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I Higher Yields and Reduction of Incidence of Stem Brittle in White Carnation by Increasing Potassium Concentration and NO_3^-:NH_4^+ Ratio in the Fertigation Medium

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Abstract

Calyx splitting and high percentage of stem brittle was observed in the carnation (*Dianthus caryophyllus* L.), cv. Standard White Candy, grown under fertigation on a sandy loam soil, in the coastal plateau of Israel, 18 km east from the Mediterranean coast. The hypothesis was tested that the incidence of this disorder could be reduced by raising the potassium (K) concentration in the plant by increasing K and the N-NO_3:N-NH_4 ratio in the fertigation medium. Five different fertigation media supplied by trickle irrigation were compared in their effects on plant growth. In three of these media, the N-NO_3:N-NH_4 ratio was kept the same (5.3:3.7) using a commercial liquid 7-3-7, N-P_2O_5-K_2O fertilizer consisting of ammonium nitrate, phosphoric acid, potassium nitrate and potassium phosphate, with the level of K (supplied as K_2SO_4) being increased from 93, to 252 and 378 mg/L in treatments one to three respectively. In a fourth treatment, nitrogen (N) was supplied totally in the form of nitrate as KNO_3 with K at 378 mg/L and thus equivalent to the highest K treatment in which N was supplied with both N forms (Treatment 3). In all four treatments the level of N supplied was the same at 126 mg/L. General farmers' practice was compared as a fifth reference commercial treatment. A 5 x 5 Latin square arrangement was used in the experiment. Soil samples were collected three times during the season and flowers were picked three to four times a week. The total number of flowers - as well as the number in which calyx splitting was present - was recorded. The number of brittle stems was counted only once a week. Meteorological data was obtained from the Israel meteorological center in Bet Dagan, 15 km north of the field site. Soil pH in water-saturated paste decreased from 6.9 at the beginning of the season to 5.8, after 40 weeks of fertigation in the field in all treatments containing ammonium, N-NH_4. In the KNO_3 treatment soil pH was kept constant at 6.6-6.9. The increase in K levels in the fertigation media was reflected in the content of K in the plant dry matter (DM). The beneficial effects of the KNO_3 treatment probably resulted because of the absence of N-NH_4 in the fertigation media. These beneficial effects were expressed in the form of a 17 per cent increase in flower yield and a minimizing of calyx splitting. When compared to the ammonium-containing fertilizer in the irrigation water, flower quality - as measured by stem brittle - was improved by the highest level of K supply, irrespective of K-fertilizer form, KNO_3 or K_2SO_4. Two bursts of activity of stem brittle incidence were recorded four to five weeks after two cold nights below 8°C each followed by a clear sunny day. When the K content in leaf No. 5 below the tip of twigs without flower was above 3.1 per cent, 162 days after planting, a significant reduction (18 per cent) in stem brittle events was observed. These findings suggest that maintaining a continuous supply of K, at a much higher concentration in the soil solution than regarded as "sufficient" for maximum yield, may be regarded as an "insurance cost" against detrimental effects of unexpected climatic events of cold nights followed by sunny days. The treatment based on common farmers' practice resulted in similar yields as compared to the K_2SO_4 treatments, but was significantly lower than that for KNO_3. Calyx splitting and stem brittle in the farmers' practice treatment were not statistically different from any of the other treatments.

White carnation (Dianthus caryophyllus L.), cv. Standard White Candy. Photo by U. Yermiyahu.

Introduction

The carnation cv. Standard White Candy is prone to stem brittle and calyx splitting disorders resulting in heavy financial losses to growers. These disorders show up mainly in winter and spring (Skalska, 1983), because calyx splitting is caused by the formation of either large numbers of petals or by lateral buds inside the calyx at low temperatures (Beisland and Kristoffersen, 1969).

A systematic study of carnation mineral deficiencies reported by Messing (1958) suggests that a shortage of K, Ca, or Mg can result in poor quality blooms and weak stems. Pember and Adams (1921) reported that when N was added to the nutrient medium in large amounts the number of split calyces was reduced in the two top grades of flowers. Successive investigations have shown that increasing N concentration in the

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soil solution reduces calyx splitting (Adams *et al*., 1979). On the other hand, increasing phosphate fertilization is reported to increase calyx splitting (Winsor *et al*., 1970). Some workers have related these disorders to boron (B) deficiency on calcareous soils (Winsor *et al*., 1970). Acidification of irrigation water also significantly decreases calyx splitting of flowers (Motallebifard *et al*., 2003).

The effect of K on this disorder is controversial, with claims that increasing K concentration reduces (Adams *et al*., 1979), increases (Winsor *et al*., 1970) and is without effect on calyx splitting (Skalska, 1983). The findings of Criley *et al*. (1983) have demonstrated that calyx splitting appears in carnations when the K content in the leaves of the third flush drops below four per cent.

The influence of high cell K content on increasing frost tolerance by plants has been related to its effect on the osmotic potential of the cell sap (Beringer and Troldenier, 1980). A distinction between frost and chilling effects must be made clear. Chilling effects in the range of +5 to +10°C are commonly reported for plants of warm climates. The temperature in which a sudden change in membrane fluidity occurs is specific to each cell and dependent on the relative composition of the various phospholipids (Özcan *et al*., 2007). The higher the ratio of unsaturated/saturated fatty acids in the cell membrane, the more tolerant the tissue is to low temperatures (Beringer and Troldenier, 1980). Fertigation is a safe practical way to maintain a continuous high level of K in a soil solution of sandy soils and in plants growing in these soils (Kafkafi, 1994).

The purpose of this work was to test the hypothesis that maintaining high levels of K in plant tissue of White Carnation reduces the incidence of calyx splitting and stem brittle, as well as to report the effects of the N-NO_3:N-NH_4 ratio in the fertigation medium in this respect.

Materials and methods

Carnation (*Dianthus caryophyllus* L.), cv. Standard White Candy plants were supplied with a fertigation medium using trickle irrigation. The commercial fertilizer 7-3-7 (N-P_2O_5-K_2O) with a N-NO_3:N-NH_4 molar ratio of 5.3:3.7 was used as a medium in three of the treatments. In these three treatments, the concentration of K was increased from 93, to 252 and 378 mg/L in the form of K_2SO_4 (Treatments 1-3 respectively). In a fourth treatment potassium nitrate (KNO_3) as the sole N source was applied to supply K at the same K level as in the highest K_2SO_4 treatment (Treatment 3). The total N level of 126 mg/L was the same in all four treatments. A farmers' practice treatment (Treatment 5) was included in the experiment and based on application of commercial liquid fertilizers. The fertilizers used, and their concentration in the irrigation water, are specified in Table 1.

The carnation seedlings were planted on July 25 1988 in six rows, 15 cm apart on elevated beds in sheds with a roof cover of polyethylene. No side walls were used. The trickle lines were placed between two adjacent rows. The discharge rate of the emitters was two liters/hour (L/h) at a distance of 0.3 m. The experimental plots were situated within a commercial carnation plastic covered house and all other practices of crop handling were carried out by the professional grower.

The statistical design of a Latin square was used. Each plot was 3.5 x 1 m and each treatment was replicated five times. A water meter was attached to each main treatment to ensure exact delivery of water and nutrients. The fertilizers were supplied to the irrigation lines by stainless steel Venturi pumps. To ensure an accurate rate of application, the daily fertilizer supply was given before each irrigation cycle.

The fifth fully open leaf from the tip, from twigs without flowers, was sampled from 20 plants to determine their nutrients content. The leaves were dried at 60°C, ground to pass through a 30 mesh screen, and 100 mg DM were washed in 5 ml concentrated sulphuric acid and 20 drops of 30 per cent hydrogen peroxide. The solution was used to determine total K content.

Flowers were harvested three to four times a week starting on 24 January 1989 from the centre of 2 m^2 of each plot. The total numbers of cut flowers were counted for each plot and the number of flowers with split calyces noted. All the flowers from each plot were cut at 65 cm from the top of the flower and the stem was held by hand at the bottom and was tilted slightly. The number of brittle stems at the fifth joint below the flower was counted for one of the harvests each week.

Table 1. Fertilizers and amounts used in the fertigation practice.

Treatment	Fertilizer			Nutrient concentrations						Molar ratio	
	7-3-7[(1)]	K_2SO_4	KNO_3	N-NH_4	N-NO_3	Total N	K	S[(2)]	P	N:K	N-NO_3:N-NH_4
	L/m³	*kg/m³*	*kg/m³*	---------------------------*mg/L*------------------------						-----------*ratio*-----------	
1	1.5	0	0	52	74	126	93	0	24.1	9:2.4	5.3:3.7
2	1.5	0.4	0	52	74	126	252	65	24.1	9:6.4	5.3:3.7
3	1.5	0.7	0	52	74	126	378	117	24.1	9:9.6	5.3:3.7
4	0	0	0.97	0	126	126	378	0	24.1	9:9.6	9.0:0
5	Farmers' practice			89	128	217	161	0	41.7	15:4.1	9.1:2.3

[(1)]7-3-7 is a solution fertilizer with 7% N, 3% P_2O_5 and 7% K_2O.

[(2)]S values given in the table are from the fertilizers added. Irrigation water contains over 300 g m^{-3} SO_4.

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Data was analyzed using JMP 5.0 software (SAS Institute Inc., USA). Effects of the various treatment on carnation yield and quality were examined using analysis of variance (ANOVA), and whenever the F statistic was significant, differences between treatments were determined using Tukey-Kramer HSD test (at $P < 0.05$).

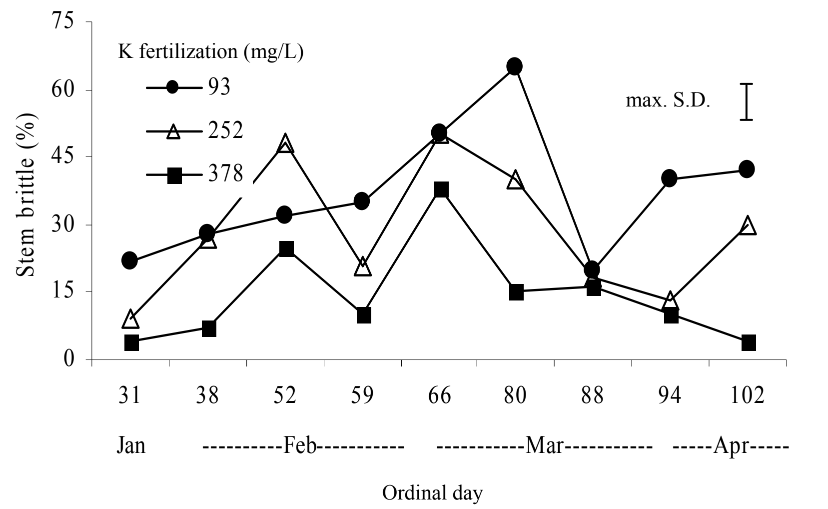

Fig. 1. Stem brittle rate as a function of time for different K fertilization rates with identical (5.3:3.7) N-NO_3:N-NH_4 ratios.

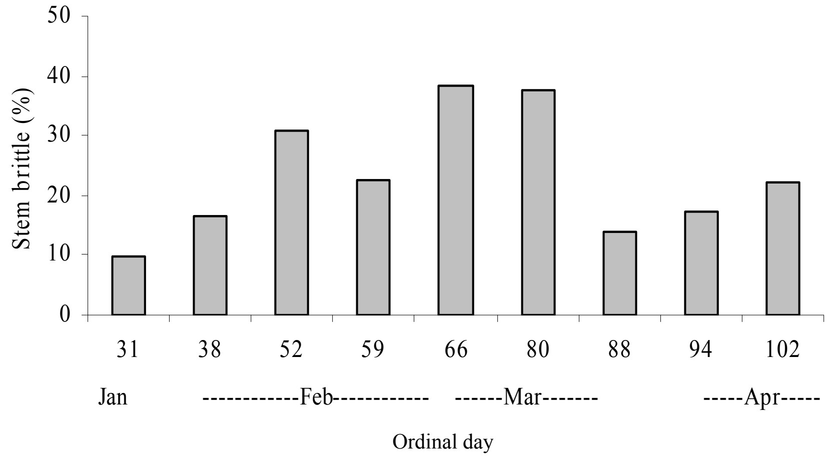

Fig. 2. Stem brittle rate as a function of time for all treatments.

Results and discussion

The percentage of stem brittle incidences showed a peak both on Feb 28 and Mar 14 (ordinal days 52 and 66; Fig. 1 and 2 respectively). These two peaks both occurred five to six weeks after cold night events below 8°C followed by clear sunny days. The K content in the fifth leaf at three specific growing periods and the overall yield per m^2 are shown in Table 2.

Throughout the experiment, higher K concentration in the fertigation was associated with lower flower yield loss due to stem brittle. When K in the fifth leaf from the apex was below four per cent, an overall seasonal average of about 31 per cent stem brittle was recorded with heavy losses to the grower. When K was above four per cent in leaves only, 18 per cent loss due to stem brittle was recorded (Table 2).

Similar responses to K levels in the leaves were reported regarding calyx splitting (Criley *et al.* 1983). Calyx splitting behavior during the growth season is presented in Fig. 3 and 4. Similar to stem brittle, calyx splitting incidences peaked twice; each event occurring a few weeks after a cold night (below 8°C) followed by a clear sunny day (Fig. 4). The peaking was most evident in treatment with ammonium (Fig. 3). The highest yield of flowers and the minimum calyx splitting was obtained in the KNO_3 treatment (210 flowers per m^2; Table 2). This treatment, in which all the N supplied was as nitrate (no ammonium), yielded about 17 per cent above the other treatments that contained ammonium in the daily fertigation. This result shows the beneficial effects from the increased nitrate. The fact that the K content of the leaves of the KNO_3 treatment was the same as that of the high K level in the K_2SO_4 treatment (with ammonium) suggests that the beneficial effect was not due to the depressing effect of ammonium on K uptake (Table 2). The flower quality, as measured by stem brittle, was improved by the highest level of K irrespective of the K-fertilizer form, KNO_3 or K_2SO_4 (Table 3). The treatment based on common farmers' practice resulted in similar yields as compared to the K_2SO_4 treatments but were significantly lower than for KNO_3. Calyx splitting and stem brittle in the farmers' practice treatment were not statistically different from any of the other treatments.

Stem brittle susceptibility was significantly reduced by maintaining high levels of K in the irrigation water throughout the season at a constant level of total N concentration. As long as the temperatures did not drop below 12ºC the high doses of K could have been regarded a luxury supply, or even a waste of K fertilizer, since no increase

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Table 2. Fertilizers and amounts used in the fertigation practice; effects on yield, percentage of split calyxes and brittle stems, water soluble K in the soil at 1:5 soil: solution weight ratio and K content of leaf No. 5.

Treatment	Fertilizer			Yield	Calyx splitting	Stem Brittle	Water soluble soil K content weeks after planting			K content of 5th leaf weeks after planting		
	7-3-7(1)	K_2SO_4	KNO_3				18	26	40	18	26	40
	L/m³	*kg/m³*	*kg/m³*	*flowers/m²*	---------%---------		-------------*mg/kg dry soil*-----------			-------------*mg/kg DM*-------------		
1	1.5	0	0	179.2 b	27.8 a	31.8 a	40 b	66 c	127 b	42.4 bc	32.4 b	24.6 c
2	1.5	0.4	0	179.6 b	29.9 a	30.9 a	145 a	162 b	300 a	45.8 ab	37.2 ab	27.2 b
3	1.5	0.7	0	179.6 b	25.0 ab	16.9 b	146 a	231 a	356 a	48.9 a	40.5 a	32.6 a
4	0	0	0.97	210.0 a	21.5 b	18.5 b	149 a	223 a	307 a	47.5 ab	40.4 a	29.8 ab
5	Farmers' practice			183.0 b	24.0 ab	24.7 ab	51 b	79 c	116 b	40.9 c	38.1 ab	26.5 bc

(1)7-3-7 is a solution fertilizer with 7% N, 3% P_2O_5 and 7% K_2O.

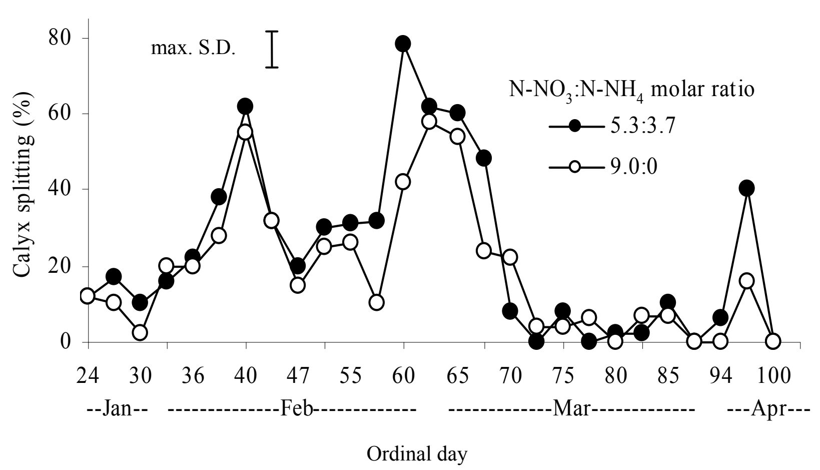

Fig. 3. Calyx splitting as a function of time for different N-NO_3:N-NH_4 ratios and constant K concentration (378 mg/L) in irrigation solution.

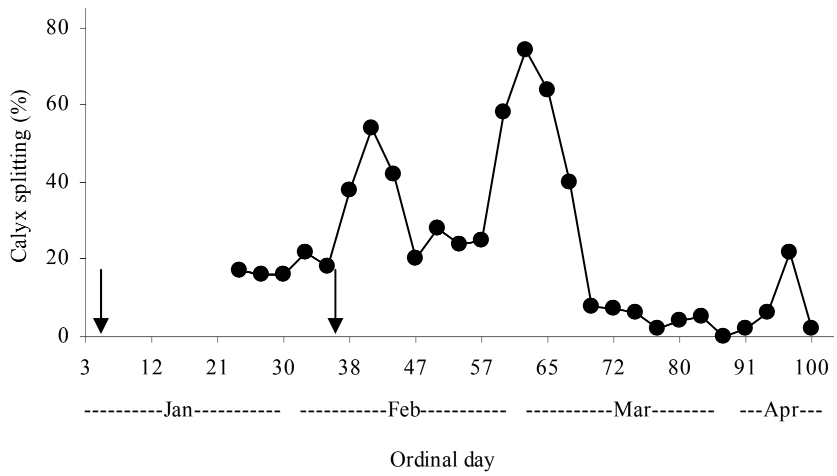

Fig. 4. Calyx splitting rate as a function of time for all treatments. The arrows indicate nights with below zero temperatures.

in flower yield or quality was observed. However, the economic benefits to the grower by maintaining high K in the soil solution is clear, even after only a single night event of low temperature. The financial consequence of the damage caused during this one night exceeds the total fertilizer costs for the whole season. The positive K effect in preventing stem brittle is only detected about five weeks after the cold night events, so it is difficult to directly relate the influence of K on flower quality. It may be suggested that the continuous supply of K, at a much higher concentration in the soil solution than regarded as "sufficient" for maximum yield, may be regarded as an "insurance cost" against unexpected climatic events.

High K content in the fifth leaf reduced stem brittle in the White Carnation. The point of breakage occurred in the tissue connecting the stem nodes, the weak point developing during the cold event, which later allowed breakage even with the stem only slightly tilted. A possible explanation of this phenomenon might be postulated as follows: The low temperature is most likely to have impaired the development of the cell wall structure in the youngest and most vulnerable joint of the stem but the resulting damage would not be immediately apparent. However, with progressive growth and increasing weight of the stem this weakened structure would become unstable with a

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break occurring in the fifth joint below the flower, as observed at flower harvest five weeks after the original damage.

The actual physiological mechanism operating in the carnation is not clear. The susceptibility to such cold events is also very much dependent on the plant variety. Huett (1994) in Australia reported that flowers produced in March had thinner (3.11 v. 5.24 mm diameter) and weaker stems than those produced in October.

The changes in varietal response to chilling effects might be due to differences in the fatty acid composition of their membranes since these membranes in root cells affect the rates of ion and water transport in the root, as well as the carbohydrate content of the plant and the translocation of nutrients and metabolites in the plant (Marschner, 1995).

In tomato production, high levels of K in the root medium results in increased K concentration in the leaf and improved fruit quality (Adams et al., 1979). Concentration of 100 and 300 ppm K in the liquid feed resulted in 4.8 and 7.0 per cent of K in the leaves respectively, with high leaf level producing the best quality fruit. High levels of K were also recommended to reduce hollow fruit in tomato, which is associated with low light in the greenhouse (Winsor, 1968).

The effect of soil temperature around the crown node of wheat on growth and nutrient translocation was studied by Boatwright *et al*. (1976). Careful chilling only to the crown zone enabled these workers to demonstrate that the cold zone restricted translocation of rubidium (^{86}Rb) to the top and, also by inference, that of K.

The concentration of K in the cytoplasm must be maintained at a constant level of 150 mM and that in the vacuole at a minimum level of 20 mM (Leigh and Wyn Jones, 1984). Any further decline below these values causes a severe reduction in plant growth. When the K supply is abundant, the cell accumulates K in the vacuole and, as a result, the total K content, as expressed as dry matter, increases. This increase in the content of K on the whole plant, without further increase in plant growth, is usually referred to in the agronomic literature as "luxury consumption" or range of high level (Bergmann and Bergmann, 1985). This "luxury consumption" may be considered a good "insurance policy" which growers may take out against environmental cold stresses. Such a policy might prove profitable when quality of the plant product is taken into account. Flower yield losses due to increased stem brittle and calyx splitting in winter seasons might be reduced when high K supply is maintained during the whole growing season.

Classification of carnation flowers before marketing. Photo by Sima Kagan.

References

Adams, P., M.A. Brebda, and G.W. Winsor. 1979. Some effects of boron, nitrogen and liming on the bloom production and quality of glasshouse carnations. J. Hort. Sci. 54:149-154.

Beisland, A., and T. Kristoffersen. 1969. Some effects of temperature on growth and flowering in the carnation cultivar "William Sim". Acta Hort. 14:97-108.

Bergmann, E., and H.W. Bergmann. 1985. Comparing diagrams of plant/ leaf analysis presenting by rapid inspection the mineral nutrient element status of agricultural crop plants. Potash Review, Subject 5 No. 2/1985 p. 1-10.

Beringer, H., and G. Troldenier. 1980. The influence of K nutrition on the response of plants to environmental stress. Potassium Research-Review and Trends, 11th Congress of the International Potash Institute. p. 189-222. Horgen, Switzerland.

Boatwright, G.O., H. Ferguson, and J.R. Sims. 1976. Soil temperature around the crown node influences early growth, nutrient uptake and nutrient translocation of spring wheat. Agron. J. 68:227-231.

Criley, R.A., P.E. Parvin, T.M. Hori, and K.W. Leonhardt. 1983. Carnation calyx tip dieback. II International Symposium on Carnation Culture- ISHS. 141:125-131.

Huett, D.O. 1994. Production and quality of sim carnations grown

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hydroponically in rockwool substrate with nutrient solutions containing different levels of calcium, potassium and ammonium-nitrogen. Austr. J. Exp.Agric. 34:691-697.

Kafkafi, U. 1994. Combined irrigation and fertilization in arid zones. Israel. J. Plant Sci. 42(4):301-303.

Leigh, R.A., and R.G. Wyn Jones. 1984. A hypothesis relating critical potassium concentrations for growth to the distribution and functions of this ion in the plant cell. The New Phytologist. p. 1-13.

Marschner, H. 1995. Mineral nutrition of higher plants, second edition. Academic Press, London.

Messing, J.H.L. 1958. Mineral nutrition of carnations. J. Sci. Food. 9(4):228-234.

Motallebifard, R., M. Kafi, and M.J. Malakouti. 2003. Effect of different sources and levels of potassium and acidified water on quality and quantity of carnation flower. Proceedings of the Applied-Scientific Seminar on Flowers and Ornamental Plants, Mahallat, Iran. (www.fao.org/agris/search/display.do?f=2008/IR/IR0816.xml;IR2008003089)

Özcan, N., C.S. Ejsing, A. Shevchenko, A. Lipski, S. Morbach, and R. Krämer. 2007. Osmolality, temperature, and membrane lipid composition modulate the activity of betaine transporter BetP in *Corynebacterium glutamicum*. J. of Bacteriology. 189(20):7485-7496.

Pember, F.R., and G.E. Adams. 1921. A study of the influence of physical soil factors and of various fertilizer chemicals on the growth. Bull. R.I. Agr. Exp. Sta. Bui. 187.

Skalska, E. 1983. The influence of fertilization on flower calyx splitting in carnations. Acta Hort. 141:133-138.

Winsor, G.W. 1968. Potassium and the quality of the glasshouse crops. Proceedings of the 8th Congress of the International Potash Institute in Brussels 1966. p. 303-312.

Winsor, G.W., M.I.F. Long, and B.M.A. Hart. 1970. The nutrition of glasshouse carnation. J. Hort. Sci. 45:401-413. ■

The paper "Higher Yields and Reduction of Incidence of Stem Brittle in White Carnation by Increasing Potassium Concentration and NO_3^-:NH_4^+ Ratio in the Fertigation Medium" appears also at:

K Center/Nitrogen and Potassium Interactions

Carnation plants grown on a commercial soilless culture. Photo by Sima Kagan.