Changes of nutrient concentration in chrysanthemum leaves under influence of solar radiation

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Abstract. Eleven pot cultivars of the chrysanthemum (*Chrysanthemum* x *grandiflorum* /Ramat./ Kitam.) were grown in 12 year-round cycles. Starting with 2 January 2002, on the second day of each successive month, rooted cuttings of all the chrysanthemum cultivars were planted into pots 14 cm in diameter, 5 cuttings per pot. From the day of potting, the plants were exposed to short-day treatment. In periods of naturally long days, the day was shortened to 10.5 hours. From November till mid-February (days under 10 hours), no supplementary assimilation light was used to improve the light conditions in the period of insolation deficit. Depending on weather conditions, the electrolytical conductivity of the nutrient solution used for plant feeding varied between 1.8 mS cm^{-1} (in summer) and 2.2 mS cm^{-1} (in winter). To prepare the nutrient solution rainwater was used. When 30% of inflorescences were in flower, for chemical analysis well-developed leaves from plants were sampled. The total concentrations of macro- and microelements in plant tissue were determined. To find the relationship between nutrient concentration in plant tissue and radiation, data were analysed using simple linear regression models. Radiation had an effect on nutrient concentration in chrysanthemum leaves. The highest determination coefficient R^2 for P and Ca, the lowest for N and K were calculated.

Key words: *Chrysanthemum* x *grandiflorum,* Time group, AYR, solar radiation, nutritional status of plant, statistical model

INTRODUCTION

Chrysanthemum cultivation is possible all year round (AYR). The condition for success is the day-length control. Plants cultivated in wintertime, in light shortage conditions, considerably differentiated from the plants that are cultivated in favourable lighting conditions. This especially applies to the decorative value of chrysanthemum (Breś & Jerzy, 2004a). According to Karlsson & Heins (1992) the dry mass of chrysanthemum leaves increased with decreased light intensity, whereas the day and night temperature seemed to have little effect. Carvalho et al. (2002) found that light conditions influenced flower bud removal, flower size and number of cut chrysanthemum. Also Nothnagl & Larsen (2002) found a relationship between chrysanthemum flower diameter and light conditions. Low light integrals had a retarding effect on flower growth resulting in smaller flowers. Temperature also affects all flower characteristics, except for flower position within the plant. Higher temperatures increased the number of flowers per plant, mainly by increasing the number of flower buds, but decreased individual flower size (Carvalho et al., 2005). There is little information concerning the influence of the cultivation season or, consequently, the light conditions on the nutritional status of chrysanthemum. Zerche (1997), Breś & Jerzy (2004b) proved that the length of cultivation during AYR cultivation considerably influences nutrient concentration in chrysanthemum leaves. This problem has not been completely explained yet.

The goal of the research was to find the relationship between solar radiation and the nutritional status of chrysanthemums during AYR cultivation.

MATERIALS AND METHODS

For the experiment eleven pot cultivars of the chrysanthemum *Chrysanthemum* x *grandiflorum* /Ramat./ Kitam.) grown in sprays were selected: 'Brill Time', 'Coll Time', 'Dream Time', 'Energy Time', 'Esperanto Time', 'Icon Time', 'Jewel Time', 'Quartz Time', 'Solar Time', 'Tatoo Time', 'Tea Time'. The research embraced 12 growth cycles. Starting with 2 January 2002, on the second day of each successive month rooted cuttings of all the chrysanthemum cultivars were planted into pots 14 cm in diameter, 5 cuttings per pot. From the day of potting, the plants were given short-day treatment. In periods of naturally long days, the day was shortened to 10.5 hours using Obscura AB+B. From November till mid-February (days under 10 hours), a period of insolation deficit, no supplementary assimilation light was used to improve the light conditions. Mean temperatures in the greenhouse during the experiments are shown in Fig. 1.

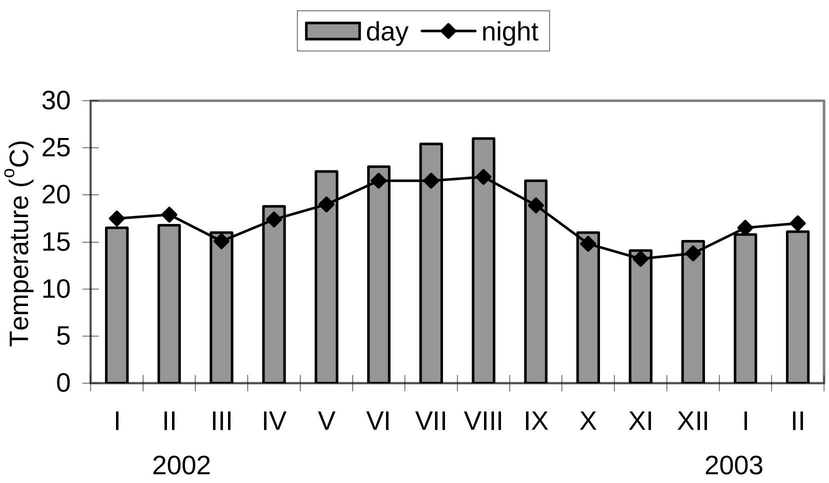

Fig. 1. Air temperature in glasshouse from January 2002 to February 2003.

Table 1. Content of components in nutrient solution used in experiments.

Nutrient	$mg \cdot dm^{-3}$	Nutrient	$mg \cdot dm^{-3}$
$N\text{-}NH_4$	1.1	Cl	2.5
$N\text{-}NO_3$	211.8	$S\text{-}SO_4$	93.5
P	53.7	Fe	2.711
K	291.2	Mn	0.875
Ca	87.8	Zn	0.489
Mg	53.0	Cu	0.070
Na	4.3	B	0.295
pH 5.5			
EC 2.28 $mS\ cm^{-1}$			

The plants were grown in a peat substrate (80% white peat, 15% mixed peat, 5% clay by volume) mixed with PGMix and Radigen fertilisers. The pots with cuttings were placed in a soil bed at a 30x30 cm spacing in a diagonal pattern (9 pots m^{-2}). For the first few days after potting, the plants were sprinkled with water; later this practice was replaced with drip fertigation. Depending on weather conditions, the electrolytical conductivity of the nutrient solution used for plant feeding varied between 1.8 mS cm^{-1} (in summer) and 2.2 mS cm^{-1} (in winter). Rainwater was used to prepare the nutrient solution. The composition of the solution prepared in a fertiliser mixer is presented in Table 1. The chrysanthemums were also fed with carbon dioxide. The gas concentration was kept at 1.100–1.200 µl dm^{-3} with closed roof vents and at 550–600 µl dm^{-3} with opened ones.

Five days after potting, shoot tips were pinched above the fifth leaf, counting from the base of the stem. The chrysanthemums were retarded using B-Nine 85 SP at a concentration of 0.3%. The treatment was applied first when lateral shoots (after pinching the main stem) attained a length of 10–15 mm. Two further treatments were given every 7–10 days. Because of severe retardation and weakening growth of the plants, B-Nine was not applied in cycle 11 (planted on 2 November). For the same reason, all cultivars from cycle 12 (planted on 2 December) were only treated with B–Nine once, when flower buds appeared on lateral shoots 5–7 cm long. In each of the 12 experiments one cultivar of chrysanthemum was represented by 20 pots.

When 30% of inflorescences were in flower, for chemical analysis well-developed leaves from plants were sampled (three samples for each chrysanthemum cultivar). The concentrations of macro- and microelements in plant tissue were determined in dried plant material after its mineralisation in strong acids. The levels of K, Ca, Mg, Fe and Cu were determined using absorption spectrophotometry. For analysis of P and B spectrophotometric methods were used. Total N was determined by micro-Kjeldahl procedure. The total solar radiation was measured through the duration of experiment by pyranometer (Theodor Friedrichs and Co. Hamburg, type 6500). To find the relationship between nutrient concentration in plant tissue and radiation, data were analysed using simple linear regression models.

RESULTS AND DISCUSSION

In north and central Europe light is a limiting factor in greenhouses during the majority of the year. The time of cultivation strongly modified the photoperiodic response of chrysanthemums - the longest photoperiod in months with insufficient natural light was observed, except in June, when high temperature delayed the time of flowering (Jerzy & Borkowska, 2004). It is known that the supplementary assimilation lighting and the period of long days preceding the start of shading affect the plant quality and nutritional status of chrysanthemums (Carvalho et al., 2002; Nothnagl & Larsen, 2002; Jerzy et al., 2004a, 2004b; Breś et al., 2005).

There are few publications referring to the effect of natural radiation on the nutritional status of chrysanthemum.The different responses of chrysanthemums to fertilization depending on the season were noted by Joiner & Smith (1962), but their research was not detailed. Willits et al. (1992) also confirm the influence of light on nutrient uptake by chrysanthemums. Raper et al. (1991) showed an increase of nitrate uptake by soybean plants during interruption of the dark period with low intensity light. One can presume that a similar effect will appear during short day interruption in controlled cultivation of chrysanthemum.

Research by Baille (1993) and Kedziora (1995) assumed that photosynthetically active radiation (PAR) comprises 50% of total radiation. The effect of total solar radiation on nutrient concentration (mean values for 11 chrysanthemum cultivars) is summarized in Figs 2–9. The increase of radiation (in MJ m^{-2}) caused decreased concentration of nitrogen, phosphorus, potassium, calcium, magnesium, cuprum and boron in chrysanthemum leaves. Reverse regularity in the case of iron was measured. The highest determination coefficient R^2 for P (0.9556) and Ca (0.8024), lower values were calculated for Cu (0.5187), B (0.4816), Mg (0.4277), and the lowest for Fe (0.3991), N (0.3646) and K (0.342) were calculated. It is distinctly visible that during controlled chrysanthemum cultivation, the concentration of Cu, B, Fe, Mg, N and K in leaves, next to radiation, is strongly influenced also by other factors (low R^2). Increase of radiation by 100 MJ$^{\cdot}$ m^{-2} caused the decrease of a mean concentration of N by 0.09%, P 0.08%, K 0.13%, Ca 0.06%, Mg 0.005%, Cu 0.26% and B 1.93%. Simultaneously increasing radiation by 100 MJ m^{-2} caused the increase of mean concentration of Fe by 3.69%.

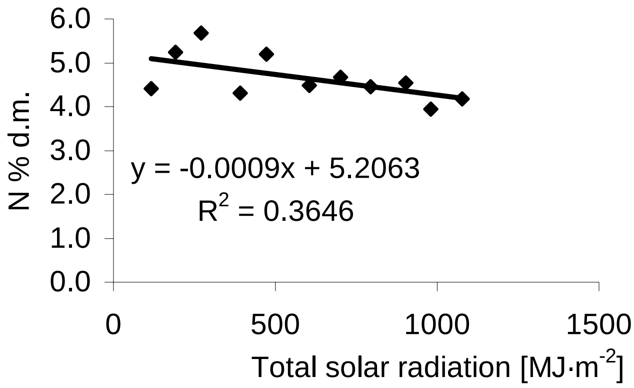

Fig. 2. Effect of total solar radiation on mean nitrogen content in chrysanthemum leaves (n = 11).

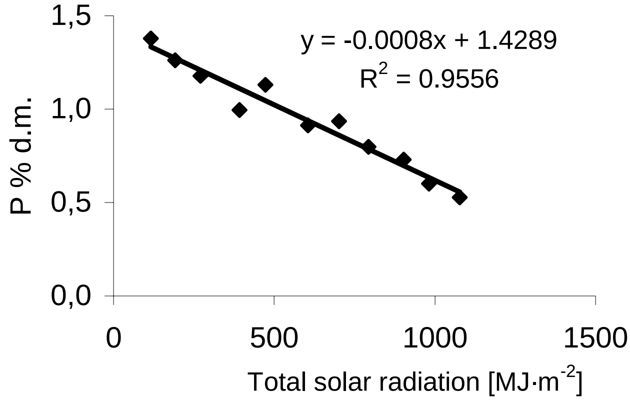

Fig. 3. Effect of total solar radiation on mean phosphorus content in chrysanthemum leaves (*n* = 11).

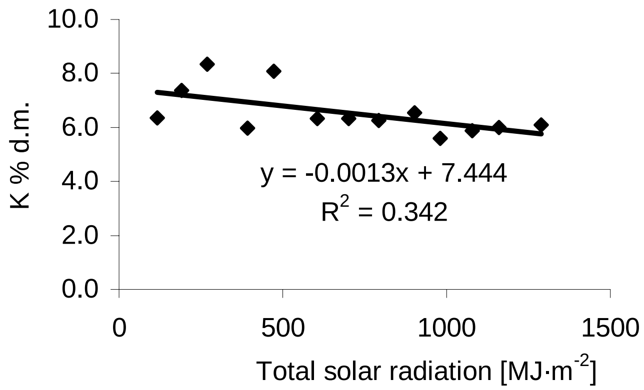

Fig. 4. Effect of solar radiation on mean potassium content in chrysanthemum leaves (*n* = 11).

Nowadays in horticultural practice the composition of nutrient solution is altered mostly in the high temperature periods. In farms with a higher level of management, the content of nutrients in the solution is changed 2–3 times, depending on the growth stage of plants. Results obtained in this work indicate that the absence of a differentiation of compounds in the nutrient solution, depending on solar radiation, leads to an unnecessary accumulation of elements in plant tissue. Plants regulate their mineral composition. For most ions, the uptake is the net result between simultaneous influx from the solution to the roots and efflux from the roots to the solution (Aslam et al., 1996). However, this mechanism depends on many factors, e.g. soil or root temperature (BassiriRad et al., 1993), CO_2 concentration (BassiriRad et al., 1997). The content of nutrients in plants depends also on their availability in the nutrient solution or in the medium – increase of availability leads to increase of macro- and microelements concentration in plant tissue (Mengel & Kirkby, 1982). In the described experiments in the results of fertigation controlled by the intensity of solar energy, the fertilization was relatively stable.

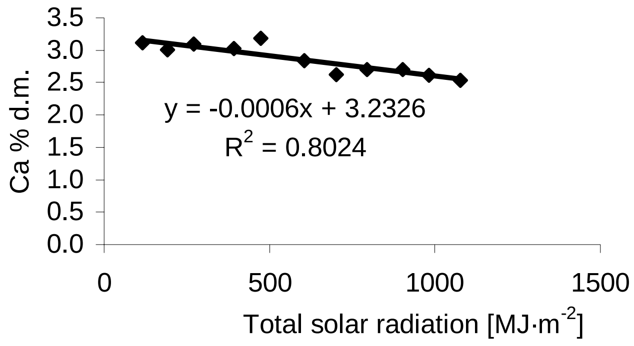

Fig. 5. Effect of solar radiation on mean calcium content in chrysanthemum leaves (n = 11).

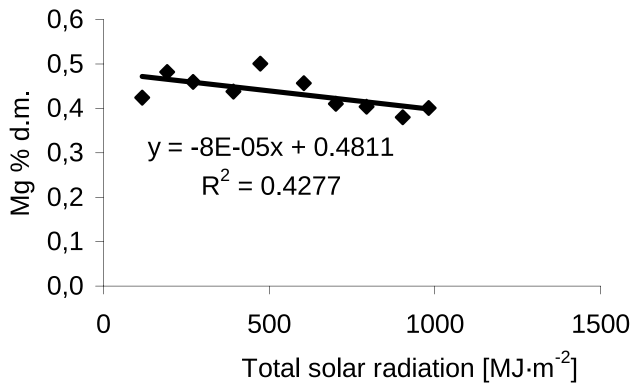

Fig. 6. Effect of solar radiation on mean magnesium content in chrysanthemum leaves (n = 11).

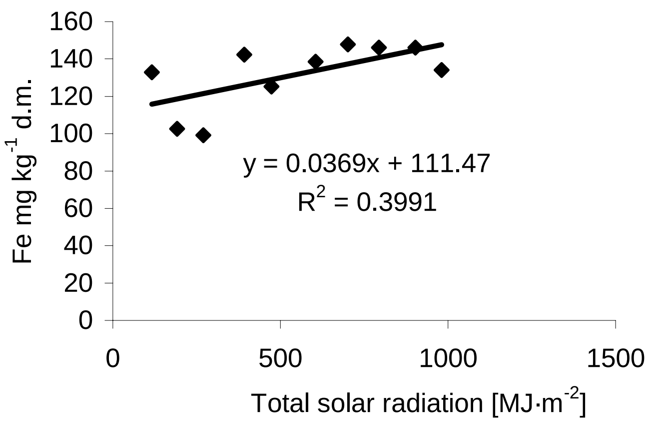

Fig. 7. Effect of solar radiation on mean iron content in chrysanthemum leaves (n = 11).

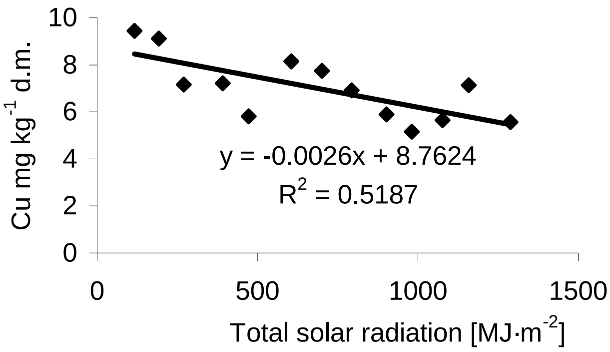

Fig. 8. Effect of solar radiation on mean cuprum content in chrysanthemum leaves (n = 11).

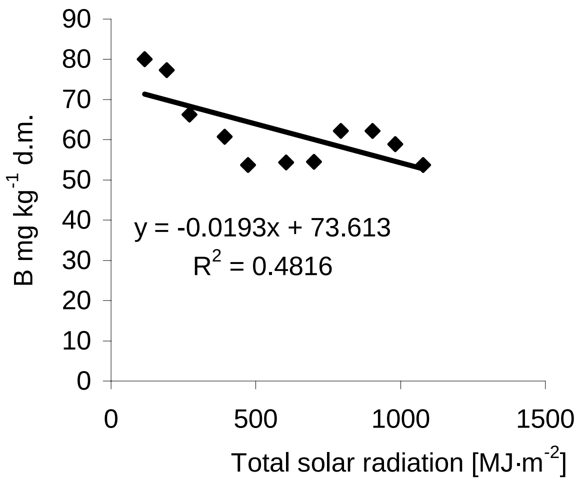

Fig. 9. Effect of solar radiation on mean boron content in chrysanthemum leaves (n = 11).

The obtained curves (Figs 2–9) indicate that plants grown during the light deficiency period accumulated more N, P, K, Ca, Mg, Cu and B in leaves than chrysanthemums grown in better light conditions. At the same time, the number of fluorescens of chrysanthemums was lower (Fig. 10). According to Bouma (1983), higher light intensity reduces the level of phosphorus in the leaves, petioles, and roots of plants. Also, standards determining the admissible level of nitrate in certain vegetables takes into consideration the natural light conditions dominant during growing – they are higher from October to March and lower from April to September (Commission of Regulation (EC), 2005). Investigations of Meziane & Shipley (2001) with 22 species of herbaceous plants showed that at low nutrient supply the mass concentration of nitrogen was basically constant despite quantum irradiance changing from 200 to 1100 µmol m^{-2} s^{-1}. At high nutrient supply the mass concentration of nitrogen decreased with increasing irradiance. In an experiment performed in Italy with geranium, total nutrient uptake of N, P, Ka and Mg was significantly greater in winter than in spring (Rouphael et al. 2008).

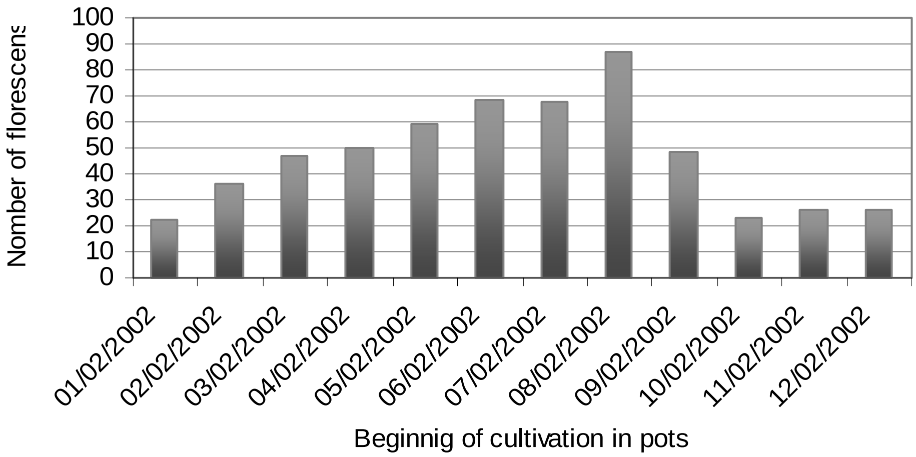

Fig. 10. Number of fluorescens of chrysanthemums at the end of growth cycle (mean value for 11 cultivars).

The above research does not clarify all the relationships that may have influence on the uptake and consequently on the nutritional status of chrysanthemum in controlled day length conditions. Further research is required primarily regarding the relationship between individual ions, radiation and uptake of nutrients by the plant. In the open fertigation systems adjusting the composition of nutrient solution to the plant requirements as well as to the radiation, one can reduce the soil and water pollution caused by drainage water leaking from growing media (Breś & Roszyk, 2003). Reduction of water and nutrient use as a result of intelligent management is the most promising method of reduction of greenhouse effluent (Nelson, 1990). Other approaches to decreased fertilizer use are worth consideration. According to Huang et al. (1997) and Macz et al. (2001) by adequate S fertilization the amount of N applied to hydroponically grown chrysanthemums can be reduced during the fall without causing stem length, delayed inflorescence initiation or decreasing of flower diameter.

CONCLUSIONS

- Radiation had an effect on nutrient concentration in chrysanthemum leaves. The highest determination coefficient R^2 for P and Ca were calculated.
- In chrysanthemum leaves the most changeable variable dependent on radiation was the iron and boron concentration.
- The concentration of elements in the nutrient solution for chrysanthemums grown in greenhouse AYR should depend on solar radiation. It concerns particularly phosphorus and calcium: in autumn and winter (with light deficiency and lower temperature) the nutrient solution may contain fewer phosphate and calcium ions compared to the nutrient solution used in late spring and summer. It will have an impact on the decrease of fertilizer use and

on the reduction of environmental pollution caused by drainage water leaking from growing media**.**

REFERENCES

Aslam, M., Travis L.M. & Rains, D.W. 1996. Evidence for substrate induction of a nitrate efflux of a nitrate efflux system in barley roots. *Plant Physiol.* **112**, 1167–1175.

Baille, A. 1993. Artificial light sources for crop production. In Varlet-Grancher, C., Bonhomme, R. & Sinoquet, H. (eds): *Crop structure and light microclimate. Characterization and applications*. INRA, Paris, pp. 17–43.

BassiriRad, H., Caldwell, M.M. & Bilbrough, C. 1993. Effects of soil temperature and nitrogen status on kinetics of NO_3^- uptake by roots of field-grown Agropyron desertorum (Fisch. ex Link) Schult. *New Phytol.* **123**, 485–489.

BassiriRad, H., Reynolds, J., Virginia, R. & Brunelle, M. 1997. Growth and root NO_3^- and PO_4^{3-} uptake capacity of three desert species in response to atmospheric CO_2 enrichments. *Australian J. Plant Physiol.* **24**, 353–358.

Bouma, D. 1983. Diagnosis of mineral deficiencies using plant tests. In Läuchli A. & Bielski R.L. *Inorganic plant nutrition*. Springer Verlag, Berlin, Heidelberg, New York, Tokyo. **15A**, 124–140.

Breś, W. & Jerzy, M. 2004a. Effect of the planting date on the quality of pot chrysanthemums from the Time group in all-year-round culture. *Folia Hortic.* **16**(2), 119–126.

Breś, W. & Jerzy, M. 2004b. Effect of the planting date on macronutritional status of pot chrysanthemums from the Time group in all-year-round culture. Folia Hortic. **16(2)**, 127–140.

Breś, W. Jerzy, M., Pawlak, P. & Sztuka, A. 2005. Effect of long-day on macronutritional status of spray chrysanthemums from Santini group growing in the Spring-summer season. *Zesz. Probl. Post. Nauk Roln.* **504**, 43–49 (in Polish, with English abstract).

Breś, W. & Roszyk, J. 2003. Soil deposits of elements during plant growing in open fertigation systems. *Folia Hortic.* Suplement, **1,** 492–494.

Carvalho, M.P.S, Heuvelink, E. & van Kooten, O. 2002. Effect of light intensity, plant density, and flower bud removal on flower size and number in cut chrysanthemum. *Acta Hort.* **593**, 33–38.

Carvalho, M.P.S, Abi-Tarabay, H. &, Heuvelink, E. 2005. Temperature affects chrysanthemum flower characteristics differently during three phases of the cultivation period. *J. Hort. Sci. Biotechnol.* **80**(2), 209–216.

Commission of Regulation (EC), 2005. Regulation 1822 of 8 November 2005 amending Regulation (EC) 466/2001 as regards nitrate in certain vegetables. *Official Journal of European Union* **293**, 11–13.

Huang, L., Paparozzi, E.T. & Gotway, C. 1997. The effect of altering nitrogen and sulfur supply on the growth of cut chrysanthemums. *J.Amer. Soc. Hort. Sci.* **122**(4), 559–564.

Jerzy, M. & Borkowska, J. 2004. Photoperiodic response of pot chrysanthemums in twelve all-year-round production cycles. EJPAU. *Horticulture* **7**(2), art-07.html.

Jerzy, M., Breś, W. & Pawlak, P. 2004a. Supplementary lighting of pot chrysanthemums cultivated under low level of real insolation. *Acta Scien. Pol. Hortorum Cultus* **3**(2), 41–46 (in Polish, with English abstract).

Jerzy, M., Breś, W. & Pawlak, P. 2004b. Effect of supplementary lighting on nutritional status of chrysanthemums grown in the period of natural light deficit. *Acta Scien. Pol. Hortorum Cultus* **3**(2), 47–56 (in Polish, with English abstract).

Joiner, J.N. & Smith, T.C. 1962. Effects of nitrogen and potassium levels on the growth, flowering responses and foliar composition of *Chrysanthemum morifolium* “Bluechip”. *Proc. Am. Soc. Hort. Sci.* **80**, 571–580.

Karlsson, M.G. & Heins, R.D. 1992. Chrysanthemum dry matter partitioning patterns along irradiance and temperature gradients. *Canadian Journal of Plant Science* **72**, 307–316.

Kedziora, A. 1995. *Bases of agrometeorologie*. PWRiL, Poznań, pp. 5–255 (in Polish).

Macz, O., Paparozzi E.T. & Stroup, W.W. 2001. Effect of nitrogen and sulfur applications on pot chrysanthemum production and postharvest performance. I. Leaf nitrogen and sulfur concentrations. *J. Plant Nutr.* **24**(1), 111–129.

Mengel, K. & Kirkby, E. A. 1982. *Principles of plant nutrition*. 3. ed. International Potash Institute Bern 655pp.

Meziane, D. & Shipley, B. 2001. Direct and indirect relationships between specific leaf area, leaf nitrogen and gas exchange. Effects of irradiance and nutrient supply. *Ann. Bot.* **88**, 915–927.

Nelson, P.V.1990. Developing root zone management strategies to minimize water and fertilizer waste: The United States perspective with emphasis on surface applied non-recirculated systems. *Acta Hort.* **272**, 178–184.

Nothnagl, M. & Larsen, R. U. 2002. The relationship between chrysanthemum flower diameter and light conditions in the greenhouse – a modeling approach. *Acta Hort.* **593**, 179–183.

Raper, C.D., Vessey, J.K. & Henry L.T. 1991. Increase of nitrate uptake by soybean plants during interruption of the dark period with low intensity of light. *Physiol. Plantarum* **81**, 183–189.

Rouphael, Y., Cardarelli M., Rea E. & Colla G. 2008. The influence of irrigation system and nutrient solution concentration on potted geranium production under various conditions of radiation and temperature. *Sci. Hort.* **118**(4), 328–337.

Willits, D. H., Nelson, P. V., Peet, M. M., Depa, M. A. & Kuehny, J. S. 1992. Modeling nutrient uptake in chrysanthemum as a function of growth rate. *J. Amer. Soc. Hort. Sc.* **117**(5), 769–774.

Zerche, S. 1997. Nitrigen uptake and total dry matter production of cut chrysanthemum (*Dendranthema – Grandiflorum* - Hybrids) in relation to shoot height and planting date. *Gartenbauwiss.* **62**(3), 119–128.