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Original Article

# Phosphorus, Potassium and Nitrate Contents in Fruit of Pickling Cucumbers Grown in a High Tunnel

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**Abstract**

Pickling cucumbers are highly important both for fresh consumption and for canning industry. This study aimed to compare differences in yield and quality of eight pickling cucumber cultivars, including 'Cor 12004', 'IGG 2010', 'IGG 2020', 'SM 5322', 'SM 5323', 'Zayin 201', 'Zayin 175201' and 'Trilogy'. The cucumber cultivars were laid out in a high tunnel crop and evaluated for vegetative traits (i.e. vine length, nodes per vine and branches per vine), yield attributes (i.e. fruits per main stem, average weight of fruit and fruits weight per plant) and fruits quality components (nitrate, phosphate and potassium mg kg$^{-1}$). The results showed significant differences ($P<0.05$) in vegetative traits and yield attributes among cultivars. The analysis of correlation coefficients revealed that total yield (kg ha$^{-1}$) was positively correlated with two out of three vegetative traits (with exception nodes per plant) and with all yield attributes. The highest total yield (101.17 t ha$^{-1}$) was reached by 'SM 5322' cultivar, followed by the 'IGG 2010' and 'SM 5323' cultivars. The nitrates content in fruits, assessed on three categories of length (6-9 cm, 9-12 cm and >12 cm), revealed a declining value with increase in the cucumber length. The study findings suggest that irrespective of the cultivar, the amount of nitrate was higher in shorter cucumbers (6-9 cm length) although all recorded values (between 192.7 and 364.3 mg kg$^{-1}$ fresh matter) being under maximum accepted limit concentrations. The amount of phosphate was higher in medium to long cucumbers, while the amount of potassium was higher in shorter cucumbers.

***Keywords:*** cucumbers, cultivar, growth, minerals, quality, yield

## Introduction

Cucumber (*Cucumis sativus* L.) is the fourth most widely cultivated vegetable crop after tomato (*Lycopersicon esculentum* Mill.), cabbage (*Brassica oleracea* var. *capitata* L.) and onion (*Allium cepa* L.), (Shetty and Wehner, 2002; Shu *et al.*, 2016). The soft and succulent pulp of cucumbers is used as either fresh (Shetty and Wehner, 2002), processed or cooked with other vegetables (Nwofia *et al.*, 2015), while the immature cucumbers are used in pickles (Ahmed *et al.*, 2004). Cucumber has a low caloric value (15 kcal 100 g$^{-1}$) but it is a moderate source of vitamins (A, C, E, K and B complex) and a good source of minerals (K, Ca, P, Mg, Fe, Na and Zn) (USDA National Nutrient Database for Standard Reference, 2016). Due to its high content of water (95.23%) and good mineral balance, cucumber plays an important role in maintaining body hydration and as a natural diuretic (Jilani *et al.*, 2009). Cucumbers may also protect against digestion disorders such as gastric hyperacidity and constipation (Rahman, 2008). Cucumber can be highly useful for both high and low blood pressure conditions due to its high content of potassium (147 mg 100 g$^{-1}$ fresh matter), (Ahmed *et al.*, 2007). This discussion highlights the importance of considering potential variation in potassium and phosphorus content among different pickling cucumber cultivars.

In Romania, the total land area cultivated with vegetables, including open field, greenhouses and high tunnels crops, was 150.000 ha in 2014. Total cucumbers production reached 181,000 tons in the same year, representing approximately 5%

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of the EU production (INSSE, 2015). According to Scurtu *et al.* (2016), high protected cultivation area will expand from 7,500 ha currently to 20,000 ha in 2020. To enhance the economic feasibility of growing pickling cucumber under high tunnels necessitates the use of high yielding cultivars (Wehner, 1989), improved diseases resistance (Peterson, 1975), and improvement of cultural practices (fertilization, irrigation etc) (Shetty and Wehner, 2002; Jilani *et al.*, 2009). The use of high tunnels for vegetable crops continued to expand over the past five years (Lamont, 2009) due to the low start-up and operating costs, and the quick rate of return on investment. They are also more accessible than greenhouses to small farmers.

The advantages of high tunnels include season extension (Lamont, 2005), greater and more predictable yield, improved cucumber quality, and protection from wind, insect and rainfall adversities (Wien and Pritts, 2009), potentially reducing foliar diseases (Orzolek *et al.*, 2004). Câmpeanu *et al.* (2013) stated that the assortment of cucumbers has evolved over the past years due to increasing the number of gynoecious pickling cucumber cultivars which present parthenocarpic fruiting, while being very productive. Moreover, according to Scurtu *et al.* (2016), an important result of the Romanian vegetable research is the creation of tastefully vegetable cultivars, including cucumbers. Unfortunately, the spreading of cucumber cultivars in production ranges from 5% for cultivars recommended for protected cultivation to 90% for cultivars recommended for open field cultivation. Therefore, the use of imported cucumber cultivars for protected crops represents a viable solution. However, current literature indicates that cultivars' production performance varies with the climatic conditions (Ahmed *et al.*, 2004; Tuzel *et al.*, 2005), place of cultivation (open field, high tunnels, greenhouses) (Sharma *et al.*, 2000), growing season (Nwofia *et al.*, 2015) and technical practices (Singh and Ram, 2012). It is important therefore to identify cucumbers cultivars best adapted to cultivation in our country.

Being a natural component of vegetables, nitrate is considered one of the most important factors influencing vegetables quality (Tamme *et al.*, 2010). In the human organism nitrates are degraded into nitrites which have higher toxicity compared to nitrates (Susin *et al.*, 2006). As vegetables and fruit are rich in nitrate (Gorenjak and Cencic, 2013), a large proportion of the human dietary nitrate exposure (as much as 60-80% according to EFSA, 2008)) arises from the consumption of vegetables and fruit. Generally, vegetables consumed as roots, stems or leaves are considered to be more susceptible to nitrates accumulation, whereas those consumed as fruit are less susceptible to nitrates accumulation (Zhou *et al.*, 2000). Cucumbers are classified as low nitrates concentration (200-500 mg $kg^{-1}$) (Santamaria, 2006; Lidder and Webb, 2012). In a study performed by the Scientific Panel on Contaminants in the Food chain, requested by European Commission (EFSA, 2008), cucumber was found to contain the third lowest median concentration of nitrate (156 mg $kg^{-1}$), after the legumes and bulb vegetables. However, the nitrates content in vegetables can vary within species and cultivars (Blom-Zandstra, 1989). Thus, selection of cucumber cultivars which accumulate less nitrates may significantly reduce the nitrates' consumption by humans (Umar and Iqbal, 2007), adding value for vegetable products (Santamaria, 2006).

Considering the high demand for pickling cucumbers in Romania and the scarce availability of Romanian cultivars recommended for protected cultivation, the present study aimed to assess eight foreign cucumber cultivars with respect to their yielding capacity and quality under modern high tunnels crops. More specifically, the aim of this study was to correlate specific vegetative and yield traits with each other and with total yield in order to identify highly yielding cultivars and to determine the nitrate, phosphate and potassium contents of cucumber fruits as qualitative attributes.

## Materials and Methods

*Experimental design*

The experiment was conducted in 2015 in a high tunnel at the Vegetable Growing Department of Horticulture Faculty, University of Agricultural Sciences and Veterinary Medicine, Bucharest. Eight foreign pickling cucumber hybrids (i.e. 'Cor 12004', 'IGG 2010', 'IGG 2020', 'SM 5322', 'SM 5323', 'Zayin 201', 'Zayin 175201' and' Trilogy') were cultivated on a chromic luvosol in short term crop system and assessed as morphological traits, yielding capacity and fruits quality. The experiment was implemented in a randomized complete block design with three replications, each consisting of 15 plants. Cucumber seedlings were produced in a nursery starting at the end of February, by sowing the seeds in pots of 10 cm diameter using a peat based mixture. Prior to the establishment of the experiment, the soil was fertilized with 20 tons $ha^{-1}$ composted manure and prepared by tilling, weeds removing, laying out of drip irrigation system, and mulching with plastic sheet.

The seedlings were planted on the $8^{th}$ of April in rows at 80 cm apart and at 50 cm between plants on a row, to result in a density of 2.5 plants $m^{-2}$ and 25,000 plants $ha^{-1}$, respectively. During the cropping season, 2 g per plant complex fertilizer 11:11:21 (N:P:K) was applied as fertigation, followed during the intensive fructification period with a supplement of 0.6 g calcium nitrate for each plant. Other cultural practices such as gap filling, trellising cucumber vine with string, pinch out of side branches after 2 leaves, drip irrigation and protection against diseases and pests were carried out throughout the cropping season. Fruit harvesting started at the end of April and was done gradually once every two days, as the majority of fruit reached approximately 3 cm in diameter, and continued until the beginning of July.

*Plant sampling and biometrical determinations*

Biometric measurements concerning plant growth (i.e. vine length, nodes per vine, branches per vine) and fructification (i.e. number of fruits on the main stem, average weight of fruit, fruits weight per plant, total yield) were performed during cropping season. Five randomly selected plants per plot were chosen in the beginning of cropping season to determine growth parameters. Measurements of growth parameters were recorded 7 weeks after planting. Cucumber vine length was measured by using of flexible tape rule while number of nodes per vine and number of branches per vine were determined by visual count. Among the yield component, number of fruits per main stem, average weight of fruit and fruits weight per plant were also determined for five sampled plants per plot by counting or weighting the fruits with an electronic scale, respectively. Total yield was the sum of all harvests during the vegetative period.

*Fruit sampling and analysis*

Cucumber fruits were sorted on three levels of length (6-9 cm, 9-12 cm and >12 cm) according to the commercial quality. Five fruit samples for each of the three quality levels were taken in the maximum fructification period in order to determine some quality parameters (nitrate, phosphorus and potassium contents of fruits). Cucumber fruits were washed and then grounded in order to obtain the analysis sample and afterward the clear filtrate.

The assessment of nitrates concentration ($NO_3$) was based on nitrites measurement levels, after reduction with cadmium powder, using the spectrophotometric method with Peter-Griess reagent. The nitrites resulted after reduction react in an acidic medium with sulfanilic acid to form an intermediate diazonium salt, which coupled with alfa-naphthylamine leads to a purple colored azo compound, with maximum absorption at $\lambda$=520 nm. Simultaneously two determinations were conducted, one for total nitrites (obtained after nitrate reduction to nitrite) and one for nitrites. The difference between the two results was used as a measure of the nitrates content.

The phosphorus and potassium were determined through extraction with acetic acid 2% in an extraction ratio of 1:20. A sample of 5 g fruit was grinded with quartz sand and animal charcoal, followed by addition of 100 ml acetic acid 2% and filtration through a qualitative filter in an Erlenmeyer glass. For phosphorus determination at 0.5 ml extract 8.5 ml of distilled water, 1 ml Duval reagent and 1 ml ascorbic acid 1% was added, followed by boiling in water bath and determination with Spekol spectrophotometer at $\lambda$=720nm. The obtained values were compared with a standard scale. Potassium content was determined directly through flame photometric method, and the results were compared with a standard scale. The agrochemical methods of analyses, used for quality parameters determination, are in accordance with the methods agreed by National Institute for Agrochemistry, Pedology and Environmental Pollution, Bucharest, Romania.

*Statistical analysis*

The obtained results for vegetative traits, yield attributes, total yield and cucumber fruits quality parameters were statistically analyzed by using Duncan's multiple range test, while correlation coefficient analysis was performed in order to evaluate the relation between vegetative traits and yield attributes.

## Results and Discussion

*Vegetative traits*

Statistical analysis of the means for the measured parameters showed that there were significant differences in vegetative traits and yield attributes among the studied cultivars.

The vegetative traits of the five pickling cucumber cultivars which were assessed in this study are presented in Table 1. The vine length varied from 186.0 cm to 220.6 cm, the highest value of this trait being recorded for 'SM 5323' and the lowest for 'Cor 12004'. Cucumber vine length varied significantly ($P<0.05$) among assessed cultivars only for 'SM 5323', 'Trilogy' and 'Cor 12004'. The vigorous vegetative growth of all cultivars might be determined by enhanced daily split application of fertilizers during all vegetative period, observation which is in line with that reported by Bindiya *et al.* (2012). The number of nodes per vine ranged from 28.8 to 33.5 but the differences among cultivars were not statistically significant ($P>0.05$). The number of branches per vine within vegetative traits ranged from 2.2 for 'Trilogy' to 9.6 for 'SM 5323', suggesting significant differences ($P<0.05$) among all studied cultivars.

*Yield and yield components*

The evolution of total yield and yield attributes of the five studied pickling cucumber cultivars are presented in Table 2. The number of fruits per main stem ranged from 22.7 for 'Cor 12004' to 42.0 for 'SM 5322'. 'SM 5322' yielded the highest number of fruits per main stem but was closely followed by 'IGG 2010', the difference between the two cultivars being not statistically significant.

The average weight of fruit was comprised between 57.1 g for 'Cor 12004' and 69.5 g for 'SM 5322', revealing a significant ($P<0.05$) variation among cultivars, with the exception of 'Cor 12004' and 'IGG 2020'. The fruits weight per plant ranged from 1.84 kg to 4.01 kg, being the highest for 'SM 5322' and the lowest for 'Cor 12004'.

It is evident from the data presented in Table 1 and 2 that cultivar 'SM 5322' revealed significantly different vegetative and yield traits such as number of branches per vine, fruits per main stem, average weight of fruit, fruits weight per plant as compared with all the other tested cultivars. 'SM 5322' reached the highest total yield (101.17 t $ha^{-1}$) followed by 'IGG 2010' and 'SM 5323', while the lowest total yield (48.07 $tha^{-1}$) was obtained by 'Cor 12004' cultivar. These differences were not statistically significant, however. The higher yield of 'SM 5322' could be attributed to a higher number of fruits and a higher average weight of fruit compared to the other cultivars, findings which are in agreement with Hochmuth *et al.* (2004) that reported that different cultivars of cucumbers resulted in different yields. The difference in vegetative and yield traits among cultivars may be due to their genetic composition and/or to their ability to perform well in a new environment, (Eifediyi and Remison, 2009; Ene *et al.*, 2016).

*Correlations of vegetative traits and yield attributes*

In order to identify highly yielding pickling cucumber cultivars, correlations among vegetative traits, yield components and total yield were performed since they are considered important in indirect selection of genotypes for yield improvement (Machikowa and Laosuwan, 2011).

Table 1. Vegetative traits of five pickling cucumber cultivars in high tunnel crop

| Cultivar | Vine length (cm) | Nodes per vine (no) | Branches per vine (no) |
|---|---|---|---|
| 'Cor 12004' | 186.0 d | 28.8 a | 3.0 g |
| 'IGG 2010' | 203.8 bc | 30.9 a | 8.9 b |
| 'IGG 2020' | 202.8 bc | 29.5 a | 4.8 f |
| 'SM 5322' | 211.5 ab | 32.0 a | 8.1 c |
| 'SM 5323' | 220.6 a | 32.8 a | 9.6 a |
| 'Zayin 201' | 202.6 bc | 30.8 a | 6.5 d |
| 'Zayin 175201' | 206.8 bc | 32.1 a | 5.7 e |
| 'Trilogy' | 197.8 c | 33.5 a | 2.2 h |

Note: values followed by the same letters not significantly different at P≤0.05, according to Duncan's test

Table 2. Yield and yield attributes of five pickling cucumber cultivars in high tunnel crop

| Cultivar | Fruits per main stem (no) | Average weight of fruit (g) | Fruit weight per plant (kg) | Total yield (t ha$^{-1}$) |
|---|---|---|---|---|
| 'Cor 12004' | 22.7 f | 57.1 f | 1.84 e | 48.07 d |
| 'IGG 2010' | 40.9 a | 66.1 c | 3.70 b | 97.30 a |
| 'IGG 2020' | 28.9 e | 56.7 f | 2.11 d | 55.57 cd |
| 'SM 5322' | 42.0 a | 69.5 a | 4.01 a | 101.17 a |
| 'SM 5323' | 35.0 c | 68.0 b | 3.54 b | 93.27 a |
| 'Zayin 201' | 32.0 d | 61.0 d | 2.65 c | 69.13 b |
| 'Zayin 175201' | 33.3 cd | 59.3 e | 2.54 c | 67.20 bc |
| 'Trilogy' | 38.4 b | 53.5 g | 2.26 d | 58.30 bcd |

Note: values followed by the same letters not significantly different at P≤0.05, according to Duncan's test

The results of the correlation coefficients (r) among studied traits of the five pickling cucumber cultivars assessed in this study are presented in Table 3. The vine length was positively and distinct significantly correlated with number of branches per vine (r=0.804) and positively significant correlated with average weight of fruit (r=0.721), fruit weight per plant (r=0.740) and total yield (r=0.754). Similar results were obtained by Ene *et al.* (2016) which attributed the superior performance in total yield of some cucumber cultivars to their longer vines and higher number of branches. In this study the number of branches per plant revealed also a very significant positive correlation with average weight of fruit, fruits weight per plant and total yield, results which are in agreement with those obtained by Cramer and Wehner (2000).

The data presented in Table 3 emphasize that the total yield per hectare was positively correlated with all yield components, namely fruits per main stem, average weight of fruit and fruits weight per plant. Moreover, the specialty literature recommends selecting for yield component (Uguru, 1995) in the selection of genotypes instead of the total yield, which is considered a complex quantitative trait, considerably affected by environment (Cetin *et al.*, 2009). Thus, besides the cultivar which reached the highest yield in this study, good choices can be the cultivars which exhibited a big number of fruits per main stem, high average weight of fruit and high fruits weight per plant.

*Cucumber fruits quality*

Pickling cucumbers are widely consumed as fresh or processed products, thus assessment of nitrates content, as an important indicator of their quality, should be taken into consideration due to their potential impact on people health (Susin *et al.*, 2006). Various studies have reported the nitrates content of cucumbers resulted from field crops (Mahmoud *et al.*, 2009), protected crops (Ruiz and Romero, 2002; Tamme *et al.*, 2010), different growing seasons (Tamme *et al.*, 2010), different time of harvest (Amr and Hadidi, 2001) and domestic or import supply (Tamme *et al.*, 2010).

Considering the great importance of pickling cucumbers for internal supply and as export commodity, both for fresh consumption and processing industry, it was considered necessary to assess the nitrates content depending on fruit size, such as they are classified according to commercial quality (6-9 cm, 9-12 cm and >12 cm) and according to recommendation for use – consumption or processing, respectively.

Maximum limit concentrations for nitrates of leafy vegetable (lettuce, spinach and rocket) grown in open air or in protected crop and depending on harvesting time, were established by the EU by Commission Regulation (EU) No 1258/2011. However, concentration limits for other highly accumulating nitrate vegetables (celery, Chinese cabbage, red beetroot, parsley etc.) or for widely cultivated vegetables (tomato, onion, cabbage, cucumbers etc.) were not developed. Nevertheless, the nitrate maximum accepted limits in cucumbers have been standardized by W.H.O as 700 mg kg$^{-1}$ fresh product, according to Mahmoud *et al.* (2009).

The nitrates content of cucumber fruits of the cultivars evaluated in the experiment ranged from 192.7 mg kg$^{-1}$ for 'SM 5323' and fruits over 12 cm length to 364.3 mg kg$^{-1}$ for the same cultivar and fruits with 6-9 cm length (Table 4). The results are in agreement with published data related to nitrates content of Estonian cucumbers compared with imported products, with mean values of 335 mg kg$^{-1}$ and 240 mg kg$^{-1}$, respectively (Tamme *et al.*, 2010).

The nitrates content revealed a statistical significant (P<0.05) decrease as the fruit length increased, the highest values being obtained for fruits with 6-9 cm length, irrespective of the cultivar. Comparable results were obtained by Beis *et al.* (2002) which reported higher nitrate content in younger leaves than in older leaves in spinach. The mean nitrates content by cultivar in this study, irrespective of the fruit length, ranged between 219.8 mg kg$^{-1}$ for 'Cor 12004' and 283.6 mg kg$^{-1}$ for 'SM 5323'. The variation of nitrate content among cultivars was statistically significant (P<0.05). In an experiment with kale Korus and Lisiewska (2009) found that the compared cultivars differed significantly in their nitrates' content. However, Amr and Hadidi (2001) in an experiment with two cultivars each of squash, cucumber, and tomatoes grown in polypropylene-covered greenhouses found that cultivar had a significant effect only on the nitrates content of tomatoes and squash. Conversely, Behr and Wiebe (1992) stated that the nitrates content of butter head lettuce (highly susceptible to

Table 3. Correlation coefficients between vegetative and yield traits of five pickling cucumber cultivars in high tunnel crop

| Traits | Vine length | Nodes per vine | Branches per vine | Fruits per main stem | Average weight of fruit | Fruits weight per plant | Total yield |
|---|---|---|---|---|---|---|---|
| Vine length | - | 0.590 | 0.804** | 0.571 | 0.721* | 0.740* | 0.754* |
| Nodes per vine | - | - | 0.215 | 0.716* | 0.213 | 0,429 | 0.426 |
| Branches per vine | - | - | - | 0.517 | 0.938*** | 0,886*** | 0.907*** |
| Fruits per main stem | - | - | - | - | 0.547 | 0,796** | 0.785** |
| Average weight of fruit | - | - | - | - | - | 0.941*** | 0.942*** |
| Fruits weight per plant | | | | | | | 0.998*** |

* = significant at 5%; ** = significant at 1%; *** = significant at 0.1%

Table 4. The nitrates ($NO_3$) content of pickling cucumbers depending on fruit size (mg kg$^{-1}$)

| Cultivar | Fruit length (cm) | | | Mean per cultivar |
|---|---|---|---|---|
| | 6-9 | 9-12 | >12 | |
| 'Cor 12004' | 246.8 i | 216.2 k | 196.5 m | 219.8 E |
| 'IGG 2010' | 352.5 b | 282.0 f | 211.5 k | 282.0 A |
| 'IGG 2020' | 270.3 g | 258.5 h | 199.8 lm | 242.9 C |
| 'SM 5322' | 340.8 c | 282.0 f | 199.8 lm | 274.2 B |
| 'SM 5323' | 364.3 a | 293.8 e | 192.7 m | 283.6 A |
| 'Zayin 201' | 270.3 g | 216.3 k | 209.2 kl | 231.9 D |
| 'Zayin 175201' | 317.3 d | 282.0 f | 211.5 k | 270.3 B |
| 'Trilogy' | 258.5 h | 216.2 k | 210.3 kl | 228.3 D |
| Fruit length average | 302.6 X | 255.9 Y | 203.9 W | |

Note: values followed by the same letters not significantly different at P≤0.05, according to Duncan's test

Table 5. The phosphates ($PO_4$) content of pickling cucumbers depending on fruit size (mg kg$^{-1}$)

| Cultivar | Fruit length (cm) | | | Mean per cultivar |
|---|---|---|---|---|
| | 6-9 | 9-12 | >12 | |
| 'Cor 12004' | 195.7 ef | 202.3 ef | 205.3 e | 201.1 D |
| 'IGG 2010' | 256.7 cd | 264.03 cd | 296.3 ab | 272.3 B |
| 'IGG 2020' | 312.2 a | 303.0 a | 278.2 bc | 297.8 A |
| 'SM 5322' | 250.4 d | 262.3 cd | 208.3 e | 240.3 C |
| 'SM 5323' | 185.2 ef | 201.3 ef | 198.7 ef | 195.1 D |
| 'Zayin 201' | 193.7 ef | 198.5 ef | 202.5 ef | 198.2 D |
| 'Zayin 175201' | 204.5 e | 200.3 ef | 179.8 f | 194.9 D |
| 'Trilogy' | 200.4 ef | 202.3 ef | 195.7 ef | 199.5 D |
| Fruit length average | 224.9 X | 229.3 XY | 220.6 Y | |

Note: values followed by the same letters not significantly different at P≤0.05, according to Duncan's test

nitrates accumulation) depends on the highly different nitrates uptake of the cultivar. Moreover, Umar and Iqbal (2007) recommend the selection of vegetable cultivars that accumulate less nitrates or the breeding of cultivars which do not accumulate nitrates, even under heavy nitrogen fertilization, in order to reduce nitrates consumption by humans through vegetables.

Phosphorus has important roles in photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement and several other processes in the plant (Tirasoglu *et al.*, 2005). Adequate phosphate is essential for plant growth and it is also vital for early root formation.

The phosphate content of fruits in this study ranged from 179.8 mg kg$^{-1}$ for 'Zayin 175201' and fruits over 12 cm length to 312.2 mg kg$^{-1}$ for 'IGG 2020' and fruits with 6-9 cm length (Table 5). These results are in agreement with those of Ward and Miller (1970) who reported that P and K were present in small cucumber fruits in relatively high proportion, while values declined rapidly to constant levels as the fruits size increased. However, if the phosphate content of fruits for each cultivar is analyzed, only for 'IGG 2020' and 'Zayin 175201' the phosphate content decreased as the fruit length increased. Conversely for 'Cor 12004', 'IGG 2010' and 'Zayin 201' the phosphate content increased as the fruit length increased while for 'SM 5322', 'SM 5323' and 'Trilogy' the phosphate content of fruits was higher in medium sized fruits.

Potassium has a significant role in the synthesis of amino acids and proteins (Malik and Srivastava, 1982) and a key role in stomata' functioning thus helping plant to use water more efficiently by promoting turgidity to maintain internal pressure (Tirasoglu *et al.*, 2005).

The potassium content of cucumber fruits (Table 6) ranged from 5210 mg kg$^{-1}$ for 'SM 5322' and fruits with 9-12 cm length to 6700 mg kg$^{-1}$ for 'IGG 2020' and fruits with 6-9 cm length. Five of the studied cultivars (i.e. 'IGG 2010', 'IGG 2020', 'Zayin 201', 'Zayin 175201' and 'Trilogy') revealed high potassium content in fruits with 6-9 cm length, two of them (i.e. 'SM 5322' and 'SM 5323') in fruits over 12 cm length while one of them ('Cor 12004') in fruits with 9-12 cm length. The evolution of potassium content of cucumber fruits according fruit size was in agreement with Ward and Miller (1970) but the obtained values were considerably higher than those reported by Gajc-Wolska *et al.* (2008).

Table 6. The potassium (K) content of pickling cucumbers depending on fruit size (mg kg$^{-1}$)

| Cultivar | Fruit length (cm) | | | Mean per cultivar |
|---|---|---|---|---|
| | 6-9 | 9-12 | >12 | |
| 'Cor 12004' | 5520 h | 5920 f | 5520 h | 5653.3 D |
| 'IGG 2010' | 5510 h | 5420 hi | 5310 ijk | 5413.3 F |
| 'IGG 2020' | 6700 a | 6620 ab | 6510 bc | 6610.0 A |
| 'SM 5322' | 5510 h | 5210 k | 6020 ef | 5580.0 E |
| 'SM 5323' | 5720 g | 5340 ij | 6010 ef | 5690.0 D |
| 'Zayin 201' | 6500 c | 6230 d | 6050 e | 6260.0 B |
| 'Zayin 175201' | 6020 ef | 5700 g | 5800 g | 5840.0 C |
| 'Trilogy' | 5700 g | 5250 jk | 5375 i | 5441.7 F |
| Fruit length average | 5897.5 X | 5711.3 Z | 5824.4 Y | |

Note: values followed by the same letters not significantly different at P≤0.05, according to Duncan's test

## Conclusions

Three of the studied pickling cucumber cultivars revealed high yields ('SM 5322', 'SM 5323' and 'IGG 2010'). These yields were not significantly different among them but were significantly different from the yield of all the other tested cultivars. The same cultivars revealed the best values for yield attributes (fruits per main stem, average weight of fruit and fruits weight per plant). These findings suggest that these three cultivars can be good recommendations for the Romanian high tunnel protected crops. Considering the high amount of nitrates observed with the small sized fruits (6-9 cm) and the high demand of the canning industry for this cucumber size category, the sampling and testing of cucumber large batches before processing is a major concern. The high amounts of phosphorus and potassium revealed in cucumber offers them firmness, long shelf life and carriage resistance.

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