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Influence of urban gardening conditions on the concentration of antioxidant secondary plant metabolites in kale

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Summary

During the COVID-19 pandemic urban gardening became popular across the globe. Leafy vegetables supplement the daily diet and contribute to consumers health. Within the last decade kale (*Brassica oleracea* var. *sabellica* L.) gained popularity in urban gardening. However, shading due to unfavourable cardinal directions may reduce plant growth and accumulation of health-promoting secondary plant metabolites such as polyphenols, carotenoids and glucosinolates in kale. We compared authentic urban gardening conditions for kale grown in all four cardinal directions of a residential building. The overall concentration of carotenoids did benefit from sun exposed growing locations, including indoor cultivation behind UV light filtering glass windows, while concentrations of nutritionally important lutein did not differ among the locations and their altered growth conditions regarding abiotic stressors such as sun exposure, temperature, and water consumption. Total concentration of phenolics profited the most from direct sunlight but is severely reduced behind glass windows. Overall, satisfying growth rates of kale were achieved under all applied conditions, encouraging outdoor urban gardening with kale plants even in shaded locations.

Keywords: Urban gardening, kale, *Brassica oleracea* var. *sabellica* L., flavonoids, carotenoids, glucosinolates

Introduction

Urban gardening became a global trend not only in one's own balcony or garden, but also community gardens, guerrilla gardening projects, self-harvesting fields or solidarity agriculture in urban and suburban areas (Kalantari et al., 2018). Singapore, being highly urbanized, wants to grow 30% of its food within the city by 2030 (Montesclaros and Teng, 2019). Within the European Union, urban gardening is promoted, highlighting its positive contribution to EU's economic, social, and environmental goals. In long-term, growing plants as part of urban gardening can have positive impact on environment and climate. The green spaces that are created can, for example, provide habitats and food for pollinating insects such as bees, contributing to urban biodiversity (Matteson et al., 2008). Furthermore, urban gardening involves a more diverse range of varieties contributing to agro-biodiversity (Galluzzi et al., 2010). In cities urban gardening causes less transportation related emissions and urban gardens can reduce the „heat island effect" of largely urbanized areas and provide shading (Wolf and Robbins, 2015). During the COVID-19 pandemic people had to stay at home and consequently invested in their gardens which lead to a large increase of urban gardening activities worldwide (Mullins et al., 2021). Positive impacts of urban gardening during the COVID-19 pandemic have been focused in several recent publications. Under lockdown conditions long stretched supply chains, spanning across borders were suddenly interrupted while demand for fresh foods increased up to 44% in Germany (Pulighe and Lupia, 2020). Meanwhile consumers started to grow their own vegetables at home. In Canada 17.4% of home gardeners started during the COVID-19 pandemic, which further improved self-rated physical, emotional, and mental health with older (> 70 years of age) people (Corley et al., 2021; Mullins et al., 2021).

Abiotic stress such as high temperatures, water deficit or direct sun light does enhance the accumulation of health promoting secondary plant metabolites such as phenolic compounds and carotenoids. For most urban gardeners, location is an unchangeable factor but influences plant growth decisively. Shading in northern-located and lack off (UV) radiation indoors are widely believed to be unsuitable for cultivation.

Kale (*Brassica oleracea* var. *sabellica* L.) belongs to the Brassicaceae family, and is regarded a "superfood", rich in health beneficial calcium, folate, riboflavin, vitamin K, vitamin A, lutein, and glucosinolates (Miękus et al., 2020). Kale is predominantly cultivated in the northern hemisphere, and its cultivation in northern Germany has a long tradition. Depending on selected variety and weather conditions, kale can tolerate temperatures as low as -8 °C, being also suitable for late cultivation. In Germany 18.500 tons of kale were harvested in 2020, accounting for no significant change within the last 10 years (Statistisches Bundesamt, 2021). Kale, is considered a rich source of phenolic compounds as high as 300 mg per 100 g fresh matter (Schmidt et al., 2010). Flavonoids in kale are predominantly kaempferol and quercetin glycosides, with quercetin being the more effective antioxidant (Mageney et al., 2017). Flavonoids possess a variety of biological activities that protect against cardiovascular diseases or cancer (Dabeek and Marra, 2019). Within plant tissue flavonoids are important for plant defence against abiotic stressors such as UV radiation (D'Amelia et al., 2018). Analogously, carotenoids are health-beneficial lipophilic compounds and β-carotene and lutein are important quality traits of kale (Lee et al., 2018). Furthermore, kale is a rich source of lutein (Lee et al., 2018) which is important for eye and skin health. Their concentration is largely effected by irradiation and 4-fold longer photoperiods may increase β-carotene and lutein concentrations by more than 50% to 10.4 ± 0.4 and 13.5 ± 0.6 mg per 100 g fresh weight (Lefsrud et al., 2006). Glucosinolates are predominantly found in Brassicaceae vegetables, including kale. Among the 120 different glucosinolates, in kale predominantly glucoiberin, gluconapin, progoitrin, glucoraphanin, gluconasturtiin, and glucobrassicin are reported (Kusznierewicz et al., 2013; Hahn et al., 2016). For the plant glucosinolates are of great importance in herbivore defense upon enzymatic breakdown by myrosinase (EC 3.2.1.147) and the release of toxic nitriles, isothiocyanates, epithionitriles, and thiocyanates (Kusznierewicz et al., 2013). For human nutrition their pungent aroma is characteristic, being accompanied by their antimicrobial and anticancerogenic properties (Miękus et al., 2020).

Consequently, it is of great interest for urban farmers to cultivate vegetables rich in diverse secondary plant metabolites to boost their immune system. With high food prices adequate nutrition and supply with essential vitamins and minerals becomes challenging for people

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with low income and limited capacities for self-supply. Therefore, it is important for this group to use the limited available space to supplement their diet with healthy food and reduce food costs. Vegetables are an important source of vitamins, secondary plant metabolites, and minerals that can supplement caloric staple foods for a healthy lifestyle. Due to the orientation of balconies and other shading sources light conditions might be unfavorable throughout growth in urban gardening. Therefore, the aim of the study was to evaluate the concentration of health-promoting secondary plant metabolites in kale under realistic urban gardening conditions by comparing plants grown in all four cardinal directions of a residential house and considering indoor and outdoor growing.

A step towards Sustainable Development Goal 2 "Zero Hunger"

The findings should be beneficial for not only low income consumers from developing countries, but also encourage urban gardeners worldwide to grow healthy food.

Materials and method

Experimental site and plant growth

Kale plants were grown from 20.05.2020 (sowing) to 01.07.2020 (harvest) inside and outside of a residential building in Mecklenburg Lake District (Germany). Plants were placed outside in the four cardinal directions (north, east, west, and south) and inside in southern and eastern location of the building. Noteworthy, the building was rotated 20° westwards. Outdoor plants were placed on a small balcony like structure approximately 70 cm above ground level directly attached to the building. Indoor grown plants were placed directly behind windows. Each of the six repetitions consisted of 10 individual plants. For cultivation 10 pots were filled with Fruhstorfer soil (Hawita, Vechta, Germany). For germination a thin layer of sowing soil (Evergreen Garden Care, Mainz, Germany) was added, into which two kale seeds cv. Winterbor F1 (Bejo, Warmenhuizen, Netherlands) per pot were sown with a sowing depth of 0.5 cm and placed after 3 days of vernalization at their destined location. After one week the plants were separated and the weaker of the two plants was removed. Throughout the experiment plants were supplied with water according to their needs. Applied water doses were recorded daily and plant highs in were documented weekly, using the highest part of the plant. Local precipitation for outdoor grown plants was recorded with a precipitation gauge. Plant development was evaluated according to the BBCH scale (Meier, 2018). For harvest, three times three plants were pooled and five youngest fully developed leaves were combined, resulting in three subsamples per treatment and a total of 18 samples of six locations. Whole leaves were immediately frozen and transferred to freeze drying and further analysis.

Extraction of phenols

The method for identification and quantitation of was based on a previously established method from Neugart et al. (2014). In brief, 10 mg of above-mentioned freeze-dried samples were extracted in duplicate with 600 µl of 60% methanol (v/v) in a thermoshaker (Eppendorf, Hamburg, Germany) at 1400 rpm and 20 °C for 40 min. Subsequently, samples were centrifuged at 4500 rpm and 20 °C for 10 min. The supernatant was collected in a new reaction vessel and the pellet was redissolved in 300 µl 60% MeOH and reextracted at 1400 rpm and 20 °C for 15 min, before centrifuging again. This procedure was repeated once, resulting in a total of three extraction steps. The combined supernatants were evaporated to total dryness in an RVC 2-25 CD plus vacuum centrifuge (Christ, Osterode am Harz, Germany). The residue was redissolved in 250 µl 10% methanol and clarified in Spin-X/Filter tubes with a 0.22 µm cellulose acetate membrane (Corning Costar Spin-X, Sigma Aldrich, St. Louis, MI, USA) at 3000 rpm and 20 °C for 5 min. The filtrate was used for subsequent HPLC analyses and antioxidative assays.

Extraction of carotenoids

For identification and quantitation of carotenoids from kale, 10 mg of above-mentioned freeze-dried sample was extracted in duplicate in 500 µl of a 1:1 methanol/tetrahydrofurane (THF) mixture (v/v). The sample was vortexed and mixed at 1400 rpm and 20 °C for 10 min. Subsequently, samples were centrifuged at 4500 rpm and 20 °C for 5 minutes and the supernatant was collected. This procedure was repeated twice, resulting in a total of 1.5 ml extracted sample. All samples were evaporated to total dryness in above-mentioned vacuum evaporator. 100 µl of methyl *tert*-butyl ether (MTBE) was added to the dry residue to re-dissolve the sample. To each test tube additional 150 µl methanol (MeOH 100%) was added, thus resulting in a total volume of 250 µl. Subsequently, samples were passed through polytetrafluoroethylene filters with a pore size of 0.2 µm (Chromafil Xtra, Macherey-Nagel, Düren, Germany) and the filtrate was used for further HPLC measurements and antioxidative assays.

Extraction of glucosinolates

For the identification and quantitation of glucosinolates in kale a modified method according to Grosser and van Dam (2017) was applied in duplicate. 20 mg of above-mentioned freeze-dried sample was weighed in before adding 750 µl of 70% hot methanol (70 °C). Half of the samples were also spiked with 100 µl of a sinigrin internal standard solution. Differences between spiked and unspiked samples was used to determine internal standard area and unspiked samples were subsequently used for sinigrin determination, while other glucosinolates were analyzed in duplicate. Samples were subsequently shaken at 1400 rpm in the abovementioned thermoshaker for 10 min. Afterwards, the mixture was centrifuged at 4500 rpm for 5 min and the supernatant was collected, while the pallet was reextracted twice with 500 µl hot 70% methanol under the same conditions. For solid phase extraction (SPE), syringes were filled with a thin layer of glass wool, to which 500 µl of a DEAE Sephadex (Cytiva, Marlborough, MA, USA) suspension was pipetted. The SPE column was pre-conditioned twice with 1 ml of imidazole solution and washed twice with 1 ml ultrapure water. The above-mentioned extract was then added to the column. Afterwards, each test tube was rinsed twice with ultrapure water to ensure transfer of all residues. Subsequently, absorber columns were rinsed twice with 1 ml of sodium acetate buffer (pH 4.3). 75 µl of purified arylsulfatase (EC 3.1.6.8) (Merck, Darmstadt, Germany) was added and for at least 16 h, enzymatic desulphurisation was conducted. Desulfoglucosinolates were eluted twice with 500 µl of ultrapure water and transferred to above-mentioned Spin-X filters. These were centrifuged at 4000 rpm at 20 °C for two min before HPLC measurement.

Antioxidant TEAC and DPPH assays

The antioxidant activity was either measured in phenolic or in carotenoid extracts. The Trolox equivalent antioxidant capacity (TEAC) assay and well as the 2,2-diphenyl-1-picrylhydrazyl-hydrate (DPPH) assay were performed based on a slightly modified 96 microwell plate method. Both assays used individual calibration series of Trolox on each plate. For the TEAC assay, 10 µl sample or Trolox standard solution were mixed with 150 µl working solution in a 96 microwell plate and measured in a Synergy HTX microwell plate reader (BioTek Instruments, Bad Friedrichshall, Germany) at a wavelength of 734 nm after six min. For the DPPH assay 20 µl sample or Trolox standard solution were mixed with 180 µl DPPH solution. After incubation for 30 min under darkness plates were measured at a wavelength of 515 nm.

HPLC Measurement of phenols

Phenolic compounds including hydroxycinnamic acid derivatives and flavonoids glycosides were quantitated based on a method by NEUGART et al. (2014) using a Shimadzu prominence HPLC (Shimadzu, Kyoto, Japan) equipped with a DGU-20A5 degasser, LC-20AT pump, SIL-20AC autosampler, CTO-10AS column oven, and SPD-M20A photodiode array detector. An Ascentis Express F5 column (150 × 4.6 mm i.d., 5 µm particle size, Merck, Darmstadt, Germany) protected by an Ascentis F5 guard column (5 × 4.6 mm i.d., 5 µm particle size, Merck) was used at 25 °C. Eluent A was 0.5% acetic acid, and eluent B was 100% acetonitrile. The gradient (eluent B) was 5-12% (0-3 min), 12-25% (3-46 min), 25-90% (46-49.5 min), 90% isocratic (49.5-52 min), 90-5% (52-52.7 min), and 5% isocratic (52.7-59 min) at a flow rate of 0.85 ml * min^{-1}. Phenolic compounds were measured at wavelengths of, 320 nm for hydroxycinnamic acid derivatives, 330 nm for acylated flavonoid glycosides, and 370 nm for non-acylated flavonoid glycosides. For quantitation authentic standards of quercetin-3-glucoside, kaempferol-3-glucoside, and chlorogenic acid were used (Roth, Karlsruhe, Germany).

HPLC Measurement of carotenoids and chlorophylls

Carotenoids and chlorophylls were quantitated using the above-mentioned Shimadzu prominence HPLC system with a C30 Carotenoid column (250 × 4.6 mm i.d.; 5 µm particle size) (YMC, Kyoto, Japan) protected by a YMC C30 guard cartridge (10 × 4.6 mm i.d.; 5 µm particle size) (YMC). Eluents A and B consisted of methanol, methyl *tert*-butyl ether (MTBE), and water (80:18:2, v/v/v, eluent A; 8:90:2, v/v/v, eluent B (SCHEX et al., 2018). The gradient used (eluent A) was 90-40% (0-30 min), 40-0% (30-35 min), isocratic at 0% (35-37 min), 0-90% (37-40 min), followed by an isocratic step at 90% (40-45 min) at a flow rate of 0.6 ml * min^{-1} at an oven temperature of 30 °C. Carotenoids were detected at a wavelength of 454 nm and chlorophyll a and b were measured at 663 and 647 nm, respectively. Furthermore, UV/vis spectra were recorded between 200 and 600 nm. For identification and quantitation authentic standards of β-carotene (Roth), lutein, zeaxanthin (Extrasynthese, Lyon, France), chlorophyll a, and chlorophyll b (Sigma-Aldrich) were used. Furthermore, spectra of carotenoids and chlorophylls were compared to those reported previously (SCHEX et al., 2018).

HPLC Measurement of glucosinolates

Glucosinolates were identified and quantitated based on a previously published method by GROSSER and VAN DAM (2017), using refence factors and calculations, suggested by CLARKE (2010). For separation a Jasco 4000 series HPLC, equipped with a PU-4185 pump, AS-4250 autosampler, UV-4070 UV/vis detector, and CO-4060 column oven was used. A Nucleodur 100 (125 × 2 mm i.d.; 5 µm particle size; Macherey-Nagel, Düren, Germany) column was used for separation. at a flow rate of 0.6 ml * min^{-1}. Eluents were ultrapure water (eluent A) and acetonitrile (eluent B). The applied gradient (eluent B) was 1- 20% (0-20 min), isocratic 20% (20-25 min), 20- 1% (25-27 min), and isocratic 1% (27-35 min). Detection wavelength was 229 nm. For identification retention times were compared to those of authentic standards of sinigrin, progoitrin, glucobrassicanapin, and glucobrassicin (PhytoLab, Vestenbergsgreuth, Germany).

Statistical analysis

Statistical analysis of the results was performed using R statistical software, version 4.1.0. Analysis of variance (ANOVA) with post-hoc Tukey-test was performed across all growth locations. All analytical measurements were conducted in duplicate. Values are means ± standard deviation of three biological repetitions. For this investigation, a significance level of $\alpha \leq 0.05$ was applied.

Results

Temperature

Average morning temperatures measured inside and in eastern location were highest, reaching 20.0 to 20.7 °C due to indoor heat storage and early solar radiation exposure in the east. At noon temperatures were highest inside in southern and (28.9 °C) and eastern (26.6 °C) locations as well as southern location outside (23.7 °C), following the suns position. During evening hours location in southern (inside), northern, and western location were warmest, reaching 21.6 to 23.6 °C. Changing sun exposure throughout the day lead to the described pattern and further, indoor locations favored heat storage. In addition to the daily documented temperature data, meteorological data from within 15 km of the experimental site was used for independent temperature data collection (Appendix). Overall temperature increased from an average of 12.9 °C in the first week to 19.6 °C in week 6 of the experiment. Analogously, minimum temperature increased from only 3.5 °C to above 10 °C from week 4 onwards. Hot days were absent during the experiment, reaching a maximum of 28.3 °C.

Water supply of the plants and plant growth

Water supply of plants was ensured by natural precipitation and additional watering according to necessity. Particularly the first half of the growing season was dry, in total there were only 15.6 litres of precipitation per square meter in the first three weeks, which was less than observed at the nearby weather station (31.1 litres per m^2). Watering ranged from 30 ml to 175 ml per day and increased throughout the experiment. In southern located plants (outside) most supplemental water, accounting for a total of 1550 ml, was needed, followed by the southern indoor location with 1025 ml over the experimental period. The northern (405 ml) and western (455 ml) locations required the least amount of supplemental water.

Plants grown inside (southern and eastern location) were in average 83 and 12% higher than their outside grown counterparts (south and east, respectively) during the first two weeks of cultivation. During growth, differences between location vanished until week 4. However, at harvest shortest plants were observed in outside grown plants in the south while being uniform in between other locations (Tab. 1). Analogously, leaf development of the main shoot was ahead at early stages for indoor grown plants, as well as for plants grown in southern location. In the third week of the experiment, east (outside) and west showed a fully unfolded leaf on average (BBCH-code: 11), while the inner sites already had two leaves (BBCH-Code: 12), and in southern location (outside) there was an average of 1.6 deciduous leaves. Until the fifth week, plants grown outside in southern location were the most developed while plants grown in northern and eastern location (outside), which were lagging behind up to third week, have almost caught up. Meanwhile, plants grown in western location still lagged behind in their development. At the end of the experiment all plants grown outside were comparably developed, ranging between an BBCH index of 6.2 and 6.8, while indoor grown plants were most developed, reaching 7.2 and 7.8.

Phenolics

Kale samples contained a variety of different quercetin and kaempferol glycosides including acylated and non-acylated flavonoids. Overall, the sum of flavonoid glycosides was lowest in plants grown inside (southern and eastern location) and in western location (outside), ranging from 28.0 ± 3.4 to 33.2 ± 7.1 mg per 100 g fresh weight (FW) (Tab. 2). Highest concentrations were found outside in eastern, and southern location, ranging between 265.6 ± 25.7 and 272.8 ± 65.4 mg per 100 g FW. Highest concentrations were found of quercetin-3,7,4'-*O*-triglucoside, kaempferol-3-*O*-caffeoyl-sophoroside-7-*O*-

Tab. 1: Average height of kale plants in cm, grown between 31.05.2020 and 01.07.2020. Different letters indicate significant differences of means according to Tukey's test ($p \leq 0.05$).

	05/31/2020	06/05/2020	06/11/2020	06/16/2020	06/22/2020	06/28/2020	07/01/2020
North (outside)	2.3 ± 0.2^{b}	4.1 ± 0.2^{d}	7.2 ± 1.3^{d}	13.5 ± 1.3^{a}	17.9 ± 1.9^{ab}	23.4 ± 2.3^{ab}	23.4 ± 1.6^{ab}
East (inside)	4.5 ± 0.8^{a}	6.5 ± 0.6^{a}	8.1 ± 1.7^{a}	14.6 ± 0.9^{a}	19.7 ± 1.7^{a}	23.1 ± 2.0^{ab}	28.3 ± 2.1^{ab}
East (outside)	2.4 ± 0.2^{b}	4.3 ± 0.4^{d}	7.9 ± 1.0^{d}	14.9 ± 0.8^{a}	18.8 ± 1.4^{a}	22.5 ± 1.5^{ab}	22.9 ± 2.2^{ab}
South (inside)	4.3 ± 0.5^{a}	6.0 ± 1.1^{ab}	8.3 ± 1.7^{ab}	14.7 ± 1.9^{a}	18.3 ± 2.2^{a}	20.7 ± 2.0^{b}	27.8 ± 4.1^{a}
South (outside)	2.4 ± 0.2^{b}	5.3 ± 0.6^{bc}	8.1 ± 1.1^{bc}	15.3 ± 1.7^{a}	18.9 ± 2^{a}	25.4 ± 3.5^{a}	20.8 ± 1.4^{b}
West (outside)	2.5 ± 0.2^{b}	4.5 ± 0.5^{cd}	6.2 ± 1.4^{cd}	14.4 ± 1.4^{a}	15.7 ± 1.7^{b}	24.0 ± 2.8^{a}	25.0 ± 2.8^{a}

Tab. 2: Flavonoid glucosides [mg * 100 g^{-1} FW] in kale leaves harvested after 7 weeks of growth under urban gardening conditions in northern, eastern, western, and southern locations, including 2 indoor locations (east and south). Different letters indicate significant differences of means according to Tukey's test ($p \leq 0.05$).

	North (outside)	East (outside)	East (inside)	South (outside)	South (inside)	West (outside)
K-3-*O*-cou-soph-7-*O*-glc	11.6 ± 2.5^{ab}	14.8 ± 1.3^{a}	2.0 ± 0.3^{c}	14.5 ± 7.0^{a}	1.9 ± 0.1^{c}	4.9 ± 0.6^{bc}
K-3-*O*-caf-soph-7-*O*-glc	35.2 ± 3.1^{a}	38.0 ± 5.3^{a}	3.3 ± 0.5^{b}	27.8 ± 11.0^{a}	3.8 ± 0.9^{b}	10.8 ± 3.9^{b}
K-3-O-caf-soph-7-*O*-diglc	1.7 ± 1.2^{a}	0.0 ± 0.0^{b}	0.2 ± 0.0^{ab}	0.8 ± 0.7^{ab}	0.2 ± 0.0^{ab}	0.3 ± 0.2^{ab}
Q-3-*O*-fer-soph-7-*O*-glc	1.0 ± 0.2^{a}	1.0 ± 0.3^{a}	0.2 ± 0.1^{b}	1.2 ± 0.5^{a}	0.2 ± 0.1^{b}	0.3 ± 0.0^{b}
K-3-*O*-fer-soph-7-*O*-glc	9.4 ± 2.6^{ab}	15.8 ± 4.2^{a}	2.1 ± 0.5^{b}	15.1 ± 7.8^{a}	1.9 ± 0.1^{b}	2.2 ± 1.1^{b}
K-3-*O*-fer-soph-7-*O*-diglc	13.2 ± 1.9^{ab}	20.6 ± 1.8^{a}	3.7 ± 1.6^{b}	25.8 ± 6.5^{a}	2.5 ± 1.3^{b}	6.5 ± 0.8^{b}
K-3-*O*-hfer-soph-7-*O*-glc	10.8 ± 1.0^{a}	12.5 ± 1.1^{a}	2.1 ± 0.2^{b}	11.8 ± 2.8^{a}	2.3 ± 0.1^{b}	4.9 ± 1.4^{b}
K-3-*O*-hfer-soph-7-*O*-diglc	4.1 ± 0.4^{c}	10.7 ± 1.5^{b}	0.6 ± 0.3^{c}	17.3 ± 3.7^{a}	0.5 ± 0.4^{c}	1.6 ± 0.2^{c}
Q-3-*O*-sin-soph-7-*O*-glc	7.7 ± 2.6^{a}	1.8 ± 0.7^{b}	0.7 ± 0.1^{b}	0.0 ± 0.0^{b}	0.7 ± 0.0^{b}	0.7 ± 0.2^{b}
K-3-*O*-sin-soph-7-*O*-glc	9.8 ± 2.8^{b}	25.7 ± 4.9^{a}	1.0 ± 0.3^{b}	35.7 ± 8.0^{a}	0.8 ± 0.3^{b}	2.6 ± 0.3^{b}
K-3-*O*-sin-soph-7-*O*-diglc	14.2 ± 4.7^{b}	26.8 ± 3.6^{a}	0.6 ± 0.1^{c}	28.0 ± 7.2^{a}	0.7 ± 0.2^{c}	3.2 ± 0.7^{c}
Q-3-*O*-soph-sin-7-*O*-diglc	17.9 ± 4.3^{a}	14.9 ± 5.4^{ab}	4.2 ± 1.6^{b}	10.4 ± 8.2^{a}b	3.1 ± 1.0^{b}	2.8 ± 1.3^{b}
Q-3,7-di-*O*-glc	9.5 ± 1.7^{a}	7.9 ± 3.0^{ab}	3.4 ± 1.2^{ab}	5.3 ± 5.3^{ab}	2.2 ± 0.4^{b}	3.2 ± 0.1^{ab}
K-3-*O*-soph-7-*O*-glc	8.9 ± 1.2^{c}	16.4 ± 1.2^{b}	1.3 ± 0.2^{d}	29.0 ± 3.4^{a}	1.2 ± 0.2^{d}	3.1 ± 1.1^{d}
Q-3-*O*-soph-7-*O*-glc	6.0 ± 1.3^{b}	15.5 ± 1.7^{a}	0.5 ± 0.1^{b}	19.1 ± 5.5^{a}	0.5 ± 0.1^{b}	1.3 ± 0.2^{b}
Q-3,7,4'-triglc	20.2 ± 2.3^{bc}	39.7 ± 4.0^{a}	6.7 ± 1.2^{cd}	27.6 ± 11.9^{ab}	5.0 ± 0.8^{d}	17.6 ± 3.8^{bcd}
I-glc	2.6 ± 0.4^{b}	3.6 ± 1.1^{a}	0.6 ± 0.1^{b}	3.5 ± 11.7^{a}	0.6 ± 0.1^{b}	0.8 ± 0.1^{b}
Total Flavonoids	183.7 ± 30.7^{b}	265.6 ± 25.7^{ab}	33.2 ± 7.1^{c}	272.8 ± 65.4^{a}	28.0 ± 3.4^{c}	66.6 ± 12.8^{c}

*Abbreviations: Q: quercetin, K: kaempferol, I: Isorhamnetin, cou: coumaroyl, caf: caffeoyl, fer: feruloyl, hfer: hydroxyferuloyl, sin: sinapoyl, glc: glucoside, soph: sophoroside, n.d.: not detectable.

glucoside, and kaempferol-3-*O*-sinapoyl-sophoroside-7-*O*-glucoside in southern and eastern outside locations, respectively. Noteworthy, quercetin-3-*O*-sinapoyl-sophoroside-7-*O*-glucoside concentrations were highest in northern location. Furthermore, concentrations of the quercetin glycosides quercetin-3-*O*-caffeoyl-sophoroside-7-*O*-glucoside, and quercetin-3-*O*-sophoroside-sinapoyl-7-*O*-diglucoside were highest in northern located plants. Kaempferol-3-*O*-sinapoyl-sophoroside-7-*O*-diglucoside represented 8 to 10% of all flavonoids in locations with high total flavonoid concentrations, namely northern, eastern, and southern (outside) located plants, while their concentration was especially low in plants grown in all other locations. The lowest concentrations for almost all flavonoid glycosides are found in eastern inside (12% when being compared to the southern outside location) and southern inside (10% when being compared of the southern outside location) locations. In western located plants quercetin-3,7,4'-*O*-triglucoside represented a quarter of all flavonoids. Hydroxycinnamic acids were comparably distributed to the flavonoid glycosides, also being lower in their total concentration, ranging between 12.3 ± 0.4 and 36.4 ± 5.4 mg per 100 g FW. Highest concentrations were measured in northern, eastern (outside), and southern (outside) locations, while concentrations were lowest in eastern (inside), southern (inside), and western locations. Neochlorogenic acid and disinapoyl-gentiobiose were highest in their concentration, accounting for approximately 65% of total hydroxycinnamic acids, regardless of their growth location.

Carotenoids and chlorophylls

Characteristic carotenoids of kale such as lutein, violaxanthin, neoxanthin, zeaxanthin, and β-carotene were found in samples gathered from all locations. Total concentrations of carotenoids were highest in eastern and southern located samples, regardless of their position

Tab. 3: Concentrations of hydroxycinnamic acids [mg * 100 g^{-1} FW] in kale samples harvested after 7 weeks of growth under urban gardening conditions in northern, eastern, western, and southern locations, including 2 indoor locations (east and south). Different letters indicate significant differences of means according to Tukey's test ($p \leq 0.05$).

	North (outside)	East (outside)	East (inside)	South (outside)	South (inside)	West (outside)
Neochlorogenic acid	13.9 ± 1.2^{ab}	17.4 ± 3.6^{a}	5.8 ± 0.8^{c}	16.3 ± 5.8^{a}	4.5 ± 0.2^{c}	6.3 ± 0.9^{bc}
Disinapoyl-gentiobiose	6.3 ± 0.7^{ab}	8.3 ± 0.8^{a}	4.8 ± 0.7^{bc}	6.6 ± 2.1^{ab}	3.4 ± 0.3^{c}	2.9 ± 0.5^{c}
Sinapoylferuloyl-gentiobiose	2.4 ± 0.6^{ab}	2.6 ± 0.1^{a}	2.1 ± 0.2^{ab}	2.9 ± 0.9^{a}	1.3 ± 0.1^{b}	1.3 ± 0.1^{b}
Trisinapoyl-gentiobiose	3.9 ± 0.6^{ab}	4.6 ± 0.5^{a}	2.4 ± 0.2^{bc}	4.7 ± 1.4^{a}	1.9 ± 0.1^{c}	2.0 ± 0.3^{c}
Disinapoylferuloyl-gentiobiose	2.5 ± 0.3^{ab}	3.5 ± 0.9^{a}	1.6 ± 0.1^{bc}	3.4 ± 0.6^{a}	1.2 ± 0.1^{c}	1.4 ± 0.1^{bc}
Total hydroxycinnamic acid glycosides	29.2 ± 3.2^{ab}	36.4 ± 5.4^{a}	16.6 ± 1.9^{bc}	33.9 ± 10.3^{a}	12.3 ± 0.4^{c}	14.0 ± 1.9^{c}

Tab. 4: Concentration of carotenoids and chlorophyll a and b [mg * 100 g^{-1} FW] in kale samples harvested after 7 weeks of growth under urban gardening conditions in northern, southern, western, and eastern locations, including 2 indoor locations (east and south). Different letters indicate significant differences of means according to Tukey's test ($p \leq 0.05$).

	North (outside)	East (outside)	East (inside)	South (outside)	South (inside)	West (outside)
Lutein	3.8 ± 0.1^{a}	4.8 ± 0.5^{a}	4.8 ± 0.5^{a}	4.6 ± 0.2^{a}	4.4 ± 0.3^{a}	3.9 ± 0.7^{a}
Violaxanthin	0.7 ± 0.3^{a}	0.6 ± 0.0^{a}	0.7 ± 0.1^{a}	0.5 ± 0.1^{a}	0.7 ± 0.2^{a}	0.5 ± 0.1^{a}
Neoxanthin	0.5 ± 0.2^{c}	0.4 ± 0.1^{c}	2.8 ± 0.6^{a}	0.5 ± 0.1^{c}	2.3 ± 1.1^{ab}	0.8 ± 0.5^{bc}
(all-*E*)-β-Carotene	1.0 ± 0.1^{a}	1.4 ± 0.1^{a}	1.4 ± 0.3^{a}	1.3 ± 0.1^{a}	1.2 ± 0.1^{a}	1.1 ± 0.2^{a}
(9Z)-β-Carotene	0.3 ± 0.2^{a}	0.3 ± 0.0^{a}	0.2 ± 0.0^{a}	0.3 ± 0.0^{a}	0.2 ± 0.0^{a}	0.4 ± 0.4^{a}
Zeaxanthin	0.1 ± 0.0^{abc}	0.2 ± 0.0^{ab}	0.0 ± 0.0^{c}	0.3 ± 0.0^{a}	0.1 ± 0.1^{bc}	0.1 ± 0.0^{bc}
Total Carotenoids	6.4 ± 0.4^{c}	7.6 ± 0.7^{abc}	9.8 ± 0.3^{a}	7.5 ± 0.3^{abc}	8.9 ± 1.1^{ab}	6.8 ± 1.6^{bc}
Chlorophyll a]	26.0 ± 1.6^{a}	33.3 ± 2.2^{a}	41.4 ± 17.7^{a}	28.6 ± 6.0^{a}	34.6 ± 14^{a}	48.7 ± 2.9^{a}
Chlorophyll b	14.9 ± 0.5^{ab}	16.3 ± 1.1^{a}	9.8 ± 2.8^{b}	15.1 ± 1.2^{ab}	10.0 ± 2.9^{b}	11.5 ± 2.1^{ab}
Total Chlorophylls	40.9 ± 1.9^{a}	49.6 ± 3.3^{a}	51.2 ± 20.5^{a}	43.7 ± 7.2^{a}	44.6 ± 16.3^{a}	60.2 ± 3.9^{a}

Tab. 5: Concentration of glucosinolates progoitrin, epiprogiotrin, sinigrin, glucobrassicanapin, glucobrassicin, and total glucosinolates [mg * 100 g^{-1} FW] in kale samples harvested after 7 weeks of growth under urban gardening conditions in northern, southern, western, and eastern locations, including 2 indoor locations (east and south).
Different letters indicate significant differences of means according to Tukey's test ($p \leq 0.05$).

	North (outside)	East (outside)	East (inside)	South (outside)	South (inside)	West (outside)
Progiotrin	0.6 ± 0.3^{ab}	0.5 ± 0.2^{ab}	0.2 ± 0.1^{ab}	0.6 ± 0.1^{a}	0.1 ± 0.0^{b}	0.4 ± 0.2^{ab}
Epiprogiotrin	0.8 ± 0.2^{a}	0.3 ± 0.0^{bc}	0.2 ± 0.1^{c}	0.6 ± 0.1^{ab}	0.3 ± 0.0^{bc}	0.2 ± 0.2^{c}
Sinigrin	3.8 ± 0.8^{bc}	5.3 ± 0.6^{ab}	1.5 ± 0.7^{d}	5.9 ± 0.9^{a}	2.6 ± 0.6^{cd}	2.7 ± 0.8^{cd}
Glucobrassicanapin	0.5 ± 0.4^{b}	0.5 ± 0.1^{b}	0.3 ± 0.0^{b}	2.3 ± 0.7^{a}	0.3 ± 0.1^{b}	1.1 ± 0.2^{b}
Glucobrassicin	11.7 ± 3.2^{b}	8.9 ± 2.1^{b}	5.8 ± 0.6^{b}	34.5 ± 10.6^{a}	4.9 ± 2.4^{b}	17.6 ± 3.0^{b}
Total Glucosinolates	17.5 ± 4.5^{b}	15.5 ± 1.9^{b}	8.0 ± 0.8^{b}	43.9 ± 11.6^{a}	8.1 ± 3.2^{b}	21.9 ± 2.4^{b}

Tab. 6: Antioxidant activity in phenolic and carotenoid extracts [mmol Trolox equivalent * 100 g^{-1} FW] in kale samples harvested after 7 weeks of growth under urban Different letters indicate significant differences of means according to Tukey's test ($p \leq 0.05$).

	North (outside)	East (outside)	East (inside)	South (outside)	South (inside)	West (outside)
DPPH phenolics	3.7 ± 0.8^{b}	4.2 ± 0.2^{ab}	1.0 ± 0.2^{c}	4.9 ± 0.3^{a}	0.8 ± 0.2^{c}	1.2 ± 0.2^{c}
TEAC phenolics	6.0 ± 0.6^{c}	8.0 ± 0.4^{b}	2.0 ± 0.4^{d}	9.3 ± 0.4^{a}	1.8 ± 0.4^{d}	2.9 ± 0.2^{d}
DPPH carotenoids	6.1 ± 1.1^{bc}	8.7 ± 1.7^{ab}	3.9 ± 0.4^{c}	10.6 ± 2.3^{a}	2.4 ± 0.9^{c}	3.4 ± 1.1^{c}
TEAC carotenoids	8.9 ± 0.7^{bc}	10.8 ± 1.9^{ab}	4.7 ± 0.6^{d}	13.3 ± 2.2^{a}	5.1 ± 1.0^{d}	6.1 ± 0.2^{cd}

inside or outside, ranging between 7.5 ± 0.3 and 9.8 ± 0.3 mg per 100 g FW. Neoxanthin concentration was strongly increased to 2.8 ± 0.6 and 2.3 ± 1.1 mg per 100 g FW at both inside locations in southern and eastern location, compared to those concentrations measured outside in northern, eastern, and southern locations. Zeaxanthin was present only in small concentrations and was only found at minimum concentrations under indoor conditions. Lutein was found at high concentrations in all locations, ranging from 3.8 ± 0.1 to 4.8 ± 0.5 mg per 100 g FW. β-Carotene concentration was between 1.0 ± 0.1 and 1.4 ± 0.3 mg per 100 g FW in all samples.

Total chlorophyll concentrations did not differ between any of the chosen locations ranging between 40.0 ± 1.9 and 60.2 ± 3.9 mg per 100 g FW. Furthermore, concentrations of chlorophyll a were not different, but tended to be elevated inside (east and south) and western locations. However, the ratio of chlorophyll a to chlorophyll b was highest in inside locations (east and south) and in western location, being in clear contrast to the other three locations (south, north, and east).

Glucosinolates

Glucosinolates progiotrin, epiprogoitrin, sinigrin, glucobrassicanapin, and glucobrassicin were found in all kale samples of our study. Highest overall concentrations of 43.9 ± 11.6 mg per 100 g FW were found in samples grown in southern (outside) location, reaching twofold the concentration of glucosinolates in the location with the second highest concentrations (west; 21.9 ± 2.4 mg per 100 g FW). Concentrations were highest for glucobrassicin and sinigrin, comprising for approximately 90% of all found glucosinolates, regardless of their location. Glucobrassicin concentration was highest in southern outside location, reaching 34.5 ± 10.6 mg per 100 g FW, while other locations were between 4.9 ± 2.4 and 17.6 ± 3.0 mg per 100 g FW. Noteworthy, all five reported glucosinolates were highest in southern (outside) location and the surplus in comparison to other locations was especially pronounced for glucobrassicin (148% higher than average). Furthermore, kale grown indoors tended to have the lowest glucosinolate concentration, also not being significantly lower than other outdoor grown kale samples (northern, eastern, and western locations).

Antioxidant activity

Antioxidant activity, measured by the DPPH assay in methanolic extracts for determination of phenolic compounds was highest for samples grown at outside locations oriented towards the south and east, reaching 4.9 ± 0.3 and 4.2 ± 0.2 mmol Trolox equivalent (TE) per 100 g FW. Meanwhile, antioxidant activity was between 0.8 ± 0.2 and 3.7 ± 0.8 mmol TE per 100 g FW in indoor locations (south and east), as well as in western located plants. Differences reached a 4 to 5-fold difference between highest and lowest recorded concentrations. Analogously, TEAC assay was highest in southern located and outside grown plants (9.3 ± 0.4 mmol TE per 100 g FW), while plants grown inside and in western location were lowest (1.8 ± 0.4 to 2.9 ± 0.2 mmol TE per 100 g FW), also reaching a 5-fold difference between the extrema. In lipophilic extracts being used for the determination of carotenoids and chlorophylls highest antioxidant activity was found in southern and eastern located plants, reaching 8.7 ± 1.7 to 10.6 ± 2.3 mmol TE per 100 g FW in the DPPH assay and 10.8 ± 1.9 to 13.3 ± 2.2 mmol TE per 100 g in the TEAC assy. Meanwhile, lowest antioxidant activity was found at locations inside in both antioxidant assays.

Discussion

Growth conditions and adaption

Growth conditions were sufficient to grow kale at all urban gardening locations that were part of our investigation. Non-surprisingly, indoor cultivated plants had a clear advantage during early stages of growth when outside temperatures were still below 10 °C during night-time. Regarding overall plant height there was no difference after 7 weeks of cultivation, suggesting that all applied conditions are suitable to grow kale in urban gardening. Kale is a known frost tolerant vegetable (Heyduck et al., 2020) and therefore not prone to cold night-time temperatures, as present in spring and early summer. Furthermore, kale is known to grow also under unfavourable light conditions. These attributes make kale a typical German winter vegetable that is also suitable for cultivation in northern locations with extensive shading, as being part of our study, or late autumn and winter harvests. The relatively short growth period of 7 weeks resulted in substantial leaf material for consumption, especially considering trending uses as baby leaf salad and is in agreement with previous reports (Heyduck et al., 2020). However, while kale cultivation is stagnating in Germany, the US marked saw a boost in kale growth within the last decade (Kirby and Granatstein, 2018; Statistisches Bundesamt, 2021). During our study irrigation, but no fertilization, was applied to provide optimum growth condition as it is achievable in residential urban gardening. However, highest water consumption in southern outside location clearly shows that a sufficient supply with water must be provided to heat exposed plants as water reservoirs on balconies are limited. Although short-term drought stress in kale resulted in an increase in phenolics and glucosinolates (Barickman et al., 2020), this was not the subject of this research.

Phenolic compounds in kale

Highest concentrations of total phenolic compounds were found in our southern located cultivation side due to most extensive sun exposure (Majer et al., 2014). However, plants grown in eastern and, most surprising, northern location were almost equally rich in phenolic compounds. Meanwhile, plants grown indoor behind glass protection or in the shaded western location side were drastically lower in their phenolic content (flavonoids and hydroxycinnamic acids), containing only 14 to 17% of the maximum concentration found in southern located plants. Comparable observations were made with the same cultivar under artificial light conditions, where lowest PAR light intensities did not reduce kaempferol-*O*-hydroxyferuloyl-sophoroside-*O*-glucoside concentrations, while highest concentrations under poor light conditions were observed (Neugart et al., 2013). Noteworthy, our concentrations were approx. 50% of previously reported concentrations. Concentrations of other flavonoids were also comparable to those reported in this study, also variations due to our different locations were much more pronounced than those based solely on PAR light differences between 200 and 800 mmol m^{-2} s^{-1} The accumulation of phenolic compounds is known to be largely light dependent. Especially UV radiation exposure leads to the increase of phenolic compounds in kale (Neugart et al., 2014; Neugart et al., 2016). Window glass is blocking a substantial share of UV radiation and especially UVB radiation, responsible for the upregulation of phenol biosynthesis (Neugart et al., 2014). Thus, the growth outside and at sun exposed locations has a clear advantage regarding the dietary phenol intake and possible health benefits thereof. The distribution of flavonoid glycosides in shaded locations with a known low concentration in total phenolics favored quercetin glycosides which represented 42 to 47% of all flavonoid glycosides, while in sun exposed locations their share decreased to 23 to 39% and a higher share of acylated kaempferol glycosides. The shift of mono-hydroxylated to di-hydroxylated B-ring compounds or increase of acylation is a well-known response to UV radiation (Agati et al., 2011). For human consumption and urban gardeners the higher share of quercetin glycosides may result in a higher antioxidant activity and better radical oxygen species (ROS) scavenging potential (Fiol et al., 2012). Nevertheless, kaempferol glycosides contribute to the antioxidant activity in kale, dependent on the acylated hydroxycinnamic acid (Fiol et al., 2012). Consequently, kaempferol-3-*O*-sinapoyl-sophoroside-7-*O*-diglucoside, and kaempferol-3-*O*-caffeoyl-sophoroside-7-*O*-glucoside were drastically elevated under full sunlight in the southern outside location. However, in contrast to previous findings we could not find a decrease in kaempferol glycosides but a more pronounced increase in quercetin glycosides (Neugart et al., 2016). Both kaempferol and quercetin are abundantly available in the

human diet and known for their health beneficial effects (Dabeek and Marra, 2019; Pan et al., 2010). One of the characteristics of urban gardening is shading due to buildings or other plants comparable to a canopy (Martínez-Lüscher et al., 2019). Consequently, phenolic concentration and composition could be affected by different shading conditions in urban gardeing.

Carotenoids

Kale (cv. 'Winterbor') was found to be an excellent source for lutein also concentrations were 50% lower than reported by Becerra-Moreno et al. (2014). Concentrations of carotenoids β-carotene and violaxanthin were also 20 to 50% lower than reported in the same study. Those differences can be due to the young age of our leaves. The concentration of carotenoids depended on the location of the cultivation site of kale plants and was not influenced by indoor or outdoor cultivation except for neoxanthin. Locations with limited sun light availability, i.e. northern and western located plants, were lowest in total carotenoids. Previous studies showed that longer photoperiods increase lutein and β-carotene concentrations and red light (640 nm) stimulates the accumulation of lutein in kale (Lefsrud et al., 2008). Concentrations of lutein were independent of their growth location during our study. In agreement to our results Lefsrud et al. (2006) found no influence on lutein, β-carotene, and chlorophyll a concentrations at low irradiance doses in growth chambers between 125 and 460 µmol * m^{-2} * s^{-1}. Irradiance doses of 620 µmol * m^{-2} * s^{-1} resulted in slightly higher concentrations of lutein, β-carotene, and chlorophyll a. In urban gardening shading depends on the actual growth location and time of year, which are unchangeable factors. Nevertheless, extended exposure to sun light might be beneficial to achieve higher carotenoid concentrations but effects are limited and also shaded plants provide a considerable supply of health beneficial carotenoids. This observation is especially interesting for consumers as lutein is of great nutritional value due to its antioxidant activity, eye protective potential against UV radiation and its contribution to brain development (Ochoa Becerra et al., 2020). Due to the limited stability of lutein its application in the food industry is limited and fresh sources are valuable for consumers. Noteworthy, neoxanthin concentrations were highest in indoor grown plants. Even though the actual function of neoxanthin is still disputed (Giossi et al., 2020) our results indicate that it has a role in the UV response in outdoor conditions but not in indoor conditions.

Glucosinolates

Glucosinolates were not affected by growth conditions, except for 50% higher concentration in southern located plants. Those elevated glucosinolate concentrations can be caused by abiotic stresses, such as drought (Schreiner et al., 2009) or elevated temperature (Bohinc and Trdan, 2012). Mild drought events in our southern locations might be evident as sun exposure and water consumption were highest. Furthermore, the strongly elevated concentrations of indolic glucobrassicin might be a result of high temperatures as shown by Bohinc and Trdan (2012). Composition of glucosinolates in all samples was dominated by glucobrassicin and sinigrin that were previously found in substantial amounts in kale by Hahn et al. (2016) and Kusznierewicz et al. (2013). Highest concentrations of glucobrassicin and substantial concentrations of sinigrin are characteristic for cv. 'Winterbor' under sufficient sulfur supply (Kopsell et al., 2003). Furthermore, total glucosinolates, sinigrin, and glucobrassicin ranked lowest when being grown indoor, indicating that light conditions might influence their accumulation and consequently taste. Modification of aforementioned glucosinolates has recently been achieved by white, blue, and red LEDs in *Brassica juncea* sprouts (Park et al., 2020). For consumers and urban gardeners with might be of particular interest since glucosinolates do contribute to healthy secondary plant metabolites in kale (Mięku s et al., 2020) but also have characteristic pungent flavor that can lead to rejection, especially by children. Based on our results there is no clear explanation for the strongly elevated concentrations in southern located plants, but overall results suggest that all chosen locations were suitable for urban gardening and no location is favorable, when aiming for especially mild kale leaves, also indoor cultivation might be favorable with lowest overall concentrations.

Antioxidant activity

Due to the large contribution of phenolics to the antioxidant activity their occurrence explains the high overall antioxidant activity of samples grown in southern and eastern located plants. Overall concentrations of phenolic compounds showed a clear differentiation between highly sun exposed locations without reduction of PAR or UV radiation provided by glass windows. Such an effect was previously found in linden leaves where sun exposed leaves had a higher singlet oxygen neutralizing capacity compared to shade leaves (Majer et al., 2014) and is known in many other species (Shahidi and Ambigaipalan, 2015). Concentrations in carotenoids, including β-carotene and lutein, did not differ to the same extent. Noteworthy, concentrations of phenolic compounds were surprisingly high in our samples grown in northern located with no direct sunlight but were lowest in their carotenoid concentration. Western located plants were lowest in their content of phenolic compounds as well as carotenoids. Nevertheless, carotenoids contribute to the antioxidant activity in the plants and humans even though their bioavailability follows a different mechanism and requires some fat as vehicle.

Conclusion

Cultivation of kale was feasible under all applied conditions, having no significant reduction in growth at locations with expected lower light intensities. Regarding the nutritional value it can be concluded that all samples contain healthy secondary plant metabolites, including phenolics, glucosinolates, and carotenoids. Kale is known for its, in general, high carotenoid concentration and therefore, its beneficial effects on human vision. Especially when aiming at lutein supply the location of cultivation site was wildly irrelevant while phenolic compounds, rather known for their general antioxidant and anti-inflammatory effects, are triggered by direct sunlight. Glucosinolates known for their anticarcinogenic effects, but also a pungent cabbage-like aroma, are low in kale and mainly not affected by the growing conditions in urban farming. However, indoor farming can presumably shield insects and light and preventing intensive glucosinolate accumulation. In summary, urban gardening offers a great way to provide consumers with fresh and healthy, fast-growing vegetables, especially for use as baby leaf salads.

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Conflict of interest

No potential conflict of interest was reported by the authors.

Note by the editor

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Appendix

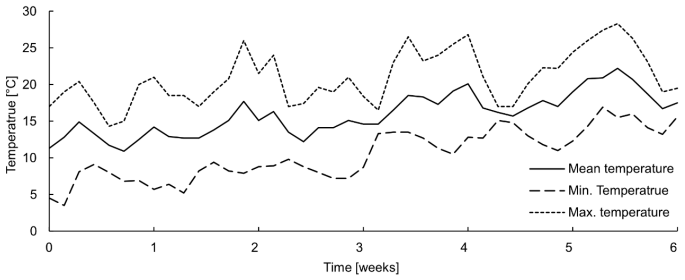

Fig. 1: Minimum, maximum and mean temperature measured at the Trollenhagen weather station (University of Applied Sciences Neubrandenburg) during the experiment.

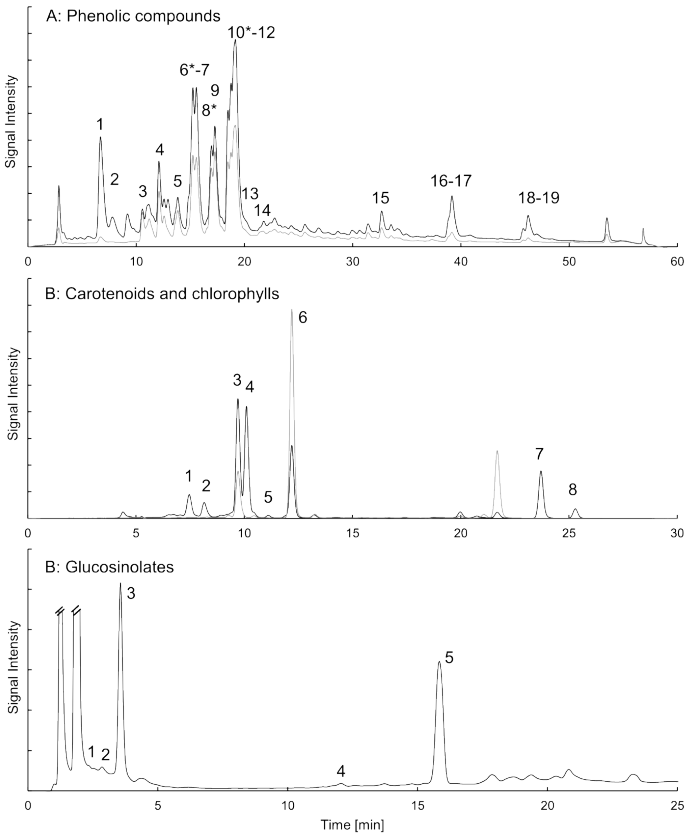

Fig. 2: Exemplary chromatograms of northern located kale (*Brassica oleracea* var. *sabellica* L.) samples, gathered after 6 weeks of growth. A: phenolic compounds measured at 330 nm (black line) and 370 nm (grey line); **1:** neochlorogenic acid, ***2:*** Q-3,7,4'-triglc, **3:** K-3-*O*-soph-7-*O*-glc, **4:** Q-3-*O*-soph-7-*O*-glc, **5:** K-3-*O*-hfer-soph-7-*O*-glc, **6:** K-3-*O*-hfer-soph-7-*O*-diglc; **6*:** Q-3,7-di-*O*-glc (shoulder peak at low concentration) **7:** K-3-*O*-caf-soph-7-*O*-glc **8:** Q-3-*O*-sin-soph-7-*O*-glc, **8*:** K-3-*O*-caf-soph-7-*O*-diglc (shoulder peak at low concentration), **9:** Q-3-*O*-soph-sin-7-*O*-diglc, **10:** K-3-*O*-sin-soph-7-*O*-glc, **10*:** Q-3-*O*-fer-soph-7-*O*-glc (small shoulder peak), **11:** K-3-*O*-sin-soph-7-*O*-diglc, **12:** K-3-*O*-fer-soph-7-*O*-glc, **13:** K-3-*O*-fer-soph-7-*O*-diglc, **14:** K-3-*O*-cou-soph-7-*O*-glc, **15:** I-glc, **16:** Disinapoyl-gentiobiose, **17:** Sinapoylferuloyl-gentiobiose, **18:** Trisinapoyl-gentiobiose, **19:** Disinapoylferuloyl-gentiobiose; B: Carotenoids and chlorophylls measured at 450 nm (grey line) and 660 nm (black line). Abbreviations referrer to footnotes explained in Tab. 2.; **1:** Violaxanthin, **2:** Neoxanthin, **3:** Chlorophyll b, 4: Lutein, **5:** Zeaxanthin, **6:** Chlorophyll b, **7:** (all-*E*)-β-Carotene, **8:** (9Z)-β-Carotene. C: Glucosinolates measured at 259 nm: **1:** Progoitin, **2:** Epirogoitin, **3:** Sinigrin, **4:** Glucobrassicanapin, **5:** Glucobrassicin.