Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 22, issue 1, 2012, pp. 117-123

DETERMINATION OF ASSIMILATOR PIGMENTS CONTENT IN COTYLEDONS OF *PINUS NIGRA* ARN. PLANTLETS ILLUMINATED WITH LIGHT-EMITTING DIODES (LEDS)

Mirela Maria Matioc-Precup[1]*, Dorina Cachiţă-Cosma[2]
[1]Faculty of Sciences, University of Oradea, Oradea
[2]Faculty of Natural Sciences,"Vasile Goldiş" Western University of Arad, Arad

ABSTRACT
The experiment focused on determining the *assimilator pigments* content in the cotyledons of the black pine plantlets (*Pinus nigra* Arn.) derived from seeds germinated and grown for **21 days**, 16 hours/day, under light emitted by Light-Emitting Diodes (LEDs), of different colours (respectively, of different wavelengths). The light intensity was constant, of 1200 lx. The highest *chlorophyll a* content was recorded at the seedlings exposed to the ***red*** light produced by LEDs, which, compared with the plantlets grown in ***natural*** light, marked an increase of 26.3%, and, as against to those exposed to fluorescent ***white*** light, was 18.1% higher. Instead, the seedlings exposed to ***white*** LEDs light, in relation to those illuminated with ***natural*** light, have registered the highest values of *chlorophyll b* (+159%) and *carotenoid* pigments (+95.2%), and of the total *chlorophyll pigments* content (+74.7%), respectively, of the *total assimilator pigments* (+77.1%). The lowest values of the *assimilator pigments* content were marked at the plantlets exposed to the ***green*** light of LEDs, at which the *chlorophyll a* content was reduced with 25.7%, and the content in *chlorophyll b* with 31.3%, in comparison with the results noted at the group of plantlets lighted with ***white*** fluorescent tubes; therefore, the total *green pigments* were diminished with 28.9%, respectively, the content in *total asimilator pigments* with 28.8%. Thus, from all the types of lightings used, the most effective light for the *assimilator pigments* accumulation, in the cotyledons of black pine seedlings, proved to be the ***white*** one of LEDs.
Keywords: assimilator pigments, *Pinus nigra*, cotyledons, Light-Emitting Diodes, fluorescent light

INTRODUCTION
As *Tikhomirov* (1994) stated, the spectral changes of light, at plants, cause the record at the level of green organs of each plant - of different morphogenetic and photosynthetic reactions, with interspecific and intraspecific or intraindividual variations. The plants' reaction to light is important because this modulates their growth and development, namely the quality of their nutrition.

Due to some of the incontestable technical advantages of the Light-Emitting Diodes (LEDs), in relation to other lighting sources, it had been proved that they can be successfully used in ornamental plant growth, but also, in forest nurseries, greenhouses or in space ships (*Bula* et al., 1994).

Yorio and collaborators (2001) noted that, after 21 days of exposure of the seedlings of: radish, spinach and lettuce, to the ***red*** light of LEDs, with or without its supplementation with ***blue*** light produced by fluorescent tubes, respectively to ***white*** fluorescent light (the control lot), with a photosynthetic photons flux (PPF) of 300 $\mu mol \cdot m^{-2} \cdot s^{-1}$, in regime of 18 hours of light / 24 hours - for lettuce and radish, and in regime of 12 hours of light / 24 hours - for spinach, the greatest values of the *dry weight* of plantlets had been registered at the cultures illuminated with ***white*** fluorescent light. In descending order followed the values that were recorded at the radish and spinach plants which were illuminated with the light combination – 90% ***red*** light emitted by LEDs + 10% ***blue*** fluorescent light. Therefore, the highest *total chlorophyll pigments* content was marked at the radish and lettuce seedlings exposed to the ***white*** fluorescent light, exception were the plantlets of lettuce illuminated with combined light - ***red***, emitted by LEDs and ***blue***, produced by fluorescent tubes – at which an increase with 7.7% in *total chlorophyll pigments* content was noted, as against to the control group, lot illuminated with ***white*** fluorescent tubes.

Researches concerning the influence of LEDs light exercised on lettuce plants were continued by *Kim* and colleagues (2004), which concluded that the exposure of the lettuce seeds and of the plants resulted from them, time for 28 days, at combined light: in a proportion of 61% ***red*** light and 15% ***blue*** light, emitted by LEDs, supplemented with 24% ***green*** fluorescent light (500-600nm) - with a photosynthetic photons flux (PPF) of 150 $\mu mol \cdot m^{-2} \cdot s^{-1}$, in regime of 18 hours light / 24 hours, compared to the plantlets grown under the ***white*** fluorescent light incidence (control lot), there was registered an increase of their *dry weight* with 28.4%, but not the *chlorophyll pigments* content in their leaves. Adding a higher percentage of 24% of ***green*** fluorescent light, contrarily, lowered the *dry weight* of seedlings.

Urbonavičiūtė and collaborators (2007), experimenting with plants of lettuce, illuminated with LEDs issuing ***red*** light, supplemented with LEDs emitting light ***UV*** (365 nm), ***blue*** (460 nm) or ***cyan*** (505 nm), with a photosynthetic photons flux (PPF) of

*Email: mirelamatioc@yahoo.com

200 µmol·m^{-2}·s^{-1}, time for 39 days from when the seeds were put to germinate, in regime of 18 hours light/24 hours, demonstrated the fact that the combined light, ***red*** (90%) + ***cyan*** (10%), has determined the growth of the *chlorophyll a* content in leaves at levels close to those recorded at the control batch, cultures exposed throughout the whole experiment to ***white*** fluorescent light.

Vidican and *Cachiţă* (2010), making determinations regarding the total content in *assimilator pigments* of the *Opuntia fragilis* var. fragilis cladodes, exposed to the light of LEDs, with a luminous intensity of 1000 lx and an illumination regime of 16 hours light from 24 hours, for 90 days, concluded that, compared to the control version, batch lighted with ***white*** fluorescent tubes, reference values, considered 100%, at the variant of vitroplantlets of *Opuntia fragilis* exposed to the ***white*** LEDs light, the *chlorophyll a* quantity was reduced with 10.6%, that of *chlorophyll b* with 31.3%, and of the *carotenoides* only with 5.7%, than the control lot.

In this study, we aimed to determine the *assimilator pigments* content in the cotyledons of black pine seedlings (*Pinus nigra* Arn.), exposed during their germination and growth at the incidence of the different coloured light, emitted by Light-Emitting Diodes (LEDs).

MATERIALS AND METHODS

The vegetal material used in the experiments with LEDs consisted of seedlings of black pine (*Pinus nigra* Arn.), resulted from seeds germinated and grown, for a period of 21 days, on filter paper substrate moistened with tap water, being exposed in regime of 16 hours from 24 hours, at light of different colours, emitted by LEDs. Luminous intensity – at all experimental variants exposed to artificial light – was 1200 lx. The temperature (20±2°C) and relative humidity of the laboratory air (50-60%) were maintained constant, throughout the whole experiment. As controls variants we used both the black pine seedlings (*Pinus nigra* Arn.) germinated and grown at the ***natural*** light (V_0) of the lab, being located at northern oriented windows, and plantlets exposed to ***white*** light emitted by fluorescent tubes (V_{00}) (Fig.1). The remaining variants (V_1-V_5) consisted of seedlings lighted with LEDs, of different wavelengths, as follows:

V_0 – plantlets exposed to ***natural*** light;
V_{00} – plantlets exposed to ***white*** fluorescent light (380 -760 nm);
V_1 – plantlets exposed to ***white*** LED's light (380 -760 nm);
V_2 – plantlets exposed to ***blue*** LED's light (465 nm);
V_3 – plantlets exposed to ***green*** LED's light (520 nm);
V_4 – plantlets exposed to ***yellow*** LED's light (590 nm);
V_5 – plantlets exposed to ***red*** LED's light (650 nm).

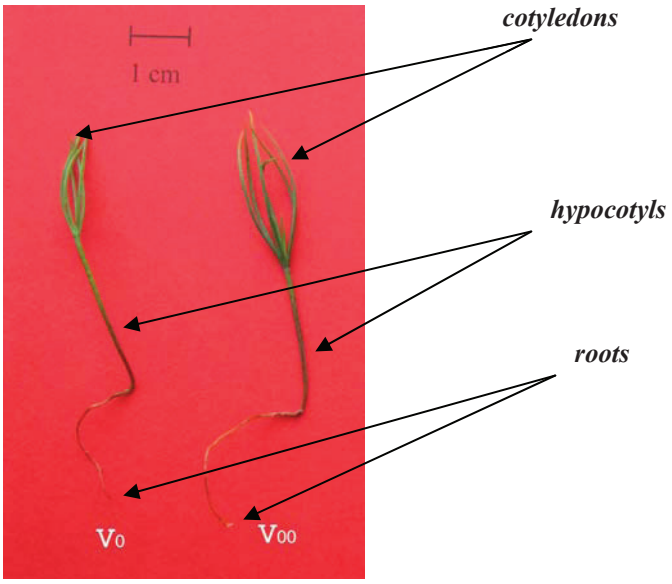

Fig. 1. *The black pine seedlings aspect (Pinus nigra Arn.), in the* **21st day** *from the moment when the seeds were put to germinate: (where: V_0 – seedlings exposed to* ***natural*** *light; V_{00} – plantlets lighted with* ***white*** *fluorescent light).*

Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 22, issue 1, 2012, pp. 117-123

The assessment of the effect exercised by the LEDs light of different colours, on the content in *chlorophyll pigments* and in *carotenoides*, in the cotyledons of black pine plantlets, was realised in the **21st day** from the putting of seeds to germinate. In this respect, the plant material (100 mg) was triturated in 2.5 ml of pure dimethylformamide (DMF, 99.99% Merck). The extraction of assimilator pigments was made in dark, at a temperature of 4°C (*Moran* and *Porath*, 1980). After 72 hours, the supernatant was decanted, and *chlorophyll a*, *chlorophyll b* and *carotenoid pigments* were quantitatively determined in the respective liquid. Extinction readings were made at a spectrophotometer type Spekol 11, Carl Zeiss Jena, using filters for the following wavelengths: 664 nm for *chlorophyll a*, 647 nm for *chlorophyll b* and 480 nm for *carotenoids*. The *assimilator pigments* quantity was determined by using the coefficients proposed by *Wellburn* (1994):

Chlorophyll a (mg/g SP) = (11.65 A_{664} – 2.69 A_{647}) · v/SP

Chlorophyll b (mg/g SP) = (20.8 A_{647} – 3.14 A_{664}) · v/SP

Carotenoides (mg/g SP) = (1000A_{480} – 1.28 *chlorophyll a* – 56.7 *chlorophyll b*) /245 · v/SP

where:

$A_{664,}$ A_{647} and A_{480} = the values of the pigments absorbance at respective wavelengths;

V = the volume of extract in millilitres;

SP = the fresh weight of the tissue in milligrams.

In the case of each experimental variant, arithmetic mean of the three extinction readings, for each category of *assimilator pigments*, in part, and the standard deviation - from the average of these - was calculated. The total of *chlorophyll pigments* was calculated by summing the *chlorophyll a* and *b* quantities, and a total amount of the *assimilator pigments* extracted was obtained by adding the *carotenoides* values to those of the total *chlorophyll pigments*.

The results obtained in the case of each experimental variant were reported to the data recorded at the respective parameters from the control variant, lot illuminated with the ***natural*** light (V_0), and, separately, to the similar data obtained at the group illuminated with the ***white*** light, produced by fluorescent tubes (V_{00}), being, one by one, considered as reference, of 100%. The graphical representation of the average data was made in percentage values (Fig. 2 A and B). All data were statistically processed by calculating the ***t*** test**,** for independent sample groups (two-tailed P value) at a level of confidence of 95% ($p \leq 0.05$), achieving the statistical probability of the experimental variants averages to be or not significantly different from those of the control variants.

RESULTS AND DISCUssIONS

In comparison to the *chlorophyll a* content determined in the black pine plantlets cotyledons belonging to the control variant (V_0), which were grown in ***natural*** light (reference values, considered 100%), at the plantlets subjected to the ***white*** light emitted by fluorescent tubes - V_{00} variant, in the **21st day** of germination, the increase of the *chlorophyll a* content was 6.9%, that of the *chlorophyll b* was 120.5%, the *total green pigments* (*chlorophyll a* + *chlorophyll b*) amount registering a growth with 52.4%. The *carotenoids* content was 60.5% greater than that marked at the V_0 variant, respectively the *total assimilator pigments* recorded an increase by 53.4%, compared to it (Fig. 2 A). The mentioned differences were statistically significant.

But, in relation with the same parameters determined, in the **21st day** of germination, in the cotyledons' seedlings illuminated with ***white*** fluorescent light (V_{00}) (Fig. 2 B) (values which were considered - in this case - as reference), it had been remarked the fact that, at the variant of plantlets exposed to ***natural*** light (V_0) the cotyledons content in *chlorophyll a* was lowered with 6.4% as against to the V_{00} batch values, and that in *chlorophyll b* was more reduced with 54.7%, respective, the *total chlorophyllian pigments* amount was diminished by 34.3%. In the same time, as against to those values noted to the plantlets grown in ***white*** fluorescent light (V_{00}), the ***natural*** light (V_0) decreased the *carotenoids* quantity with 37.7% and the content in *total assimilator pigments* (*chlorophyllian* and *carotenoids*) with 34.8%.

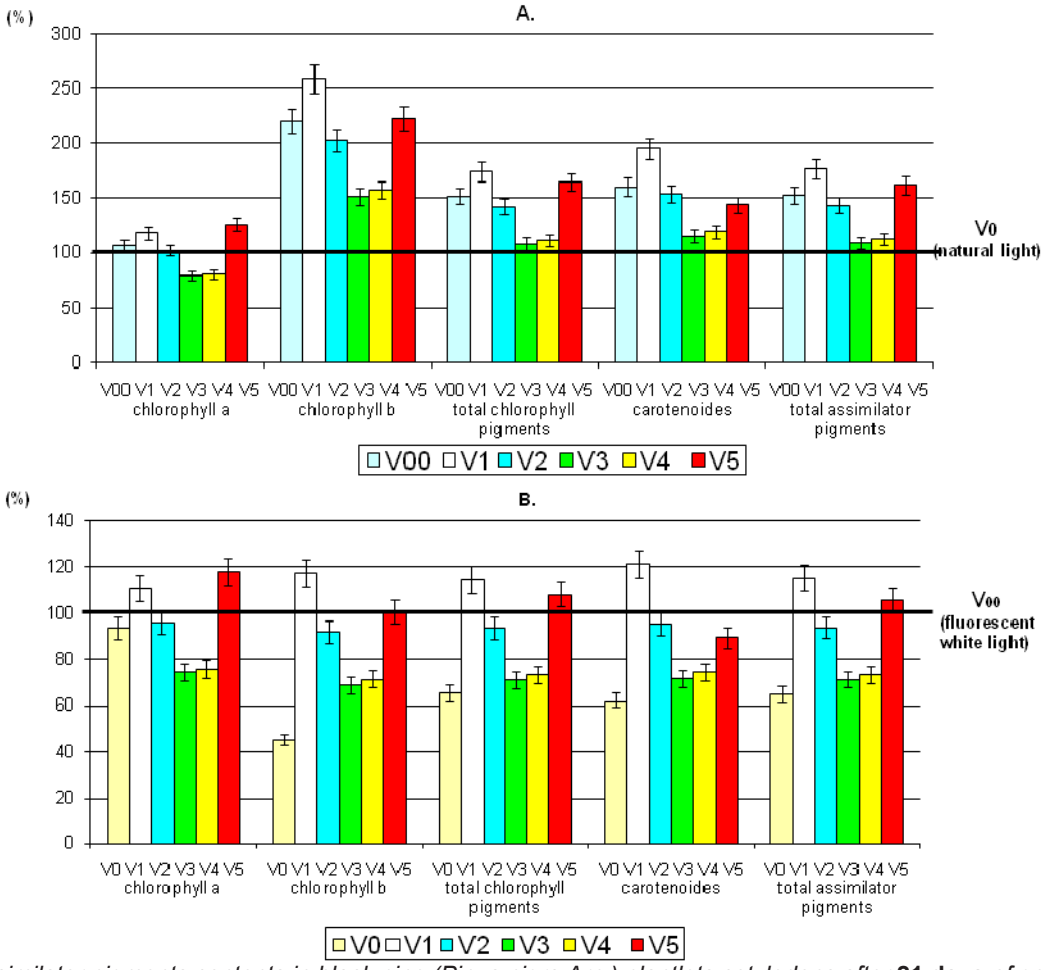

Fig. 2. *Assimilator pigments contents in black pine (Pinus nigra Arn.) plantlets cotyledons after* **21 days** *of germination, being illuminated with LEDs light, as following: V_0 – **natural** light; V_{00} – **white** fluorescent light (380-760 nm); V_1 – **white** LEDs light (380-760 nm); V_2 – **blue** LEDs light (465 nm); V_3 – **green** LEDs light (520 nm); V_4 – **yellow** LEDs light (590 nm); V_5 – **red** LEDs light (650 nm):* **A***. values compared with V_0 variant, exposed to **natural** light, reference values considered 100%;* **B***. values compared with the V_{00} variant, illuminated with **white** fluorescent light, reference values considered 100%.*

On the other hand, in comparison with the *chlorophyll a* content determined in the black pine plantlets exposed for **21 days** to ***natural*** light (V_0), the ***white*** light of LEDs (V_1) (Fig. 2 A) provoked a growth with 18.3% of this parameter. At the same V_1 variant, the cotyledons content in *chlorophyll b* was greater with 159% than that was found at the control variant (V_0), and the *total chlorophyllian pigments* quantity was increased by 74.7%, respective the *carotenoids* content by 95.2% as against to this. Thus, in the case of seedlings' cotyledons subjected to ***white*** LEDs light (V_1), the total content in *assimilator pigments* was 77.1% greater than that determined in the case of the control batch (V_0), samples exposed for **21 days** to ***natural*** light.

If compared the content in *assimilator pigments* determined in the black pine seedlings cotyledons illuminated for **21 days** of germination with ***white*** fluorescent tubes (V_{00}) (values considered – in this case – as 100%), to that recorded at the batch of seedlings maintained in a lighting regime with LEDs issuing ***white*** light (V_1), we observed – according to the plotted data (Fig. 2 B) – that the *chlorophyll a* content was increased with 10.7%, *chlorophyll b* content with 17.3%, and the total quantity of *green pigments* (*chlorophyll a* + *chlorophyll b*) with 14,5%. The *carotenoids* pigments registered rises of 21.2%; in this way, the total *assimilator pigments* quantity being 15.4% higher, which indicates us that the ***white*** LEDs light had a more stimulating effect on *assimilator pigments* synthesis in black pine seedlings' cotyledons than the ***white*** fluorescent light.

The black pine seedlings illuminated with ***blue*** LEDs light (V_2) had cotyledons with a *chlorophyll a* content greater just with 2.5% as against to the values of the similar parameter determined in the black pine plantlets' cotyledons derived from seeds germinated and grown in ***natural*** light (values considered 100% - V_0), the primary benchmark group; instead, *chlorophyll b* content was increased by 102.7%, and that in *carotenoids* was

amplified with 53.8%. Therefore, at this experimental variant (V_2), the total quantity of *green pigments* was larger with 42.7% in relation to the same parameter determined at the control group (V_0); by summing the values of the *chlorophyllian pigments* (*chlorophyll a* + *chlorophyll b*) with those of the *carotenoids*, and by reporting the obtained result to that of the control samples, an increase of 43.9% in *total assimilator pigments* had resulted (Fig. 2 A). The signaled differences were statistically significant ($p \leq 0.05$).

Reporting the data obtained at the lighting variant with ***blue*** light (V_2), to those of the group of seedlings exposed to ***white*** fluorescent tubes (V_{00}) (the secondary benchmark) (Fig. 2 B), slight decreases have been registered both in *chlorophyll a* (-4,1%) and *b* (-8,2%) contents, respective, in total content of *chlorophyllian pigments* (-6.5%) and of *carotenoids* content (-4,5%). So, we can say that the ***blue*** light of LEDs (V_2) showed an inhibitory effect on the formation of the *assimilator pigments* in black pine seedlings' cotyledons, of minus -6.2%, in relation to the benchmark samples (V_{00}).

The ***green*** light of LEDs (V_3), in comparison with the V_0 control variant (Fig. 2 A), produced a 20.5% decrease of the *chlorophyll a* content in the cotyledons of the black pine seedlings germinated and grown for **21 days** under this type of light; in contrast, the *chlorophyll b* content was stimulated with 51.7%, and the amount of *carotenoids* was 15.5% higher than that determined at the control group - V_0. Thus, in the case of samples illuminated with LEDs issuing ***green*** light, the total amount in *chlorophyllian pigments* (*chlorophyll a* and b) was 8.4% greater, and the total content in *assimilator pigments* was increased by 9.2%, than the values recorded at these parameters at the control samples, plantlets grown in ***natural*** light (V_0), reference values which were considered 100%. All stated data were statistically significant at $p \leq 0.05$.

The *chlorophyll a* content of the black pine seedlings' cotyledons which were exposed to the ***green*** light of LEDs (V_3) was 25.7% lower than that registered in the cotyledons of the plantlets illuminated with ***white*** fluorescent light (V_{00}) (Fig. 2 B), and the *chlorophyll b* content was more reduced with 31.3%; by making the sum of the gross amounts of the *chlorophyllian pigments* and by reporting these to the benchmark V_{00} group values, we can say that the total *green pigments* (*chlorophyll a* + *chlorophyll b*) content was 28.9% smaller than the content in these pigments determined at the V_{00} variant; also, at the V_3 variant, the *carotenoids* content was decreased by 28.3%, and the total amount of the *assimilator pigments* was 28.8% diminished in relation to the results signaled at the lot of plantlets illuminated with ***white*** fluorescent tubes (V_{00}). Thus, in connection with the variant of black pine seedlings grown in ***white*** fluorescent light (V_{00}), the ***green*** LEDs light (V_3) inhibited the *assimilator pigments* accumulation.

The cotyledons of the plantlets exposed to the ***yellow*** light of LEDs (V_4) (Fig. 2 A) registered a content in *chlorophyll a* more reduced with 18.9% than that marked at the V_0 control lot (plantlets grown in ***natural*** light); on the other hand, the *chlorophyll b* content of the respective seedlings was 57.6% higher than the same parameter noticed at the control samples (V_0). At the plantlets lighted with LEDs emitting ***yellow*** light (V_4), cotyledons had an increase in *total green pigments* of 11.7%, and in *carotenoids* pigments of 19,7%, the total amount of *assimilator pigments* being raised with 12.6%, as against to the data obtained at the samples extracted from the cotyledons of seedlings grown in ***natural*** light (V_0).

If we compare the *chlorophyll a* content of the plantlets grown in the ***yellow*** light issued by LEDs (V_4) (Fig. 2 B) with that of the plantlets illuminated with ***white*** fluorescent light (V_{00}), it can been observed a 24.2% decrease of this parameter and a 28.6% diminution of the *chlorophyll b* content. Also, at the lot lighted with ***yellow*** LEDs (V_4), it was found a 25.7% reduction of the *carotenoids* content; therefore, the total quantity of *green pigments* (*chlorophyll a* + *chlorophyll b)* was 26.8% lower, respective, the content in *total assimilator pigments* more diminished with 26.6%, than the similar parameters found at the control samples, originated from plantlets exposed to ***white*** fluorescent light (V_{00}).

The ***red*** LEDs light (V_5), in comparison with the ***natural*** light (V_0) (Fig. 2 A), increased by 26.3% the *chlorophyll a* content, by 122.6% that in *chlorophyll b*, and by 64.8% the content in *total green pigments* (*chlorophyll a* + *chlorophyll b*) of the cotyledons of seedlings exposed to it. In the same time, this light (V_5) grew with 44.2% the *carotenoids* amount, and, respective, with 62% the total content in *assimilator pigments*, compared with the same parameters values remarked in the samples extracted from cotyledons of plantlets grown in ***natural*** light (V_0).

But, in relation to the values marked at the variant of plantlets grown at ***white*** fluorescent light (V_{00}), the secondary benchmark group, the ***red*** light produced by LEDs (V_5) (Fig. 2 B) caused an increase of just 18.1% in the *chlorophyll a* content, the *chlorophyll b* content being identical to that recorded in the seedlings' cotyledons illuminated with ***white*** fluorescent light (V_{00}); contrarily, the content in *carotenoids* was lowered - with 10.4% - as against to that noticed at the V_{00} variant, at which we were reporting in this case (Fig. 2B). These data determined that the *total chlorophyllian pigments* content, which resulted by summing the values of the *chlorophyll a* content with the one of the *chlorophyll b*, in the seedlings' cotyledons exposed to LEDs issuing ***red*** light (V_5) to mark an increase of only 8.1%, and the content in total *assimilator pigments* to present a growth of just 5.6% compared to the similar parameters determined in the cotyledons of plantlets subjected to the ***white*** fluorescent light (V_{00}).

Referring to the data concerning the **growth** in length of the black pine plantlets' *cotyledons* exposed to the ***white*** fluorescent light (V_{00}) (Fig. 3), resulted from previous determinations (Matioc-Precup and Cachiţă-Cosma, 2011), performed in the **21st day of germination**, as against to the benchmark group values – cultures exposed to ***natural*** light (V_0), we noticed that, the increase in growth of the *cotyledons* was of 86%, while that marked by the content in *total assimilator pigments* was situated just at 53.4%.

At the variant illuminated with ***white*** LEDs (V_1), the growth in size of the *cotyledons* marked an increase of 51.3% (Matioc-Precup and Cachiţă-Cosma, 2011), the content in *total assimilator pigments* of these recording a plus of 77,1% (Fig. 3), compared to the same parameter placed under observation at the control variant (V_0), cultures grown in ***natural*** light.

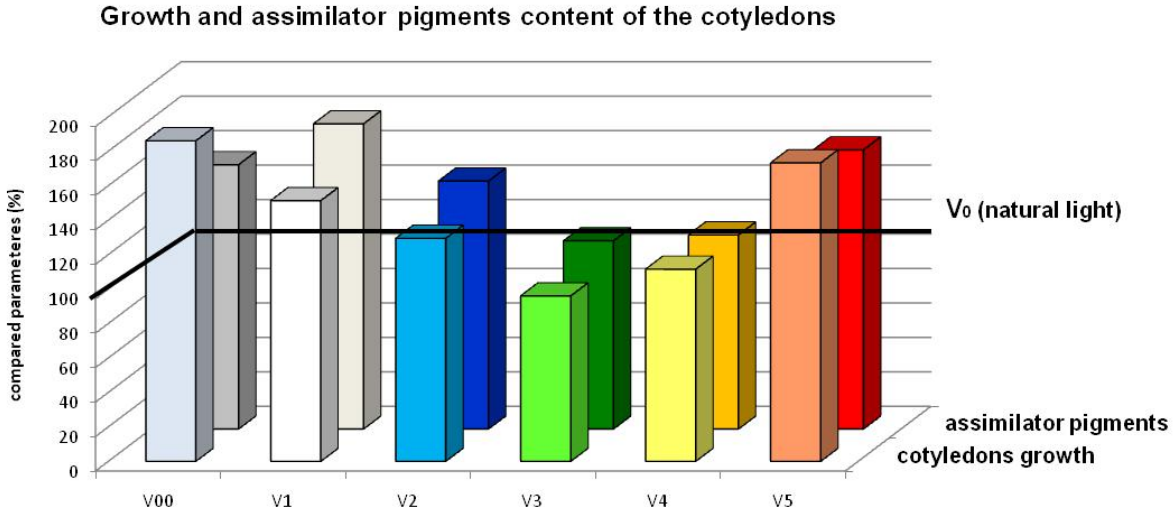

Fig. 3. *Comparative data regarding the average* **growth** *in length of the black pine plantlets' cotyledons (Pinus nigra Arn.) and their* **content** *in total assimilator pigments, in the* **21st day** *of germination, under conditions of illumination, 16 ore/zi, with* ***white*** *fluorescent light (V_{00}), with* ***white*** *or* ***coloured*** *light issued by LEDs, as follows:* ***white*** *(V_1),* ***blue*** *(V_2),* ***green*** *(V_3),* ***yellow*** *(V_4) and* ***red*** *(V_5), in relation to* ***natural*** *light (V_0), values considered as reference, of 100%.*

Although the increase of the content in *total assimilator pigments* marked in the black pine seedlings' cotyledons exposed to the ***blue*** LEDs light (V_2) was of 43.9%, at this category of light, the average growth increase of the *cotyledons* was situated at 29.4% (Fig. 3), reported values to those of the samples illuminated with ***natural*** light (V_0) (Matioc-Precup and Cachiţă-Cosma, 2011).

Instead, the results regarding not only the growth in length of the *cotyledons* but also the content in *total assimilator pigments* of the cotyledons subjected to the ***green*** light provided by LEDs (V_3) were closed to those registered at the benchmark group – V_0, lot of plantlets illuminated with ***natural*** light (Fig. 3).

Also, the ***yellow*** light of LEDs (V_4) raised the cotyledons' size with 11.5% (Matioc-Precup and Cachiţă-Cosma, 2011), and with 12.6% the content in *total assimilator pigments* of the plantlets cotyledons subjected to this type of light (Fig. 3), parameter values compared with those marked in the control group seedlings (V_0).

Among the lighting variants with LEDs, the ***red*** light produced by LEDs (V_5) largely stimulated the cotyledons growth (+73.2%) (Matioc-Precup and Cachiţă-Cosma, 2011), but to a lesser extent the accumulation of *total assimilator pigments* (+62%) in the black pine seedlings cotyledons exposed to it (Fig. 3), being reported to the values marked at the samples illuminated with ***natural*** light (V_0).

CONCLUSIONS

During of the **21 days** from the moment when the black pine seeds (*Pinus nigra* Arn.) were put to germinate, the ***red*** light of LEDs largely stimulated the *chlorophyll a* accumulation in cotyledons, its content being with 26.3% higher than that registered in the seedlings cotyledons grown at ***natural*** light, respective 18.1% greater than the content of plantlets exposed to the light emanated by ***white*** fluorescent tubes.

Compared to the *assimilator pigments* content recorded in the cotyledons of seedlings grown in ***natural*** light, the highest values were reported in the samples extracted from the plantlets treated with ***white*** light produced by LEDs at which the *chlorophyll b* content was stimulated in a proportion of 159%, and the content in *total green pigments* (*chlorophyll a* and *b*) grew with 74.7%. Also, at this lighting we noticed the highest content in *carotenoids*, the increase remarked being of

95.2%. Thus, the quantity of *total assimilator pigments* (*carotenoids* + *chlorophyllian pigments*) was risen with 77.1% as against to that marked in the cotyledons of the control batch, cultures grown in ***natural*** light. Being reported to the data obtained at the group of seedlings subjected to the ***white*** fluorescent tubes, the gains scored at the variant illuminated with ***white*** LEDs were: +10.7% for *chlorophyll a*, +17.3% for *chlorophyll b*, +14.5% for *green pigments*, +21.2% for *carotenoids pigments*, respective, +15.4% for *total assimilator pigments* content.

Between all types of LEDs illuminations, compared with the levels recorded in the cotyledons of the black pine plantlets grown under ***white*** fluorescent light, the illumination with ***green*** light provided by LEDs determined the lowest values of the *total assimilator pigments* content, the minus noticed being of 28.8%.

REFERENCES

Bula R.J., Tennessen D.J., Morrow R.C., Tibbitts T.W., (1994) - Light emitting diodes as a plant lighting source. T.W.Tibbitts (ed.), International Lighting in Controlled Environments Workshop, pp. 255-267.

Kim H.H., Goins G.D., Wheeler R.M., Sager J.C., (2004) - Green-light supplementation for enhanced lettuce growth under Red- and Blue-light-emitting Diodes. HortScience, Vol. 39, Nr. 7, pp. 1617-1622.

Matioc-Precup M.M., Cachiţă-Cosma D., (2011) - Effects of light of different wavelengths, emitted by Light-Emitting Diodes (LEDs) on the germination of seeds of *Pinus nigra* Arn. and on the growth of the plantlets resulted from their embryos. Studia Universitatis "Vasile Goldiş", Life Sciences Series, Vol. 21, Nr. 3, pp. 625-632.

Moran R., Porath D., (1980) - Chlorophyll determination in intact tissues using N,N-dimetylformamide. Plant Physiology, Vol. 65, pp. 478 – 479.

Tikhomirov A.A., (1994) - Spectral composition of light and growing of plants in controlled environments. T.W.Tibbitts (ed.), International Lighting in Controlled Environments Workshop, pp. 25-29.

Urbonaviciute A., Pinho P., Samuoliene G, Duchovskis P., Vitta P., Stonkus A., Tamulaitis G., Zukauskas A., Halonen L., (2007) - Effect of short-wavelength light on lettuce growth and nutritional quality. Scientific Works of the Lithuanian Institute of Horticulture and Lithuanian University of Agriculture, Vol. 26, Nr. 1, pp. 157-165.

Vidican T.I., Cachiţă C.D., (2010) - Determination of assimilator pigment content in cladodes of *Opuntia fragilis* var. fragilis exposed to light of different colors emitted by LEDs. Studia Universitatis "Vasile Goldiş", Life Sciences Series, Vol. 20, Nr. 2, pp. 49-54.

Wellburn A.R., (1994) - The spectral determination of chlorophylls a and b, as well as total carotenoides, using various solvents with spectrophotometers of different resolution. Plant Physiology, Vol. 144, Nr. 1, pp. 307 – 313.

Yorio N.C., Goins G.D., Kagie H.R., Wheeler R.M., Sager J.C., (2001) - Improving spinach, radish, and lettuce growth under red Light-emitting Diodes (LEDs) with blue light supplementation. HortScience, Vol. 36, Nr. 2, pp. 380-383.