HORTSCIENCE 33(4):668–671. 1998.

Stock and Snapdragon as Influenced by Greenhouse Covering Materials and Supplemental Light

B. Dansereau[1], **Y. Zhang**[2], **and S. Gagnon**[3]
Horticultural Research Center, Laval University, Quebec G1K 7P4, Canada

H.L. Xu[4]
International Nature Farming Research Center, Hata, Nagano 390-14, Japan

Additional index words. Antirrhinum majalis, flowering, *Matthiola incana*, photosynthesis

Abstract. **We examined effects of single-layer glass and double-layer antifog polyethylene films on growth and flowering of stock (*Matthiola incana* L.) and snapdragon (*Antirrhinum majalis* L.) in a 3-year period. Stock produced more buds/spike with shorter but thicker stems under single-layer glass and under antifog 3-year polyethylene, and showed higher photosynthetic capacity (P_C) under single-layer glass than under other covers regardless of light regimes. Similarly, growth and flowering of snapdragon were significantly better under single-layer glass than in polyethylene houses. A supplemental light of 60 μmol·m^{-2}·s^{-1} accelerated flowering by 20 to 25 days, improved flower quality, and eliminated differences in plant growth and quality of snapdragon between covering treatments. The P_C of stock was lower under all polyethylene covers than under single-layer glass. Among the three antifog polyethylene films, a slightly higher P_C was measured for plants under antifog 3-year polyethylene. However, there was no difference among covering treatments in the net photosynthetic rate (P_N) at low light level (canopy level). Supplemental lighting reduced P_C of stock leaves, especially under single-layer glass, and diminished differences in P_C among covering treatments. Dry mass was more influenced by larger leaf area caused by higher leaf temperature than by P_N. Overall, antifog 3-year polyethylene was a good covering material when both plant quality and energy saving were considered.**

Energy consumption is an important concern of greenhouse growers and has resulted in the use of double covers and thermal screens (Ferare and Goldsberry, 1984). However, these structures restrict air exchange, reduce light transmission and increase temperature and humidity (Boulard et al., 1989; Holder and Cockshull, 1990; Starkey, 1985; Steinbuch and van de Vooren, 1984). Reductions in yield and quality of roses (Ferare and Goldsberry, 1984) and delays in flowering of chrysanthemum (Bjerre, 1981; Ferare and Goldsberry, 1984; Reiersen and Sebesta, 1981) have been observed in double-layer thermal screen greenhouses. Ferare and Goldsberry (1984) attributed alterations in growth and development under a double-layer cover to the reduction in light transmission caused by condensation. To counter this problem, antifog films have been tested for the inner layer of double polyethylene covers (Lagier, 1991). Such films can increase light transmission 15% to 20% (Jaffrin and Morisot, 1994). Supplemental lighting can also improve greenhouse light conditions. In order to select an antifog film suitable for greenhouse production and elucidate the mechanism of its effect on flower growth and development, we carried out a 3-year study on the effects of covering materials and supplemental lighting on microclimate, leaf photosynthesis, plant growth, and flower quality of two cut flower crops.

Materials and Methods

Covering materials and environment. The experiment was conducted from Jan. 1991 to Apr. 1993 in a multi-span greenhouse located at Laval Univ., Que., Canada (46°47´N, 71°16´W). The greenhouse, oriented northeast–southwest, was covered with double 8-mm polycarbonate walls and air-inflated double-layer polyethylene roofs. The four separate and contiguous compartments (6.4 m long × 6 m wide, ridge height 4.65 m; eave height 3.15 m) were situated at the southernmost span of the greenhouse. Compartment #3 was covered with 4-mm single-layer glass; all other compartments were covered by double-layer polyethylene films with the same standard outside layer of polyethylene film (AT D3 40; AT Plastics, Ont., Canada) and different inside layers as follows: #1, antifog 3-year polyethylene (AT D3 AF80); #2, antifog thermal polyethylene (CIL DT 59); and #4, antifog 1-year polyethylene (CIL D1 AF40; AT Plastics, Ont., Canada).

Air temperature in all compartments was controlled at 18 ± 1 °C during the day and 14 ± 1 °C during the night using a heating-ventilation system equipped with two electric unit heaters (7.5 kW each) and a fan jet. The fan jet was controlled by a programmable digital thermostat (White-Rodgers, Emerson Electric Co., Ont., Canada) and was used to ensure constant air mixing and cooling of inside air by injecting outside air when necessary.

There were two light treatments in each compartment: 1) natural, which varied with covering materials, and 2) supplemental of 60 μmol·m^{-2}·s^{-1} from high-pressure sodium vapor lamps (HPS 400W) for 16 h per day (from 2400 to 1600 HR). A Li-190SB quantum sensor (LI-COR, Lincoln, Nebr.) was mounted horizontally beneath the roof to monitor the light level in each compartment. Leaf temperature was monitored by thermocouples (copper–constantan) that were inserted superficially into abaxial sides of leaves at the middle of the leaf canopy.

Plant materials and experimental design. Four production cycles were carried out from Jan. 1991 to Apr. 1993. Seeds of stock, 'Ball Supreme', and snapdragon, 'Totem Dark Pink', were sown in seedling packs containing a peat moss–based substrate (Pro-Mix, fine granulation; Premier Peat-Moss, Riviere-du-Loup, Que., Canada). Substrate temperature was maintained at 24 °C and air temperature at 23 °C for germination. High humidity was assured by placing transparent plastic sheets over the trays. Seedbeds were filled with an artificial soil mix (40% sand, 45% loam, and 15% sphagnum peat by volume) to a depth of 40 cm. Plants were transplanted from seedling packs into seedbeds (0.9 × 2.45 m) with a density of 75 and 112 plants/m^2 for stock and snapdragon, respectively, at the 10 true-leaf stage. A split-plot design was used with the cover materials as the main plot (two replicates) and the lighting treatment as the subplot (two replicates per main plot). A complete nutrient solution containing (mg·kg^{-1}) 125N–25P–150K–100Ca–40Mg–2Fe–0.75Mn–0.3Zn–0.25B–0.046Mo–0.13Cu was provided by a drip irrigation system supplying 2 to 5 L·d^{-1}·m^{-2}, depending on plant development (plant size) and the growing season (winter or summer).

Measurements and analyses. Morphological characteristics, such as flower stem length, spike length, stem diameter, and number of buds/spike, were measured at harvest for both stock and snapdragon. Total leaf area on each stem was measured with a portable leaf area meter (Li-3000; LI-COR, Lincoln, Nebr.). Data were analyzed by Statistical Analysis System (SAS Institute, Cary, N.C.) with the general linear model procedure and compared by the Waller–Duncan multiple range test.

Photosynthesis was measured only for stock. Plants used for photosynthetic measurement were transplanted into 1.5-L pots on 4 Sept. 1991 and placed near the treatment plot

---

Received for publication 27 Nov. 1996. Accepted for publication 30 Dec. 1997. The authors thank André Boisvert, Jean-Francois Goulet, René Pouliot, and Rachel Daigle for their professional and technical assistance. The financial support for this work from Institut Québecois de Développement de l'Horticulture Ornementale, AT Plastics, Industries Harnois, Ciba Geigy Canada, and Ministere de l'Energie et des Ressources du Québec, is gratefully acknowledged. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1] Professor.

[2] Currently a postdoctoral fellow at Agriculture Canada Research Station, Harrow, Ont. N0R 1G0.

[3] Research Associate.

[4] Senior Researcher/Professor.

under the same conditions. In Jan. 1992, four pots from each treatment were moved to the laboratory and the photosynthetic activity for single leaves measured using an open gas exchange system (Yue et al., 1992). Two high-pressure sodium vapor lamps (1000 W) were suspended above a 3-cm deep water filter. Photosynthetic photon fluxes (*PPF*) of 0, 45, 200, 400, 600, and 800 μmol·m^{-2}·s^{-1} were provided by changing the height of the lamps during successive measurements for the same leaf. An attached leaf (the twelfth leaf from bottom) was enclosed in an assimilation chamber, where the air humidity was 60% ± 5% with fluctuations according to leaf transpiration. The air temperature was 22 ± 1 °C with fluctuations according to the light level. The air in the assimilation chamber was mixed by a small fan to dissipate heat from the leaf and provide uniform laminar air flow over the leaf surface. The leaf temperature was measured with a fine thermocouple (0.1 mm) placed beneath the blade. The rate of air flow was 2490 mL·min^{-1}. Ambient CO_2 concentration from the inlet of the chamber was 380 μL·L^{-1}. Fifteen minutes of equilibration time was needed to stabilize the response of each light level. Calculation of the photosynthetic rate was based on the CO_2 concentration difference (CO_2) between the inlet and outlet of the chamber. An exponential model (Xu et al., 1995) was used to fit the photosynthetic light-response curve as follows:

$$P_N = P_C\,(1\text{-}e^{-Ki})\text{-}R_D,$$

where P_N is the net photosynthetic rate; P_C, the maximum gross photosynthetic capacity; K, the half time constant; i, the *PPF*; and R_D, the dark respiration rate. P_CK shows the initial slope of the curve and indicates the maximum quantum yield (Y_Q). A nonlinear least square iteration procedure in SAS was applied to the exponential model.

Results

During the growth period, light intensity in the greenhouse was in the order of single glass > antifog 3-year polyethylene > antifog 1-year polyethylene > antifog thermal polyethylene (Table 1). Relative humidity in the single glass house was 36% lower than that in the other compartments. Leaf temperature of stock plants grown under antifog 3-year polyethylene was 0.6–1.3 °C lower both in the day and during the night than that of plants growing under other covers.

Plant growth and flower development

Effects of covering materials. There were only slight differences in stem length, spike length, stem diameter, number of buds/flower, and days to flowering, between plants grown under single glass and those grown under double antifog polyethylene covers (Table 2). Under antifog thermal polyethylene, the flower stems of stock plants were 4 cm longer and the stem diameter 0.9 mm less than those of plants growing under single-layer glass. Flower quality under antifog 3-year polyethylene was comparable to or slightly better than that under single glass, with longer stems and spikes, thicker stems, and similar numbers of buds/flower. Covering did not affect the total number of flowers.

Under natural light conditions, flower quality of snapdragon plants grown under single glass was better than that of those grown in polyethylene houses (Table 2), with stems 0.4 mm larger in diameter and five more buds/spike. There was no significant effect of covering material on spike length. Leaf area of stock plants grown under both 1- and 3-year antifog polyethylene was less than that under single-layer glass or antifog thermal polyethylene (Table 3). The leaf specific dry mass was lower for plants grown under antifog 1-year polyethylene than for those under other covers.

Effects of supplemental lighting. The most significant benefit from supplemental lighting for stock was 20 to 25 d earlier flowering. The lengths of flower stem and spike were reduced by supplemental lighting regardless of covering materials, but all the stems surpassed the commercial requirement of 60 cm. In contrast, the stem diameter was increased by supplemental lighting, especially under antifog 1-year polyethylene and antifog thermal polyethylene, whereas stems were thinner under natural light. Leaves developing under antifog 3-year polyethylene were smaller than those under natural light conditions in the same compartment (Table 3). Leaf specific dry mass under antifog thermal polyethylene was increased 13% by supplemental lighting.

Whole plant dry mass production

Effects of covering material. Dry mass of stock plants grown during Sept.–Dec. 1992 was least under antifog 3-year polyethylene, where leaf temperature was lowest, and greatest under antifog thermal polyethylene, where leaf temperature was highest. Trends for dry mass for other growing cycles (data not shown) were similar.

Effects of supplemental lighting. Supplemental lighting significantly increased dry mass of stock plants under all covering materials. The effect of supplemental lighting was greater for plants under single-layer glass and under antifog thermal polyethylene than under other covering materials.

Photosynthetic capacity, quantum yield, and respiration rate

Effects of covering material. The photosynthetic capacity (P_C) of stock leaves was lower under all polyethylene covers than under single glass (Table 4). However, covering material did not affect net photosynthetic rate (P_N) at low *PPF*, such as at 200 μmol·m^{-2}·s^{-1}, which was close to the real *PPF* in the canopy. There was no difference in quantum yield (Y_Q) between plants grown under polyethylene covers vs. single glass. The P_C was 1.8–2.7 μmol·m^{-2}·s^{-1} higher for plants grown under antifog 3-year polyethylene than in those grown under the other two antifog polyethylene films. Respiration rate of stock plants was not affected by covering materials.

Effect of supplemental lighting. Supplemental lighting reduced P_C of stock plants, especially under single glass, as well as the differences in P_C among covering treatments (Table 4). The maximum quantum yield, a limiting factor at low *PPF*, was not affected by supplemental lighting, with the exception of plants under antifog 1-year polyethylene. The respiration rate of stock plants was not affected by supplemental lighting.

Discussion

Stock plants grown under antifog thermal polyethylene covers had thinner stems, larger leaves, and higher dry mass than those grown under single glass. Thin stems under thermal polyethylene might be attributed to low light transmission. Bjerre (1981) also found that *Kalanchoe*, *Saintpaulia*, *Codiaeum*, and *Dieffenbachia* plants grown under double-acrylic covers, which reduced light 22%, were taller and thinner than those grown under glass covers. Large leaves under antifog thermal cover might be due, at least in part, to low irradiance. One of the mechanisms by which the shaded leaf maintains a positive carbon balance is by increasing leaf area, thereby increasing light absorption (Fitter and Hay, 1987). An extreme case was reported by Evans and Hughes (1961); specific leaf area of *Impatiens parviflora* increased almost 3-fold when grown in 7% of full daylight. We attribute the high dry mass under antifog thermal polyethylene to a larger leaf area, resulting in a larger total canopy photosynthesis, rather than to a higher photosynthetic rate. Although P_C was lower under antifog thermal polyethylene film than under single glass in our experiment, P_N was not low at low *PPF* (for example, 200 μmol·m^{-2}·s^{-1}), which was close to the level of actual light conditions in the canopy. This might be one of the reasons why the dry mass was higher under this kind of cover. Our results suggest that thermal films can save

Table 1. Effects of covering materials on average photosynthetic photon flux (*PPF*), relative humidity (RH), and leaf temperature (T_L) during growth (Sept. to Apr., 1991–93) of stock plants.

Cover	*PPF* (mol·m^{-2}·d^{-1})	RH (%) Day	RH (%) Night	Day T_L (°C)	Night T_L (°C) –TS[z]	Night T_L (°C) +TS
SG[y]	8.72[x]	52	65	16.7	10.0	9.8
AF1	8.08	58	68	16.8	10.6	11.5
AF3	8.40	56	69	15.7	9.7	11.1
AFT	7.86	58	69	17.0	10.6	12.1

[z] Thermal screen (single glass was always used in combination with TS during night).

[y] Single glass; AF1, polyethylene (PE) + antifog 1-year PE; AF3, PE + antifog 3-year PE; AFT, PE + antifog thermal PE.

[x] Mean of the daily average values for all days of four cropping cycles.

Table 2. Mean[z] effects of covering materials and supplemental lighting on growth and flowering of stock and snapdragon plants during four cropping cycles (Sept. to Apr. of 1991–93).

	Stem length (cm)		Spike length (cm)		Stem diam (mm)		Buds/spike		Days to flowering
Cover	Stock	Snap	Stock	Snap	Stock	Snap	Stock	Snap	Stock
				Natural light conditions					
SG[y]	89 b[x]	127 b	31 b	18 a	6.8 a	4.7 a	43 a	32 a	141 a
AF1	89 b	129 ab	33 a	17 a	6.0 b	4.3 b	42 a	27 b	143 a
AF3	92 a	122 b	33 a	17 a	7.2 a	4.4 b	44 a	27 b	145 a
AFT	93 a	131 a	32 ab	18 a	5.9 b	4.3 b	42 a	27 b	141 a
				Supplemental light conditions					
SG	82 ab	120 bc	26 a	20 b	7.2 a	4.3 a	38 a	29 bc	120 a
AF1	81 b	117 c	26 a	20 b	7.0 a	4.2 b	36 b	28 c	120 a
AF3	83 a	125 ab	27 a	21 a	7.5 a	4.8 a	38 a	31 ab	121 a
AFT	82 ab	125 ab	26 a	21 a	7.3 a	4.8 a	37 a	32 a	120 a

[z] Average values for four cropping cycles (total of 207 plants per treatment).
[y] See Table 1.
[x] Mean separation within columns and light conditions by Waller–Duncan multiple range test, $P \leq 0.05$.

Table 3. Effects of covering materials on leaf development and shoot dry mass of stock plants grown under natural (NL) and supplemental light (SL) conditions during Sept. to Apr. of 1991 to 1993.

	Leaf number		Leaf area (cm^2/stem)		Leaf specific dry mass ($mg \cdot cm^{-2}$)		Dry mass (g/plant)[x]	
Cover	NL	SL	NL	SL	NL	SL	NL	SL
SG[z]	35 a[y]	36 a	1396 b	1355 b	3.7 a	3.8 b	7.2 bc	10.9 a
AF1	35 a	33 a	1318 c	1324 b	3.4 b	3.5 c	7.8 ab	9.0 b
AF3	34 a	35 a	1314 c	1180 c	3.6 ab	3.6 c	6.3 c	7.8 c
AFT	35 a	34 a	1499 a	1461 a	3.8 a	4.3 a	8.4 a	11.4 a

[z] See Table 1.
[y] Mean separation within columns by Waller–Duncan multiple range test, $P \leq 0.05$.
[x] Data only for plants grown during Sept.–Dec. 1992.

Table 4. Effects of covering materials on photosynthetic capacity (P_C), photosynthetic rate at 200 $\mu mol \cdot m^{-2} \cdot s^{-1}$ *PPF* (P_{200}), the half time constant (K), quantum yield (Y_Q), and dark respiration rate (R_D) of stock plants grown under natural and supplemental light conditions (Sept. 1991 to Jan. 1992).

	P_C	P_{200}	R_D	K	Y_Q
Cover		($\mu mol \cdot m^{-2} \cdot s^{-1}$)		(10^{-3} $m^2 \cdot s \cdot \mu mol^{-1}$)	(mmol CO_2/mol *PPF*)
			Natural light conditions		
SG[z]	21.7 a[y]	6.9 a	0.39 a	2.2 c	48 b
AF1	13.1 c	6.8 a	0.38 a	3.9 a	51 ab
AF3	15.8 b	6.8 a	0.33 a	3.1 b	49 b
AFT	14.0 bc	7.4 a	0.30 a	3.9 a	55 a
			Supplemental light conditions		
SG	16.5 a	7.1 a	0.37 a	2.8 b	47 a
AF1	14.9 ab	4.7 c	0.34 a	2.1 b	31 b
AF3	12.2 bc	6.3 ab	0.39 a	3.7 a	45 a
AFT	11.7 c	6.1 b	0.35 a	3.6 a	43 a

[z] See Table 1.
[y] Mean separation within columns and light conditions by Waller–Duncan multiple range test, $P \leq 0.05$.

energy, while the decreasing light transmission may be a disadvantage for some crop species.

Antifog 3-year polyethylene film had relatively high light transmission and acceptable energy savings compared with antifog 1-year polyethylene and antifog thermal films. The ratio of the benefit from energy savings to the reduction in light intensity is higher under antifog 3-year polyethylene than under antifog thermal polyethylene. In a sense, antifog 3-year polyethylene film is an ideal material with a relatively high energy saving effect and less light reduction. Better quality and less P_C reduction of crops grown under antifog 3-year polyethylene film vs. those under antifog thermal polyethylene might be attributed to the relatively high light transmission. Shoot dry mass of crops grown under antifog 3-year polyethylene was lower than that of crops grown under other covers, mainly because of less leaf area. Therefore, antifog 3-year film could be recommended for the inner layer of double covers when the quality (instead of dry mass) of cut flowers is a concern.

We found that leaf area and shoot dry mass of stocks was proportional to leaf temperature for all cover materials. The relatively low leaf temperature under antifog 3-year polyethylene film resulted in a small leaf area and, as a consequence, a low shoot dry mass in spite of the higher light transmission in this compartment. In contrast, the negative effect of reduced light in antifog thermal film seems to be compensated for by enhanced leaf temperature. Thus, leaf temperature may play a more important role than light intensity in synthesis of biomass in conditions of our experiment. O'Flaherty and Maher (1980) reported that leaf temperature had a greater effect than light intensity on biomass production in tomato plants grown under a double-layer tunnel.

Supplemental lighting greatly accelerated flowering and improved flower quality regardless of covering materials. The lengths of flower stem and spike were reduced by supplemental lighting but remained within the commercial requirement. The stem diameter was increased by supplemental lighting. This was especially important under antifog 1-year and antifog thermal polyethylene, where stems were thin under natural conditions. Tsujita and Dutton (1983) reported a significant increase in stem diameter of rose given supplemental light of 55 $\mu mol \cdot m^{-2} \cdot s^{-1}$. In our experiment, flower spike length of snapdragon plants was increased by supplemental lighting regardless of coverings. This might be due to the extended day length, since previous studies indicated that extending day length to 16 h increased the inflorescence size of *Sphaerocephalon* (Berghoef and Zeverbergen, 1992). The differences in plant growth and flower quality between plants grown under single glass vs. polyethylene houses were diminished by supplemental lighting. Supplemental lighting significantly increased dry mass at harvest, in agreement with the data of Hopper and Hammer (1991) for roses.

Although P_C was decreased by supplemental lighting, P_N at low light level was not changed by supplemental lighting, with the exception of that under antifog 1-year polyethylene film. This might be due to the prolonged light period rather than to increased light intensity. In an experiment with *Setaria* and *Poa*, Burian and Winter (1976) found that P_C was considerably higher in the plants grown under 8-h lighting than under 16-h lighting when the same light intensity was used. Our study indicated that the use of supplemental light for a longer photoperiod decreased the P_C while Y_Q and P_N at low light level were not affected. Therefore, a similar P_N at canopy light level and a longer illumination period, together with a larger leaf area, logically would result in a higher shoot dry mass under supplemental than under natural light conditions.

From our results, we conclude that supplemental lighting increased leaf size, thickness, dry mass density, and quality. Improvement in quality was especially important for plants grown under antifog thermal covers. Antifog 3-year polyethylene is the best among the three antifog films for stock and snapdragon.

Since supplemental light is usually used in greenhouses at northern latitudes, antifog thermal film could be a wise choice for reducing energy consumption without affecting flower quality. Supplemental lighting improves quality and the heat released by the lamps provides an additional benefit. Supplemental lighting is especially important for thermal covers under which light level is relatively low. With supplemental lighting, crop quality under antifog thermal covers was comparable to that under single glass. Therefore, our study suggests that, for greenhouses at northern latitudes, antifog thermal film could be used as the inner layer of double inflated roof for more energy saving and equal plant growth.

Literature Cited

Berghoef, J. and A.P. Zevenbergen. 1992. Effect of environmental conditions on flower initiation and development of *Allium sphaerocephalon* L. Acta Hort. 325:91–96.

Bjerre, H. 1981. Plant production in a greenhouse covered with double-acryl. Acta Hort. 115:105–112.

Boulard, T., A. Baille, J. Lagier, M. Mermier, and E. Vanderschmitt. 1989. Water vapor transfer in a plastic house equipped with a dehumidification heat pump. J. Agr. Eng. Res. 44:191–204.

Burian, K. and W. Winter. 1976. Die Wirkung verschieden langer Licht Perioden auf die Photosynthese einiger Graser. Photosynthetica 10:25–32.

Evans, G.C. and A.P. Hughes. 1961. Plant growth and aerial environment. I. Effect of artificial shading on *Impatiens parviflora*. New Phytol. 60:150–180.

Ferare, J. and K.L. Goldsberry. 1984. Plant responses to different plastic greenhouse covers. Acta Hort. 148:619–626.

Fitter, A.H. and R.K.M. Hay. 1987. Environmental physiology of plants. 2nd ed. Academic, London.

Holder, R. and K.E. Cockshull. 1990. Effects of humidity on the growth and yield of glasshouse tomatoes. J. Hort. Sci. 65:31–39.

Hopper, D.A. and A. Hammer. 1991. Regression models describing *Rosa hybrida* response to day/night temperature and photosynthetic photon flux. J. Amer. Soc. Hort. Sci. 116:609–617.

Jaffrin, A. and A. Morisot. 1994. Role of structure, dirt and condensation on the light transmission of greenhouse covers. Plastic 101:33–44.

Lagier, J. 1991. Choice of flexible cover materials in relation to greenhouse and plant growth. Plastic 90:33–44.

O'Flaherty, T. and M.J. Maher. 1980. Fuel consumption and crop performance in double-covered polyethylene greenhouses. Acta Hort. 107:81–85.

Reiersen, D. and Z. Sebesta. 1981. A comparison of the effect of single glass and double acrylic sheeting on plant growth and development. Acta Hort. 115:401–408.

Starkey, N.G. 1985. The effect of secondary glazing and fixed screens on greenhouse environment and crop response of tomatoes. Acta Hort. 174:331–339.

Steinbuch, F. and van de Vooren. 1984. Production and quality of cut flowers and pot plants grown in greenhouses covered with energy saving double layer materials. Acta Hort. 148:555–559.

Tsujita, M.J. and R.G. Dutton. 1983. Root zone temperature effects on greenhouse roses in relation to supplementary lighting at reduced air temperature. HortScience 18:874–876.

Xu, H.L., L. Gauthier, and A. Gosselin. 1995. Effects of fertigation management on growth and photosynthesis of tomato plants grown in peat, rockwool and NFT. Scientia Hort. 63:11–20.

Yue, D., Y. Desjardins, M. Lamarre, and A. Gosselin. 1992. Photosynthesis and transpiration of in vitro cultured asparagus plantlets. Scientia Hort. 49:9–16.