TRANSPLANT DEPTH, IRRIGATION, AND SOILLESS MEDIA EFFECT ON "ELEPHANT'S FOOT" PLANT DISORDER IN A HYDROPONIC GREENHOUSE SWEET PEPPER CROP

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Summary

A physiological disorder in greenhouse hydroponic sweet pepper (*Capsicum annuum* L.), where the base of the plant's stem becomes swollen below the cotyledon level and wounds develop at the base of the stem's epidermis has been named "Elephant's Foot". The disorder might predispose the plant to a localized rot and result in sudden plant wilt. Factors that might cause the disorder are not known; however salt accumulation at the base of the stem could be a possible cause of the epidermal wounds. The effects of soilless media (perlite, coconut coir, pine bark, and peat-perlite-vermiculate mix), transplant depth, and amount of nutrient solution applied per day were studied to evaluate the development of "Elephant's Foot" on a summer-fall sweet pepper (cv. Kelvin) greenhouse crop in Gainesville, FL, USA. Seedlings in 370 cm^3 cell polyethylene containers were transplanted (29 June, 1999) into 11.4-liter pots at three transplant depths: a) at half of the cell height, discarding only the bottom of the container, b) at the cotyledons level, and c) at the 2nd stem node. Plants were irrigated with the same frequency but with different irrigation periods in order to give per day volumes of solution of 2, 2.5, 3, 3.5, and 4 liters per plant. Salt accumulation at the base of the stem level was determined indirectly by measuring the electrical conductivity (EC) on a solution obtained from washing the stem epidermis. The percentage of plants with epidermal wounds at the base of the stem was highest (82.50%) on plants transplanted at half of the cell height, compared to plants transplanted to the cotyledonary level (5.83%) and the 2nd stem node (0%). Plants transplanted at half of the cell height had higher values of EC than plants transplanted to the cotyledon level and to the 2nd node. There was a positive linear relationship ($r = 0.82$) between the percentage of plants with epidermis wounds and the EC. The EC increased with the amount of nutrient solution applied per day, particularly in plants transplanted at the cotyledonary level and at the 2nd stem node. The type of soilless media did not influence in salt accumulation at the base of the stem. The practice of transplanting sweet pepper with the cotyledonary node under the surface of the soilless media could minimize salt accumulation and epidermal damage at the base of the stem level and avoid the development of the "Elephant's Foot" disorder.

1. Introduction

Cultivation of sweet pepper (*Capsicum annuum* L.) in the greenhouse allows the production of high quality colored fruits year round. Pepper crops cultivated in greenhouse may be grown in soilless media and frequent irrigation with a complete nutrient solution (Ministry of Agriculture, Fisheries and Food, Province of British Columbia, 1996; Nuez *et al.*, 1996). The use of a hydroponic system is an alternative for soil cultivation and will be the production method after banning of methyl bromide in 2005 (VanSickle *et al.*, 2000).

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Seedlings are usually transplanted to the cotyledonary level directly in the container (bag or pot filled with the soilless medium) where the plant will grow. In another transplant system, plants that are raised in small polyethylene containers or rockwool cubes are planted directly in the pot or bag burring 10 to 20 mm the bottom of the container or rockwool cube into the soilless media (Resh, 1996).

A physiological disorder, "Elephant's Foot", has been described in greenhouse hydroponic sweet pepper (Jovicich *et al.*, 1999). The stem of a plant with this disorder becomes swollen below the cotyledon level and cracks develop in the epidermis of this region at the air-media level. Rotting can occur in these wounds and reach the internal stem vessels, particularly if fungus gnats (*Bradysia* spp.) act as vectors of *Fusarium oxysporum* (Gillespie and Menzies, 1993). Adventitious roots may also abscise, leading to a major reduction of water absorption. The affected plants may wilt suddenly with no diagnosable pathogenic disease. The disorder on the base of the stem, which rarely appears in soil grown plants, has been observed in commercial hydroponic greenhouses in USA, Spain, and Canada. In Spain, greenhouse soil-grown (a layered mulch of loamy soil, organic mater and coarse sand) sweet pepper is usually transplanted with the cotyledons under the soil and the occurrence of the disorder seems to be diminished.

Factors that might cause the disorder are not known; however the wounds and cracks on the base of the stem epidermis might be a plant response to salt accumulation. Salts might accumulate on the top of the soilless media as a result of nutrient solution evaporation. The evaporation of nutrient solution around the base of the stem might depend on the amount and concentration of nutrient solution applied, the placement of the emitter with respect to the transplant, and on the physical and chemical characteristics of the soilless media (Burés, 1997). A relative value of the accumulated salt on the base of the stem could be determined indirectly by washing the stem epidermis and measuring the electrical conductivity (EC) of the solution. The salt accumulation and damage of the stem base epidermis of sweet pepper plants were studied for the effects of daily nutrient solution volumes, soilless media type and transplant depth. The identification of factors that that will reduce or avoid the "Elephant's Foot" disorder will help to improve management practices in hydroponic grown sweet pepper.

2. Material and Methods

'Kelvin' (De Ruiter Seeds Inc., Bergschenhoek, Holland) sweet pepper (*Capsicum annuum* L.) seedlings were grown on a 70-30% peat-moss vermiculite substrate mix in 200-cell (2.5 x 2.5 x 6.5 cm) Styrofoam transplant flats (Speedling, Sun City, FL). After 35 days the seedlings were transplanted to the cotyledonary level into 7.6 x 7.6 x 8.3 cm (side x side x height) polyethylene containers (model VSR325, Lerio Corp., Kissimmee, FL) with the same substrate. On 29 June, 1999 (Summer season) seedlings raised in the containers (45 days-old) were transplanted into cylindrical 11.4-l polyethylene pots (model A-30, Lerio Corp., Kissimmee, FL) at three transplant depths (Figure 1): a) at half of the container height (3.8 cm), discarding only the bottom of the container, b) at the cotyledon level, and c) at the second stem node (3 cm depth).

Plants were irrigated during daylight, with the same frequency (34 times per day, from 6:00 AM to 8:00 PM) but with different irrigation periods in order to give per day volumes of 2, 2.5, 3, 3.5, and 4 liters of nutrient solution per plant. In order to establish all plants in the pots irrigation treatments were started 20 days after transplanting. During this first period plants were irrigated with a volume of 1.4 liters of nutrient solution per plant. A timing irrigation controller (Pro Rain, Antelco Corporation, Longwood, FL) was used to program the irrigation treatments. Each plant was irrigated with a pressure compensated irrigation emitter (Netafim, Israel) with a flow discharge of $2 \, l \cdot h^{-1}$.

At transplant the emitter stake was placed 2.5 cm from the base of the stem. In plants transplanted with the polyethylene container the emitter stake was moved from the top to the bottom of this container three weeks after transplanting, when roots from these plants were growing into the media (Resh, 1996).

Irrigation and transplant depth treatments were tested in four soilless media: a) perlite (Chemrock Corp., Jacksonville, FL), b) coconut coir (Scotts-Sierra Horticultural Products Company, Marysville, OH), and c) peat-vermiculite-perlite mix (60-20-20%) (Speedling, Bushnell, FL) and non-aged pine bark (particle size smaller than 2.5 cm^2) from a local wood mill. The experiment was arranged as a split-split-plot design with three blocks. Irrigation was the main plot, transplant depth the sub-plot, and media the sub-sub-plot.

Plants were grown in an 8 x 32 x 4 m (width x length x height) bay of a 7-bay passive ventilated greenhouse (Top, Israel) located at the Horticultural Sciences Department Research Unit of the University of Florida, Gainesville, USA. Pots were aligned in double rows with 1.6 m between center of the rows (4.2 plant$\cdot$ m^{-2}).

Plants were irrigated with a complete nutrient solution with nutrient concentration levels developed for greenhouse-grown hydroponic tomatoes (Hochmuth, 1991). Nutrient levels (mg$\cdot$ l^{-1}) from transplanting until 15 July were N: 80, P: 50, K: 120, Ca: 127, Mg: 40, S: 56 and EC: 1.4 mS$\cdot$ cm^{-1}. From 15 July to 1 August nutrient levels (mg$\cdot$ l^{-1}) were N: 100, P: 50, K: 148, Ca: 143, Mg: 40, S: 56, and EC: 1.8 mS$\cdot$ cm^{-1}. After 1 August levels were N: 120, P: 50, K: 174, Ca: 143, Mg: 48, S: 66 mg$\cdot$ l^{-1}, and EC: 2.0 mS$\cdot$ cm^{-1}.

Plants were pruned twice to leave two main stems after the crown flower, which was pulled from the plants together with the second order flowers in order to encourage vegetative growth. Lateral horizontal plastic twines and iron stakes were used to support the plants.

On 25 November the percentage of plants showing “Elephant’s Foot” symptom (wounds and cracks on the stem epidermis at the air-soilless media level) was determined. Salt accumulation at the base of the stem was determined by measuring electrical conductivity of a solution obtained from washing a sample of epidermal tissue taken from the lower part of the stem. Two plants per plot were used for the salt accumulation determination. The base of the plant stem was cut (10 cm length) at the air-media level, and a cylinder of 2.5 cm length of epidermal tissue was peeled with a grafting knife from the end portion close to the soilless medium. The stem diameter on the upper portion of the epidermal cylinder was measured with a caliper, and the area of the epidermis sample was calculated as Area (mm^2)= Stem Diameter (mm)* 2.5 (mm)* 3.14. The epidermis sample was placed in a cup with 20 ml of deionized water (EC: 0.005 mS$\cdot$ cm^{-1}), stirred in water for 1 minute and after 3 more minutes, electrical conductivity was measured with a portable electrical conductivity meter (Twin Cond B-173, Horiba Ltd., Kyoto, Japan) and expressed on an epidermis area basis (mS$\cdot$ $cm^{-1}\cdot$ mm^{-2}).

Analysis of variance was performed on epidermis EC, and percentage of “Elephant’s Foot” symptom observation (SAS, 1989). Records from percentage of plants with wounds on the epidermis were arc sine transformed for data analysis. Correlation analysis between epidermal EC and percentage of plants showing the “Elephant’s Foot” symptom was conducted. Mean values for percentage of plants with epidermis damage were separated by Duncan’s Multiple Range at $P\leq 0.05$, and soilless media type was analyzed for its polynomial effects by regression analysis.

3. Results

The highest percentage of plants with wounded epidermis (82.5%) was observed on the plants transplanted with the polyethylene container (Figure 2). The percentage of plants with the disorder symptoms was significantly lower (5.8%) in the plants transplanted to the cotyledonary level, and plants transplanted to the depth of the second node did not show damage on the epidermis at the soilless level. When stems of the plants transplanted deep were unburied no apparent damage could be observed on the epidermal tissue at the cotyledonary level, and the development of some lenticels was observed on the buried epidermis above the cotyledons level. The percentage of plants with basal stem epidermal damage was not significative different (*P*>0.05) among irrigation and media treatments, nor their interactions (data not shown).

Electrical conductivity of the solution obtained from washing the epidermis, *i.e.* salt accumulated on the base of the stem, was highest on the plants transplanted with the polyethylene container to half of the cell height (EC values > 1 $mS \cdot cm^{-1} \cdot mm^{-2}$) (Figure 3). Locating the emitter at the base of the polyethylene container creating greater evaporation at the top of the container might have concentrated a greater amount of salts at the surface compared to those transplants where the root ball was planted directly in the soilless media.

The EC increased slightly in a linear fashion with higher amounts of nutrient solution. This was more notorious in plants transplanted to the cotyledonary level and to the depth of the second node than in plants transplanted with the container to half of the cell height (Figure 3). Although the EC had different polynomial effects (linear and quadratic) for the soilless media (interaction not shown) there were very similar trends in salt accumulation with increased amounts of nutrient solution per plant per day.

Treatments with a high percentage of plants with epidermal tissue damage corresponded with high values of EC in the solution that washed the stem base. A positive linear relation (r = 0.82) was obtained between the EC and the percentage of plants with epidermal damage (Figure 4). All plants transplanted deep did not show any stem epidermal damage at the air-media level and their epidermal tissues had low EC values (< 1.3 $mS \cdot cm^{-1} \cdot mm^{-2}$). Treatments with higher epidermal EC and high percentage of epidermal damage (> 75%) corresponded to plants transplanted with the polyethylene container to half of the cell height.

High salt accumulation on the base of the stem was a cause for the development of epidermal wounds, and may be a major factor involved in the development of the "Elephant's Foot" disorder. Planting the seedling container over the soilless media level resulted in a high accumulation of salts and a high occurrence of epidermal wounds around the stem base. Planting seedlings with the cotyledonary node under the soilless media level avoided wounds on the epidermis. Further research might determine if there is a differential sensitivity to salts on the epidermal region above and below the cotyledonary level. Transplanting the seedling with the cotyledonary node under the soilless media surface may be a simple management practice to elude the development of the "Elephant's Foot" disorder in hydroponic greenhouse sweet pepper regardless of media used.

4. References

Burés, S. 1997. Sustratos. 342 p. Ediciones Agrotécnicas S. L., Madrid, España.

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

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, Institute of Food and Agricultural Services, 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.

Jovicich, E., and D. J. Cantliffe, and G. J. Hochmuth. 2000. "Elephant's Foot", a plant disorder in hydroponic greenhouse sweet pepper. Proceedings Florida Society for Horticultural Science. Vol 112 (in print).

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.

VanSickle, J. J., C. Brewster, and T. H. Spreen. 2000. Impact of a Methyl Bromide Ban on the U.S. Vegetable Industry. Food & Resource and Economics Department, University of Florida, Institute of Food and Agricultural Services, Bulletin 333.

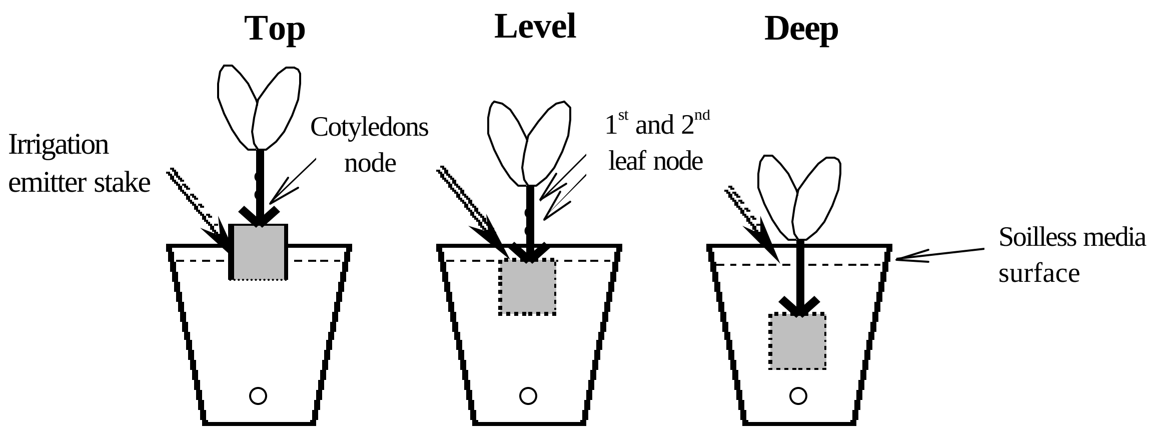


Figure 1. Transplant depth treatments: “Top” plants transplanted to half of the polyethylene container height –bottom removed-, “Level” plants transplanted to the cotyledons level, and “Deep” plants transplanted to the 2nd leaf node.

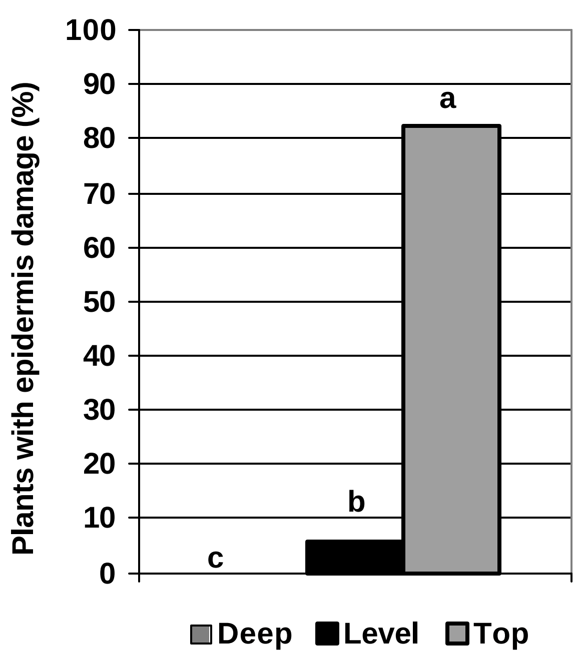


Figure 2. Percentage of plants with basal stem epidermis damage in “Deep” plants transplanted to the 2nd node, “Level” plants transplanted to the cotyledons level, and “Top” plants transplanted to half of the container height. Treatment means with different letters are significantly different at the 5% significance level using Duncan’s Multiple Range Test.

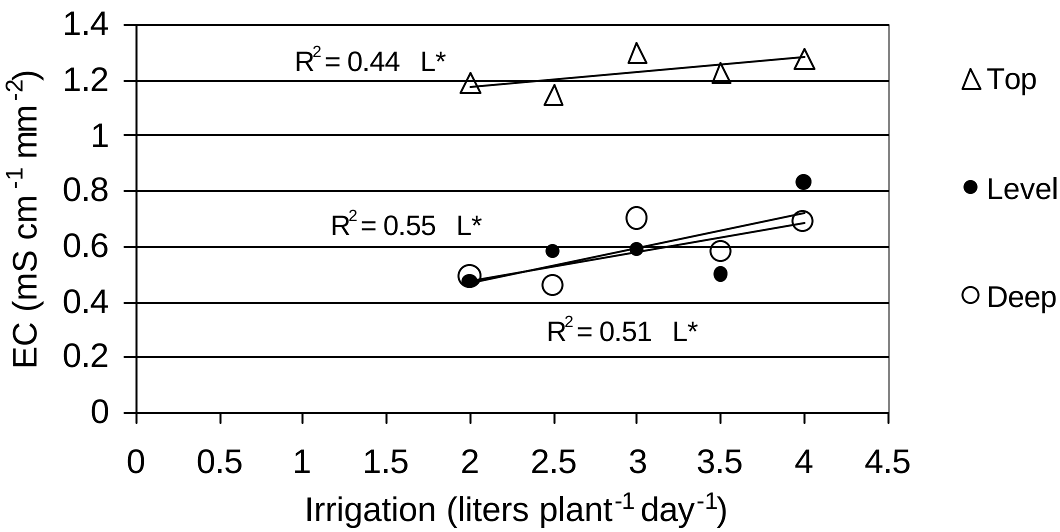
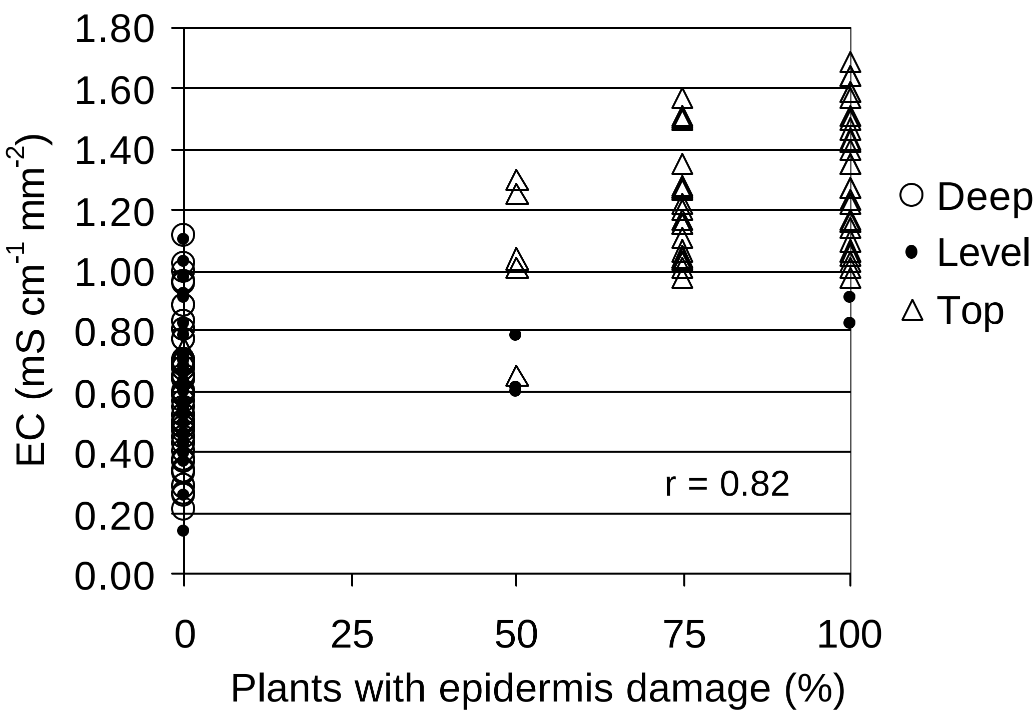


Figure 3. Salt accumulation on the stem base (measured by EC) and volumes of nutrient solution per plant per day at the three transplant depths: “Top”: plants transplanted to half of the container height, “Level”: plants transplanted to the cotyledons level, and “Deep”: plants transplanted to the 2nd node. Electrical conductivity values for each transplant depth and irrigation volume average four soilless media type (coconut coir, peat mix, perlite, and pine bark). L*, linear polynomial effect at 5% level of significance.



<u>Figure 4.</u> Correlation between salt accumulation on the stem base (measured by EC) and percentage of plants with epidermis damage. All values from samples and observations are plotted (n = 180), being "Deep" (Ï) plants transplanted to the 2nd node, "Level" (·) plants transplanted to the cotyledons level, and "Top" (Ä) plants transplanted to half of the container height.