Evaluation of growth and nutritional value of Brassica microgreens grown under red, blue and green LEDs combinations

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32 **Abstract**

33 Microgreens are rich functional crops with valuable nutritional elements that have health
34 benefits when used as food supplants. Growth characterization, nutritional composition profile of 21
35 varieties representing 5 species of the *Brassica* genus as microgreens were assessed under light-
36 emitting diodes (LEDs) conditions. Microgreens were grown under four different LEDs ratios (%);
37 red:blue 80:20, and 20:80 (R₈₀:B₂₀, and R₂₀:B₈₀), or red:green:blue 70:10:20, and 20:10:70
38 (R₇₀:G₁₀:B₂₀, and R₂₀:G₁₀:B₇₀). Results indicated that supplemental lighting with green LEDs
39 (R₇₀:G₁₀:B₂₀) enhanced vegetative growth and morphology, while blue LEDs (R₂₀:B₈₀) increased the
40 mineral and vitamin contents. Interestingly, by combining the nutritional content with the growth
41 yield to define the optimal LEDs setup, we found that the best lighting to promote the microgreen
42 growth was supplying the green LEDs combination (R₇₀:G₁₀:B₂₀). Remarkably, under this proper
43 conditions, Kohlrabi purple, Cabbage red, Broccoli, Kale Tucsan, Komatsuna red, Tatsoi, and
44 Cabbage green had the highest growth and nutritional content as microgreens, which being a health-
45 promoting in a diet support strategy required for the human health under certain isolated of limited
46 food conditions.

47 **Keywords:** Brassicaceae; Functional Crops; Light Emitting Diodes; Microgreens; Nutritional quality

48

49 **1. Introduction**

50 As the world's population is rapidly growing, with an increasing demand for sustainable sources
51 of food products such as the rich-nutrient functional crops, ongoing efforts are aimed to find new
52 strategies for food production to meet the demands of the growing world population. Recently, the
53 consumption of microgreens has increased due to its high level of nutritional components such as
54 vitamins, minerals, and antioxidants compared to mature greens, which are helpful in filling the

55 nutritional gap challenges (**Burlingame, 2014**). Furthermore, microgreens being valuable functional
56 crops for their rich-phytonutrients content (**Bulgari et al., 2017; Kyriacou et al., 2016**). Microgreens
57 are harvested at the base of the hypocotyl, when the first true leaves start to emerge with a growth
58 rate of up to 3 weeks after sowing (**Treadwell et al., 2010; Xiao et al., 2012**). Despite their small
59 size, they can provide a high concentration of health-promoting phytochemicals (**Xiao et al., 2012**).
60 Commercially greenhouse growers became more interested in the microgreen for their high market
61 values (**Treadwell et al., 2010**). Specifically, microgreens of the family *Brassicaceae* have become
62 a popular choice due to its easy way for germination and short growth length and providing wide
63 flavors and colors (**Xiao et al., 2012**). *Brassicaceae* microgreens species could be used as a new
64 ingredient that provides a wide variety of novel foods (**Lee et al., 2004; Murphy and Pill, 2010;**
65 **Xiao et al., 2012**), and valued for containing high amounts of cancer-fighting glucosinolates (**Kopsell**
66 **and Sams, 2013**). They are also rich in carotenoids, especially lutein, zeaxanthin, and β -carotene
67 (**Björkman et al., 2011; Carvalho and Folta, 2014; Lefsrud et al., 2007**). Thus, *Brassica*
68 microgreens are considered as a functional food, which serves as a health-promoting or disease
69 preventing supplementals (**Kou et al., 2013; Xiao et al., 2012**).

70 Several strategies were used and developed for providing optimal growth conditions to increase
71 the microgreens yield. Light-emitting diodes (LEDs) is a new light source technology used for plant
72 growth chambers (**Yano and Fujiwara, 2012; Yorio et al., 2001**). It becomes more economically
73 viable with high efficiency and low cost, as well as the ability to select light qualities and intensities
74 (**Goto, 2012**). Plants responded to the different light intensity and wavelength (**Dong et al., 2014;**
75 **Samuolienė et al., 2013a**). Microgreens have a lower demand for photon flux compared to long-
76 cycle crops, thus are ideally adapted to chamber environments. Recently, many studies demonstrated
77 the influence of LEDs (blue and/or red) lighting on the plant vegetative parameters (**Matsuda et al.,**
78 **2004; Matsuda et al., 2008; Yorio et al., 2001**) and demonstrated the effect of light quality on the
79 growth of the cultivated plants (**Kopsell and Sams, 2013; Samuolienė et al., 2013b; Stutte et al.,**

2009; Tarakanov et al., 2012). Nevertheless, there is a lack of information regarding the combined effect of red and blue and other LEDs lighting such as green light on the plant growth, morphology, and nutrition content of microgreens (Ouzounis et al., 2015; Samuolienė et al., 2013b).

Although microgreens have been considered as valuable and nutritionally beneficial functional crops, a little is known on the integrity of individual and combined influence of green, red, and blue LEDs on *Brassica* species microgreens growth and nutritional composition. Therefore, the main purposes of the current study are to define the influence of alternative LEDs light regimens on *Brassica* species microgreens growth, and nutritional composition, and to define which species could serve well as a life support component in many cases. We explored the impact of different LEDs lighting ratios (Red, Blue, and Green) on 21 *Brassica* microgreens growth and nutritional profile.

90

2. Material and methods

2.1. Plant materials and growth chamber environment

Twenty-one varieties of microgreens representing 5 species of *Brassica* genus of the *Brassicaceae* family (Table 1) were grown in controlled-growth chambers in a collaborated study between the Faculty of Agriculture in Zagazig University and Cairo University. We used the recommended soil and fertilization properties (Xiao et al., 2012). About 10-25 g of seeds, varying based on the seed index of each variety (Table 1) were sown in peat moss in Rockwool tray in a controlled conditions growth chambers (3 trays per each variety for 3 replicates), cultivated under relative humidity (RH), and carbon dioxide (CO₂) concentration of 70%, and 500 μmol.mol⁻¹, respectively. Each day, 100 mL of CaCl₂ solution was added to each tray to further stimulate seedling growth. Once cotyledons were fully reflexed 5 d after sowing, 300 mL of 25% nutrient solution was added to each tray daily until harvest. This experiment was carried out simultaneously for three replicates in the summer

season of 2018 from May to September with as a growth length for each species ranging from 6-12 days (**Table 1**).

2.2. LEDs lighting treatments

Brassica microgreen plants were grown under LEDs (Light-emitting diode arrays) lighting provided by four different light quality ratios (%) treatments of red:blue 80:20, and 20:80 (R₈₀:B₂₀, and R₂₀:B₈₀), or red:green:blue 70:10:20, and 20:10:70 (R₇₀:G₁₀:B₂₀, and R₂₀:G₁₀:B₇₀) (Philips GreenPower LED production modules; Koninklijke Philips Electronics, N.V., Amsterdam, The Netherlands), using 0.5 W per LED chip. Each LEDs treatment was carried out in a different room. In the controlled environment growth chamber, the LEDs were placed horizontally, above the benchtop, at a height of 50 cm. We adjusted the photosynthetic photon flux density (PPFD) average to 150 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ that was provided by the fluorescent lamps and bar-type LEDs. The experiment was performed three times replications with the same conditions.

2.3. Harvest and growth measurements

Microgreen samples were harvested after the growth length for each species (**Table1**) without seed coats or roots as recommended (**Xiao et al., 2012**). Each replicate used for the measurements consisted of at least 10 grown seedlings. Ten seedlings of each microgreen variety were randomly selected and measured to determine Hypocotyl Length (HL), Leaf Area (LA), for each LEDs treatment. Hypocotyl (HL) measurements of the harvested seedlings were measured from the tip where the cotyledons split, to the end of the base of the hypocotyl. LA of cotyledons and fully expanded leaves were measured by LA meter (LI-3100; LI-COR Inc. Linclolin, NE) by recording the average of five scans. Furthermore, another ten randomly selected seedlings for each variety used to assess both, Fresh weight (FW), and Dry weight percentage (DW%). After FW data were measured, samples were oven-dried at 80°C for 72 h, then DW data were measured. FW and DW values were used to calculate DW% [DW% = (DW/FW x 100)].

128 **2.4. Elemental analysis**

129 Fresh microgreens (50 g FW per each sample) were collected and rinsed 3X using H₂O to
130 remove any surface residue. Dried microgreens (2 g per replicate) were grounded into a fine powder
131 to analysis the elemental composition. Each of the 21 samples was subjected to acid digestion
132 procedures and quantitative measurements of P, K, Ca, Na, Fe, Mn, Cu, and Zn using inductively
133 coupled plasma optical emission spectrometry (ICP-OES) following the methods of **Huang and**
134 **Schulte (Huang and Schulte, 1985)**. To assure the accuracy of the method, standard reference
135 materials (Apple leaves, NIST® SRM® 1515, NIST1515, SIGMA, USA, and Spinach leaves, NIST®
136 SRM® 1570a, NIST1570A) were used and evaluated using the same digested procedure. For each
137 ICP-OES analyte, the limit of detection (LOD) and limit of quantification (LOQ), which are a
138 function of the sample mass were determined (Supplementary Table 1).

139 **2.5. Vitamin and carotenoid concentrations**

140 **2.5.1. Phylloquinone**

141 Phylloquinone was determined according to a previously reported method (**Booth et al., 1994**).
142 Under dime light, 0.2 g of dried microgreens were homogenized in 10 mL of H₂O and 0.4 mL of 200
143 µg/mL menaquinone used as an internal standard. The sample was supplied with 15 mL of 2-
144 propanol/hexane (3:2, v/v) and vortexed for 1 min. The sample was centrifuged at 1500g at 21°C for
145 5 min. The upper layer (hexane) was transferred into a new glass tube and dried using a stream of N₂.
146 The residues of the sample were dissolved using 4 mL of hexane. To purify the extract, 1 mL of the
147 dissolved extract was loaded onto preconditioned silica gel columns (4 mL of 3.5% ethyl ether in
148 hexane, followed by 4 mL of 100% hexane). Two mL of hexane was used to wash the columns.
149 Phylloquinone was eluted with 8 mL of 3.5% ethyl ether in hexane and then evaporated at 40 °C
150 under N₂ flow. Further, it was reconstituted in 2 mL of mobile phase (99% methanol and 1% 0.05 M
151 sodium acetate buffer, pH = 3.0) and filtered through a 0.22 µm nylon syringe filter (Millipore,
152 Bedford, MA). To detect the phylloquinone, we used a photodiode array detector (DAD) (G1315C,

Agilent, Santa Clara, CA) on Agilent 1200 series HPLC system, wherein the absorbance wavelength was 270 nm. 20 μ L of the extract was injected into the HPLC and being run through a C18 column (201TP, 5 μ m, 150 $\times$ 4.6 mm, Grace, Deerfield, IL) flowing at the rate of 1 mL/ min. The phyloquinone content was measured according to the internal standard method based on peak areas.

2.5.2. Carotenoids and tocopherols

To extract both carotenoids and tocopherols, we followed the procedure described (Lester et al., 2010) and modified by Xiao et al. (Xiao et al., 2012). In 15 mL screw-cap glass vial, 0.05 g of dried fine powder was homogenized in 7.5 mL of 1% butylated hydroxytoluene in ethanol and 500 μ L of 86.82 μ M trans- β -apo-8 carotenal as an internal standard was added. 180 μ L of 80% KOH was supplied to the mixture and, the vials were capped and placed in a dry bath at 70 $^{\circ}$ C for 15 min. The vials were removed and being cooled on ice 4 $^{\circ}$ C for 5 min. The mixture was transferred into 15 mL centrifuge tubes supplied with 3.0 mL of deionized water, and 3.0 mL of hexane/toluene solution (10:8, v/v). The mixture was carefully vortexed for 1 min then centrifuged at 1000g for 5 min. After centrifugation, the upper organic layer was collected into an 8 mL glass culture tube and immediately placed into a nitrogen evaporator set at 30 $^{\circ}$ C. On the other hand, the lower layer was extracted with 3.0 mL of hexane/toluene (10:8, v/v). This extraction process was repeated at least four times until the upper layer is colorless. After evaporation, the residue was diluted in 500 μ L of mobile phase acetonitrile/ethanol (1:1, v/v), filtered into an HPLC amber vial using nylon filter (0.22 μ m, Millipore, Bedford, MA). Subsequently, 20 μ L was inoculated for HPLC analysis. Carotenoid and tocopherol concentrations were measured using isocratic reverse-phase high performance liquid chromatography (RP-HPLC). Absorbance was measured at 290 nm (for tocopherols) and 450 nm (for carotenoids).

2.5.3. Ascorbic acid

Total ascorbic acid (TAA) was assessed spectrophotometrically (Hodges et al., 2001). 3 g fresh microgreens were homogenization in 10 mL of ice-cold 5% metaphosphoric acid (w/v) at 15000 rpm for 1 min at 4 $^{\circ}$ C. The homogenized centrifuged at 7000g for 20 min at 4 $^{\circ}$ C. The supernatant was

178 filtered through Whatman 4 filter paper. TAA was measured spectrophotometrically at 525 nm.
179 Concentrations of TAA was calculated from L-ascorbic acid standard curve.

180 **2.6. Clustering hierarchical analysis**

181 In order to extrapolate the similarities and the dissimilarities among the 21 microgreens in growth
182 and nutritional assessment, hierarchical cluster analysis was performed using the normalized data set
183 using *class Orange clustering hierarchical* using *ORANGE version 3.7* (Demsar et al., 2013).

184 **2.7. Statistical analysis**

185 The experiment was laid out in a randomized block design in a factorial arrangement with LEDs
186 (four levels) and Microgreens (Twenty-one varieties) for three different biological replicates. Data
187 were collected and analyzed (Steel and Torrie, 1980). SPSS_{v.22} software was used to analyze the
188 variance of differences using ANOVA test statistically followed by LSD analysis. The degree of
189 freedom was followed as $P \leq 0.05$, $P \leq 0.01$, and $P \leq 0.001$ considers the statistical significance and
190 represents as *, **, *** respectively.

192 **3. Results**

193 **3.1. The influence of LEDs on microgreens growth and nutritional profile**

194 In the present work, four different LEDs lighting ratio (%) treatments of R₈₀:B₂₀, R₂₀:B₈₀,
195 R₇₀:G₁₀:B₂₀, and R₂₀:G₁₀:B₇₀ were implemented. Growth parameters of the 21 varieties were analyzed
196 (Figure 1). Results revealed that those microgreens are grown under the R₇₀:G₁₀:B₂₀ had the highest
197 growth and morphology targeted parameter, while the lowest growth parameters were observed under
198 R₂₀:B₈₀ (Figure 1). The HL and LA of the microgreens were significantly elongated in plants grown
199 under R₇₀:G₁₀:B₂₀ compared to those grown under R₈₀:B₂₀, R₂₀:B₈₀, and R₂₀:G₁₀:B₇₀, respectively
200 (Figure1). FW and DW% of those microgreens grown under R₇₀:G₁₀:B₂₀ treatment showed the
201 highest values; on average; 0.4g (FW), and 6.27 %(DW%), indicating that R₇₀:G₁₀:B₂₀ combination

induces an increase in all studied growth and morphology parameters in comparison with the other LEDs lighting treatments (**Figure1**).

Considering that R₇₀:G₁₀:B₂₀ LEDs lighting combination has an impact on targeted growth parameters, we investigated whether it has a functional influence on the nutritional composition profile by conducting an ICP analysis of macro and microelements from 21 varieties *Brassicaceae* microgreen using the lowest growth enhancer combination as internal references. Unexpectedly, relative macro and microelements content were showed a dramatic decreased compared to R₂₀:B₈₀ and the other LEDs ratios (**Figures 2 and 3**). While the highest levels were obtained in microgreens were growing under R₂₀:B₈₀ combination. However, the analysis also did not take the yield into consideration.

Considering the influence of LEDs lighting combination on the microgreen's growth together with nutrition components value, we analyzed deeper the vitamin and carotenoid contents. Agreeing with our previous result obtained in the macro- and microelements, we found that the contents of phyloquinone, α -tocopherol, TAA, and β -carotene of 21 varieties of *Brassica* microgreens grown under red:blue 80:20 (R₈₀:B₂₀), were significantly increased compared to other combination (**Figure 4**).

3.2. Concluding the optimum LEDs conditions for *Brassica* microgreens growth conditions

Our previous data showed that LEDs lighting combination has an impact on all growth and nutritional parameters. More precisely, we found that *Brassica* microgreen varieties were grown under the LEDs lighting of R₇₀:G₁₀:B₂₀ combination enhances the HL, LA, FW, and DW% compared to other LEDs combinations, while minerals (macro and microelements) and vitamins were significantly increased corresponding to plants grown under R₈₀:B₂₀. To detect the best LEDs combination, taking into consideration the actual yield of microgreens, we conducted a correlation analysis with the yield. We estimated the minerals and vitamin concentrations corresponding to the actual fresh weight yielded (**Figures 5 and 6**). Interestingly, we found that mineral compositions and

227 vitamins content in the yielded fresh weight were significantly increased in the microgreen varieties
228 grown under the LEDs lighting of R₇₀:G₁₀:B₂₀ combination compared to other combinations (**Figures**
229 **5 and 6**).

230 **3.3. Hierarchical cluster analysis of 21 varieties of *Brassica* microgreens**

231 A hierarchical cluster analysis profiled growth, mineral compositions and vitamin content of 21
232 microgreens varieties grown under R₇₀:G₁₀:B₂₀ family has been performed using *class Orange*
233 *clustering hierarchical* using *ORANGE version 3.7* (**Demsar et al., 2013**). Data of microgreens
234 grown under R₇₀:G₁₀:B₂₀, which presents the highest values of growth and nutritional profile are
235 shown in **Figure 7** and **Table 2**. The hierarchical analysis methods (average-linkage distance between
236 two clusters) was utilized to evaluate whether these trends were consistent across the 21 varieties.
237 The hierarchical cluster analysis shows that the 21 microgreens are classified into five groups. Among
238 the five groups, the highest distance group (**Figure 7**, cluster group in yellow color + Kale Tucsan in
239 green cluster) contained 7 microgreens (Kohlrabi purple, Cabbage red, Broccoli, Kale Tucsan,
240 Komatsuna red, Tatsoi, and Cabbage green) which are representing 3 species (*B. oleracea*, *B. rapa*,
241 and *B. narinosa*).

242

243 **4. Discussion**

244 Due to the increased interest with providing the controlled environment growth chambers with
245 LEDs lighting and for increasing the microgreen growth and nutritional profile, we investigated the
246 impact of four different LEDs lighting ratios on the growth and nutritional quality assessment of 21
247 varieties belong to *Brassica* genera of the family *Brassicaceae* grew as microgreens. Microgreens are
248 reported in many studies as valuable source vitamins, phenolics and minerals (**Mir et al., 2017**).
249 Enhancing their nutritional qualities and growth is an exciting avenue of research and agriculture
250 biotechnology.

251 In our study, we revealed various effects on the combination ratios between blue LEDs, red and
252 green LEDs. A plant was grown under a monochromatic light beam also stimulate specific
253 photoreceptors that are involved in numerous biological processes. Enhance the nutritional profile
254 and plant growth was demonstrated in many species, such as rice (**Chen et al., 2014**), *Brassica* spp.
255 (**Samuolienė et al., 2013a; Samuolienė et al., 2013b; Xiao et al., 2012**), etc. It has been reported
256 that red and blue light are important for the expansion of hypocotyl elongation, pigment
257 accumulation, and enhancement of biomass (**Li et al., 2010**). In contrast, exposure to green LEDs
258 increases biomass at high intensity (**Johkan et al., 2010**). We noticed that growing microgreens under
259 R₇₀:G₁₀:B₂₀ showed the highest value of the vegetative parameters, taking in our consideration the
260 yield produced under all combination treatments (**Figure 1**). These results provide a clear indication
261 that blue LEDs in combination with red LEDs and high-intensity green LEDs are more efficient for
262 plants microgreen growth. Providing green lighting within the growing conditions enhances *Brassica*
263 microgreens growth, while, increasing the blue light ratio had a passive response to the growth.

264 Many reports demonstrated the positive influence of the red:blue lighting plant growth and
265 photosynthesis (**Brazaitytė et al., 2015; Dong et al., 2014; Kang et al., 2013; Potter et al., 1999;**
266 **Samuolienė et al., 2013a; Tarakanov et al., 2012; Yano and Fujiwara, 2012**). Furthermore, a red,
267 blue, and green light combination has an effective source for photosynthesis (**Muneer et al., 2014**).
268 Consequently, supply the red and blue LEDs combined with a green light has a significant impact on
269 lettuce leaves growth and photosynthetic rate compared with the red and blue LEDs only (**Kim et al.,**
270 **2004; Kim et al., 2006**). It appears that blue and red light enhances the anthocyanins accumulation
271 in leaves and become black, while green light stimulates phytochrome, shifting the active pool of
272 Type I and Type II phytochromes to include reverse accumulation of anthocyanins (**Carvalho and**
273 **Folta, 2016**).

274 Consequently, we demonstrated the positive influence of providing green light improving
275 microgreens growth and morphology. It is reported that HL and LA of kohlrabi, mizuna, and mustard
276 were increased when grown under green light R₇₄:G₁₈:B₈ compared with the R₈₇:B₁₃, while FW and
277 DW% were greater of those microgreens grown under providing green light than blue/red (Gerovac
278 et al., 2016). Moreover, FW of broccoli microgreens grown under light ratios of R₈₅:G₁₀:B₅ and
279 R₈₀:B₂₀ were higher than under R₇₀:G₁₀:B₂₀ (Kopsell et al., 2014). The same influence was observed
280 on chlorophyll content, which improved significantly of the plant grown under additional green light
281 (Gerovac et al., 2016; Samuolienė et al., 2013b). Furthermore, the reduction on the growth
282 parameters due to the increased of blue lighting was reported. It was found that the hypocotyl
283 elongation of kohlrabi, mizuna, mustard was decreased under the red:blue light combination due to
284 the inhibition of the gibberellins (GA), which inhibit the hypocotyl elongation (Potter et al., 1999).

285 Growing microgreens plants under blue LEDs R₂₀:B₈₀ in our study enhanced the minerals
286 composition and the vitamin content accompanied by the less growth yield compared with the green
287 LEDs R₇₀:G₁₀:B₂₀. It is reported that broccoli microgreens grown under blue light (R₀:B₁₀₀) produced
288 higher nutrient-dense microgreens (Kopsell and Sams, 2013; Kopsell et al., 2014). Blue light could
289 be shown as a dominant means of regulating nutrient content syntheses such as proton pumping, ion
290 channel, activities, and membrane permeability (Gerovac et al., 2016; Kopsell et al., 2014).

291 Comparing the LEDs lighting ratios to conclude the proper conditions, we accompanied the
292 nutritional profile with the actual growth yielding. We found that green LEDs R₇₀:G₁₀:B₂₀ had the
293 proper yielded influence, and produced final higher mineral concentration and vitamin contents due
294 to the high growth yield. Despite the blue LED treatment increased the mineral and vitamin contents,
295 but it is accompanied by less growth yield.

296 In conclusion, the assessment of 21 *Brassica* microgreens growth and nutritional profile grown
297 under LEDs technology provides a satisfactory growing condition examination of microgreens.

298 Providing green lighting ratio of R70:G10:B20 shows a positive influence on the growing microgreens
299 growth and morphology. Interestingly, Kohlrabi purple, Cabbage red, Broccoli, Kale Tucsan,
300 Komatsuna red, Tatsoi, and Cabbage green are presented as the top microgreen's candidates of our
301 study assessment, that serve as a life support component in limited space-based conditions and
302 controlled environment growth chambers.

303

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309

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311 A.A.N, M.A.S.A. and S.J. L.Z. performed the experiment. K.Y.K., D.A.M., A.A.S, S.M.A and S.Y.M
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Figure legends

Figure 1. Box plot of growth and morphological measurements of *Brassica* microgreens grown under LEDs treatments. The plot illustrates the Mean and median of [Hypocotyl Length (mm), Leaf Area (cm²), Fresh weight (g), and Dry weight (%)] of 21 varieties of *Brassica* microgreens represented 5 species grown under different light-emitting diodes (LEDs) ratio (%) of red:blue 80:20 (R₈₀:B₂₀), red:blue 20:80 (R₂₀:B₈₀), red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀), or red:green:blue 20:10:20 (R₂₀:G₁₀:B₇₀) (Supplemental Tables 2 and 3) . Resulting ranking could be analyzed with point values of Mean and Median or uncertainty range with box. Statistical analysis is performed using a one-way ANOVA test ($P \leq 0.05$). Small letters denote statistically significant differences.

Figure 2. Box plot of mineral composition and content of macroelements of *Brassica* microgreens grown under LEDs treatments. The plot illustrates the Mean and median of macroelements concentrations; P, K, Ca and Na (mg/100 g FW) of 21 varieties of *Brassica* microgreens represented 5 species grown under different light-emitting diodes (LEDs) ratio (%) of red:blue 80:20 (R₈₀:B₂₀), red:blue 20:80 (R₂₀:B₈₀), red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀), or red:green:blue 20:10:20 (R₂₀:G₁₀:B₇₀) (Supplemental Tables 4 and 5) . Resulting ranking could be analyzed with point values of Mean and Median or uncertainty range with box. Statistical analysis is performed using a one-way ANOVA test ($P \leq 0.05$). Small letters denote statistically significant differences.

Figure 3. Box plot of mineral composition and content of microelements of *Brassica* microgreens grown under LEDs treatments. The plot illustrates the Mean and median of microelements concentrations; Fe, Zn, Cu and Mn (mg/100 g FW) of 21 varieties of *Brassica*

microgreens represented 5 species grown under different light-emitting diodes (LEDs) ratio (%) of red:blue 80:20 (R₈₀:B₂₀), red:blue 20:80 (R₂₀:B₈₀), red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀), or red:green:blue 20:10:20 (R₂₀:G₁₀:B₇₀) (Supplemental Tables 6 and 7). Resulting ranking could be analyzed with point values of Mean and Median or uncertainty range with box. Statistical analysis is performed using a one-way ANOVA test ($P \leq 0.05$). Small letters denote statistically significant differences.

Figure 4. Box plot of vitamin and carotenoid concentrations of *Brassica* microgreens grown under LEDs treatments. The plot illustrates the Mean and median of vitamin and carotenoids concentrations; phyloquinone ($\mu\text{g/g}$ FW), α -tocopherol, total ascorbic acid (TAA), and β -carotene (mg/100 g FW) of 21 varieties of *Brassica* microgreens represented 5 species grown under different light-emitting diodes (LEDs) ratio (%) of red:blue 80:20 (R₈₀:B₂₀), red:blue 20:80 (R₂₀:B₈₀), red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀), or red:green:blue 20:10:20 (R₂₀:G₁₀:B₇₀) (Supplemental Tables 8 and 9). Resulting ranking could be analyzed with point values of Mean and Median or uncertainty range with box. Statistical analysis is performed using a one-way ANOVA test ($P \leq 0.05$). Small letters denote statistically significant differences.

Figure 5. Mineral composition and content of *Brassica* microgreens under LEDs treatments. A) Mean macroelement concentration of P, K, Ca, and Na. **B)** Mean microelement concentration of Fe, Zn, Cu, and Mn of 21 varieties of *Brassica* microgreens exposed to different light-emitting diodes (LEDs) ratio (%) of red:blue 80:20 (R₈₀:B₂₀), red:blue 20:80 (R₂₀:B₈₀), red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀), or red:green:blue 20:10:20 (R₂₀:G₁₀:B₇₀). Data represents as a mean concentration corresponding to the actual Fresh weight (fresh weight results of each LEDs treatments of the 21 varieties (Supplementary Table 3) [Actual concentration (mg/g actual FW) = Concentration (mg/100

490 g FW) X Fresh weight (g)/100]. Mean±SE values are based on a representative sample from each
491 treatment across three experimental replications. * for significant at $P \leq 0.05$.

492

493 **Figure 6. Assessment of vitamin and carotenoid concentrations of *Brassica* microgreens under**
494 **LEDs treatments. A)** Mean α -tocopherol, total ascorbic acid (TAA), and β -carotene (mg/100 g FW)
495 concentration. **B)** Mean phyloquinone ($\mu\text{g/g}$ FW) concentration of 21 varieties of *Brassica*
496 microgreens exposed to different light-emitting diodes (LEDs) ratio (%) of red:blue 80:20 (R₈₀:B₂₀),
497 red:blue 20:80 (R₂₀:B₈₀), red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀), or red:green:blue 20:10:20
498 (R₂₀:G₁₀:B₇₀). Data represents as a mean concentration corresponding to the actual Fresh weight
499 (fresh weight results of each LEDs treatments of the 21 varieties (supplementary Table 3) [Actual
500 concentration (mg/g actual FW) = Concentration (mg/ 100 g FW) X Fresh weight (g)/100]. For
501 phyloquinone [Actual concentration (mg/g actual FW) = Concentration ($\mu\text{g/g}$ FW) X Fresh weight
502 (g)]. Mean±SE values are based on a representative sample from each treatment across three
503 experimental replications. * for significant at $P \leq 0.05$.

504

505 **Figure 7.** The average-linkage on the normalized data sets of mineral composition and vitamin and
506 carotenoid concentrations corresponding to the actual fresh weight by means of the Hierarchical
507 method using growth and morphology measurements data of 21 varieties *Brassica* microgreens
508 grown under light-emitting diodes (LEDs) ratio (%) of red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀). The
509 complete profile of the highest cluster value (Yellow cluster) microgreens presented in Table 2.

510

511

Tables

Table 1. Twenty-one varieties of *Brassica* microgreens represented 5 species *Brassica* genera assayed in this study. Growth length (day) and seed index (g) show each variety growth period and the number of seeds used for the sowing.

Commercial name	Scientific name (genus and species)	Growth length (day)	Seed index (g)
Broccoli	<i>Brassica oleracea</i> L. var. <i>italica</i>	9	10
Brussel sprouts	<i>Brassica oleracea</i> L. var. <i>Gemmifera</i>	10	15
Cabbage green	<i>Brassica oleracea</i> L. var. <i>capitata</i> f. <i>alba</i>	9	10
Cabbage red	<i>Brassica oleracea</i> L. var. <i>capitata</i> f. <i>rubra</i>	8	10
Cabbage savoy	<i>Brassica oleracea</i> L. var. <i>capitata</i> f. <i>sabauda</i>	8	10
Cauliflower	<i>Brassica oleracea</i> L. var. <i>botrytis</i>	9	15
Collard	<i>Brassica oleracea</i> L. var. <i>viridis</i>	10	15
Kale Chinese	<i>Brassica oleracea</i> L. var. <i>alboglabra</i>	10	15
Kale red	<i>Brassica oleracea</i> L. var. <i>acephala</i>	9	10
Kale Tucsan	<i>Brassica oleracea</i> L. var. <i>acephala</i>	9	15
Kohlrabi purple	<i>Brassica oleracea</i> L. var. <i>gongylodes</i>	7	25
Cabbage Chinese	<i>Brassica rapa</i> L. var. <i>pekinensis</i>	6	15
Komatsuna red	<i>Brassica rapa</i> L. var. <i>perviridis</i>	8	15
Mizuna	<i>Brassica rapa</i> L. var. <i>nipposinica</i>	8	15
Pak choy	<i>Brassica rapa</i> L. var. <i>chinensis</i>	8	15
Rapini	<i>Brassica rapa</i> L. var. <i>ruvo</i>	9	15
Turnip	<i>Brassica rapa</i> L. var. <i>rapa</i>	9	10
Mustard Dijon	<i>Brassica juncea</i> (L.) Czern.	12	15
Mustard red	<i>Brassica juncea</i> (L.) Czern.	10	10
Rutabaga	<i>Brassica napus</i> L. var. <i>napobrassica</i>	9	10
Tatsoi	<i>Brassica narinosa</i> L. var. <i>rosularis</i>	7	10

Table 2. Growth, and nutritional composition of highest Brassica microgreens grown under light-emitting diodes (LEDs) ratio (%) of red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀). A list of the 7 brassica microgreens is exported from the hierarchical cluster analysis (**Figure 7**)

	Kohlrabi purple	Cabbage red	Broccoli	Kale Tucson	Komatsuna red	Tatsoi	Cabbage green
Hypocotyl Length (mm)	46	47	42	49	44	46	45
Leaf Area (cm ²)	1.82	1.93	1.65	2.02	1.75	1.86	1.83
Fresh weight (g)	0.44	0.46	0.42	0.47	0.41	0.45	0.44
Dry weight (%)	6.65	6.18	6.55	6.90	6.57	6.34	6.25
P (mg/100 g FW)	68	62	59	63	66	64	62
K (mg/100 g FW)	322	224	319	280	320	300	183
Ca (mg/100 g FW)	65	84	92	55	53	44	87
Na (mg/100 g FW)	46	40	50	46	28	35	69
Fe (mg/100 g FW)	0.77	0.69	0.74	0.76	0.76	0.65	0.67
Zn (mg/100 g FW)	0.43	0.40	0.42	0.38	0.38	0.41	0.33
Cu (mg/100 g FW)	0.08	0.10	0.11	0.07	0.05	0.08	0.06
Mn (mg/100 g FW)	0.39	0.35	0.41	0.46	0.34	0.35	0.37
Phylloquinone (µg/ g FW)	2.6	2.3	2.0	1.7	2.2	1.5	1.4
α-Tocopherol (mg/100 g FW)	17.6	29.5	17.3	19.4	25.0	29.3	14.3
Total ascorbic acid (mg/100 g FW)	77.1	127.4	84.6	73.2	97.5	99.5	118.9
β-Carotene (mg/100 g FW)	6.6	9.9	6.9	5.4	7.1	10.6	9.6

Supplemental Table 1. Limit of detection (LOD/mg/kg DW) and limit of quantification (LOQ/mg/kg DW) based on background equivalent concentration

	LOD mg/Kg DW	LOQ mg/Kg DW
P	0.0018	0.005
K	25.0068	80.004
Ca	0.0108	0.055
Mg	0.0004	0.016
Na	0.0116	0.204
Fe	0.0034	0.002
Zn	0.0004	0.006
Cu	0.0002	0.006

Supplemental Table 2. Growth and morphological measurements [Hypocotyl Length (mm), and Leaf Area (cm²)] of 21 varieties of *Brassica* microgreens represented 5 species grown under different light-emitting diodes (LEDs) ratio (%) of red:blue 80:20 (R₈₀:B₂₀), red:blue 20:80 (R₂₀:B₈₀), red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀), or red:green:blue 20:10:20 (R₂₀:G₁₀:B₇₀). Mean±SE values are based on a representative sample from each treatment across three experimental replications. NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Commercial name	Hypocotyl Length (mm)				Leaf Area (cm ²)			
	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀
Broccoli	37.4	27.2	42.2	33.1	1.42	1.07	1.65	1.26
Brussel sprouts	34.2	27.6	39.6	36.3	1.29	0.94	1.52	1.13
Cabbage green	38.5	29.7	45.8	37.3	1.63	1.25	1.83	1.44
Cabbage red	39.2	28.4	47.7	35.7	1.72	1.34	1.93	1.53
Cabbage savoy	31.7	25.9	38.2	33.9	1.22	0.87	1.45	1.06
Cauliflower	32.5	27.2	40.7	34.6	1.35	0.99	1.58	1.18
Collard	34.2	27.1	41.1	33.5	1.37	1.01	1.61	1.25
Kale Chinese	29.5	24.2	35.3	31.6	1.08	0.72	1.31	0.91
Kale red	28.2	23.2	36.8	31.1	1.15	0.80	1.38	0.99
Kale Tucsan	38.6	33.8	49.5	41.4	1.79	1.43	2.02	1.62
Kohlrabi purple	37.2	31.2	46.2	38.6	1.62	1.27	1.82	1.46
Cabbage Chinese	33.9	26.4	39.4	32.7	1.28	0.93	1.51	1.12
Komatsuna red	31.5	28.2	44.2	36.6	1.52	1.17	1.75	1.36
Mizuna	38.4	30.7	44.8	36.3	1.55	1.20	1.78	1.39
Pak choy	35.2	29.1	40.3	36.1	1.33	0.97	1.56	1.65
Rapini	38.6	28.8	38.2	33.9	1.22	0.87	1.45	1.06
Turnip	41.8	31.4	43.3	36.2	1.45	1.12	1.71	1.31
Mustard Dijon	34.9	24.3	42.5	33.1	1.44	1.08	1.67	1.27
Mustard red	39.1	31.1	42.8	37.1	1.45	1.10	1.68	1.29
Rutabaga	31.7	23.5	38.7	29.7	1.25	0.89	1.48	1.08
Tatsoi	41.2	33.1	46.3	39.1	1.63	1.27	1.86	1.46
LEDs			***				**	
Varieties	**	*	*	*	*	**	***	*
LEDs X Varieties			*				**	

Supplemental Table 3. Growth parameters [Fresh weight (g), and Dry weight (%)] of 21 varieties of *Brassica* microgreens represented 5 species grown under different light-emitting diodes (LEDs) ratio (%) of red:blue 80:20 (R₈₀:B₂₀), red:blue 20:80 (R₂₀:B₈₀), red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀), or red:green:blue 20:10:20 (R₂₀:G₁₀:B₇₀). Mean±SE values are based on a representative sample from each treatment across three experimental replications. NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Commercial name	Fresh weight (g)				Dry weight (%)			
	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀
Broccoli	0.38	0.30	0.42	0.36	5.96	5.32	6.55	5.65
Brussel sprouts	0.36	0.30	0.38	0.35	5.88	5.10	5.80	5.44
Cabbage green	0.40	0.33	0.44	0.39	6.2	5.46	6.25	5.79
Cabbage red	0.40	0.32	0.46	0.39	6.20	5.43	6.18	5.77
Cabbage savoy	0.34	0.28	0.36	0.33	5.67	5.01	6.17	5.34
Cauliflower	0.35	0.29	0.39	0.35	5.78	5.11	6.23	5.44
Collard	0.36	0.29	0.39	0.35	5.83	5.19	6.46	5.53
Kale Chinese	0.32	0.26	0.34	0.31	5.45	4.79	5.94	5.12
Kale red	0.31	0.25	0.35	0.31	5.38	4.74	5.99	5.07
Kale Tucsan	0.41	0.36	0.47	0.42	6.45	5.78	6.90	6.12
Kohlrabi purple	0.39	0.33	0.44	0.39	6.23	5.55	6.65	5.89
Cabbage Chinese	0.35	0.29	0.37	0.34	5.76	4.98	5.70	5.32
Komatsuna red	0.34	0.30	0.41	0.36	5.85	5.24	6.57	5.57
Mizuna	0.40	0.33	0.43	0.38	6.19	5.36	5.80	5.69
Pak choy	0.37	0.31	0.39	0.36	5.96	5.24	6.14	5.57
Rapini	0.39	0.31	0.38	0.35	6.01	5.31	6.33	5.65
Turnip	0.42	0.34	0.42	0.38	6.32	5.46	5.82	5.79
Mustard Dijon	0.36	0.28	0.41	0.35	5.80	5.10	6.13	5.44
Mustard red	0.40	0.33	0.42	0.38	6.22	5.37	5.78	5.70
Rutabaga	0.33	0.26	0.37	0.32	5.53	4.94	6.40	5.27
Tatsoi	0.42	0.35	0.45	0.41	6.45	5.67	6.34	6.00
LEDs			**				**	
Varieties	**	***	**	**	*	**	*	*
LEDs X Varieties			**				**	

Supplemental Table 4. Mineral composition and content of macroelements; P and K (mg/100 g FW) of 21 varieties of *Brassica* microgreens represented 5 species grown under different light-emitting diodes (LEDs) ratio (%) of red:blue 80:20 (R₈₀:B₂₀), red:blue 20:80 (R₂₀:B₈₀), red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀), or red:green:blue 20:10:20 (R₂₀:G₁₀:B₇₀). Mean±SE values are based on a representative sample from each treatment across three experimental replications. NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Commercial name	P (mg/100 g FW)				K (mg/100 g FW)			
	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀
Broccoli	57	65	59	60	300	371	319	335
Brussel sprouts	53	68	57	60	287	365	308	325
Cabbage green	61	69	62	64	183	199	183	188
Cabbage red	59	71	62	64	218	254	224	233
Cabbage savoy	56	68	59	61	206	236	210	218
Cauliflower	56	72	60	63	199	272	218	234
Collard	66	76	67	70	274	300	275	283
Kale Chinese	62	69	64	66	220	298	244	261
Kale red	50	65	55	58	317	383	336	350
Kale Tucsan	60	69	63	65	268	310	280	289
Kohlrabi purple	65	75	68	70	306	362	322	334
Cabbage Chinese	63	72	65	67	211	280	231	245
Komatsuna red	62	77	66	70	298	370	320	335
Mizuna	52	71	58	62	315	402	341	359
Pak choy	51	60	54	56	282	290	284	286
Rapini	68	85	73	77	324	411	350	368
Turnip	49	68	55	59	296	301	297	299
Mustard Dijon	57	68	60	62	323	400	346	362
Mustard red	43	49	44	46	257	311	273	284
Rutabaga	58	75	63	67	206	249	218	228
Tatsoi	62	71	64	66	275	359	300	318
LEDs			*				**	
Varieties	**	*	**	**	*	**	*	*
LEDs X Varieties			*				**	

Supplemental Table 5. Mineral composition and content of macroelements; Ca and Mg (mg/100 g FW) of 21 varieties of *Brassica* microgreens represented 5 species grown under different light-emitting diodes (LEDs) ratio (%) of red:blue 80:20 (R₈₀:B₂₀), red:blue 20:80 (R₂₀:B₈₀), red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀), or red:green:blue 20:10:20 (R₂₀:G₁₀:B₇₀). Mean±SE values are based on a representative sample from each treatment across three experimental replications. NS, *, **, ****Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Commercial name	Ca (mg/100 g FW)				Na (mg/100 g FW)			
	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀
Broccoli	84	112	92	98	50	59	50	53
Brussel sprouts	62	75	65	68	54	55	51	52
Cabbage green	84	100	87	91	74	79	69	72
Cabbage red	79	100	84	89	42	46	40	42
Cabbage savoy	85	105	89	94	57	68	56	59
Cauliflower	79	100	84	89	76	83	72	75
Collard	62	74	64	67	47	49	44	45
Kale Chinese	39	52	43	46	39	45	40	41
Kale red	42	53	45	48	40	52	43	45
Kale Tucsan	54	58	55	56	46	51	46	48
Kohlrabi purple	63	72	65	67	45	53	46	48
Cabbage Chinese	69	78	71	73	25	27	24	25
Komatsuna red	48	63	53	56	24	38	28	31
Mizuna	36	54	42	45	39	46	40	42
Pak choy	45	57	49	51	28	35	31	32
Rapini	85	94	87	89	58	65	58	60
Turnip	42	52	45	47	18	29	22	24
Mustard Dijon	40	50	43	45	30	31	29	30
Mustard red	47	60	51	54	28	34	29	31
Rutabaga	53	61	55	57	43	57	46	49
Tatsoi	43	48	44	45	35	39	35	36
LEDs			**				**	
Varieties	*	**	*	*	*	*	*	**
LEDs X Varieties			*				**	

Supplemental Table 6. Mineral composition and content of microelements; Fe and Zn (mg/100 g FW) of 21 varieties of Brassica microgreens represented 5 species grown under different light-emitting diodes (LEDs) ratio (%) of red:blue 80:20 (R₈₀:B₂₀), red:blue 20:80 (R₂₀:B₈₀), red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀), or red:green:blue 20:10:20 (R₂₀:G₁₀:B₇₀). Mean±SE values are based on a representative sample from each treatment across three experimental replications. NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Commercial name	Fe (mg/100 g FW)				Zn (mg/100 g FW)			
	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀
Broccoli	0.73	0.85	0.47	0.47	0.47	0.47	0.47	0.47
Brussel sprouts	0.61	0.72	0.36	0.36	0.36	0.36	0.36	0.36
Cabbage green	0.66	0.77	0.36	0.36	0.36	0.36	0.36	0.36
Cabbage red	0.68	0.79	0.44	0.44	0.44	0.44	0.44	0.44
Cabbage savoy	0.59	0.68	0.35	0.35	0.35	0.35	0.35	0.35
Cauliflower	0.66	0.76	0.37	0.37	0.37	0.37	0.37	0.37
Collard	0.70	0.80	0.48	0.48	0.48	0.48	0.48	0.48
Kale Chinese	0.70	0.80	0.41	0.41	0.41	0.41	0.41	0.41
Kale red	0.51	0.59	0.32	0.32	0.32	0.32	0.32	0.32
Kale Tucsan	0.77	0.88	0.42	0.42	0.42	0.42	0.42	0.42
Kohlrabi purple	0.78	0.90	0.48	0.48	0.48	0.48	0.48	0.48
Cabbage Chinese	0.70	0.81	0.44	0.44	0.44	0.44	0.44	0.44
Komatsuna red	0.78	0.90	0.43	0.43	0.43	0.43	0.43	0.43
Mizuna	0.61	0.71	0.32	0.32	0.32	0.32	0.32	0.32
Pak choy	0.54	0.68	0.44	0.44	0.44	0.44	0.44	0.44
Rapini	0.88	1.05	0.68	0.68	0.68	0.68	0.68	0.68
Turnip	0.62	0.73	0.40	0.40	0.40	0.40	0.40	0.40
Mustard Dijon	0.60	0.70	0.32	0.32	0.32	0.32	0.32	0.32
Mustard red	0.68	0.84	0.27	0.27	0.27	0.27	0.27	0.27
Rutabaga	0.58	0.72	0.36	0.36	0.36	0.36	0.36	0.36
Tatsoi	0.61	0.75	0.44	0.44	0.44	0.44	0.44	0.44
LEDs			***				**	
Varieties	*	***	*	**	*	**	***	*
LEDs X Varieties			**				**	

Supplemental Table 7. Mineral composition and content of microelements; Cu and Mn (mg/100 g FW) of 21 varieties of Brassica microgreens represented 5 species grown under different light-emitting diodes (LEDs) ratio (%) of red:blue 80:20 (R₈₀:B₂₀), red:blue 20:80 (R₂₀:B₈₀), red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀), or red:green:blue 20:10:20 (R₂₀:G₁₀:B₇₀). Mean±SE values are based on a representative sample from each treatment across three experimental replications. NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Commercial name	Cu (mg/100 g FW)				Mn (mg/100 g FW)			
	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀
Broccoli	0.10	0.16	0.11	0.13	0.40	0.49	0.41	0.46
Brussel sprouts	0.09	0.15	0.10	0.12	0.41	0.50	0.42	0.46
Cabbage green	0.05	0.11	0.06	0.08	0.35	0.43	0.37	0.41
Cabbage red	0.09	0.15	0.10	0.12	0.33	0.42	0.35	0.39
Cabbage savoy	0.06	0.09	0.08	0.09	0.42	0.49	0.44	0.48
Cauliflower	0.07	0.10	0.09	0.09	0.34	0.41	0.36	0.39
Collard	0.10	0.14	0.12	0.13	0.39	0.46	0.41	0.44
Kale Chinese	0.06	0.10	0.04	0.05	0.30	0.36	0.27	0.30
Kale red	0.06	0.10	0.04	0.05	0.35	0.42	0.32	0.36
Kale Tucsan	0.09	0.15	0.07	0.09	0.48	0.57	0.46	0.50
Kohlrabi purple	0.12	0.17	0.08	0.11	0.42	0.50	0.39	0.43
Cabbage Chinese	0.04	0.10	0.05	0.07	0.33	0.41	0.34	0.38
Komatsuna red	0.08	0.14	0.05	0.07	0.37	0.45	0.34	0.37
Mizuna	0.06	0.11	0.03	0.05	0.39	0.47	0.36	0.39
Pak choy	0.06	0.16	0.13	0.15	0.32	0.44	0.40	0.41
Rapini	0.14	0.23	0.23	0.24	0.45	0.57	0.54	0.58
Turnip	0.08	0.13	0.09	0.10	0.44	0.53	0.45	0.50
Mustard Dijon	0.07	0.12	0.03	0.05	0.43	0.51	0.39	0.43
Mustard red	0.06	0.16	0.05	0.08	0.25	0.36	0.24	0.28
Rutabaga	0.08	0.17	0.13	0.14	0.43	0.56	0.49	0.53
Tatsoi	0.05	0.14	0.08	0.10	0.32	0.43	0.35	0.39
LEDs			***		**			
Varieties	*	**	**	*	**	*		**
LEDs X Varieties			*				***	

Supplemental Table 8. Vitamins concentrations [phyloquinone ($\mu\text{g/g}$ FW), and α -tocopherol ($\text{mg}/100 \text{ g}$ FW)] of 21 varieties of *Brassica* microgreens represented 5 species grown under different light-emitting diodes (LEDs) ratio (%) of red:blue 80:20 (R₈₀:B₂₀), red:blue 20:80 (R₂₀:B₈₀), red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀), or red:green:blue 20:10:20 (R₂₀:G₁₀:B₇₀). Mean $\pm$ SE values are based on a representative sample from each treatment across three experimental replications. NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Commercial name	Phylloquinone ($\mu\text{g/g}$ FW)				α -tocopherol ($\text{mg}/100 \text{ g}$ FW)			
	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀
Broccoli	1.9	2.3	2.0	2.2	16.2	20.0	17.3	19.0
Brussel sprouts	1.3	2.0	1.5	1.6	16.3	20.2	17.5	19.2
Cabbage green	1.1	1.9	1.4	1.4	13.4	16.6	14.3	15.8
Cabbage red	2.2	2.5	2.3	2.6	27.6	34.0	29.5	32.4
Cabbage savoy	2.3	2.8	2.5	2.7	19.5	24.1	20.9	23.0
Cauliflower	1.7	2.1	1.8	2.0	14.9	18.4	16.0	17.6
Collard	1.9	2.3	2.0	2.0	17.5	21.6	18.5	19.0
Kale Chinese	1.2	1.5	1.3	1.3	13.5	16.7	14.3	14.7
Kale red	1.4	1.7	1.5	1.5	16.4	20.3	17.4	17.9
Kale Tucsan	1.6	2.0	1.7	1.7	18.4	22.7	19.4	20.0
Kohlrabi purple	2.5	3.1	2.6	2.7	16.7	20.6	17.6	18.1
Cabbage Chinese	1.6	2.1	1.8	1.9	17.8	21.9	19.0	20.9
Komatsuna red	2.1	2.6	2.2	2.3	23.7	29.2	25.0	25.7
Mizuna	1.3	1.6	1.4	1.4	25.1	31.0	26.5	27.3
Pak choy	1.7	2.1	1.8	1.9	17.2	21.3	18.8	20.0
Rapini	1.1	1.4	1.2	1.4	17.6	21.7	18.3	20.9
Turnip	1.4	1.7	1.6	1.6	17.5	21.6	19.7	20.2
Mustard Dijon	1.3	1.6	1.4	1.5	20.2	25.0	22.0	23.5
Mustard red	2.0	2.5	2.2	2.4	23.3	28.8	25.4	27.1
Rutabaga	1.6	2.0	1.7	1.9	31.6	39.0	32.9	37.6
Tatsoi	1.3	1.6	1.5	1.5	26.1	32.2	29.3	30.1
LEDs			***				**	
Varieties	***	*	**	*	***	*	**	**
LEDs X Varieties			*				**	

Supplemental Table 9. Vitamin and carotenoid concentrations [Total ascorbic acid (mg/100 g FW) and β -carotene (mg/100 g FW)] of 21 varieties of *Brassica* microgreens represented 5 species grown under different light-emitting diodes (LEDs) ratio (%) of red:blue 80:20 (R₈₀:B₂₀), red:blue 20:80 (R₂₀:B₈₀), red:green:blue 70:10:20 (R₇₀:G₁₀:B₂₀), or red:green:blue 20:10:20 (R₂₀:G₁₀:B₇₀). Mean $\pm$ SE values are based on a representative sample from each treatment across three experimental replications. NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Commercial name	Total ascorbic acid (mg/100 g FW)				β -Carotene (mg/100 g FW)			
	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀	R ₈₀ :B ₂₀	R ₂₀ :B ₈₀	R ₇₀ :G ₁₀ :B ₂₀	R ₂₀ :G ₁₀ :B ₇₀
Broccoli	79.2	97.7	84.6	93.2	6.4	8.0	6.9	7.6
Brussel sprouts	89.7	110.7	95.8	105.6	5.1	6.3	5.5	6.0
Cabbage green	111.3	137.4	118.9	131.0	9.0	11.1	9.6	10.6
Cabbage red	119.3	147.2	127.4	140.4	9.3	11.4	9.9	10.9
Cabbage savoy	116.6	143.9	124.6	137.3	10.5	13.0	11.2	12.4
Cauliflower	90.1	111.2	96.3	106.1	7.4	9.2	7.9	8.7
Collard	70.7	87.2	74.6	76.8	4.9	6.1	5.3	5.4
Kale Chinese	73.2	90.4	77.4	79.6	7.3	9.0	7.7	8.0
Kale red	59.1	72.9	62.4	64.2	6.1	7.5	6.4	6.6
Kale Tucsan	69.4	85.6	73.2	75.4	5.1	6.3	5.4	5.6
Kohlrabi purple	73.0	90.1	77.1	79.3	6.3	7.7	6.6	6.8
Cabbage Chinese	110.4	136.3	118.0	130.0	8.3	10.2	8.9	9.8
Komatsuna red	92.3	113.9	97.5	100.3	6.7	8.3	7.1	7.3
Mizuna	44.4	54.8	46.9	48.3	6.0	7.4	6.3	6.5
Pak choy	40.6	50.0	44.2	47.0	6.4	8.0	7.0	7.5
Rapini	79.1	97.6	82.2	94.0	8.3	10.2	8.6	9.9
Turnip	61.7	76.1	69.4	71.2	8.1	10.0	9.2	9.4
Mustard Dijon	78.5	96.9 $\pm$	85.5	91.1	5.5	6.8	6.0	6.4
Mustard red	48.9	60.4	53.3	56.8	3.8	4.7	4.1	4.4
Rutabaga	78.0	96.3	81.1	92.7	6.0	7.4	6.2	7.1
Tatsoi	88.4	109.0	99.5	102.0	9.5	11.7	10.6	10.9
LEDs			***				**	
Varieties	*	*	*	**	*	**	*	**
LEDs X Varieties			*				**	