (12 cm) from the base of the stem might help to alleviate the "Elephant's Foot" problem, but it should be done gradually after transplanting in order to reduce any stress on water uptake by the localized roots. In bags filled with perlite, emitters could be moved 1 cm every 3-4 days, starting this practice the second week after transplanting (emitter placed 2 cm from the seedling stem) to reach a final distance of 12 cm from the base of the stem. Differential water holding capacity of substrates used in hydroponic production (*i.e.* perlite, coconut coir, pine bark, rockwool) might require a specific irrigation management and emitter location to avoid this disorder.

To our knowledge, a disorder with the described characteristics has not been reported to occur in Florida in field soil-grown sweet pepper. Morató (1996) reported a similar physiological disorder named sweet pepper "basal stem rot", developed as a plant response from a localized area with high humidity and lack of aeration around the stem base. He differentiated the disorder from a root anoxia caused by a general soil flooding that also ends with a root rot and consequent plant wilt. The basal stem rot can be caused by a constant or frequent drip of solution due the proximity of the irrigation tubing to the stem base (Morató, 1996). Cartia *et al.* (1988) also reported the formation of a corky tissue on the root crown followed by a rapid plant wilting and necrosis in over-irrigated soil-grown pepper plants in the greenhouse.

The substrate used in hydroponic systems is generally a sterile soilless media, and as such, root rot infections are less common than in soil-grown pepper plants. *Fusarium oxysporum* has been found as an secondary pathogen in the base of the stem of pepper plants from both greenhouse grown crops that were tested for pathogenic organisms (Plant Disease Clinic, Inst. Food Agric. Sci. Plant Pathology Department, University of Florida). Nuez *et al*. (1996) mentioned that saprophyte fungi from the genus *Fusarium* were isolated from the necrotic area of the stem crown from wilted pepper plants grown in a greenhouse under high soil moisture conditions. However, the isolated inoculum did not reproduce the root anoxia symptom when healthy plants were inoculated (Nuez *et al*., 1996). It is known that water management in soil-grown pepper plants has a direct effect on the plant's susceptibility to fungal infections. Greenhouse pepper plants with the irrigation emitter located on the soil surface and close to the plant stem had higher disease levels than plants where emitters were buried or placed far from the stem (Cafe Filho and Duniway, 1996).

Vectors that can carry pathogenic and/or non-pathogenic fungi to the epidermis wounds might aggravate the disorder by causing the rot and following wilt of the pepper plant. Fungus gnats (genus *Bradisia*), small flies present around algae that develop on drained solution, have been observed in the greenhouse in both seasons. It has been reported that fungus gnats can be especially harmful in greenhouse production (Harris *et al*., 1996). Both, larvae and adults of fungus gnats indirectly contribute to plant damage through the spread of fungal pathogens by transporting the inoculum to the open wounds (Harris *et al*., 1996; Gillespie and Menzies, 1993). In greenhouses, fungus gnats have been associated with plants that were severely affected by Fusarium crown rot and root rot in tomato (Gillespie and Menzies, 1993). Biological, chemical control, and draining wet spots where nutrient solution and algae accumulate are management measures for controlling these insects (Harris *et al*., 1996; Ministry of Agriculture, Fisheries and Food, Province of British Columbia, 1996).

In Spain and Canada growers try to avoid the “Elephant’s Foot” disorder by transplanting a young seedling into a 7.5 x 7.5 x 10 cm rockwool block to the cotyledonary node level. The plant in the rockwool cube will later be placed on the top of the soilless media bag or rockwool slab (A. Hernandez, Murcia, personal communication; S. Khosla, Ontario, personal communication). When roots start growing inside the media, the irrigation emitter is moved from the top to the bottom of the block (Resh, 1996). In this way, the base of the stem is kept dry and the disorder seems to diminish (A. Hernandez, Murcia, personal communication; S. Khosla, Ontario, personal communication). However, the disorder has been observed in Spanish greenhouses on hydroponic pepper plants grown with the mentioned transplant practice either in perlite or coconut fiber as soilless medium.

Summary

The development of “Elephant’s Foot” disorder most likely requires a localized zone around the stem base with high humidity and/or salt accumulation. The basal stem epidermis might weaken and develop cracks and wounds as a plant response to this environment. The affected tissue then may be susceptible to the entrance of pathogens (that might be carried by a vector, *i.e.* fungus gnats) leading to the rot, which might then reach the plant’s vascular system, diminish the plant’s water uptake and consequently end with a rapid wilting of the plant. Factors other than emitter location might lead to the development of “Elephant’s Foot”. The disorder could also be related to greenhouse temperatures as the disorder occurred in seasons with similar temperatures (maximum 30^{o}C, minimum 15^{o}C), and to the manner in which irrigation and fertilization are managed, particularly regarding frequency and amount of solution applied to the plant. This disorder is not known to occur in Florida in field-grown pepper plants. The occurrence of the disorder in hydroponic production systems might be related to the frequent irrigation with a nutrient solution, which might give the conditions of high humidity around the stem base and/or salt accumulation at this level. The use of other soilless media, which *per se* might affect differently the environment around the base of the stem, may or may not lead to the development of this disorder. Additional research related to these factors is presently being conducted. More information and knowledge about the factors that cause the “Elephant’s Foot” disorder will help avoid this problem in greenhouse hydroponic sweet pepper production.

Literature Cited

Cafe Filho, A. C., and J. M. Duniway. 1996. Effect of location of drip irrigation emitters and position of *Phytophtora capsici* infections in roots on Phytophtora root rot of pepper. Phytopatology 86:1364-1369.

Cartia, G., T. Cipriano, and M. Napoli. 1987. Osservazioni sulla eziologia di una necrosi basale del peperone. Colture Protette 1:71-75

Gillespie, D. R., and J. G. Menzies. 1993. Fungus gnats vector *Fusarium oxysporum* f. sp. *radicis-lycopersici*. Annals of Applied Biology 123:539-544.

Harris, M. A., W. A. Gardner, and R. D. Oetting. 1996. A review of the scientific literature on fungus gnats (Diptera: Sciaridae) in the genus *Bradysia*. Journal of Entomological Science. 31:252-276.

Hochmuth, G. J. 1991. Fertilizer Management for Greenhouse Vegetables. 13-31. In: G. J Hochmuth (ed.). Florida Greenhouse Vegetable Production Handbook Vol. 3. University of Florida, Inst. Food Agr. Sci., Circular SP 48.

Jovicich, E., D. J. Cantliffe, and G. J. Hochmuth. 1999. Plant density and shoot pruning on yield and quality of a summer greenhouse sweet pepper crop in Northcentral Florida. 184-190. In: K. D. Batal (ed.). Twenty-Eighth National Agricultural Plastics Congress. Proc. American Society for Plasticulture, Tallahassee, FL. 19-22 May. 1999. ASP, State College, PA.

Kozlowski, T. T. 1997. Responses of woody plants to flooding and salinity. Tree Physiology monograph No. 1. Heron Publishing, Victoria, Canada.

Morató, G. M. 1996. Enfermedades fúngicas, bacterianas y fisiopatías. 60-66 In: A. Namesny (ed.). Pimientos. Compendios de Horticultura No. 9 Ediciones de Horticultura, S.L. Reus, España.

Ministry of Agriculture, Fisheries and Food, Province of British Columbia. 1996. Greenhouse Vegetable Production Guide for Commercial Growers. J. Portree (ed.). Extension Systems Branch, Province of British Columbia.

Nuez, F., R. Gil, y J. Costa. 1996. El cultivo de pimientos chiles y ajíes. 607 p. Ediciones Mundi-Prensa, Madrid, España.

Resh, H. M. 1996. Hydroponic food production. 5th ed. 510 p. Woodbridge Press Publishing Co., Santa Bárbara, CA.

Figure 1. Sudden greenhouse sweet pepper plant wilt on 25 November 1998 in Gainesville, FL.

Figure 2. Wounded epidermis below the cotyledons' node of greenhouse-grown sweet pepper in perlite medium. 10 March 1999, Gainesville, FL

Figure 3. Longitudinal crack-wound below the cotyledon node in a fall sweet pepper grown in perlite medium (40 days after transplant).