Europ.J.Hort.Sci., **71** (6). S. 259–261, 2006, ISSN 1611-4426. © Verlag Eugen Ulmer KG, Stuttgart

Fruit Yield, Starch Content and Leaf Chlorosis in Cucumber Exposed to Continuous Lighting

S.A. Wolff and A. Langerud
(Norwegian Crop Research Institute, Kvithamar Research Centre, Stjørdal, Norway)

Summary

Fruit production, leaf chlorosis and starch content were examined in cucumber plants under 18 and 24 h (continuous) photoperiods. Light levels were adjusted to provide daily quantum integrals of 16.4 mol m^{-2} day^{-1} in both treatments. Continuous light reduced fruit production, induced development of chlorosis on young, fully expanded leaves and gave lower starch content, primarily in leaves, compared to 18 h photoperiods. No correlation between chlorosis and hyper-accumulation of starch was found at the onset of visible leaf injury. The present study indicated that a lighting regime with continuous illumination should not be implemented in commercial cucumber production.

Key words. *Cucumis sativus* L. – daily quantum integral – hyper-accumulation – photoperiod – supplemental lighting

Introduction

In Norway, winter production of greenhouse crops is totally dependent on supplemental lighting. The year-round production of cucumber is currently carried out under light levels as high as 250 µmol m^{-2} s^{-1}, and considerable amounts of heat energy are ventilated out of the greenhouse together with some of the CO_2 supplied to support the production. To minimize the heating costs in the night period and the losses of energy and CO_2, the daily light integral (DQI) from artificial sources ought to be spread over as many hours as possible. Lighting regimes with short nights should, however, not be chosen if long photoperiods appear to affect the yield negatively. The recommended daylength in cucumber nurseries is presently 18–20 h (Dorais 2003; Grimstad pers. comm.). Before even longer photoperiods are implemented, the stress they eventually impose on the plants at different stages and the gains and losses related to them need to be quantified.

The present study was undertaken to find out whether the most radical lighting regime, continuous lighting, affects cucumber plant vitality and harvestable yield and is to be considered as an alternative at all. As leaf chlorosis induced by long photoperiods in other species have been associated with hyper-accumulation of starch in the leaves (Bradley and Janes 1985; Murage et al. 1996; Stutte et al. 1996; Demers et al. 1998a, b), the starch content in different plant parts was also determined.

Materials and Methods

The experiment was carried out in an acrylic greenhouse located at 63° 30`N from October 2002 to February 2003. Seeds of *Cucumis sativus* L. cv. 'Euphoria' were sown in 12 cm pots with fertilized peat and grown for four weeks under 195 µmol m^{-2} s^{-1} from high pressure sodium lamps for 18 h day^{-1}. The air temperature set points were 22 and 20 °C day and night respectively, and it was ventilated when the temperature reached 24 °C. CO_2 was supplied to 900 ppm in periods with no ventilation. Four-week old plants were then either transplanted into 18 cm plastic pots or peat-boards (Kekkilä GroBoard®, vegetable board 316) and randomly distributed to two greenhouse compartments. One compartment was illuminated with 253 µmol m^{-2} s^{-1} for 18 h day^{-1} and the other one 190 µmol m^{-2} s^{-1} for 24 h from high pressure sodium lamps, giving daily quantum integrals of 16.4 mol m^{-2} (at plant height) in both compartments. Natural daylight was estimated to be 4 mol m^{-2} day^{-1}. Each compartment contained 18 plants (3 rows with 6 plants each) grown in pots and 18 plants grown in peat boards. The air temperature set point was 22 °C during the photoperiod and 20 °C during the night in the treatment with 18 h photoperiods. The ventilation and supply of CO_2 was as in the propagation period.

Nutrition was provided by drip watering with a complete nutrient solution. Electrical conductivity and pH in the nutrient solution was kept at 2.0–2.3 mS cm^{-1} and 5.6–6.0, respectively. Fruit production (kg marketable fruit m^{-2}) was recorded throughout the experiment. After four weeks of growth, at the onset of fruit production, the plants grown in pots were destructively sampled, and after nine weeks, when the plants were carrying a heavy fruit load the plants grown in peat boards were sampled. At both sampling occasions the incidence of chlorosis was recorded and samples for starch analyses were collected from top (uppermost 15 cm of the

Table 1. Accumulated fruit yield (kg m^{-2}), incidence of leaf chlorosis and starch content (mg g^{-1} dry weight) in different parts of cucumber plants grown under either 18 or 24 h photoperiod (PP) after four and nine weeks of treatment. Means at the same sampling occasion marked with different letters were significantly different ($p<0.05$) according to an ANOVA.

Weeks from start to treatment	PP (h)	Fruit yield (kg m^{-2})	Leaf chlorosis	Starch content (mg g^{-1} DW)			
				Leaf	Top shoot	Stem	Fruit
4	18	0.4	None	131.9 a	33.6 a	4.5	11.0
	24	0.3	Mild	61.4 b	23.7 b	4.1	9.1
9	18	10.2 a	None	134.6 a	36.3	6.3 a	10.9
	24	6.6 b	Severe	54.5 b	26.6	3.6 b	7.1

shoot), leaf (last fully expanded leaf), stem (stem pieces between the two internodes surrounding the last fully expanded leaf), fruit (slices from the two lowest developed fruits) and root (washed out from the growth medium). Sampling in the 18 h photoperiod treatment was performed at onset of the light period, as this was found by CHALLA (1976) (cited in XIONG 2002), to be the time when the carbohydrate content in cucumber is most stable. All samples for starch analysis were immediately frozen in liquid nitrogen and stored at −22 °C until freeze drying.

Starch analysis was performed using a spectrophotometer and an enzyme kit (Megazyme International Ireland Ltd). Starch was broken down to glucose by amyloglucosidase. Glucose Determination Reagent (GOPOD), which develops a pink colour when reacting with glucose, was then added and glucose concentration determined by absorbance at 510 nm.

The experiment was run twice (planted 21/10 and 19/12), and means for the 18 plants with the same treatment within each run were subjected to one-way ANOVA. The analyses were performed with the statistical package SAS 6.12 (SAS INSTITUTE INC. 2003).

Results and Discussion

Four weeks after the onset of treatments incipient stages of foliar chlorosis could be seen as interveinal mottled light green areas on the plants grown under continuous light. Five weeks later chlorosis had started to appear on young leaves whereas mature leaves were chlorotic and even necrotic. At this stage there were still no sign of leaf damages in the treatment with 18 h photoperiod. This difference between continous lighting and a 18 h photoperiod and the rate of injury is in accordance with what is found for tomato and eggplant (BRADLEY and JANES 1985; MURAGE et al. 1996; DEMERS et al. 1998a).

At both sampling occasions the leaf starch content was lower in the plants subjected to 24 h of light than in the plants provided with 18 h photoperiods (Table 1). Additionally, top shoot starch levels at four weeks and stems starch levels at nine weeks were lower in the plants given continuous light than in the plants provided with 18 h photoperiods (Table 1). The results for leaf starch content in the present study give no support to the hypothesis set forward by BRADLEY and JANES 1985; MURAGE et al. 1996, and DEMERS et al. 1998a, b that it is hyper-accumulation of this carbohydrate that causes leaf injuries and lower plant production under continuous lighting. However, as leaf sampling and analysis here was performed at a rather late stage in injury development, nothing is known about the starch status previous to visible symptoms. The low starch content and lowered fruit production in the plants exposed to 24 h of light (Table 1) indicate that continuous light is injurious to cucumber plants, and chlorosis could be seen as a late symptom of injury. Chlorosis induced by continuous light has been attributed to oxidative stress in butternut squash (MURAMAKI et al. 2002) and production of stress ethylene in tomato (JENSEN and VEIERSKOV 1998) but the causal chains are so far not elucidated.

In conclusion, the present study indicated that a lighting regime with continuous illumination should not be implemented in commercial cucumber production. Short periods of 24 h of light to avoid temperature drop in periods with low outdoor temperatures might cause little harm, but long term use is detrimental.

Acknowledgements

This work was financed by grants from the Norwegian Crop Research Institute and the Norwegian University of Science and Technology (NTNU). Thanks to Olav Arne Bævre for initiating the study, to Hans Ragnar Gislerød for his advice and comments and to Anne Kjersti Bakken for critical reading of the manuscript.

References

BRADLEY, F.M. and H.W. JANES 1985: Carbon partitioning in tomato leaves exposed to continuous light. Acta. Hortic. **174**, 293–302.

DEMERS, D.A., M. DORAIS, C.H. WIEN and A. GOSSELIN 1998a: Effects of supplemental light duration on greenhouse tomato (*Lycopersicon esculentum* Mill.) plants and fruit yields. Scientia Hortic. **74**, 295–306.

DEMERS, D.A., A. GOSSELIN and C.H. WIEN 1998b: Effects of supplemental light duration on greenhouse sweet pepper plants and fruit yields. J. Amer. Soc. Hort. Sci. **123**, 202–207.

DORAIS, M. 2003: The use of supplemental lighting for vegetable crop production: light intensity, crop response, nutrition, crop management, cultural practises. Canadian Greenhouse Conference October 9, pp. 1–8.

JENSEN, E.B. and B. VEIERSKOV 1998: Interaction between photoperiod, photosynthesis and formation in tomato plants (*Lycopersicon esculentum* cv. 'Ailsa Craig' and ACC-oxidase antisence pTOM13). Physiol. Plant. **103**, 363–368.

MURAMAKI, K., H. ORITA and M. MASUDA 2002: Varietal differences in continuous light-induced chlorosis and antioxidative enzymatic activities in *Cucurbita* (in japanese). J. Japan. Soc. Hort. Sci. **71**, 716–718.

MURAGE, E.N., N. WATASHIRO and M. MASUDA 1996: Leaf chlorosis and carbon metabolism of eggplant in response to continuous light and carbon dioxide. Scientia Hort. **67**, 27–37.

STUTTE, G.W., N.C. YORIO and R.M. WHEELER 1996: Interacting effects of photoperiod and photosynthetic photon flux on net carbon assimilation and starch accumulation in potato leaves. J. Amer. Soc. Hort. Sci. **121**, 264–268.

XIONG, J. 2002: Interactive effects of reversal day and night temperature, end-of-day light quality and light intensity on stem elongation in *Cucumis sativus* L.. Ph. D. thesis, Agricultural University of Norway, Ås, pp.1–33.

Received April 19, 2005 / Accepted December 19, 2005

Addresses of authors: Silje A. Wolff (corresponding author), The Plant Biocentre, NO-7049 Trondheim, Norway and Anne Langerud, Norwegian Crop Research Institute, Kvithamar Research Centre, NO-7500 Stjørdal, Norway, e-mail: siljewolff@bio.ntnu.no.