Bangladesh J. Bot. **51**(4): 987-993, 2022 (December) Special DOI: https://doi.org/10.3329/bjb.v51i40.63843

EFFECTS OF LIGHT-EMITTING DIODES LIGHT QUALITY ON GROWTH, DEVELOPMENT AND METABOLISM OF WHEAT (*TRITICUM AESTIVUM* L.) SEEDLINGS

YONGQIANG LIU, KELONG SUN, YING PENG AND JIANJUN CHEN[1*]

College of Science, Huazhong Agricultural University, Wuhan, 430070, P.R. China

Keywords: LEDs light quality, Red-blue composite light, Photosynthesis of wheat

Abstract

Light quality is considered crucial for plant growth, development and metabolism. The objective of this study was to investigate the impact of different light-emitting diodes (LEDs) light qualities on the growth of wheat (*Triticum aestivum* L.) seedlings. Five different set of LEDs light quality namely CK, 5R1B, 4R2B1G, 3B3R, 4B2R and 4B2R1G were used. The morphology, stomatal characteristic, biomass accumulation, RubisCO enzyme activity, photosynthetic pigment, value, soluble sugar and protein, Malondialdehyde (MDA) root activity and others were measured with CK as the control. The results showed that the fresh weight, RubisCO enzyme activity, photosynthetic pigment accumulation, soluble sugar content and stomatal length in 5R1B treatment were higher than other treatment group, which increased by 1, 47, 57 and 18%, respectively compared to CK,. This indicated that 5R1B treatment group is most conducive to plant growth and photosynthesis, and does not cause lipid peroxidation damage to wheat seedlings under light treatment.

Introduction

Light quality has great influence on plant morphology, photosynthesis and physiological and biochemical parameters. Red and blue light are the two main types of light that drive photosynthetic biosynthesis (Bian *et al.* 2015). Red light was beneficial to the accumulation of photosynthetic pigments, increased plant elongation, and increased the accumulation of photosynthates (Burritt and Leung 2003, Izzo *et al.* 2019, Li *et al.* 2021); blue light is beneficial to the accumulation of secondary metabolites such as phenols and flavonoids (Kapoor *et al.* 2018, Kim *et al.* 2018, Landi *et al.* 2020). Compared to the monochromatic light, red and blue light is the most effective light source for plant growth. The research, however, showed the mechanism of light quality response to LEDs varies among different plants (Zhang *et al.* 2020).

Wheat (*Triticum aestivum* L.) is the main food crop in China. At present, light quality regulation covers a variety of plants, but there are few reports on the light regulation of wheat seedlings. In this study, wheat was used as the test material, and white fluorescent lamps were used as controls to explore the effects of different LEDs light quality on wheat's morphological indicators and physiological and biochemical indicators, in order to provide a solid and reliable basis for wheat light quality control.

Materials and Methods

Wheat (*Triticum aestivum* L.) was taken as test plant material. The experiment was conducted under LEDs controlled light source in the artificial climate chamber of Huazhong Agricultural University, Wuhan, Hubei Province, China. The temperature of the climate chamber was 25±1℃, the relative humidity is 65±5%. Light duration was set to day: dark = 12h: 12h and light intensity was 150μmolm$^{-2}\cdot$s^{-1} for wheat seedling cultivation. White fluorescent light was used as the control

*Author for correspondence: <chenjianjun@mail.hzau.edu.cn>. [1]Institute of Applied Physics, Huazhong Agricultural University, Wuhan, 430070, China.

group (CK), and 5 different combinations of red, green and blue light were set, respectively: red light: blue light = 5:1 (5R1B), red light: blue light: green light = 4:2:1 (4R2B1G), red light: blue light = 3:3 (3R3B), blue light: red light = 4:2 (4B2R), blue light: red light: red light: 5:1 (5R1B) Green light = 4:2:1 (4R2B1G).

Stem diameter and plant height were measured with digital vernier calipers, and leaf length and leaf width of arbitrarily selected leaves were measured with ruler. The leaf area was obtained by multiplying the product of leaf length by leaf width by the coefficient 0.849 (Kochetova *et al.* 2022). The soluble sugar content was measured by anthrone sulfuric acid colorimetry (Tang *et al.* 2021); Soluble protein was measured by Coomassie brilliant blue G-250 staining (Bradford 1976); the content of chlorophyll was determined by grinding with 95% ethanol method (Zhang *et al.* 2022); the root vigor was determined by TCC (2,3,5-triphenyltetrazolium chloride) colorimetric method; the content of MDA was determined by TBA (4,6-Dihydroxy-2-mercaptopyrimidine) method (Xie et al 2022); RubisCO (ribulose-1,5-bishosphate carboxylase)enzyme activity was measured by ELISA kit (Wuhan Adanti Biotechnology Co., Ltd.); Leaves were collected at a consistent leaf position from different LED light treated wheat. Collected leaves were treated with electron microscope fixing solution (0.1 M phosphoric acid buffer solution containing 2.5% glutaraldehyde, pH 7.0 - 7.5). The stomatal density and stomatal size were observed with scanning electron microscopy (JSM-6390LV). Each parameter was determined using three replicates per treatment groups.

SPSS was used for statistical analysis, and the significant difference test ($P < 0.005$) was analyzed by Duncan's new complex range method. Mean values are an average of three replicates ± standard deviation.

Results and Discussion

As shown in Tables 1 and 2, increasing the proportion of blue light in the red and blue composite light can cause dwarfing of wheat, and increasing the proportion of red light can improve the stem height, stem diameter and leaf area of wheat, and a large proportion of red light is conducive to the increase of fresh weight and biomass accumulation.

Table 1. The effect of different light quality on height steam diameter and leaf area of wheat of wheat seedlings.

Treatment	Stem length (cm)	Steam diameter (cm)	Leaf length (cm)	Leaf width (cm)	Leaf area /cm^2
ck	25.72±1.85ab	2.72 ±0.27bc	20.07±1.37ab	0.73±0.11ab	10.24±5.06ab
4r2b1g	26.78±1.91a	3.27 0.33a	21.39±2.42ab	0.83±0.13a	14.83±2.92a
5r1b	27.54±1.29a	2.99 ±0.30ab	23.03±4.68a	0.73±0.10ab	14.14±3.92ab
3b3r	25.24±2.88bc	2.61 ±0.26bc	18.62±3.54ab	0.79±0.15a	12.45±4.24ab
4b2r	24.80±1.13b	2.46 ±0.25c	19.30±1.13ab	0.61±0.03b	9.73±0.71b
4b2r1g	22.97±1.59c	2.82 ±0.28c	17.79±2.63b	0.72±0.05ab	10.74±1.87ab

Photosynthesis is the basic way for plants to convert solar energy into chemical energy. Wheat is a C_3 plant, and RubisCO enzyme is the key enzyme in its carboxylation stage in the process of carbon assimilation, which is an important factor to determine the net photosynthetic rate (Chen *et al.* 2016). In addition, the content of chlorophyll and other photosynthetic pigments will directly affect the photosynthetic rate (Huang *et al.* 2018). As shown in Fig. 1, compared with CK, RubiSiCO activity of wheat was increased in red-blue composite light. The 5R1B treatment group had the highest RubisCO enzyme activity, which increased by 47% compared with CK there was a significant difference between them ($p<0.05$). The change trend of chlorophyll content in wheat was the same as that of RubisCO enzyme activity. Among them, 5R1B treatment group was most conducive to the accumulation of photosynthetic pigments. Compared with CK, its chlorophyll A (Cha), chlorophyll B (Chb) and total chlorophyll (Ch(A + B)) increased by 70%, 38% and 57%, respectively.

Table 2. The effect of different light quality on biomass accumulation of wheat of wheat seedlings.

Treatment	Fresh weight /g		Fresh weight/g	Dry weight /g		Dry weight /g
	Above ground	Underground		Above ground	Undergtound	
ck	0.90±0.16a	0.67±0.08ab	1.57±0.19a	0.09±0.02ab	0.06±0.01a	0.15±0.03a
4r2b1g	0.92±0.16a	0.60±0.10ab	1.52±0.22ab	0.10±0.02a	0.05±0.01ab	0.15±0.02a
5r1b	0.86±0.03ab	0.74±0.04a	1.59±0.06a	0.10±0.01ab	0.05±0.01ab	0.15±0.01a
3b3r	0.80±0.20abc	0.74±0.26a	1.55±0.49ab	0.09±0.02abc	0.06±0.02a	0.14±0.02a
4b2r	0.60±0.04 c	0.52±0.05bc	1.12±0.07c	0.07±0.01c	0.04±0.01b	0.11±0.01ab
4b2r1g	0.68±0.10 bc	0.48±0.04c	1.15±0.15bc	0.08±0.01bc	0.05±0.01ab	0.12±0.02b

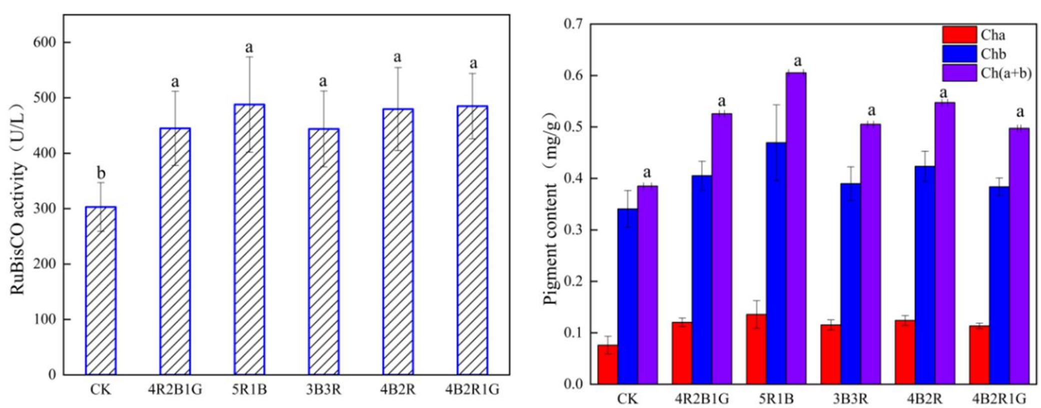

Fig. 1. The effect of different light quality on RubisCO enzyme activity and photosynthetic pigments of wheat seedlings.

Stomatal characteristics are closely related to plant photosynthesis. Current studies believe that photosynthetic restriction can be divided into non-stomatal restriction form and stomatal restriction form, the former mainly includes the destruction of chloroplast structure, the decrease of photosynthetic pigment content, the decrease of photosynthase activity, and the destruction of reactive oxygen metabolism function, while the latter may lead to the C_i (intercellular carbon dioxide) cannot meet the demand of photosynthesis (Gao *et al.* 2018). As shown in Figure 2 and Table 3, the increase of the proportion of blue light is conducive to the increase of stomatal density, in which the maximum stomatal density is 4B2R, which increases by 18% compared to

CK. The stomatal length increased slightly with the increase of red-light ratio in red-blue composite light, and the stomatal length of 5R1B treatment group was the largest, which increased by 22% compared with CK.

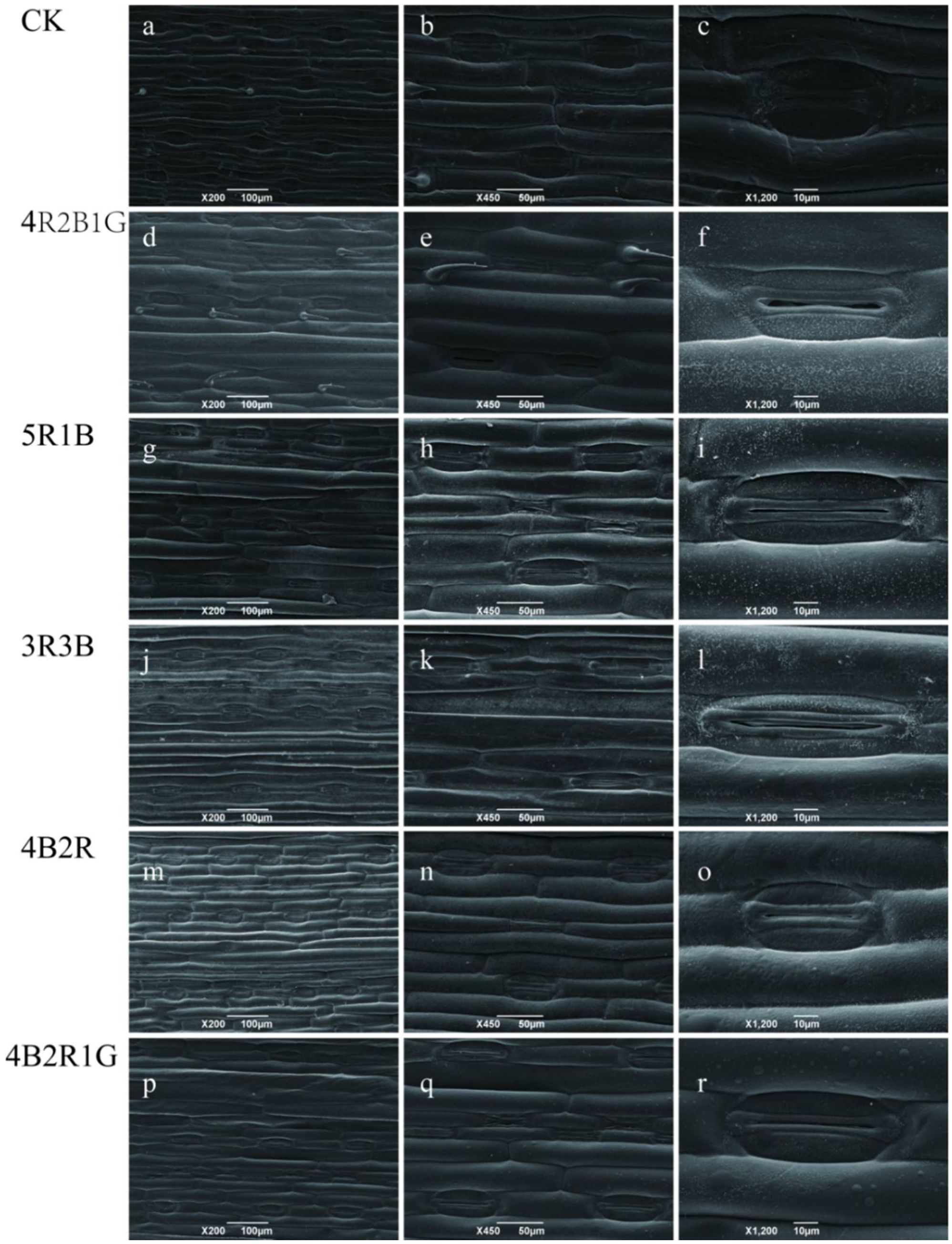

Fig. 2. The effect of different light quality on stomata of wheat seedlings.

Table 3. The statistics result of SEM micrograph.

Treatment	Stomata size (um)	(no./mm^2)
	Length (um)	Stomatal density
Ck	57.35 ±5.44b	41.00 ±3.32ab
4r2b1g	67.77 ±14.99a	31.50 ±3.35b
5r1b	69.83 ±6.54a	36.17 ±8.00b
3b3r	69.17 ±10.99a	41.04 ±12.04ab
4b2r	55.75 ±4.89b	48.46 ±5.64a
4b2r1g	68.22±2.63a	29.92 ±1.26b

Soluble sugar is a direct product of photosynthesis and an important substance regulating osmotic pressure (Tan *et al.* 2022). As shown in Fig. 3, compared with CK, soluble sugar content of wheat was increased under different light treatments, and its content increased with the increase of red-light ratio in red-blue composite light. In all treatment groups, the soluble sugar content of 5R1B treatment group was the highest, which increased by 18% compared with CK, and there was a significant difference between the two ($p < 0.05$).

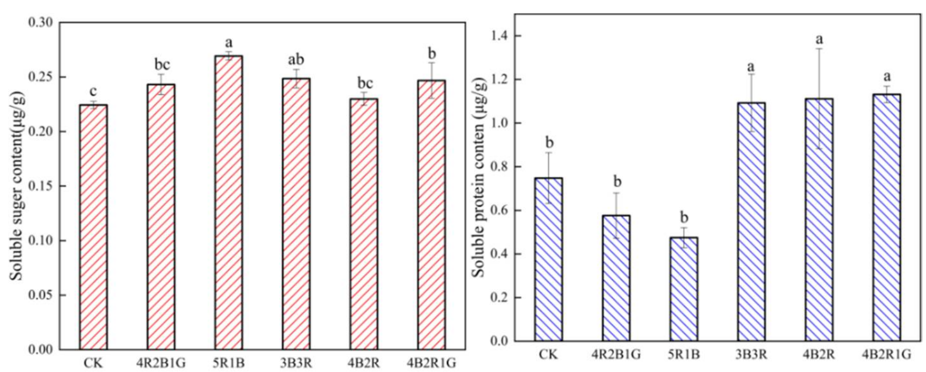

Fig. 3. The effect of different light quality on soluble sugar and protein contents of wheat seedlings.

Soluble proteins can be considered as the sum of enzymes that are not bound to cell membranes and participate in various metabolism, and their mass fraction can relatively reflect the intensity of physiological metabolic activities in this part (Wang and Wang 2020). The soluble protein content of wheat increased with the increase of blue light proportion in the red-blue composite light. The highest soluble protein content was found in 4B2R treatment group, which increased by 51% compared with CK, and there was a significant difference between them ($p < 0.05$). The lowest soluble protein content was found in 5R1B treatment group, which decreased by 37% compared with CK.

Root metabolism, namely root vigor, directly affects plant shoot growth and nutrient status and is one of the important physiological indicators of plant growth (Yan *et al.* 2016). The maximum value of root activity was 3B3R treatment group, which increased by 300% compared with CK, followed by 5R1B.

MAD is the breakdown product of unsaturated fatty acid hydroperoxides, and its content usually reflects the degree of phospholipid peroxidation, and MDA can damage DNA (Sofo *et al.* 2004). As shown in figure 4, compared with CK, MDA content of wheat in treatment group decreased in the red-blue composite light, and continued to decrease with the increase of blue light proportion.

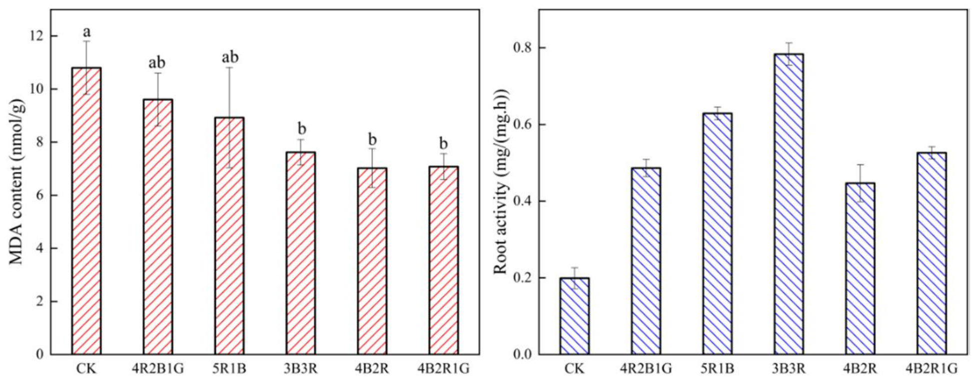

Fig. 4. The effect of different light quality on root activity and MDA conten of wheat seedlings.

Physiological and biochemical indexes are important parameters reflecting plant status and are often used to explain the changes of growth indexes. Under this light treatment, the growth trend of wheat is the best. In combination with the above physiological and biochemical parameters, it was attribute to under 5R1B light treatment, there is no peroxidation damage to wheat, which can improve the root activity of wheat, and this light treatment is most conducive to the photosynthesis of wheat. In summary, the 5R1B treatment group was most conducive to the growth of wheat, and this result provided certain data reference and corresponding theoretical basis for factory seedling raising and facility cultivation.

Acknowledgements

This work was supported by the project grant from the new agricultural research project of Huazhong Agricultural University (Project No. XNK2020072), and Horizontal scientific research project of Huazhong Agricultural University (Project No. 707121235).

References

Bradford MM 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Anal. Biochem. **72**: 248-54.

Burritt DJ and Leung DWM 2003. Adventitious shoot regeneration from Begonia x erythrophylla petiole sections is developmentally sensitive to light quality. Physiol. Plant. **118**: 289-96.

Chen H, Chen Y, Wang D and Jiang D. 2016. The role of ribulose-1,5-bisphosphate carboxylase/oxygenase activase in resistance of plant to abiotic stresses. Plant Physiol. J. **52**: 1637-48.

Gao G, Feng Q, Zhang X, Si J and Yu T. 2018. An overview of stomatal and non-stomatal limitations to photosynthesis of plants. Arid Zone Res. **35**: 929-37.

Huang B, Lin B, Li C, Liu X and Liao Z 2018. Effects of LED light quality on growth and photosynthetic physiological characteristics in spinach. J. Fujian Agriculture and Forestry University. Natural Science Edition **47**: 403-08.

Izzo LG, Arena C, De Micco V, Capozzi F and Aronne G. 2019. Light quality shapes morpho-functional traits and pigment content of green and red leaf cultivars of Atriplex hortensis. Scientia Hort. **246**: 942-50.

Li JF, Yi CY, Zhang CR, Pan F, Xie C, Zhou WZ and Zhou CF 2021. Effects of light quality on leaf growth and photosynthetic fluorescence of Brasenia schreberi seedlings. Heliyon **7**(1): e06082.

Kapoor S, Raghuvanshi R, Bhardwaj P, Sood H, Saxena S, Chaurasia OP. 2018. Influence of light quality on growth, secondary metabolites production and antioxidant activity in callus culture of Rhodiola imbricata Edgew. J. Photochem. Photobiol. B-Biol.**183**: 258-65.

Kim YJ, Kim HM, Kim HM, Jeong BR and Lee HJ 2018. Ice plant growth and phytochemical concentrations are affected by light quality and intensity of monochromatic light-emitting diodes. Hort. Environ.Biotech. **59**: 529-36.

Kochetova GV, Avercheva OV, Bassarskaya EM, Kushunina MA and Zhigalova TV. 2022. Effects of red and blue LED light on the growth and photosynthesis of barley (*Hordeum vulgare* L.) seedlings. J. Plant Growth Regul..

Landi M, Zivcak M, Sytar O, Brestic M and Allakhverdiev SI 2020. Plasticity of photosynthetic processes and the accumulation of secondary metabolites in plants in response to monochromatic light environments: A review. Biochimica et Biophysica Acta (BBA) - Bioener. **1861**: 148131

Sofo A, Dichio B, Xiloyannis C and Masia A 2004. Effects of different irradiance levels on some antioxidant enzymes and on malondialdehyde content during rewatering in olive tree. Plant Sci. **166**: 293-302.

Tan S, Qiu L, Duan A, Jia M, Liu Y and Xiong A 2022. Effects of seed-soaking with sodium hypochlorite on soluble sugar content and expression profiles of related genes of celery seedlings. Plant Physiol. J. **58**: 165-72.

Tang Y, Ren J, Liu C, Jiang J, Yang H and Li J 2021. Genetic characteristics and QTL analysis of the soluble sugar content in ripe tomato fruits. Scient. Horticul. **276**: 109785.

Wang F, Wang Y. 2020. Effects of Cu~(2+) and Pb~(2+) stresses on soluble protein content and activities of antioxidant enzymes in Kandelia obovata seedlings. Ecologic Sci. **39**: 10-18.

Xie C, Tang J, Xiao J, Geng X and Guo L 2022. Purple light-emitting diode (LED) lights controls chlorophyll degradation and enhances nutraceutical quality of postharvest broccoli florets. Scientia Horticulturae **294**: 110768.

Yan X, Yu J and Xie J 2016. Effects of supplemental light quality and durations of illumination on growth and root activity of cucumber seedling. J. Nuclear Agricul. Sci. **30**: 1211-17.

Zhang D, Liu Y, Ni C and Chen J 2022. Effect of LED light on the growth and physiological indices of blueberry. Agron. J. **114**: 2105-12.

Zhang XY, Bian ZH, Yuan XX, Chen X and Lu CG 2020. A review on the effects of light-emitting diode (LED) light on the nutrients of sprouts and microgreens. Trends Food Sci. Technol. **99**: 203-16.

Bian ZH, Yang QC and Liu WK 2015. Effects of light quality on the accumulation of phytochemicals in vegetables produced in controlled environments: a review. J.of the Sci. food and agriculture **95**: 869-77.

(Manuscript received on 19 September, 2022; revised on 1 December, 2022)