Morphological and nutritional parameters of Chinese mustard (*Brassica juncea*) in hydroponic culture

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ABSTRACT: Chinese mustard is a perspective vegetable species due to its high nutritional value. The aim of this work was an evaluation of Chinese mustard assortment for hydroponic cultivation, comparison of morphological parameters and nutritional value of fresh leaves. The highest mean weight of one plant was shown in cv. Red Giant (179 g). The biggest leaves with the length of 459 mm were formed by cv. Ta Tou Tsai. The highest cultivar was Cai Cai Tai (1,063 mm), with an abundant number of leaves (57 leaves). Cv. Osaka Purple Leaf showed the highest content of vitamin C (738 mg/kg); the highest carotenoids content (899 mg/kg) was found in cv. Swollen Stem. The mean content of chlorophyll *a* was 2,804 mg/kg; for chlorophyll *b* it was 1,103 mg/kg. In addition, the results of the content of dry matter, K, Ca, Mg, Na and nitrates are presented in this work. The evaluations showed a significant effect of cultivar on morphological and most of nutritional parameters. Chinese mustard is also suitable for soilless cultivation.

Keywords: Chinese mustard; *Brassica juncea*; cultivars; nutritional value

Chinese mustard (*Brassica juncea* Czern) is an Asian leafy vegetable, which can be cultivated for its leaves, seeds or roots. This species is rich in many nutritional compounds including antioxidants, proteins and minerals.

Duke (2002) and USDA (2006) published the following contents (per 1 kg of f.w.) of selected compounds: 9.2% of dry matter; 512–5,565 mg Ca; 320–3,837 mg Mg; 3,540 mg K; 250 mg Na; 700 mg vitamin C; 63 mg carotene; and 99 mg of lutein. Ismail and Fun (2003) reported the content of vitamin C in the range of 1,147–1,240 mg/kg and beta-carotene content 19.9 mg/kg.

For oil extraction, this plant is grown in field conditions; as a vegetable, it can be cultivated indoor. Greenhouse culture can lead to an increase in yield, better earliness and controlled quality of consumed parts.

The aim of this work was an evaluation of hydroponic culture of Chinese mustard and an evaluation of selected morphological and nutritional parameters in different genotypes of this vegetable.

MATERIAL AND METHODS

Experiments were carried out in the greenhouse of the Mendel University of Agriculture and Forestry Brno, Faculty of Horticulture Lednice. An assortment of 13 cultivars (Table 1) was tested in an open hydroponic system in rockwool. Plants were grown on benches and irrigated by ebb-flood system four times per day. Mean nutrient solution composition was as follows (in mg/kg): 300 $N\text{-}NO_3$, 1 $N\text{-}NH_4$, 43 P, 391 K, 464 Ca, 87 Mg, 78 Na, 2.6 Fe, 0.3 Mn, 0.1 Zn, 0.1 Cu, 0.2 B. Level of pH was 5.8 and EC 2.5 mS/cm.

Sowing was performed in spring and autumn cultures – on 3rd May and on 30th August 2004 to the rockwool cubes (25 × 25 mm). Plants were grown at 22°/18°C day/night temperature. They were transferred to the rockwool cubes (100 × 100 × 75 mm) on 12th May and 7th September, respectively. Plant spacing was 0.25 × 0.25 m. Each cultivar was represented by 25 individually evaluated plants.

Mean temperature, relative air humidity and the length of sun radiation in the greenhouse were 19.4°C, 73%, and 16.1 hours in the spring culture and 17.3°C, 74%, and 10.7 hours in the autumn culture.

The harvest dates were 12th July and 30th November for spring and autumn cultivation, respectively. All evaluations and analyses were made immediately after harvest; for analyses whole leaves with petioles were used.

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Table 1. Description of evaluated cultivars

Cultivar	Origin	Colour and description
Bau Sin	Taiwan	green blade with thick white petioles
Cai Cai Tai	China	green blade
Grey Leaf Root Mustard	China	green blade, strong swollen stem
King Mustard	Taiwan	green blade with violent red nerves
Late Head Mustard	China	light green and small blade with wide swollen petioles
Mustard Spinach	Japan	green blade with strong middle white nerve
Osaka Purple	USA	green blade with light red nerves and white swollen petioles
Osaka Purple Leaf	Japan	green blade with light red nerves and white swollen petioles
Pink Stem Mustard	China	green blade with strong middle white nerve
Red Giant	USA	green blade with strong red middle nerve
Suehlihung No. 2	Taiwan	green dissected blade with strong middle white nerve
Swollen Stem	Japan	green blade with swollen petioles
Ta Tou Tsai	China	green blade with swollen middle white nerve

Vitamin C content was analysed by RP-HPLC (Ecom, CZ) in the column CGC Separon SGX C18 (Tessek, CZ), with size 150 × 4.6 mm; total carotenoids and chlorophyll *a* and *b* by spectrometry in the spectrometer Jenway (Jenway, Great Britain) according to Holm (1954); mineral elements by capillary isotachophoresis in the Ionosep (Ionosep, CZ). Content of dry matter was determined by drying at 105°C; nitrate content was analysed by Ion-selective electrodes in the Ionanalyser MPH 171 (Monokrystaly, CZ).

Statistical analyses were done by using ANOVA, LSD at 95% probability in Unistat (Unistat, USA).

RESULTS AND DISCUSSION

Cultivation period of spring culture was 71 days. Cultivars Bau Sin, Suehlihung No. 2 and Cai Cai Tai formed flowers in spring culture. Autumn culture lasted 92 days and no bolting was observed. Morphological description of leaves is shown in Table 1.

Morphological parameters

Mean weight of one plant was 177 g in the spring culture. The highest weight was in cv. Red Giant (179 g), while the lowest in Late Head Mustard (65 g).

In the case of the autumn culture, mean weight was 66 g. Data of both cultures are presented in Fig. 1. Significant differences were found among cultivars, and the effect of culture was significant as well. Plant yield was between 1.0 to 2.9 kg per m^2.

Results showed that Chinese mustard can be cultivated in soilless culture while producing acceptable plant yield. Several cultivars reached yield around 2 or 3 kg per m^2 (Red Giant, King Mustard, Ta Tou Tsai).

Plant height was significantly influenced by cultivar (Table 2). The highest cultivar was Cai Cai Tai (1,063 mm), while the smallest was King Mustard (338 mm). As for the height of plants in relation to the culture, the results show that in the spring, the

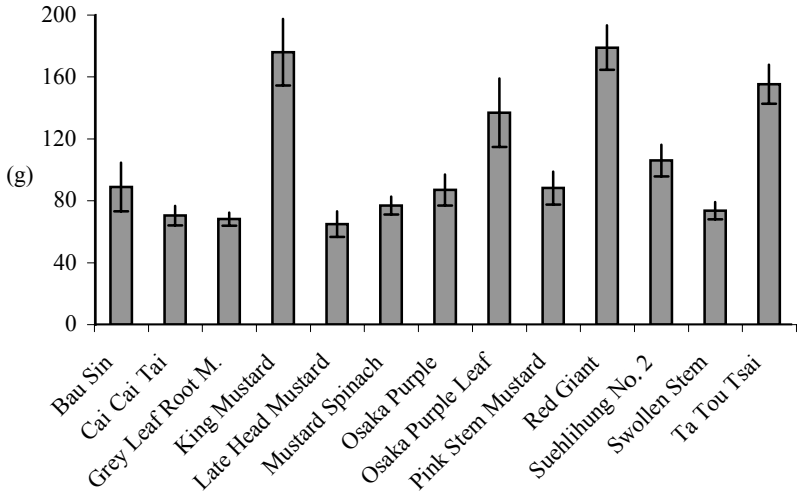

Fig. 1. Mean weight of one plant

Table 2. Mean parameters of Chinese mustard

Cultivar	Plant weight (g)	Plant height (mm)	Leaf length (mm)	No. of leaves (plant)
Bau Sin	88.9 ab	706 bc	305 b	8.4 a
Cai Cai Tai	70.5 a	1,063 e	155 a	56.5 c
Grey Leaf Mustard	68.2 a	524 abc	443 fg	9.0 a
King Mustard	175.8 d	338 a	441 fg	5.8 a
Late Head Mustard	65.0 a	358 a	293 b	5.3 a
Mustard Spinach	76.9 a	461 ab	400 def	10.8 a
Osaka Purple	87.4 a	523 ab	320 bc	6.7 a
Osaka Purple Leaf	137.2 bcd	761 cd	314 b	10.4 a
Pink Stem Mustard	88.3 ab	430 a	366 cd	9.6 a
Red Giant	178.9 d	673 bc	397 de	9.2 a
Suehlihung No. 2	105.8 abc	938 de	415 efg	26.3 b
Swollen Stem	73.7 a	358 a	315 bc	10.4 a
Ta Tou Tsai	155.3 cd	728 bcd	459 g	9.7 a

Different letters show significances among cultivars

mean height was 946 mm, while in the autumn it was only 369 mm.

Leaf length was represented by the mean values of 389 mm and 337 mm in the spring and autumn cultures, respectively (Table 2). Cultivar Cai Cai Tai had the shortest leaves (155 mm), on the other hand, the biggest leaves were found in Ta Tou Tsai (459 mm); the effect of cultivar was thus confirmed.

Mean number of leaves was 19 in spring culture and 8 in the autumn. The highest number was formed by cv. Cai Cai Tai (57 leaves), while the lowest number was found in cv. Late Head Mustard (5 leaves). The statistical effect of cultivar on this parameter was also confirmed. Data are showed in Table 2. In spring culture, the number of leaves was significantly higher if compared to the autumn cultivation. Such results are widely published in literature.

The content of selected compounds is shown in Table 3. Statistical differences are represented by different letters next to the means.

Mean content of dry matter was 6.5%. The variability was high – in cultivar Cai Cai Tai it was 8.6%, while Pink Stem Mustard had only 5.3%.

Mean content of potassium was 4,009 mg/kg in spring, as opposed to 3,795 mg/kg in autumn. The highest value was found in cv. Osaka Purple (4,429 mg), the lowest in cv. Mustard Spinach (2,945 mg). Similar values of K content reported Duke (2002) or USDA (2006).

The average content of calcium was 2,701 mg/kg and 1,374 mg/kg in spring and in autumn, respectively. Cai Cai Tai showed the highest value (3,414 mg), whereas Late Head Mustard the lowest (1,044 mg).

Mean magnesium content was 185 mg/kg in spring and 183 mg/kg in autumn; Cai Cai Tai showed 208 mg, and cv. Pink Stem Mustard 148 mg.

The content of sodium was also significantly different between seasons. While in spring, the mean was 386 mg/kg, in autumn it was only 262 mg/kg. Such

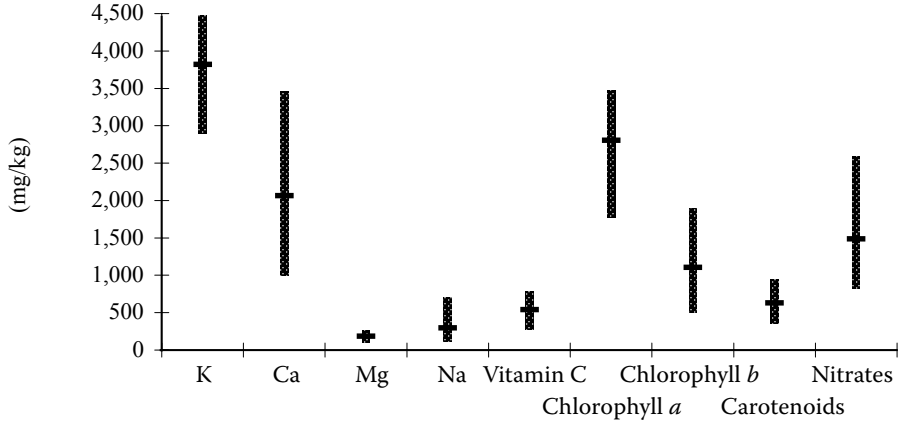

Fig. 2. Range of content of selected compounds in Chinese mustard

Table 3. Mean content of selected compounds (in F.W.)

Cultivar	Dry matter (%)	K	Ca	Mg	Na	Vitamin C	Chlorophyll *a*	Chlorophyll *b*	Carotenoids	Nitrates
		(mg/kg)								
Bau Sin	7.0 c	3,519 ab	2,696 bcd	149 a	560 b	429 ab	2,072 a	546 a	527 ab	968 ab
Cai Cai Tai	8.6 d	3,590 ab	3,414 d	208 b	178 a	472 abc	3,426 e	956 abcd	638 bc	1,433 cd
Grey Leaf Mustard	7.0 bc	3,898 bcd	1,737 abc	204 b	215 a	532 bcde	3,151 cde	1,685 de	622 bc	2,250 e
King Mustard	5.5 a	3,754 bc	2,023 abcd	191 b	233 a	671 ef	2,001 a	668 ab	409 a	1,168 bc
Late Head Mustard	5.4 a	3,868 bcd	1,044 a	163 ab	284 a	481 bc	1,828 a	693 abc	510 ab	2,533 e
Mustard Spinach	6.7 bc	2,945 a	1,167 a	175 ab	273 a	493 bcd	3,173 cde	1,529 cde	627 bc	1,050 abc
Osaka Purple	6.1 ab	4,429 d	1,508 ab	200 b	266 a	609 cde	3,123 cde	1,203 bcd	762 cd	1,542 d
Osaka Purple Leaf	6.6 bc	4,382 cd	1,836 abc	173 ab	164 a	738 f	2,537 b	1,059 bcd	673 bc	1,258 c
Pink Stem Mustard	5.3 a	3,595 abc	1,279 ab	148 a	298 a	544 bcde	2,873 bcde	1,606 cde	676 bc	1,167 abc
Red Giant	6.1 ab	4,227 bcd	2,137 abcd	196 b	247 a	580 cde	2,782 bc	1,001 abcd	621 bc	868 a
Suehlihung No. 2	7.0 bc	3,834 bcd	3,327 d	194 b	654 b	327 a	2,859 bcd	857 abc	577 b	1,065 abc
Swollen Stem	6.3 abc	4,106 bcd	1,345 ab	185 ab	284 a	493 bcd	3,317 de	1,836 e	899 d	1,733 d
Ta Tou Tsai	6.7 bc	3,516 ab	3,307 cd	205 b	196 a	654 def	3,309 de	695 abc	620 bc	2,267 e

levels are in agreement with previously reported results (USDA 2006). The highest level was found in cv. Suehlihung No. 2 (654 mg), the lowest in cv. Osaka Purple Leaf (164 mg).

Mean vitamin C content was 612 mg/kg in spring culture, in the autumn the recorded value was only 498 mg/kg. The highest and the lowest levels were 738 mg/kg and 327 mg/kg in cultivars Osaka Purple Leaf and Suehlihung No. 2, respectively. Data correspond to the literature, and are much higher if compared to many common leafy vegetables.

Total carotenoids mean content in spring and autumn cultures was 572 and 650 mg/kg, respectively. The highest level was recorded in cv. Swollen Stem (899 mg), while the lowest in King Mustard (409 mg).

Chlorophyll *a* mean content was 2,813 mg/kg in spring and 2,705 mg/kg in autumn culture. Cultivar Cai Cai Tai reached 3,426 mg, in contrast to 1,828 mg of cv. Late Head Mustard.

Mean content of chlorophyll *b* was 653 and 1,327 mg/kg in spring and autumn cultures, respectively. In this case, cv. Swollen Stem had the highest content (1,836 mg), while cv. Bau Sin the lowest (546 mg). Generally, more than double levels of chlorophyll *b* were found in the autumn culture.

Levels of nitrates were similar in both seasons; in spring, it was 1,433 mg, whereas in autumn 1,387 mg per kg. The highest level was recorded in cv. Late Head Mustard (2,533 mg) and the lowest in Red Giant (868 mg).

A significant effect of cultivar on contents of all analysed compounds was detected. Similar results were reported for other vegetables in Alasalvar et al. (2001) or Elkner and Kaniszewski (2001). The effect of growing season was confirmed in the contents of vitamin C, carotenoids, chlorophyll *b*, calcium, sodium, dry matter and nitrates. Influence of climatic conditions on the content of most nutritional compounds was previously described by Islam and Khan (2000).

Nitrate levels were highly correlated to the sun radiation and temperature in accordance to Escobar-Gutiérrez et al. (2002).

CONCLUSION

Chinese mustard can be cultivated in soilless system; it results from high yield of cultivars Red Giant or King Mustard. The effect of genotype on practically all observed parameters was confirmed. In some cases, differences in morphological parameters and levels of analysed compounds were more than 3-fold.

The importance of morphological parameters for economics of cultivation is high. According to the Chinese mustard type, there was a possibility to select suitable leaf cultivars with good relation between plant weight and number of leaves (e.g. Mustard Spinach, Osaka Purple Leaf or Swollen Stem).

Differences in nutritional values were confirmed within the evaluated assortment. Cultivars Cai Cai Tai and Osaka Purple Leaf showed good levels of selected compounds, whereas Red Giant and Bau Sin reached the lowest nitrate levels.

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Morfologické a nutriční parametry čínské hořčice (*Brassica juncea*) v hydroponické kultuře

ABSTRAKT: Čínská hořčice je perspektivní zelenina s ohledem na svou vysokou nutriční hodnotu. Cílem práce bylo zhodnocení sortimentu čínské hořčice v hydroponické kultuře a srovnání morfologických znaků a nutriční hodnoty čerstvých listů. Nejvyšší hmotnosti jedné rostliny dosáhla odrůda Red Giant (179 g); největší listy s délkou 459 mm vytvořila odrůda Ta Tou Tsai; nejvyšší byla odrůda Cai Cai Tai (1 063 mm), která se vyznačuje i značným počtem listů (57 na jedné rostlině). Nejvyšší obsah vitaminu C byl zjištěn u odrůdy Osaka Purple Leaf – 738 mg/kg; nejvyšší obsah karotenoidů – 899 mg/kg – byl nalezen u odrůdy Swollen Stem; průměrný obsah chlorofylu *a* byl 2 804 mg/kg, obsah chlorofylu *b* byl 1 103 mg/kg. Jsou uvedeny zjištěné výsledky obsahu sušiny, K, Ca, Mg, Na a dusičnanů. Práce potvrdila průkazný vliv odrůdy na morfologické parametry a na většinu nutričních parametrů, stejně tak ukázala na možnost ekonomicky perspektivního pěstování v hydroponických podmínkách.

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