Folia Hort. 31(2) (2019): 365-374

DOI: 10.2478/fhort-2019-0029

FOLIA HORTICULTURAE

Published by the Polish Society
for Horticultural Science since 1989

ORIGINAL ARTICLE | Open access | http://www.foliahort.ogr.ur.krakow.pl

The influence of genotype and season on the biological potential of chilli pepper cultivars

Tomáš Kopta[1], Miroslav Šlosár[2], Alena Andrejiová[2], Miloš Jurica[1], Robert Pokluda[1]*

[1] Department of Vegetable Growing and Floriculture, Faculty of Horticulture
Mendel University in Brno, Valticka 337, 69144 Lednice, Czech Republic
[2] Department of Vegetable Production, Faculty of Horticulture and Landscape Engineering
Slovak University of Agriculture in Nitra, Tulipánová 7, 94976 Nitra, Slovak Republic

ABSTRACT

The aim of this work was to evaluate the yield parameters (number of fruits per plant, total yield per plant and average fruit weight), level of ascorbic acid, and pungency (SHU units) of different genotypes of chilli pepper in protected cultivation in the Czech Republic in order to identify a suitable and prospective chilli cultivar which could be recommended to the Central European growers. The experiment took place in two years (2016 and 2018) in a plastic greenhouse with 17 genotypes of the species *Capsicum chinense* Jacq., *C. annuum* L., *C. baccatum* L. and *C. pubescens* Ruiz. & Pav. From the viewpoint of yield parameters and stability of yield, 'Habanero Red', 'Jamaican Yellow', 'Jwala' and 'Rocoto Orange' can be recommended for Czech conditions. The majority of the tested cultivars were a good source of vitamin C (mostly reaching a value of at least 800 mg kg^{-1}). From the perspective of pungency, the following cultivars can be recommended: low pungency – Fish, Jalapeño, Jwala, Pimiento de Padrón and Rocoto Orange; medium pungency – Cayenne Gold, NuMex Piñata and Scotch Bonnet Orange; and high pungency – Aji Lemon Drop, Cayenne Purple, TMSR and Tricolor Variegata.

Key words: *Capsicum* spp., capsaicin, SHU units, vitamin C, yield

INTRODUCTION

The genus *Capsicum* includes approximately 32 species of pepper, including five domesticated species: *Capsicum annuum* L., *Capsicum pubescens* Ruiz. & Pav., *Capsicum frutescens* L., *Capsicum chinense* Jacq., and *Capsicum baccatum* L. (Barboza, 2011). Perry et al. (2007) have documented microfossils from chilli pepper fruits as being 6000 years old.

Pepper production is found from the humid tropics to dry deserts and cool temperate climates. Peppers can be grown as an annual or perennial crop, outside in open fields or under protective cover. The ability of peppers to grow and produce a quality crop in such a wide range of climates has made them a common crop worldwide, and their annual production has increased substantially over the years (Bosland and Votava, 2012).

The main producers of dried chillies and peppers are mainly in Asia (70% of total production), with India and China accounting for the largest share, but Peru (4.7%) and Africa (21%) are also major producers. Imports of fresh chilli peppers from developing countries to the European market are in

*Corresponding author.
e-mail: tomas.kopta@mendelu.cz (T. Kopta).

sciendo

the region of 30-40 thousand tonnes a year. Spain, Germany and the United Kingdom are the main importers of chilli peppers from non-European countries. Besides being the largest importer, Spain is also the main European producer of chillies (CBI, 2016).

Even though the production of chilli peppers in the Czech Republic is minimal, smaller growers in particular are trying to enter the market by growing special species of pungent peppers (Buchtová, 2018).

Peppers are an excellent source of antioxidants such as flavonoids, capsaicinoids, vitamin C and carotenoids (Russo, 2012; Škrovánková et al., 2017). In comparison with other species of vegetable, peppers are among those with the highest antioxidant activity (Halvorsen et al., 2002). Over 30 carotenoid pigments have been found in chilli peppers. (Stommel and Griesbach, 2008). The carotenoid content is affected by genetic, physiological and developmental factors, and also the environment in which they are grown (Russo, 2012).

Peppers contain, in particular, a large amount of vitamin C and provitamin A, vitamin E, thiamine (B_1), riboflavin (B_2) and niacin (B_3) (Mozafar, 1994). Vitamin C is needed for normal physiological functions in the human body and protects it from various deleterious effects of free radicals, pollutants and toxins (Dunitz, 1996). A deficiency of this vitamin is often associated with many health problems (Chambial et al., 2013).

A wide range of factors such as the genotype as well as pre-harvest and post-harvest conditions influence ascorbic acid content (Lee and Kader, 2000; Valšíková and Paulen, 2013). According to Bartz and Brecht (2003), ascorbic acid stability is affected by a variety of factors, including heat, light, oxygen, enzymes and pH.

Vitamin C content rises during fruit maturation. The content is also affected by the climatic conditions in which the fruit is grown. The amount of vitamin C is very susceptible to post-harvest handling and storage methods, because it gradually degrades in the fruits (Bosland and Votava, 2012). Most studies of antioxidant losses have investigated ascorbic acid, since it is the most labile of all antioxidants (Hodges, 2003; Škrovánková et al., 2015).

Capsaicinoids are alkaloids that are specific to the genus Capsicum. They are synthesised on the fruits' placenta and are the source of their pungency (Russo, 2012). Capsaicinoids are compounds without taste or smell, and have no nutritional value (Bosland and Votava, 2012). However, not all species of the Capsicum genus produce capsaicinoids (Tewksbury et al., 2006). More than 20 individual capsaicinoids have been identified in chilli peppers (Schweiggert et al., 2006). The most pungent of them are capsaicin and dihydrocapsaicin, and together they constitute more than 80% of the capsaicinoid content (Topuz and Ozdemir, 2007), with capsaicin accounting for around 71% of the total capsaicinoids (Al Othman et al., 2011). The synthesis of capsaicinoids usually begins a week after the fruits begin forming and continues until the placenta evolves. Capsaicinoids reach their maximum concentration approximately 40-50 days after the fruits begin forming (Barrera et al., 2008). The capsaicinoid content in pungent chilli peppers is regarded as the main indicator of quality (Materska and Perucka, 2005). Capsaicin is used to cure serious chronic illnesses, migraines, osteoarthritis, or for lowering cholesterol levels (Bosland and Votava, 2012). The capsaicinoid content in fruits is strongly dependent on the genotype, developmental stage, and natural conditions (Barrera et al., 2008). Capsaicin in chilli peppers is distributed throughout the fruit, its highest concentration being in the placental tissue in the seeds (De Krishna, 2003).

The main objective of this work was evaluation of the yield parameters, level of ascorbic acid, and pungency, recorded in Scoville Heat Units (SHU), of different chilli cultivars under protected cultivation in the Czech Republic in two production years in order to identify suitable and stable chilli cultivars which could be recommended to Central European growers.

MATERIAL AND METHODS

The experiment took place in two years (2016 and 2018) in a plastic greenhouse in the municipality of Ladná (GPS 48°48'04.8"N 16°52'36.3"E). The experimental site is at an elevation of 160 metres above sea level. Meteorological data from the closest weather stations are shown in Table 1. Technical parameters of the plastic greenhouse: size 50 × 10 m, height 3.2 m, foil cover thickness 0.17 mm, with UV stabilisation.

The chilli pepper cultivars used for the experiment are listed in Table 2. The sowings took place at the beginning of January in plastic sowing dishes filled with sowing substrate (AGRO CS a.s.) mixed with perlite at a ratio of 3:1. During germination, the temperature was held at around 30°C, and after the formation of cotyledons, it was held at 20-25°C. The plants were at first transferred

Table 1. Meteorological data

Year	Average temperature in the vegetation period (April-October) (°C)	Total time in sunlight (h)	Time in sunlight for the vegetation period (April-October) (h)
2016	16.0	1860	1476
2018	18.3	2067	1732

Source: Vachůn (2019)

Table 2. Chilli genotypes

Species	Cultivar
Capsicum chinense Jacq.	Habanero Chocolate
	Jamaican Yellow
	Habanero Red
	Naga Morich
	TMSR
	Scotch Bonnet Orange
	Carolina Reaper
Capsicum annuum L.	NuMex Piñata
	Fish
	Cayenne Purple
	Jwala
	Jalapeño
	Tricolor Variegata
	Cayenne Gold
	Pimiento de Padrón
Capsicum baccatum L.	Aji Lemon Drop
Capsicum pubescens Ruiz. & Pav.	Rocoto Orange

into seed trays and later re-planted in containers measuring 0.10 × 0.10 m.

In the autumn, there was deep ploughing (0.4 m), in the spring stubble clearance. On the test plot, there was soil amelioration according to norms (NPK + MgO, + S: 8-13-11 + 2, + 15, with B, Cu, Mo and Zn). A non-woven fabric was used as mulch to limit the evaporation of water and restrict weeds. Drip irrigation was used for the entire cropping time. Planting in the polytunnel took place in the second half of April, in 0.25 × 0.30 m double rows. Before the first harvest, three average plants from each genotype were selected and labelled.

Growth parameters (number of fruits per plant, total yield per plant, and average fruit weight) and analytical parameters (ascorbic acid and SHU units) were evaluated. Collection of fruits took place once a week during the period of July to October. Fruits were harvested in botanical ripeness. The harvested fruits were counted and then weighed.

The HPLC method according to Sawant et al. (2010) was used for the determination of ascorbic acid (vitamin C). The analyses were performed by RP-HPLC in a C18 column at 254 nm using a UV-vis detector (ECOM, CZ). Sample preparation: 10 g of fresh sample were mixed with 0.1 M oxalic acid and made up to 100 ml in a flask. Before HPLC analysis, the samples were centrifuged and filtered. The results were calculated on a fresh weight (FW) basis.

For the HPLC analysis of capsaicin in chilli peppers, the official AOAC Method 995.03 was used (AOAC, 2005) with the above-mentioned HPLC system at the 280 nm wavelength.

Sample preparation: 5 g of dried and crushed peppers was mixed with 50 ml of 96% ethanol, placed in a water bath and kept at 80° C for 4 hours, then cooled. For the calculation of SHUs (Scoville Heat Units), the capsaicin and dihydrocapsaicin contents (μg g^{-1}) were multiplied by 15 ((capsaicin + dihydrocapsaicin) × 15).

Data were compared using analysis of variance (ANOVA) at a significance level of $p \leq 0.05$. When significant differences were detected between the treatments, the averages were compared using the Scheffe test (Statistica 12.0, StafSoft).

RESULTS AND DISCUSSION

Yield parameters

The evaluation of yield parameters is shown in Figures 1-3. It is obvious that differences between the cultivars and years have been confirmed.

The cultivars with the lowest number of fruits per plant included Carolina Reaper, Jalapeño, Naga Morich, NuMex Piñata, Pimiento de Padrón and Rocoto Orange. On the other hand, the highest amount of fruits per plant was achieved by Aji Lemon Drop, Cayenne Purple and Tricolor Variegata. Even though differences in the amount of fruits within a single cultivar were evident, there was no statistical difference between the individual years.

Muñoz-Ramirez et al. (2018) give the amount of fruits per plant in Mexican conditions, when covered, as 109 for TMSR and 98 for Carolina Reaper. Bartz et al. (2017) set the range for the Scotch Bonnet Orange at 107-713 fruits per plant

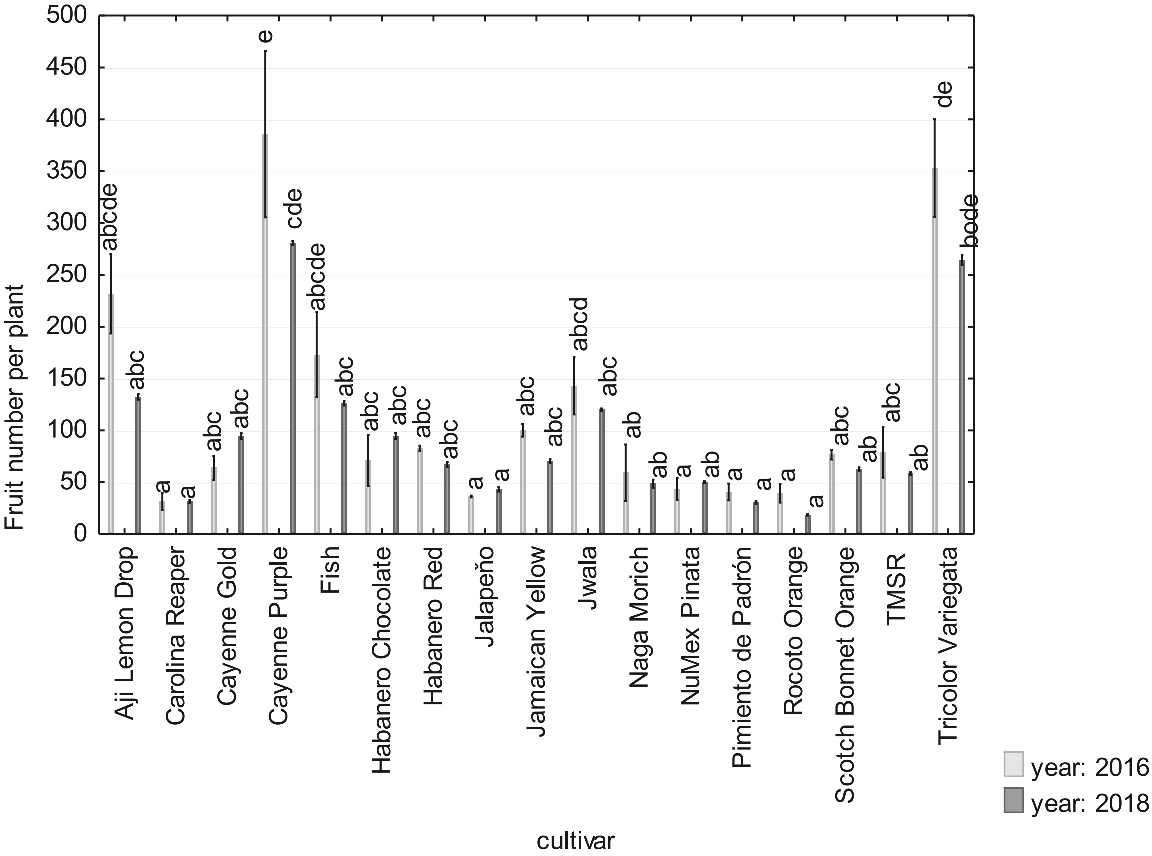

Figure 1. Number of fruits per plant (mean values +/- SE; different letters represent significant ($p < 0.05$) differences)

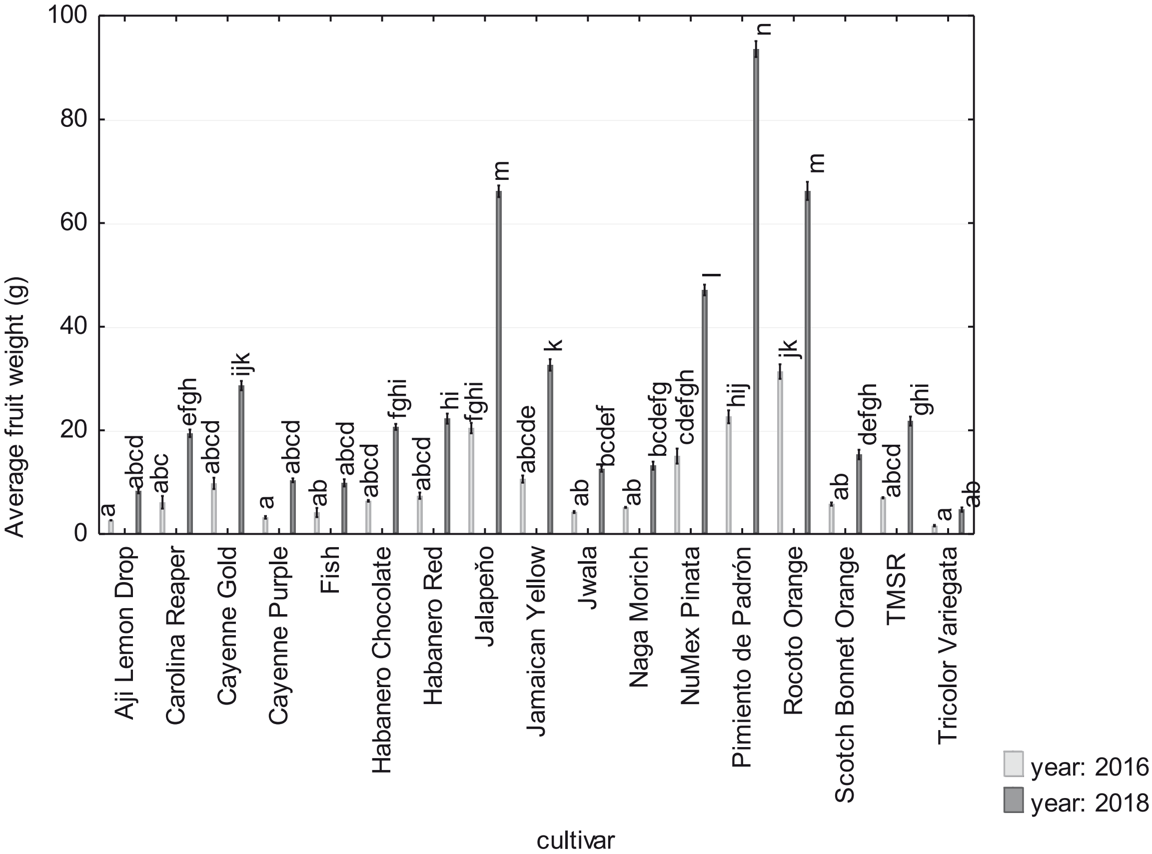

Figure 2. Average fruit weight (mean values +/- SE; different letters represent significant ($p < 0.05$) differences)

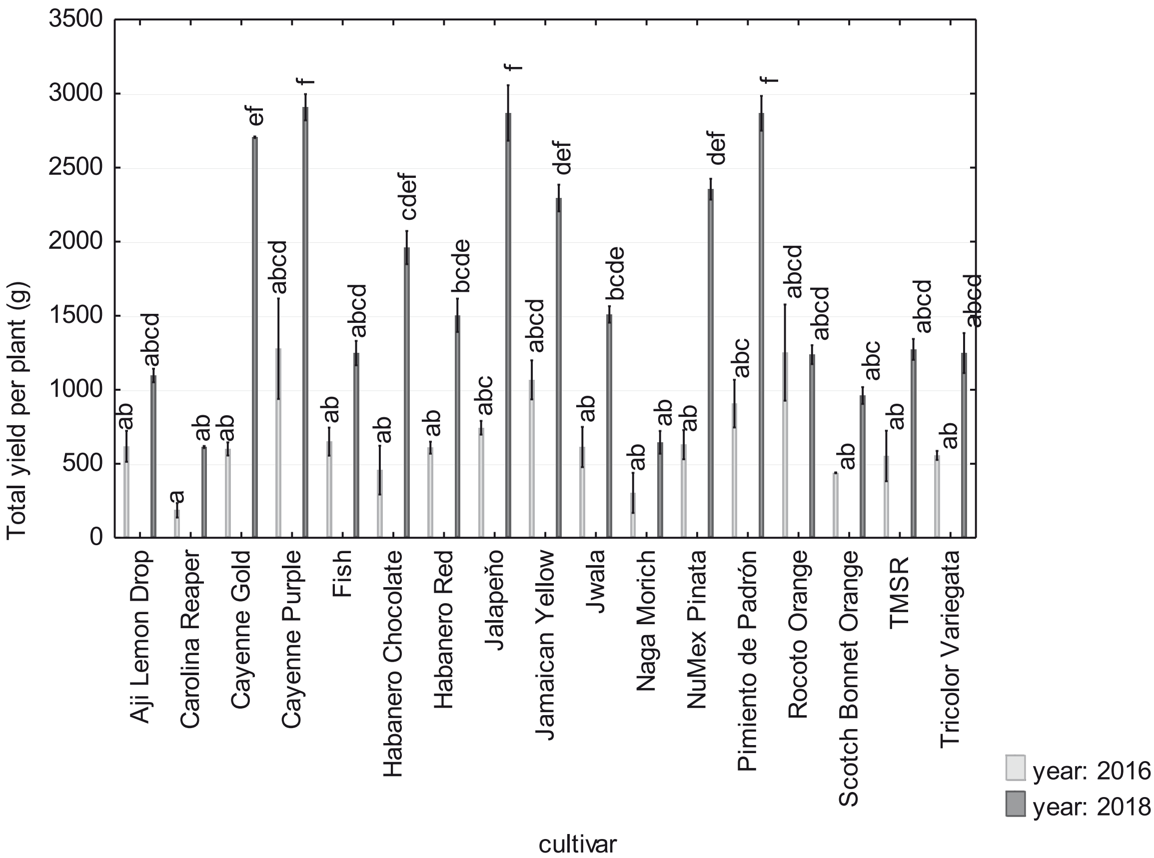

Figure 3. Total yield per plant (mean values +/- SE; different letters represent significant ($p < 0.05$) differences)

under Jamaican conditions. Chaudhary et al. (2006) give the figure for the Jwala as 100 fruits per plant. Bhuyan et al. (2015) state 91-210 fruits per plant for the Naga Morich.

Our findings are close to the compared values, even surpassing the cited value for the Jwala cultivar. The variability in the number of fruits among the individual years was not statistically significant. All the cultivars that reached at least fifty fruits per plant can be assessed as having economic potential, in case the producers are interested only in yield parameters. If there is need to harvest fruits for high pungency, even the less productive cultivars (Carolina Reaper) are prospective candidates.

The average fruit weight ranged from a few grams ('Aji Lemon Drop' and 'Tricolor Variegata') to many tens of grams ('Jalapeño', 'NuMex Piñata', 'Pimiento de Padrón' and 'Rocoto Orange'). An important role in the values found was played by the year. In all the cultivars, with the exception of Aji Lemon Drop, Cayenne Purple, Fish, Jwala, Naga Morich and Tricolor Variegata, a decidedly larger size of fruits was found in 2018 in comparison with 2016. In 2016, the average weight of fruits of the tested genotypes ranged from 1.6 to 31.3 g, whilst in 2018 it was in the range 4.7-93.6 g.

Troconis-Torres et al. (2012) give the average weight of fruits for the Jalapeño as between 26 and 47 g, depending on the locality, and 8.1 g for the Habanero cultivar. Muñoz-Ramirez et al. (2018) have stated the weight for 'TMSR' as 7.8 g, and for the 'Carolina Reaper' as 3.7 g. Bhuyan et al. (2015) give a range of 3.5-10 g for 'Naga Morich'. The values found in our study corresponded, in most cases, to the cited sources. For the cultivars Aji Lemon Drop, Cayenne Purple, Fish, Jwala, Naga Morich and Tricolor Variegata, stability of production can be expected even in changing conditions (temperature and sunlight), thanks to the lower variability in the individual years.

The lowest value of the total yield per plant was found in the Carolina Reaper cultivar (186 g) in 2016, and the highest in the Cayenne Purple cultivar in 2018 (2907 g). In all the cases, a tendency for a higher total yield was displayed in 2018; however, this was statistically confirmed only for the cultivars Cayenne Gold, Cayenne Purple, Habanero Chocolate, Jalapeño, NuMex Piñata and Pimiento de Padrón. In 2016, the yield of the tested genotypes was in the range of 186-1276 g, whilst in 2018 it was in the range of 613-2907 g. The cultivars Aji Lemon Drop, Carolina Reaper, Fish, Habanero

Table 3. Summary of analysis of variance for yield parameters in two years of cultivation

Source of variance	Number of fruits per plant	Total yield per plant	Average fruit weight
Cultivar	***	***	***
Year	**	***	***
Cultivar × year	NS	***	***

Differences in yield parameters depending on the cultivar and year according to the Scheffe test; non-significant (NS) or significant at $p \leq 0.05$ (*), 0.01 (**) or 0.001 (***), respectively

Red, Jamaican Yellow, Jwala, Naga Morich, Rocoto Orange, Scotch Bonnet Orange, TMSR and Tricolor Variegata did not conclusively differ in yield in the individual years, which points to their potential for guaranteed production even under changing growing conditions (temperature and sunlight).

Kirk and Gu (2011) describe a total yield per plant for Jalapeño in the range of 296-1608 g. Muñoz-Ramirez et al. (2018) have values of 847 g for 'TMSR' and 363 g for 'Carolina Reaper'. Bhuyan et al. (2015) found a total yield for 'Naga Morich' in the range of 455-1851 g. For the rest of the yield parameters, reference values for the remaining cultivars tested are not available.

From the multi-factorial analysis of variance (Tab. 3), it was found that, based on the total yield per plant and average fruit weight, there was a highly significant influence of the cultivar, year and the interaction of cultivar × year. In the case of the number of fruits per plant, the interaction effect (cultivar × year) was not significant.

From the rating of yield parameters, a considerable variability can be seen between the production seasons. While in 2016 the growing season was colder, with a lower average temperature and fewer hours of sunlight, in 2018 it was the reverse (Tab. 1). In the warmer year of 2018, most cultivars responded by increasing the weight of fruits and consequently gave a higher total yield per plant. The need for higher temperature and longer duration of sunlight for ideal growth and development can be anticipated due to the origin of the cultivars. An understanding of the ability of the individual cultivars to give a stable yield even in different growing conditions can serve as the key for choosing cultivars ideal for the conditions in the Czech Republic, as well as in other Central European countries, which is not the original area of pepper growing, and where the necessary temperature and light requirements cannot always be met. The number of fruits and total yield can directly affect the economic balance of production. From the perspective of yield parameters, the ideal cultivars for Central European countries include: Aji Lemon Drop, Carolina Reaper, Fish, Habanero Red, Jamaican Yellow, Jwala, Naga Morich, Rocoto Orange, Scotch Bonnet Orange, TMSR and Tricolor Variegata. The recommended cultivars have been chosen based on their stability in the yield parameters in both years of production.

Analytical parameters

The cultivar with the lowest vitamin C content is Rocoto Orange, with an average of 47.9 mg kg^{-1} (year 2016) (Fig. 4). The overwhelming majority of the rated cultivars reached in both years a value of at least 800 mg kg^{-1}, and the cultivars with the highest content include Cayenne Purple in 2018 (2176 mg kg^{-1}), Jwala in 2016 (2194 mg kg^{-1}) and Pimiento de Padrón in 2016 (2197 mg kg^{-1}). Aside from the cultivars Aji Lemon Drop, Cayenne Gold, Jalapeño and Rocoto Orange, there is a significant difference in vitamin C content between the individual years. In most cases ('Carolina Reaper', 'Habanero Chocolate', 'Habanero Red', 'Jamaican Yellow', 'Jwala', 'NuMex Piñata', 'Pimiento de Padrón', 'Scotch Bonnet Orange' and 'TMSR'), the vitamin C content was higher in 2016, whilst in the case of the remaining cultivars (Cayenne Purple, Fish, Naga Morich, Tricolor Variegata) this was true for the year 2018.

Kantar et al. (2016) compared a wide range of cultivars, with these results for vitamin C content: TMSR 1550 mg kg^{-1}, Scotch Bonnet Orange 397 mg kg^{-1}, Naga Morich 1603 mg kg^{-1}, Habanero Chocolate 443 mg kg^{-1}, Habanero Red 583 mg kg^{-1} and Jamaican Yellow 633 mg kg^{-1}. Apart from TMSR and Naga Morich, all the compared cultivars showed higher levels of vitamin C content in the current rating. With the exception of the Rocoto Orange cultivar, all of them can be identified as a great source of vitamin C. Compared to red sweet pepper (1277 mg kg^{-1}, USDA 2019), eight of the tested chilli cultivars were higher in vitamin C content.

When rating pungency, significant differences were found between the cultivars (Fig. 5). In the overwhelming majority of the evaluated cultivars, the degree of pungency reached 100 000 SHU, with the most pungent being the 'Carolina Reaper'

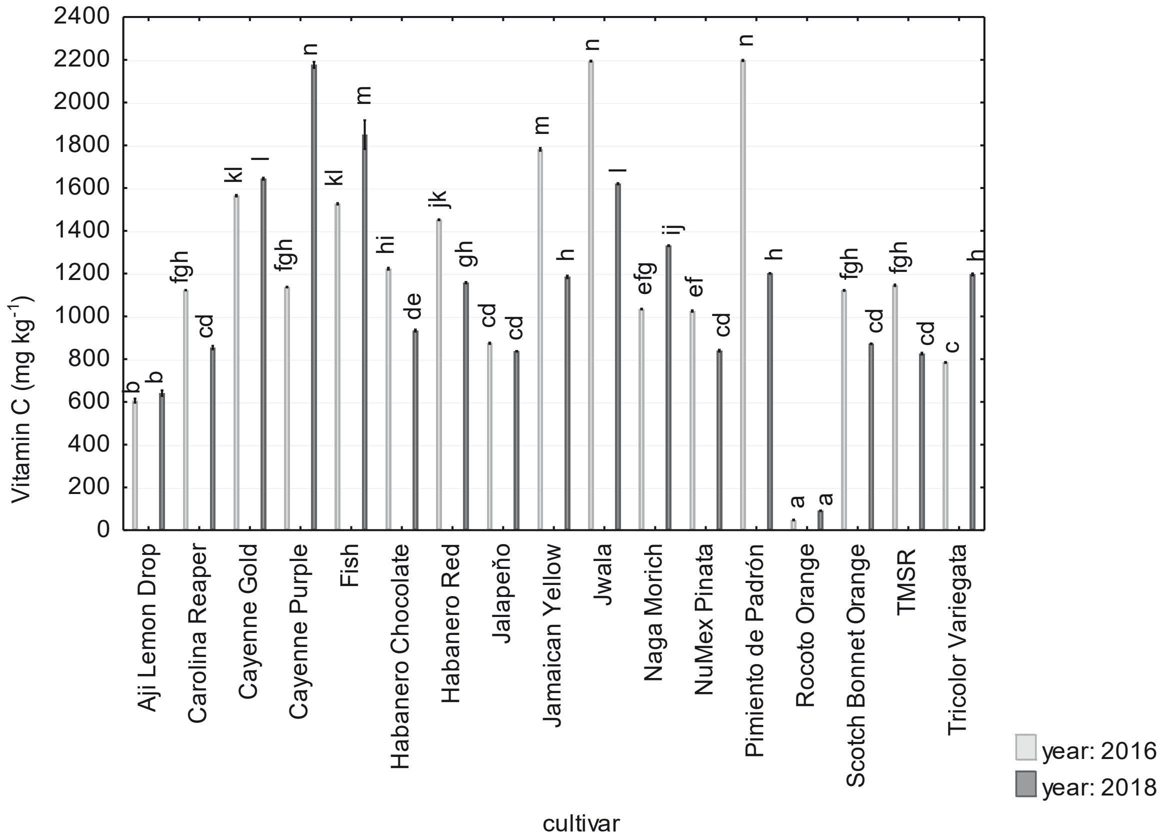

Figure 4. Vitamin C content (mean values +/- SE; different letters represent significant ($p < 0.05$) differences)

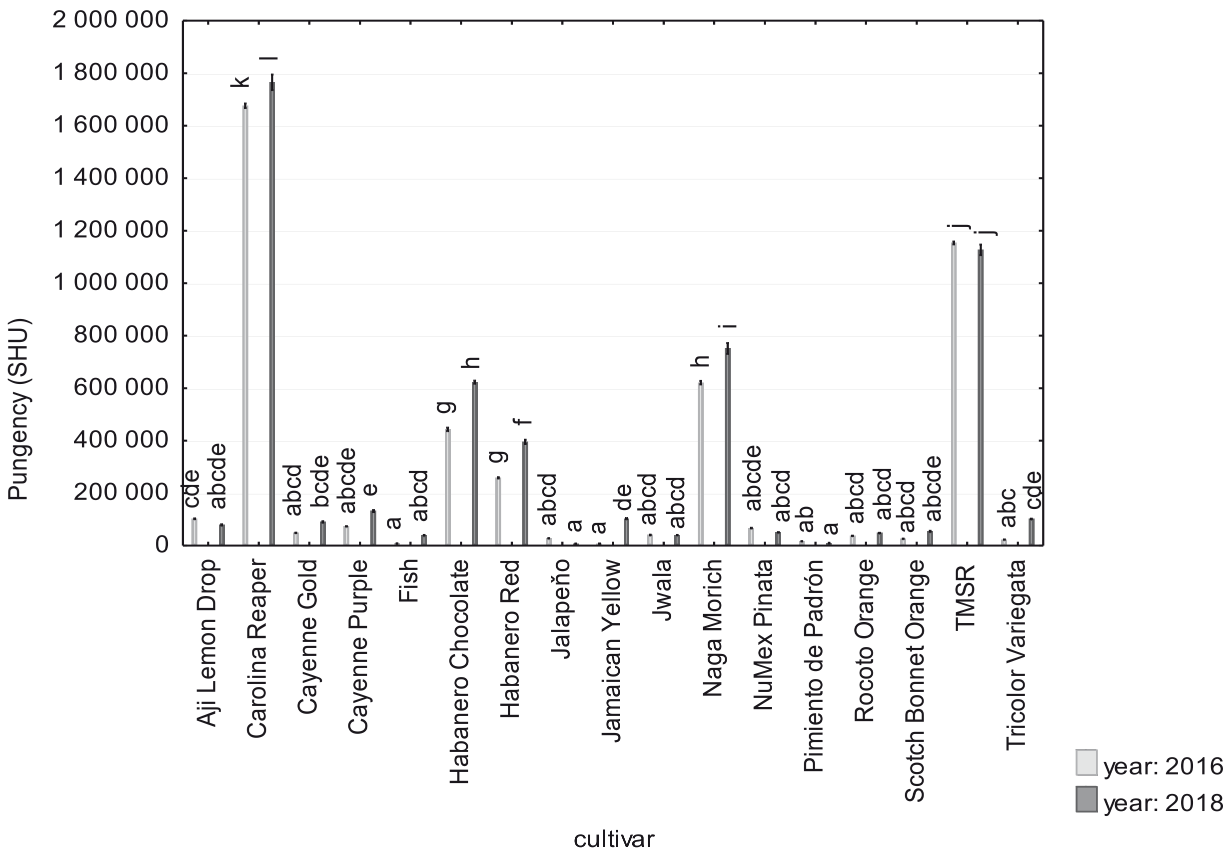

Figure 5. Pungency of chilli peppers (mean values +/- SE; different letters represent significant ($p < 0.05$) differences)

with a value of 1 765 463 in 2018. A difference in pungency between the individual years was recorded in only 5 cultivars (Carolina Reaper, Habanero Chocolate, Habanero Red, Jamaican Yellow and Naga Morich), with a higher value of SHU being achieved in all these cases in 2018.

Kantar et al. (2016) give the following values of SHU for the chosen cultivars: TMSR 604 312, Scotch Bonnet Orange 599 329, Naga Morich 582 422, Habanero Chocolate 521 007, Habanero Red 588 728 and Jamaican Yellow 215 656. Apart from the cultivars Scotch Bonnet Orange and Jamaican Yellow, where the values are significantly lower than the cited figures, the other values are comparable. Another author (Do et al., 2017) gives a value for Carolina Reaper of 2 056 026 SHU, which is slightly higher than the figure found in this study.

From the multi-factorial analysis of variance (not shown), it follows that a highly significant influence of the cultivar, year and the interaction of cultivar × year on vitamin C and pungency was found.

According to Bartz and Brecht (2003), vitamin stability in fruits and vegetables is affected by a variety of factors, including heat, light, oxygen, enzymes and pH. Most studies of antioxidant losses have investigated vitamin C, since it is the most labile of all antioxidants (Hodges, 2003). Some cultivars could have responded to the different growing conditions in the two years (temperature) with a different level of vitamin C synthesis. In this study, there is probably a combination of several factors affecting the vitamin C content (temperature, light, genotype, irrigation etc.).

Phimchan et al. (2012) indicate that drought stress is well recognised as an environmental condition that influences the accumulation of capsaicinoids. According to Al Othman et al. (2011), the capsaicin content in chilli peppers can vary depending on the temperature at which the pepper is grown, the age of the fruit, and the light. In 5 of the chilli pepper cultivars in this study, a higher level of pungency was found in 2018, which in comparison with 2016 was warmer, with a higher amount of sunlight. There was no difference found in the other genotypes. Phimchan et al. (2012) further state that the capsaicin content in drought-stressed plants of the low- and medium-pungency cultivars was significantly higher compared to the control variants, but the capsaicin content in high pungency cultivars decreased under drought stress, although not significantly. It seems that more factors, such as drought stress level, rainfall, age of plant, fruit size, increase in cultivation temperature, solar radiation, land elevation, cultivar, and others influence the capsaicin content (Tewksbury et al., 2006; Gurung et al., 2011; Bosland and Votava, 2012; Phimchan et al., 2012; González-Zamora et al., 2013).

CONCLUSIONS

According to the evaluation of the yield parameters of the chosen chilli cultivars in Czech conditions, the following findings can be stated. We can classify Jalapeño, NuMex Piñata, Pimiento de Padrón and Rocoto Orange as cultivars with the highest average fruit weight; however, from the viewpoint of production stability, thus guaranteeing minimal variability in the size of fruits in the individual production years, the cultivars Aji Lemon Drop, Cayenne Purple, Fish, Jwala, Naga Morich and Tricolor Variegate can be recommended.

The cultivars Aji Lemon Drop, Carolina Reaper, Fish, Habanero Red, Jamaican Yellow, Jwala, Naga Morich, Rocoto Orange, Scotch Bonnet Orange, TMSR and Tricolor Variegata did not conclusively differ in the total yield per plant between the individual years. The most profitable of these stable cultivars were Habanero Red, Jamaican Yellow, Jwala and Rocoto Orange. Aside from the Rocoto Orange cultivar, all of them can be identified as good sources of vitamin C.

Apart from the cultivars Carolina Reaper, Habanero Chocolate, Habanero Red, Jamaican Yellow and Naga Morich, all the other cultivars can be identified as stable from the viewpoint of pungency between the individual years. When growing the above-mentioned cultivars, a high capsaicin level should be expected, although with some variability between production seasons. Therefore, for capsaicinoid concentration, we can recommend cultivars that are adapted over a wide range of environments: low pungency – Fish, Jalapeño, Jwala, Pimiento de Padrón and Rocoto Orange; medium pungency – Cayenne Gold, NuMex Piñata and Scotch Bonnet Orange; and high pungency – Aji Lemon Drop, Cayenne Purple, TMSR and Tricolor Variegata.

FUNDING

This paper was supported by the project CZ.02.1.01/0.0/0.0/16_017/0002334 Research Infrastructure for Young Scientists, co-financed by the Operational Programme Research, Development and Education and by Project IGA-ZF/2019-AP004 from Mendel University in Brno.

AUTHOR CONTRIBUTIONS

T.K. – designed the experiments, interpreted the data, performed statistical analysis and wrote the paper; M.J. – discussed the results, gave technical support; M.S., A.A. – discussed the results, contributed to manuscript writing; R.P. – gave conceptual advice and commented on the manuscript.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

REFERENCES

Al Othman Z.A., Ahmed Y.B., Habila M.A., Ghafar, A.A., 2011. Determination of capsaicin and dihydrocapsaicin in Capsicum fruit samples using high performance liquid chromatography. Molecules 10, 8919-8929.

AOAC (Official Methods of Analysis), 2005. 18th edition. AOAC INTERNATIONAL, Gaithersburg, MD, USA, Method 995.03.

Barboza G.E., 2011. Lectotypifications, synonymy, and a new name in *Capsicum* (Solanoideae, Solanaceae). PhytoKeys (2), 23-38.

Barrera J.A., Hernandez S., Melgarejo L.M., Martinez O., Fernandez-Trujillo J.P., 2008. Physiological behavior and quality traits during fruit growth and ripening of four Amazonic hot pepper accessions. J. Sci. Food Agric. 88, 847-857.

Bartz J.A., Brecht J.K., 2003. Postharvest Physiology and Pathology of Vegetables. 2nd edition. M. Dekker (Ed), New York, USA, 733.

Bartz W.C., Evans T.A., Murphy C.A., Pill W.G., 2017. The effects of pruning and potassium fertilisation rate in the greenhouse production of Scotch bonnet pepper (*Capsicum chinense* Jacquin). J. Appl. Hortic. 19 (2), 119-124.

Bhuyan M.H.M.B, Rahman S.M.L, Ara R., Sarker J.C., 2015. Evaluation of Naga Chilli (*Capsicum chinense* Jacq.) genotypes for under North eastern region of Bangladesh. Sci. Agric. 12(1), 40-45.

Bosland P.W., Votava E.J., 2012. Peppers: Vegetable and Spice Capsicums. 2nd edition. CABI, Wallingford, UK. Crop production science in horticulture series, 22.

Buchtová I., 2018. Situační a výhledová zpráva. Praha, Ministerstvo Zemědělství České Republiky, 2018.

CBI, Product Factsheet. CBI Ministri of Foreign Affairs. The Netherlands: CBI Market Intelligence, 2016. https://www.cbi.eu/sites/default/files/market_information/researches/product_factsheet_-_chillies_in_europe_2016.pdf. Accessed 9 April 2017.

De Krishna A., 2003. Capsicum: the genus Capsicum. Taylor & Francis, London, UK.

Do T., Lacková Z., Adam V., Zítka O., 2017. Determination of the content of capsaicin and dihydrocapsaicin in twelve varieties of chilli peppers using liquid chromatography with UV/VIS detection. In MendelNet 2017, Proc. Int. PhD Students Conf. Brno, Mendel University in Brno, 861-866.

Dunitz J.D., 1996. Linus Carl Pauling. 28 February 1901-19 August 1994. Biogr. Mem. Fellows R. Soc. 42, 316-338.

González-Zamora A., Sierra-Campos E., Luna-Ortega J.G., Pérez-Morales R., Ortiz J.C.R., García-Hernández J.L., 2013. Characterization of different capsicum varieties by evaluation of their capsaicinoids content by high performance liquid chromatography, determination of pungency and effect of high temperature. Molecules 18(11), 13471-13486.

Gurung T., Techawongstien S., Suriharn B., Techawongstien S., 2011. Impact of environments on the accumulation of capsaicinoids in *Capsicum* spp. HortScience 46(12), 1576-1581.

Halvorsen B.L., Nolte K., Myhrstad M.C.W., Barikmo I., Hvattum E., Remberg S.F., et al., 2002. A systematic screening of total antioxidants in dietary plants. J. Nutr. 132, 461-471.

Hodges M.D., 2003. Post harvest oxidative stress in horticultural crops. Food Products Press, 266.

Chambial S., Dwivedi S., Shukla K.K., John P.J., Sharma P., 2013. Vitamin C in disease prevention and cure: An overview. Indian J. Clin. Biochem. 28, 314.

Chaudhary B.R., Sharma M.D., Shakya S.M., Gautam D.M., 2006. Effect of plant growth regulators on growth, yield and quality of chilli (*Capsicum annuum* L.) at Rampur, Chitwan. J. Inst. Agric. Anim. Sci. 27, 65-68.

Kantar M.B., Anderson J.E., Lucht S.A., Mercer K., Bernau V., Case K.A., et al., 2016. Vitamin variation in Capsicum spp. Provides opportunities to improve nutritional value of human diets. PLoS ONE 11(8), e0161464.

Kirk S., Gu S., 2011. Preliminary evaluation of 48 chili pepper cultivars in Central Missouri. Midwest Vegetable Trial Report for 2011. Lincoln University Cooperative Extension, Jefferson City, MO 65101.

Lee S.K., Kader A.A., 2000. Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Biol. Technol. 20, 207-220.

Materska M., Perucka I., 2005. Antioxidant activity of the main phenolic compounds isolated from hot pepper fruit (*Capsicum annuum* L.). J. Agric. Food Chem. 53, 1750-1756.

Mozafar, A., 1994. Plant Vitamins: Agronomic, Physiological and Nutritional Aspects. CRC Press, Boca Raton, FL, USA.

Muñoz-Ramírez L.S., Peña-Yam L.P., Avilóes-Viñas S.A., Canto-Flick A., Guzmóan-Antonio A.A., Santana-Buzzy N., 2018. Behavior of the hottest chili peppers in the world cultivated in Yucatan, Mexico. HortScience 53(12), 1772-1775.

Perry L., Dickau R., Zarrillo S., Holst I., Pearsall D.M., Piperno D.R., et al. 2007. Starch fossils and the domestication and dispersal of chili peppers (*Capsicum* spp. L.) in the Americas. Science 315(5814), 986-988.

Phimchan P., Techawongstien S., Chanthai S., Bosland P.W., 2012. Impact of drought stress on the accumulation of capsaicinoids in capsicum cultivars with different initial capsaicinoid levels. HortScience 47(9), 1204-1209.

Russo V.M., 2012. Peppers: botany, production and uses. CABI, Cambridge, MA, USA.

Sawant L., Prabhakar B., Pandita N., 2010. Quantitative HPLC analysis of ascorbic acid and gallic acid in phyllanthus emblica. J. Anal. Bioanal. Tech. 1:111.

Schweiggert U., Carle R., Schieber A., 2006. Characterization of major and minor capsaicinoids and related compounds in chili pods (*Capsicum frutescens* L.) by high-performance liquid chromatography/ atmospheric pressure chemical ionization mass spectrometry. Anal. Chim. Acta 557, 236-244.

Stommel J.R., Griesbach R.J., 2008. Inheritance of fruit, foliar, and plant habit attributes in *Capsicum*. J. Amer. Soc. Hort. Sci. 133, 396-407.

Škrovánková S., Mlček J., Orsavová J., Juríková T., Dřímalová P., 2017. Polyphenols content and antioxidant activity of paprika and pepper spices. Potravinarstvo Slovak Journal of Food Science 11(1), 52-57.

Škrovánková S., Mlček J., Sochor J., Baroň M., Kynický J., Juríková T., 2015. Determination of ascorbic acid by electrochemical techniques and other methods. Int. J. Electrochem. Sci. 10(3), 2421-2431.

Tewksbury J.J., Manchego C., Haak D.C., Levey D.J., 2006. Where did the chili get its spice? Biogeography of capsaicinoid production in ancestral wild chili species. J. Chem. Ecol. 32, 547-564.

Topuz A., Ozdemir F., 2007. Assessment of carotenoids, capsaicinoids and ascorbic acid composition of some selected pepper cultivars (*Capsicum annuum* L.) grown in Turkey. J. Food Compos. Anal. 20, 596-602.

Troconis-Torres I.G., Rojas-López M., Hernández-Rodríguez C., Villa-Tanaca L., Maldonado-Mendoza I.E., Dorantes-Álvarez L., et al. 2012. Biochemical and molecular analysis of some commercial samples of chilli peppers from Mexico. J. Biomed. Biotechnol. 873090.

USDA (NATIONAL NUTRIENT DATABASE FOR STANDARD REFERENCE), 2019. https://fdc.nal.usda.gov/fdc-app.html#/food-details/170108/nutrients. Accessed 13 November 2019.

Vachůn M., 2019. Meteorological data 2016, 2018, station Lednice. University information system of Mendel University in Brno. http://is.mendelu.cz/2019. Accessed 16 May 2019.

Valšíková M., Paulen O., 2013. Study of Capsicum Diversity and Quality. Profi Press, Praha, Czech Republic, 169.

Received October 17, 2019; accepted November 13, 2019