Kowalczyk K.*, Gajc-Wolska J., Bujalski D., Mirgos M., Niedzińska M.M., Mazur K., Żołnierczyk P., Szatkowski D., Cichoń M., Łęczycka N.

Warsaw University of Life Sciences – SGGW, Poland
Department of Vegetable and Medicinal Plants

* ✉ katarzyna_kowalczyk@sggw.pl

The effect of supplemental assimilation lighting with HPS and LED lamps on the cucumber growth, development, yield and fruit quality in autumn crop

INTRODUCTION

While cultivating plants in a long cycle at low radiation periods, when supplemental assimilation lighting is required, it is important to guarantee a proper lighting of lower leaves and to optimize the crop density. Therefore, the aim of the study was to evaluate the density of plants and the effect of HPS and LED assimilation and intercropping lighting on the growth, development and yield as well as cucumber fruit quality in autumn cultivation cycle.

MATERIALS AND METHODS

The study was conducted in three compartments, each of about 40 m-2 of usable area: Room I with HPS combination 200 W×m^{-2} HPS top light only; Room II with MIX (HPS + LED), top light 150 W×m^{-2} HPS top + 2 line LED interlight, each line about 50 µmol×m^{-2}×s^{-1}; Room III with 100% LED, 220 µmol×m^{-2}×s^{-1} top LED + 2 line LED interlight, each line about 50 µmol×m^{-2}×s^{-1}. In every compartment, there were almost the same calculated light within PAR (Photosynthetical Active Radiation) level ~320 µmol×m^{-2}×s^{-1} (PPFD- Photosynthetic photon flux density). A dayly light exposure equaled 18 hours. In each rooms there were 3 benches of plants (9 m long) with slabs type Grotop Master 100 × 20 × 10 cm, and 7 plants per slab were used. Each combination consisted of different plants' density: in combination HPS – 2,62×m^{-2}, HPS+LED – 3,67×m^{-2} and 100% LED – 4,19×m^{-2}. They were performed on greenhouse midi cucumber – 'Svyatogor' F1 cultivar from Rijk Zwaan, cultivated in the autumn productive cycle. Cucumber plants were planted on the rockwool slabs in three growing rooms on September 03.

The plants were trained on a single stem up a string according to the high wire system. Aassessment of plant growth and development were done on 14 plants taken from 2 slabs in each of combination rooms. The method of removing excess buds from plants in individual light combinations was adjusted according to the condition of plants in each growing room. Fruit pruning was done twice a week before anthesis in all growing rooms. Additionally, in each combination, on three randomly selected plants, all newly emerging buds were kept in order to assess the bud abortion rate at 100% of the fruit left on the plant.

The number and weight of cucumber fruits were assessed in terms of both marketable and unmarketable yield. The experiment was terminated on 22 December 2015 after 17 weeks of cultivation. To assess the harvest quality for the plants grown from 25.11.2015 and from 8.12.2015, 40 fruits were randomly selected from each experimental combination.

One part was of fruits was then examined for the chemical quality attributes of cucumber fruit. Another part of fruits was subjected to sensory analysis performed with the scaling method. Each attribute of sensory analysis was expressed in a scale from 0 to 10. Statistical analysis was elaborated using analysis of variance (ANOVA 2). Detailed comparison of means was performed by the Tukey's test at the significance level of α=0.05.

RESULTS AND DISCUSSION

After 17 weeks of cultivation with supplemental assimilation lighting, the highest fruit yield was obtained for 100% LED combination, being higher by 30% and by 14% when compared to HPS+LED and HPS combinations respectively (Table 1). The amount of marketable yield and mean fruit weight were also highest for 100% LED combination. In each combination, marketable yield was over 99.5% of the total yield (Table 1).

The produced fruits were characterized by high quality in all the combinations studied what was additionally confirmed by chemical and sensory analyses (Tables 2 and 3). Fruit quality features of cucumber were mainly affected by the date of harvest. Fruits harvested in first date showed lower contents of sugars, ascorbic acid and potassium, but higher contents of nitrates and calcium as compared to the fruits harvested in the second date (Table 2). According to sensory analysis, the cucumber fruits harvested in date 1 differed only in a slightly thicker skin and a more distinct strange smell as compared to date 2 fruits. However, it did not deteriorate fruit quality that was determined as high for fruits harvested in both dates (Table 3). Fruits coming from HPS combination showed weaker cucumber smell and stronger strange smell, comparing either to LED or mixing lighting combinations. The fruits had also lighter green color of skin, less numerous skin tubercles, firmer flesh, smaller core and were found sweeter than fruits from MIX and 100% LED combinations, however, no significantly important differences in fruit total sugar content had been revealed (Tables 2 and 3). Overall quality, taste desirability and overall desirability were similarly high for all fruits, irrespectively harvest date and light conditions of cultivation (Table 3).

The assessment of bud abortion in cucumber plants with all developing buds left untreated showed that at the density of 3.66 plants per m^2, and with the applied intercropping MIX lighting, the number of buds shed by plants was similar comparing to the one revealed for HPS supplemental lighting with 2.66 plants per m^2, and amounted to ca. 18%. Whereas at the density of 4.19 plants per m^2 and for 100% LED combination, the mean number of the buds shed was in untreated plants over 20% (Figure 1). In the case of plants where the excess buds were partially removed according to a plant condition assessed in the course of the growth (see Material and Methods), the highest buds' abortion rate was obtained for the density of 4.19 plants per m^2.

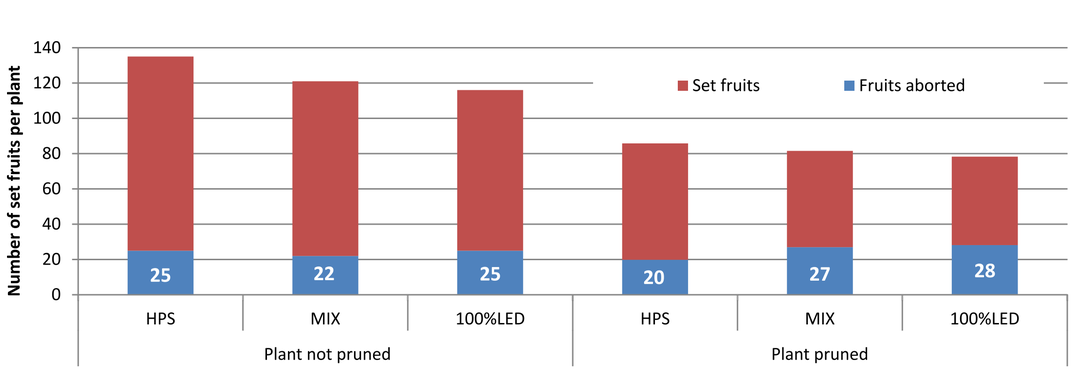

Figure 1. Scale of abortion of set fruit on the pruned and not pruned cucumber plants in different lighting

Table 1. Total and marketable yield and average weight of marketable fruit as affected by term of harvest and lighting

Lighting	Total yield		Marketable yield		
	Number of fruits (No*m^{-2})	Weight of fruits (kg*m^{-2})	Number of fruits (No*m^{-2})	Weight of fruits (kg*m^{-2})	Average weight of fruit (g)
HPS	173 b*	33.70 b	172 b	33.67 b	196 ab
HPS+LED	200 a	38.34 a	198 a	38.22 a	193 b
LED	210 a	43.89 a	208 a	43.80 a	211 a

* Mean values which do not differ according to Tukey's HSD test at P = 0.05 are marked with the same big letters

Table 2. Chemical related components of cucumber fruits as affected by term of harvest and lighting

Component	Term 1			Average for Term 1	Term 2			Average for Term 2	Average for the lighting		
	HPS	MIX	100% LED		HPS	MIX	100% LED		HPS	MIX	100% LED
Dry mass (%)	3.12 a*	3.15 a	3.04 a	3.10 A	2.83 a	2.95 a	3.12 a	2.97 A	2.97 A*	3.05 A	3.08 A
TSS (%)	3.07 a	2.80 c	2.93 b	2.93 B	2.90 bc	3.10 a	3.13 a	3.04 A	2.99 A	2.95 A	3.03 A
Total sugars (g*100 g fw^{-1})	1.17 a	1.07 a	1.12 a	1.12 B	1.28 a	1.26 a	1.20 a	1.25 A	1.23 A	1.17 A	1.16 A
Ascorbic acid (mg*100 g fw^{-1})	2.57 bc	2.27 c	2.67 bc	2.50 B	3.43 a	2.80 b	2.83 b	3.02 A	3.00 A	2.54 A	2.75 A
NO_3 (mg*kg fw^{-1})	459.20 ab	495.30 a	318.40 c	424.30 A	333.50 c	413.37 b	378.20 bc	375.02 B	396.35 AB	454.34 A	348.30 B
P (mg*kg fw^{-1})	249.00 a	241.60 a	251.30 a	247.30 A	249.50 a	252.20 a	259.00 a	253.60 A	249.28 B	246.93 B	255.20 AB
K (mg*kg fw^{-1})	1675.70 bc	1549.70 c	1591.70 c	1605.70 B	1756.80 b	1976.10 a	1934.90 a	1889.30 A	1716.24 A	1762.89 A	1763.33 A
Ca (mg*kg fw^{-1})	301.80 ab	318.00 ab	328.80 a	316.20 A	269.30 b	282.70 b	2827.00 b	278.20 B	285.55 A	300.38 A	305.13 A

* Mean values which do not differ according to Tukey's HSD test at P = 0.05 are marked with the same big letters for factors, small letters for interaction

Table 3. Sensory attributes of cucumber fruits as affected by term of harvest and lighting

Sensory attributes of cucumber		Term 1			Average for Term 1	Term 2			Average for Term 2	Average for the lighting		
		HPS	MIX	100% LED		HPS	MIX	100% LED		HPS	MIX	100% LED
Smell	Typical cucumber	4.08 ab	4.99 ab	4.54 ab	4.54 A	4.62 ab	5.52a	5.18 a	5.11 A	4.35 B	5.26 A	4.86 AB
	Strange	0.61 a	0.05 b	0.00 b	0.22 A	0.00 b	0.08 b	0.00 b	-0.02 B	0.31 A	0.03 B	0.00 B
Skin	Colour of skin	7.51 b	8.31 ab	8.74 a	8.19 A	8.10 a	7.94 a	8.17 a	8.07 A	7.81 B	8.13 AB	8.46 A
	Presense of warts	4.26 b	4.51 b	5.57 a	4.78 A	3.98 b	4.61 b	4.53 b	4.37 A	4.12 B	4.56 AB	5.05 A
	Tough of skin	5.29 a	5.52 a	5.43 a	5.41 A	5.95 a	5.86 a	6.21 a	6.01 B	5.62 A	5.69 A	5.82 A
Flesh	Colour of flesh	7.91 a	7.92 a	7.84 a	7.89 A	7.49 a	7.06 a	7.06 a	7.20A	7.70 A	7.49 A	7.45 A
	Size of the seed chamber	5.74 a	6.15 a	5.99 a	5.96 A	5.14 ab	5.76 a	5.17 ab	5.36 A	5.44 B	5.96 A	5.58 AB
	Flesh texture	6.11 a	5.78 a	6.03 a	5.97 A	5.91 a	5.17 b	5.66 ab	5.58 A	6.04 A	5.48 B	5.85 AB
	Juiciness of flesh	6.35 a	6.08 a	6.61 a	6.35 A	6.43 a	6.74 a	6.61 a	6.59 A	6.39 A	6.41 A	6.61 A
Taste	Typical cucumber	7.03 a	6.81 a	6.24 ab	6.69 A	6.77 a	6.13 ab	6.56 a	6.49 A	6.90 A	6.47 A	6.40 A
	Sour	1.11 b	1.61 a	1.48 a	1.40 A	1.74 a	1.85 a	1.96 a	1.85 A	1.43 A	1.73 A	1.72 A
	Sweet	3.18 a	2.68 ab	2.34 b	2.73 A	3.58 a	2.88 ab	3.35 a	3.27 A	3.38 A	2.78 B	2.85 B
Overall quality		7.22 a	7.29 a	7.05 a	7.19 A	7.04 a	7.08 a	6.97 a	7.03 A	7.13 A	7.19 A	7.01 A
Desirability of flavor		7.15 a	6.99 a	6.75 a	6.93 A	6.91 a	6.91 a	6.81 a	6.88 A	7.03 A	6.95 A	6.78 A
Overall desirability		7.25 a	7.00 a	6.73 a	6.99 A	6.67 a	6.56 a	6.74 a	6.66 A	6.96 A	6.78 A	6.74 A

* Mean values which do not differ according to Tukey's HSD test at P = 0.05 are marked with the same big letters for factors, small letters for interaction

CONCLUSIONS

The cucumber grown in the autumn growing cycle gave higher yield and the quality of fruits produced appeared more balanced for the plants lighted with HPS+LED or 100% LED as compared to the traditional, overhead HPS lighting. The above, together with the results from the rate of buds' abortion assessment seem to legitimate the increase in the cucumber crop density when applying LED lighting.