Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
Available online at www.inia.es/sjar

Spanish Journal of Agricultural Research 2008 6(1), 120-124
ISSN: 1695-971-X

Short communication. Irrigation temperature effects on seedling growth and transplant quality of tomato, pepper and eggplant

M. Kadri Bozokalfa

Horticulture Department. Agriculture Faculty. Ege University. 35100 Bornova (Izmir). Turkey

Abstract

During production of plug transplants, high plant density and small cell size increases seedling height. The resulting tall, weak-stemmed, plants are difficult to transplant and can be easily damaged. One technique that can prevent excessive seedling elongation is irrigation with cold water. Seedlings of tomato, pepper and eggplant were planted in cell plug trays in greenhouses and irrigated daily, in the morning, with water at different temperatures. The temperatures tested were 3°C, 9°C and tap water (15.5-16.5°C). Irrigation with cold water reduced seedling stem height by 48-58% in tomato, 24-42% in pepper and 17-36% in eggplant. Cold water irrigation significantly affected stem diameter, number of leaves, shoot and root dry weights and leaf chlorophyll content. These results show that irrigation with cold water can effectively control plant height in plug-grown seedlings.

Additional key words: *Capsicum annuum, Lycopersicon esculentum*, *Solanum melongena*, seedling, stem length, water temperature.

Resumen

Comunicación corta. Efecto de la temperatura de riego sobre el crecimiento de la plántula y la calidad del transplante en tomate, pimiento y berenjena

Durante el proceso de transplante en bandejas, debido a la alta densidad de siembra y al pequeño tamaño de las celdas, las plantas resultantes son altas y de tallo débil, por lo que pueden dañarse fácilmente al ser transplantadas. Regar con agua fría es una técnica que puede prevenir una elongación excesiva de las plántulas. Se sembraron en bandejas en invernadero semillas de tomate, pimiento y berenjena y se irrigaron diariamente por la mañana con agua a diferentes temperaturas, 3°C, 9°C y temperatura ambiente (15.5-16.5°C). El riego con agua fría redujo la altura del tallo un 48-58% en tomate, 24-42% en pimiento y 17-36% en berenjena. También afectó significativamente al diámetro del tallo, número de hojas, peso seco de brotes y raíces y al contenido de clorofila en las hojas. Estos resultados muestran que el riego con agua fría puede controlar con efectividad la altura de las plantas crecidas en bandejas.

Palabras clave adicionales: *Capsicum annuum,* longitud del tallo, *Lycopersicon esculentum,* plántulas, *Solanum melongena,* temperatura del agua de riego.

In many parts of the world, tomato (*Solanum lycopersicum* L.), pepper (*Capsicum annuum* L.) and eggplant (*Solanum melongena* L.) are field produced from transplanted seedlings previously grown in greenhouses. Commercially, the transplants are grown in plug trays with different numbers of cells. A major problem in commercial plug production is control of plant height when seedlings are grown in small plug cells at high plant densities. Small cells increase plant density and thus, stem elongation. There are several drawbacks of excessive seedling elongation; tall seedlings with weak stems are difficult to handle and often lodge after transplanting. To facilitate handling of transplants by machines, short, sturdy plug grown vegetable seedling transplants are required. Further, mechanical transplanters are designed to accommodate plants of a specific size. The goal is to produce seedlings that will withstand the physical stress of handling, shipping and transplanting, and adapt rapidly to the field environment. However, unfavourable soil and weather conditions can delay field preparation for transplanting. For these reasons, seedling height control is necessary. Many methods are used to control seedling height, one of them is the use of growth retardants. Adler and Wilcox (1987) reported a 48% reduction in the height of tomato plants

* Corresponding author: mehmet.kadri.bozokalfa@ege.edu.tr
Received: 06-06-07; Accepted: 14-01-08.

treated with chlormequat chloride. However, due to legal restrictions on their use because of their potential effects on human health and on the environment, an effective non-chemical method is needed (Moe *et al.,* 1992; Erwin and Heins, 1995).

There are several non-chemical strategies to control seedling height; shaking or brushing the shoot (Heutcher and Mitchell, 1983; Biddington and Dearman, 1985) withholding water or nutrients (Latimer, 1990), light quality manipulation (Liptay, 1985), temperature regulation in the greenhouse (Moe *et al.,* 1992) through the DIF concept (difference between day and night temperature) and clipping the shoots. These methods require high management levels and often have long-term effects on plant growth and may delay early yield (Jaworski *et al*., 1970; Adler and Wilcox, 1987; Hickman *et al.,* 1989; Heins and Erwin, 1990). Recent work (Chen *et al.,* 1999) showed that irrigation with cold water reduced stem length in tomato by 28-32% compared with irrigation with water at room temperature.

The objective of this study was to examine the effect of different irrigation water temperatures on the seedling growth and quality of tomato, pepper and eggplant transplants.

The experiment was conducted at the Department of Horticulture, Faculty of Agriculture, Ege University. Three vegetable crops tomato cv. C-33, pepper cv. Charleston and eggplant cv. Aydin siyahi (Elitra Seeds) were used. Seeds were sown into 228-cell plug trays (45 mL volume) and filled with peat (Klassman-Deilma GmbH Germany):perlite (ETİPER) (3:1) mixture. Seedlings were initially irrigated with tap water until the first true leaf stage and fertilized weekly with 100 mg L^{-1} N and 60 mg L^{-1} of P fertilizer. The plug trays were placed on metal benches in a polyethylene covered high-tunnel greenhouse. In the experiment irrigation water at two low temperature irrigation waters (3°C and 9°C) and a tap water control (15.5-16.5°C) were used. Irrigation with cool water started when the first true leaf began to expand. Plants were irrigated daily between 8:00 9:00 am and water temperature was measured. Seedling trays were irrigated until water drained from the bottom of the plug cells. Treatments were continued until plants, in any treatment, reached a height of 15 cm. This is the seedling height required for mechanical transplanting.

The experiment used a randomised complete-block design with four replicates, each treatment consisted of 75 seedlings. Twenty-five seedlings per block were randomly sampled from each treatment.

To analyse the effect of water temperature on seedling grown, seedling were examined at 15 and 30 d after the first true leaf expanded. In the experiment stem length (cm), stem diameter (cm), number of leaves seedling^{-1}, shoot dry weight (g), root dry weight (g), root:shoot ratio (on a dry weight basis) and leaf chlorophyll content were determined. Shoot and root dry weight was measured by drying in an oven at 65°C to a constant weight for > 48 h. Leaf chlorophyll content (mg g^{-1}) was determined spectrophotometrically after extraction with methanol (AOAC, 1999).

All data were subjected to analysis of variance using the general linear models procedure of SPSS (version 11.0, SPSS Inc.); mean comparisons were by Duncan's multiple range test at $p \leq 0.01$.

Irrigation with cold water significantly influenced growth of tomato, pepper and eggplant seedling 15 and 30 d after the first true leaf stage. Tomato seedling stem length was significantly reduced by irrigation with cold water. During seedling growth stem length increased steadily but at a slower rate than the control seedlings. The effect of irrigation temperature was increased at 30 d. At both sampling dates the tallest tomato seedlings were produced by the ambient temperature treatment (control). At day 30 the greatest reduction in seedling height was in plants irrigated with water at 9°C.

Cold water irrigation inhibited stem elongation, stem diameter, number of leaves, shoot dry weight, the shoot:root ratio (based on dry weight) of tomato seedlings. Seedling diameter was reduced by irrigation with cold water compared with control seedlings at 15 and 30 d after the first true leaf stage. In tomato seedlings irrigation at 3°C significantly increased both shoot and root dry weight of at 30 d. Water at 9°C water inhibited shoot dry weight production during seedling growth (Table 1).

In pepper all seedling parameters were affected by irrigation temperature except the root:shoot ratio at 15 d after the first true leaf stage. Treatment effect depended on water temperature and growth stage. Irrigation water at 9°C was more effective than the other two treatments, particularly on the number of leaves and on shoot and root dry weight. The effect of both low temperature irrigation treatments on stem length and stem diameter was very similar. The 3°C treatment was not as effective as the 9°C treatment in pepper seedlings. The 3°C and ambient temperature treatment gave similar results.

In eggplant, at 15 d irrigation temperatures significantly influenced stem length, stem diameter, shoot

Table 1. Effect of cold water irrigation on the seedling growth and transplant quality of tomato, pepper and eggplant seedlings

Growth characters	Period	Treatment								
		Tomato			Pepper			Eggplant		
		3°C	9°C	Control	3°C	9°C	Control	3°C	9°C	Control
Stem length (cm)	15d	5.1 b	4.2 c	7.2 a	5.5 b	4.2 c	7.2 a	5.3 b	4.1 c	6.3 a
	30d	6.5 b	5.3 c	15.2 a	10.6 b	0.3 b	13.1 a	1 0.3 b	8.7 c	12.7 a
Stem diameter (cm)	15d	2.6 b	2.8 ab	3.0 a	2.1 a	1.9 b	2.1 a	2.1 a	1.9 b	2.2 a
	30d	3.3 a	2.3 b	3.2 a	3.1 a	2.9 b	3.1 a	3.8 a	3.2 c	3.5 b
Number of leaves	15d	4.8 a	4.0 b	5.0 a	4.8 a	4.0 b	4.9 a	3.6	3.6	3.5
	30d	5.6 b	4.6 c	6.5 a	8.4 a	6.8 b	8.6 a	4.2 b	4.1 b	5.6 a
Root/Shoot ratio (dry)	15d	0.33	0.34	0.32	0.45	0.58	0.77	0.37	0.32	0.27
	30d	0.33 a	0.29 b	0.29 b	0.64 a	0.61 b	0.64 a	0.45 a	0.40 a	0.35 b
Shoot dry weight (g)	15d	1.78 a	1.19 c	1.54 b	0.74 a	0.23 c	0.44 b	0.63 b	0.50 c	0.75 a
	30d	2.08 a	1.14 b	1.99 ab	0.99 a	0.86 b	0.13 c	1.46 a	1.06 b	1.51 a
Root dry weight (g)	15d	0.49	0.48	0.50	0.26 a	0.13 b	0.34 a	0.23 a	0.16 b	0.21 ab
	30d	0.67 a	0.33 c	0.58 b	0.62 a	0.55 ab	0.70 a	0.61 a	0.43 b	0.59 a
Chlorophyll content	Total	11.5 b	10.3 c	12.6 a	5.7 b	4.5 c	6.0 a	8.7 b	7.2 c	10.1 a

* Within columns (for each trait), means followed by the same letter are not significantly different at the $P = 0.01$ level of probability, according to Duncan's multiple range test.

weight, root weight, number of leaves and root:shoot ratio. The stem height was reduced by 16-35% at 15 d and by 19-31% at 30 d.

Cold water treated seedlings were shorter and sturdier than the control seedlings. The effects of irrigation water temperature were more evident at 30 d. The tallest stems were obtained with ambient temperature irrigation water in tomato, pepper and eggplant. Irrigation temperature influenced most of the factors analysed. The effect on stem length was as expected.

There are two concerns with regard to low temperature treatment. Firstly irrigation of seedlings with cold water strongly retarded stem growth. The magnitude of this effect depended on irrigation temperature and species. Secondly the number of leaves per plant was also reduced. Plant height was reduced because there were fewer leaves: internode length was not significantly reduced.

Irrigation water temperature influenced the leaf chlorophyll content of the three species (Fig. 1). The highest leaf chlorophyll level was in control tomato pepper and eggplant plant. Decreasing irrigation water temperature to 3°C increased leaf chlorophyll level in the three species. Generally, growth control improves plant appearance such as chlorophyll content (Mitchell *et al.,* 1975). In contrast Chen *et al.* (1999) indicated that leaf chlorophyll content was either not affected or was increased in response to irrigation with cold water. A major problem in commercial seedling production is control of plant growth, especially the seedling height. The results of these experiments show that irrigation with cold water can reduce the stem height by 17% to 58% depending on species. These growth reductions are similar to those attained using chemical plant growth

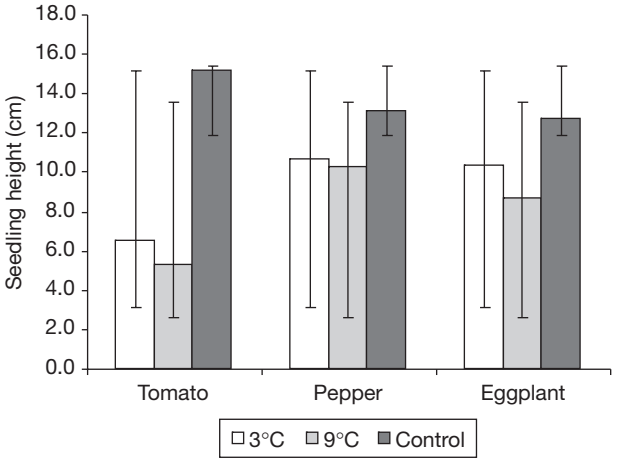

Figure 1. Effect of irrigation with water at 3°C, 9°C and at room temperature on the seedling height of tomato, pepper and eggplant. Significance at the $P = 0.01$ level of probability. Vertical bars are the standard deviation of the mean.

regulators. Adler and Wilcox (1987) reported a 48% reduction in tomato plant height treated with either chlormequat chloride or thigmic stress.

In this study, the number of leaves plant^{-1} was reduced by cold water irrigation water in all three species. Irrigation with cold water strongly retarded stem elongation. Our results indicate that it is possible to use cold water to reduce seedling height with a small decrease in the stem diameter. Stem elongation can be due to an increase in internode number or an increase in internode length. This process is controlled by temperature (Berghage and Heins, 1991). Water temperature affected shoot and root dry weight of tomato, pepper and eggplant seedlings. Shoot dry weight was increased or had the same value than control when seedlings were irrigated with water at 3°C. Chen *et al.* (1999) indicated cold water had no effect on cabbage (*Brassica oleracea* L.) even at very low temperatures or reduced shoot dry weight in tomato. Liptay (1985) indicated that vibrated tomato plants had 34% less shoot dry weight at time of transplanting but there was no difference in shoot dry weight after 3 weeks in the field. These parameters were reduced by decreased water temperature, but not as much as seedling height. This indicates that treated seedlings became more compact than control seedlings.

Mechanical stimulation by brushing (Latimer and Thomas, 1991; Johjima and Latimer, 1992) or shaking (Mitchell *et al.,* 1977) also reduced shoot dry weight in tomato. The reduction in shoot dry weight was found to be gradual with greater stimulation (Heuchert and Mitchell, 1983; Autio *et al.,* 1994). The effect was attributed to a change in the rate of photosynthesis, respiration or both (Keller and Steffen, 1995). The root:shoot ratio was affected by irrigation water temperature in all three species. Decreasing the irrigation water temperature showed either a positive or a small negative effect on the root:shoot ratio. The root:shoot ratio is an important parameter in transplant seedling because it improves their suitability for transplanting and the root and shoot dry weight affect transplant quality (Biddigton and Dearman, 1985).

The results indicate that the effects of cold water irrigation are mediated through root growth restriction and a decrease in total leaf chlorophyll. Cold water seedling irrigation improves seedling appearance, handling characteristics and overall quality. This treatment can interact with other mechanical conditioning effects on transplant establishment, plant growth and crop productivity. This will be identified in further investigation. In conclusion this simple method can be used to control seedling height in commercial nurseries and can be utilized as an alternative to the use of growth retardants for the control of seedling growth.

Acknowledgements

The author thank Professor Dr. Uygun Aksoy for the English revision and two anonymous referees for their useful suggestions to improve the manuscript.

References

ADLER P.R., WILCOX G.E., 1987. Salt stress, mechanical stress, or chlormequat chloride effects on morphology and recovery of hydroponics tomato transplants. J Am Soc Hortic Sci 112, 22-25.

AOAC, 1999. Official methods of analysis, 16th ed. Association of Official Analytical Chemists, Inc, Arlington, Virginia. 140 pp.

AUTIO J., VOIPIO I., KOIVUNEN T., 1994. Responses of aster, dusty miller, and petunia seedlings to daily exposure to mechanical stress. HortScience 29, 1449-1452.

BERGHAGE R.D., HEINS R.D., 1991. Qualifications of temperature effects on stem elongation in poinsettia. J Am Soc Hortic Sci 116, 14-18.

BIDDINGTON N.L., DEARMAN A.S., 1985. The effect of mechanically induced stress on the growth of cauliflower, lettuce and celery seedlings. Ann Bot 55, 109-119.

CHEN J.J., SUN Y.W., SHEEN T.F., 1999. Use of cold water irrigation reduces stem elongation of plug-grown tomato and cabbage seedling. HortScience 34, 852-854.

ERWIN J.E., HEINS R.D., 1995. Thermomorphogenetic responses in stem and leaf development. HortScience 30, 940-949.

HEINS R., ERWIN J., 1990. Understanding and applying DIF. Greenhouse Grower, February, pp. 73-78.

HEUCHERT J.C., MITCHELL C.A., 1983. Inhibition of shoot growth in greenhouse-grown tomato by periodic gyratory shaking. J Am Soc Hort Sci 108, 795-800.

HICKMAN G.W., PERRY E.J., MULLEN R.J., SMITH R., 1989. Growth regulator controls tomato transplant height. Calif Agric 43, 19-20.

JAWORSKI C.A., WEBB R.E., GRISON S.A., BERGMAN E.L., SHANON S., 1970. Growth retardant-treated tomato transplant. HortScience 5, 255-256.

JOHJIMA T., LATIMER J.G., 1992. Brushing influences transplant growth and subsequent yield of four cultivars of tomato and their hybrid lines. J Am Soc Hortic Sci 117, 384-388.

KELLER E., STEFFEN K.L., 1995. Increased chilling tolerance and alternative carbon metabolism in tomato leaves following application of mechanical stress. Physiol Plant 93, 519-525.

LATIMER J.G., 1990. Drought or mechanical stress affects broccoli transplant growth and establishment but not yield. HortScience 25, 1223-1235.

LATIMER J.G., THOMAS P.A., 1991. Application of brushing for growth control of tomato transplants in commercial setting. HortTechnology 1, 109-110.

LIPTAY A., 1985. Reduction of spindliness of tomato transplant grown at high densities. Can J Plant Sci 65, 797-801.

MITCHELL C.A., SEVERSON C.J., WOTT J.A., HAMMER P.A., 1975. Seismomorphogenic regulation applied during the vegetative stage. Japan J Crop Sci 57, 782-789.

MITCHELL C.A., DOSTAL H.C., SEIPEL T.N., 1977. Dry weight reductions in mechanically dwarfed tomato plants. J Am Soc Hortic Sci 102, 605-608.

MOE R., GLOMSRUD N., BRATBERG I., VALSO S., 1992. Control height in poinsettia by temperature drop and graphical tracking. Acta Hort 327, 41-48.