

The Influence of Diurnal Temperatures on the Postharvest Susceptibility of Poinsettia to *Botrytis cinerea*

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ABSTRACT

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The influence of day/night (DT/NT) temperatures of 16/16, 19/19, 22/22, 16/19, 19/22, 16/22, 19/16, 22/19, and 22/16°C during poinsettia production on postharvest bract and foliage susceptibility to *Botrytis cinerea* was investigated. Plants were inoculated with 2.7×10^5 *B. cinerea* conidia per ml of water following a 3- or 6-week temperature treatment and incubated at 20°C. Area under the disease progress curve (AUDPC) data indicated that the postharvest susceptibility of poinsettia bracts and foliage to *B. cinerea*, measured by the proportion of bracts and foliage infected and the proportion with sporulating *B. cinerea*, was not influenced by the difference in DT and NT but increased as DT or NT during production increased. As plants matured, as indicated by thermal time, AUDPC values increased ($P = 0.001$) more for the proportion of bracts infected ($R^2 = 0.73$) than for the proportion of bracts with sporulating *B. cinerea* ($R^2 = 0.86$) and the proportion of foliage with sporulating *B. cinerea* ($R^2 = 0.74$). Results suggested that commercial growers using higher NT than DT to limit poinsettia height are not increasing the postharvest susceptibility of their crop to *B. cinerea*. However, the increased susceptibility of maturing poinsettias suggests disease management strategies should be intensified during crop finishing and postharvest handling.

Cash receipts for floriculture producers in the United States with \$100 million or more in gross sales totaled \$2.83 billion in 1993 (1). The poinsettia (*Euphorbia pulcherrima* Willd. ex Klotzsch) is a significant crop for Michigan growers, who produce 5% of all poinsettias (1993 wholesale value of \$9.9 million) in the U.S. (1). Growers must suppress poinsettia height to meet contractual specifications for short, compact plants. Height of floricultural crops commonly is managed by synthetic chemical growth regulators (5). Growth regulator efficacy varies with application rate, the method of application, stage of plant development at which it is applied, and the crop treated. Improper use of growth regulators results in plant abnormalities that may compromise crop salability.

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bility of bracts and foliage to *B. cinerea*. The effect of higher NT than DT was of particular interest.

MATERIALS AND METHODS

Plant culture and treatment. Ten-week-old poinsettias (cv. Angelika White) obtained from a commercial grower (Post Gardens, Battle Creek, MI) were grown in 15.2-cm-diameter plastic pots (pot volume = 2,177 ml) containing a commercial soil-less potting mix (Mix #4, Sun Gro Horticulture, Inc., Bellevue, WA) composed of 40% perlite and 60% sphagnum peat moss. Plants were spaced 13 cm apart on benches in 4.8 × 4.2 m glass research greenhouses at Michigan State University. Plants were subirrigated as required with 200 ppm N and K₂O fertilizer solution at 2- or 3-day intervals. The irrigation water pH was maintained at 5.8. Glasshouse temperatures were maintained at 16, 19, or 22°C by means of a climate-control computer. Temperatures were monitored by a datalogger (Campbell Scientific, Inc., Logan, UT) that recorded temperatures every minute and average temperature every 15 min. Actual average temperatures during the experiment did not vary from the targeted settings by more than 1.4°C. Light levels were natural photoperiods.

Plants were grown under the following DT/NT regimes: 16/16, 19/19, 22/22, 19/16, 22/19, 22/16, 16/19, 19/22, and 16/22°C. The experimental design was completely randomized, with five plants per treatment. To achieve the specified treatments, plants were moved within 15 min among three glasshouses set at 16, 19, or 22°C at 0700 and 1900 hours each day. Plants received a 3-week temperature treatment for experiment 1 and a 6-week temperature treatment for experiment 2.

***Botrytis cinerea* culture and inoculation.** *Botrytis cinerea* was isolated from an infected geranium and grown on 20 ml of potato dextrose agar in 10-cm-diameter petri plates at 25°C for approximately 20 days. A conidial suspension was prepared by flooding plates with sterilized, distilled water and dislodging conidia by means of a glass rod. Conidial concentrations ranging from 2.2 to 3.2 × 10⁵ conidia/ml were quantified with a hemacytometer. Tween 20 (0.04%) was added to the suspension prior to inoculation.

A Prevail pressurized atomizer (Precision Valve Corp., Yonkers, NY) was used to spray plants to runoff with the conidial

Day (DT) and night (NT) temperatures can also be manipulated to regulate plant height (4). Commercial flower producers traditionally have grown crops using a DT that is higher than the NT, resulting in an increase in plant internode length. However, when NT is higher than DT, plant internode length is suppressed; therefore, temperature regulation can serve as a nonchemical method of limiting plant height. The popularity among growers of manipulating DT and NT to limit plant height has raised the question of whether current disease management strategies for *Botrytis cinerea* Pers.:Fr., a common and serious pathogen of poinsettia (19), are affected by different DT/NT regimens. Fungicide resistance (11,12) has encouraged the use of environmental manipulation such as increasing air circulation and minimizing the duration of free moisture on the plants to manage blight caused by *B. cinerea*. *Botrytis cinerea* depends on a water film for conidial germination and infection; therefore, maintaining temperatures above the dew point is an effective mechanism for preventing disease (7).

Sammons et al. (15) addressed the effects of diurnal temperature variations on the incidence and severity of *B. cinerea* and found no differences when inoculated poinsettias were grown under 17/17, 10/10, or 17/10°C (DT/NT). The objective of this study was to determine how regimes alternating between temperatures within a range of 16 to 22°C during poinsettia production would affect postharvest suscepti-

suspension after the temperature treatment. Control plants were sprayed with sterile distilled water. Each plant was placed in a 53 × 14 × 96 cm plastic bag containing a 180-ml cup of distilled water to assure constant high relative humidity. Bags were sealed and placed on benches in a walk-in chamber maintained at 20 ± 1°C with a 12-h photoperiod provided by high-pressure sodium lights.

Disease assessment. The proportion of bracts blighted and supporting *B. cinerea* sporulation was assessed 4, 6, and 8, or 3, 6, and 8 days after inoculation in experiments 1 and 2, respectively. The area under the disease progress curve (AUDPC) representing the cumulative proportion of bracts and foliage infected, and the proportion of each with sporulating *B. cinerea*, over an 8-day period following inoculation was calculated with the method of Shaner and Finney (18). The effects of DT and NT, and the difference between DT and NT, were determined by performing an analysis of variance (ANOVA) of the AUDPC data with the general linear means (GLM) procedure of the Statistical Analysis System (SAS) (16).

Quantifying plant maturity. Phenological plant development was quantified by summing daily mean temperatures and subtracting a base temperature (10) with the following formula:

$$t_n = \sum_{i=1}^n [T_i + T_n/n] - T_b$$

where t_n = degree days in C, T_i = average daily temperature, T_n = the n th average daily temperature, n = total number of average daily temperatures, and T_b = base temperature. T_b for poinsettia crops has been determined to be 5°C (R. D. Heins, Michigan State University, personal com-

munication). Thermal time measures the accumulation of heat in degrees above the temperature (5°C) at which no plant development occurs during a 24-h period. Thermal time is a more accurate descriptor of plant development than chronological time (13). Degree-day values were regressed with AUDPC means using the GLM protocol of SAS (16).

RESULTS

AUDPC data from experiments 1 and 2 indicated that the proportion of bracts infected and the proportion of bracts with sporulating *B. cinerea* postharvest were not influenced by the difference in DT and NT during production, but increased as DT or NT increased (Table 1). When DT or NT was held at 16°C and corresponding NT or DT increased from 16 to 22°C during production, the proportion of blighted bracts postharvest increased from 50 to 87% (experiment 1) and was 100% (experiment 2) 8 days after inoculation, while the proportion of bracts with sporulating *B. cinerea* postharvest increased from 5 to 32% in experiment 1 and from 16 to 72% in experiment 2 (Fig. 1). A statistical interaction between DT and NT during production occurred for AUDPC data representing the proportion of bracts infected postharvest in experiments 1 and 2 (Table 1), and resulted from a decreased amount of disease in the 22/22°C treatment compared with the other treatments 8 days after inoculation (data not shown).

The proportion of foliage infected and the proportion of foliage with sporulating *B. cinerea* (AUDPC) postharvest were not influenced by the difference between DT and NT during production in either experiment. The proportion of foliage in-

fectured postharvest was associated linearly with DT during production in experiments 1 and 2 and with NT during production in experiment 2 (Table 1). The proportion of foliage with sporulating *B. cinerea* postharvest was not influenced by DT during production in either experiment or NT during production in experiment 1 (Table 1). A statistical interaction between DT and NT during production occurred for AUDPC data representing the proportion of foliage infected postharvest in experiment 2.

As DT or NT was held at 16°C and the corresponding NT or DT increased from 16 to 22°C during production, the proportion of foliage infected postharvest 8 days after inoculation increased from 9 to 36% (experiment 1), and from 5 to 17% (experiment 2) while, the proportion of foliage with sporulating *B. cinerea* ranged from 7 to 25% in experiment 1, but did not exceed 8% in experiment 2 (data not shown).

Eight days after inoculation, the proportion of bracts infected postharvest was 99% in experiment 2 compared with 50% in experiment 1 for the treatment grown at 16/16°C (Fig. 1). However, the proportion of bracts with sporulating *B. cinerea* (19%) (Fig. 1) and the proportion of foliage with sporulating *B. cinerea* (9%) for treatment 16/16°C were similar for both experiments for the same period (data not shown).

As plants matured (as indicated by the thermal time), AUDPC values representing the proportion of bracts infected over time increased. The R^2 for regression of the proportion of bracts infected against thermal time was 0.90 ($P = 0.001$) and was described by the equation $y = 17.2 + 8.80(x)$. The AUDPC values indicated that, as thermal time increased, the proportion of bracts with sporulating *B. cinerea* also

Table 1. Influence of day temperature (DT) and night temperature (NT) on the susceptibility of poinsettia (cv. Angelika White) bracts and foliage to *B. cinerea* infection and subsequent sporulation

Temperature treatments (C)			Area under the disease progress curve							
DT	NT	Difference between DT and NT (C)	Infected bracts		Infected bracts with sporulation		Infected foliage		Infected foliage with sporulation	
			Expt. 1	Expt. 2	Expt. 1	Expt. 2	Expt. 1	Expt. 2	Expt. 1	Expt. 2
16	16	0	147.8	449.0	11.4	35.8	4.0	6.2	2.6	2.0
16	19	-3	220.6	492.2	30.7	140.8	4.4	31.8	1.4	10.8
16	22	-6	267.8	497.9	37.2	173.8	9.2	36.8	2.6	14.5
19	16	3	203.0	491.3	30.9	121.4	10.3	20.2	3.0	5.9
19	19	0	243.6	490.1	79.8	142.0	12.7	25.4	3.2	8.0
19	22	-3	335.8	500.0	110.1	192.9	26.4	67.6	6.1	24.3
22	16	6	244.4	485.3	67.5	164.1	14.1	42.0	4.6	13.5
22	19	3	283.4	495.8	68.2	178.9	11.0	47.3	4.4	14.9
22	22	0	256.0	500.0	82.8	202.5	17.3	47.8	15.7	18.4
Significance ^a										
Difference between DT and NT			NS	NS	NS	NS	NS	NS	NS	NS
Day temperature			***	*	***	**	*	**	NS	NS
Linear			***	*	***	**	*	**
Quadratic			*	NS	**	NS	NS	NS
Night temperature			***	***	***	***	NS	***	NS	**
Linear			***	***	***	***	...	***	...	**
Quadratic			NS	NS	NS	NS	...	NS	...	NS
Day × night			**	*	NS	NS	NS	*	NS	NS

^a NS, *, **, *** Nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

increased. The R^2 for the regression of the proportion of bracts with sporulating *B. cinerea* against thermal time was 0.86 ($P = 0.001$) and was described by the equation $y = -74.5 + 0.40(x)$. The AUDPC of foliage infected and of foliage with sporulating *B. cinerea* increased as thermal time increased. The R^2 values for the regression of proportion of foliage infected and of foliage with sporulating *B. cinerea* against thermal time were 0.73 ($P = 0.001$) and 0.74 ($P = 0.001$), respectively. The relationship between thermal time and the proportion of foliage infected and between

thermal time and the proportion of foliage with sporulating *B. cinerea* were described by the equations $y = -19.0 + 0.10(x)$ and $y = -7.65 + 0.04(x)$, respectively.

DISCUSSION

The difference between DT and NT during production did not influence the postharvest susceptibility of poinsettia bracts and foliage to *B. cinerea*, as measured by the proportion of tissue infected and supporting sporulation. Although manipulating DT and NT during production causes changes in plant morphology, in-

cluding alterations in plant height, internode length, and leaf orientation attributable to elongation of stem parenchyma and stem and leaf epidermal cells (4), this study suggests that these changes do not influence the postharvest susceptibility of poinsettia to *B. cinerea*.

The proportion of bracts and foliage infected and of bracts and foliage with sporulating *B. cinerea* (AUDPC) postharvest increased as DT or NT during production increased, with the exception of the proportion of foliage with sporulating *B. cinerea* in experiment 2. Elad and Yunis

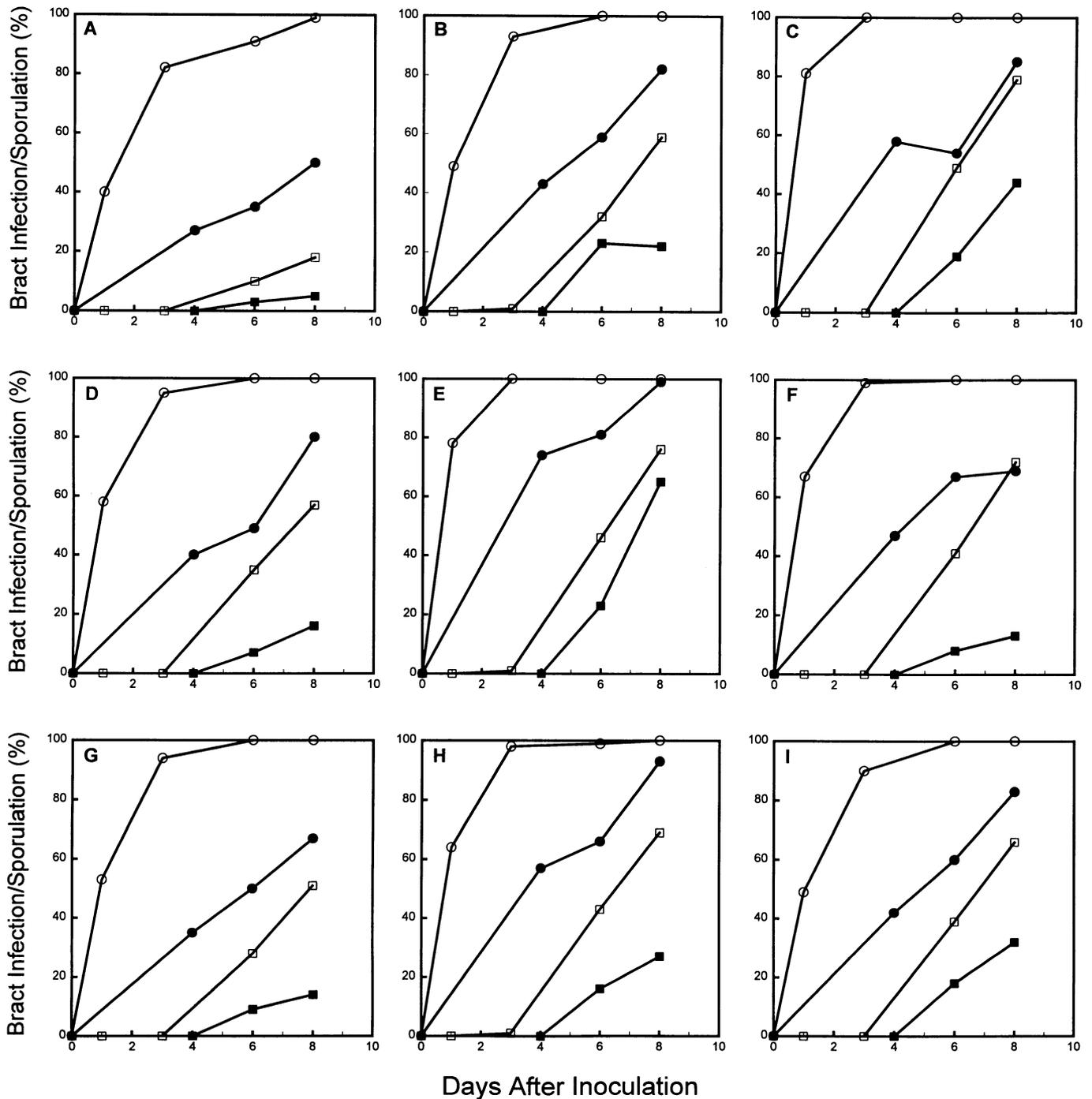


Fig. 1. Percentage of poinsettia bracts infected (circle) postharvest with *B. cinerea* and supporting sporulation (square) 8 days after inoculation in experiment 1 (solid symbols) and experiment 2 (open symbols) when plants were grown at day/night temperatures of (A) 16/16, (B) 19/19, (C) 22/22, (D) 16/19, (E) 19/22, (F) 16/22, (G) 19/16, (H) 22/19, and (I) 22/16°C.

(3) showed that greenhouse-grown cucumbers are predisposed to *Botrytis* blight when grown at temperatures higher (30°C) or lower (8°C) than optimum. Similarly, Keressies (9) determined that temperature had a significant effect on the postharvest susceptibility of gerbera flowers to *B. cinerea*. Flowers stored at temperatures ranging from 15 to 25°C prior to inoculation had more lesions than those stored at 10°C. Keressies (9) hypothesized that the increased turgor pressure resulting from the higher temperatures caused leakage of nutrients, sugars, and salts to the flower surface (20) that stimulated germination of *B. cinerea* conidia (2,14). Senecal et al. (17) observed that as NT increased from 9 to 17°C, the number of days to anthesis in poinsettias decreased. In our experiments, more mature plants, as measured by thermal time, were subsequently more susceptible to bract and foliage infection and sporulation. Hunter et al. (6) determined that increased maturity of macadamia racemes coincided with an increase in plant susceptibility to *B. cinerea* infection. Postharvest susceptibility of gerbera flowers is positively correlated to crop age (8). Therefore, greater bract infection in experiment 2 than in experiment 1 may have been related to the greater maturity of the poinsettias.

Results of this study suggest that commercial growers using higher NT than DT to limit plant height do not need to modify current *B. cinerea* disease management

programs on poinsettias. These data suggest, however, that mature plants are very susceptible to *B. cinerea* and disease management strategies should be heightened during crop finishing and postharvest handling.

LITERATURE CITED

1. Agricultural Statistics Board. 1994. Floriculture Crops: 1993 Summary. USDA, Natl. Agric. Stat. Serv., Agric. Stat. Board, Washington, DC.
2. Blakeman, J. P. 1975. Germination of *Botrytis cinerea* conidia in vitro in relation to nutrient conditions on leaf surfaces. *Trans. Br. Mycol. Soc.* 65:239-247.
3. Elad, Y., and Yunis, H. 1993. Effect of microclimate and nutrients on development of cucumber gray mold (*Botrytis cinerea*). *Phytoparasitica* 21:257-268.
4. Erwin, J. E., Heins, R. D., Carlson, W., and Newport, S. 1992. Diurnal temperature fluctuations and mechanical manipulation affect plant stem elongation. *Plant Growth Regul. Soc. Am. Q.* 20:1-17.
5. Hartley, D. 1992. Poinsettias. Pages 305-331 in: *Introduction to Floriculture*. 2nd ed. R. Larson, ed. Academic Press, San Diego.
6. Hunter, J. E., Rohrbach, K. G., and Kunimoto, R. K. 1972. Epidemiology of *Botrytis* blight of macadamia racemes. *Phytopathology* 62: 316-319.
7. Jarvis, W. R. 1989. Managing diseases in greenhouse crops. *Plant Dis.* 73:190-194.
8. Keressies, A. 1993. Influence of environmental conditions on dispersal of *Botrytis cinerea* conidia and on post-harvest infection of gerbera flowers grown under glass. *Plant Pathology* 42:754-762.
9. Keressies, A. 1994. Effects of temperature, vapour pressure deficit and radiation on infectivity of conidia of *Botrytis cinerea* and on susceptibility of gerbera petals. *Eur. J. Plant Pathol.* 100:123-126.
10. Ketring, D. L., and Wheless, T. G. 1989. Thermal time requirements for phenological development of peanut. *Agron. J.* 81:910-917.
11. Moorman, G. W., and Lease, R. J. 1992. Benzimidazole- and dicarboximide-resistant *Botrytis cinerea* from Pennsylvania greenhouses. *Plant Dis.* 76:477-480.
12. Pommer, E. H., and Lorenz, G. 1982. Resistance of *Botrytis cinerea* Pers. to dicarboximide fungicides: A literature review. *Crop Prot.* 1:221-230.
13. Rickman, R. W., Klepper, B. L., and Peterson, C.M. 1983. Time distributions for describing appearance of specific culms of winter wheat. *Agron. J.* 75:551-556.
14. Salines, J., Glandorf, D. C. M., Picavet, F. D., and Verhoeff, K. 1989. Effects of temperature, relative humidity and age on the incidence of spotting on gerbera flowers caused by *Botrytis cinerea*. *Neth. J. Plant Pathol.* 95:51-64.
15. Sammons, B., Rissler, J. F., and Shanks, J. B. 1982. Development of gray mold of poinsettia and powdery mildew of begonia and rose under split night temperatures. *Plant Dis.* 66: 776-777.
16. SAS Institute, Inc. 1988. Page 1028 in: *SAS/STAT User's Guide*. Release 6.03. SAS Institute, Cary, NC.
17. Senecal, M. D., Dansereau, B., and Paquin, R. 1989. Fertilization and night temperature effects on growth and carbohydrate status of poinsettia. *Can. J. Plant Sci.* 69:347-349.
18. Shaner, G., and Finney, R. E. 1977. The effect of nitrogen fertilization on the expression of slow mildewing resistance in Knox wheat. *Phytopathology* 67:1051-1056.
19. Strider, D. L., and Jones, R. K. 1985. Poinsettias. Pages 351-403 in: *Diseases of Floral Crops*. Vol 2. Praeger Publishers, New York.
20. van Meeteren, U. 1980. Role of pressure potential in keeping quality of cut gerbera inflorescence. *Acta Hort.* 113:143-150.