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AGRONOMIC ASSESSMENT OF *PHYSALIS* SP. ACCESSIONS FROM VEGETABLE RESEARCH DEVELOPMENT STATION BUZĂU, ROMANIA

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Abstract

Physalis sp. is widely cultivated in South America, but little known and cultivated plant in Romania, although varieties belonging to the species are found in wild flora. The aim of this paper was to assess agronomic traits with emphasis on the phenotypic expressiveness of the accessions in terms of yield, quality and earliness production. The research consisted in agronomic evaluation of seven genotypes of Physalis (P. peruviana, P. ixocarpa, P. philadelphica and P. alkekengi) and the selection of valuable genotypes suitable for cultivation under the pedoclimatic conditions of the southern part of Romania. The study targeted 30 qualitative descriptors and 16 quantitative descriptors subjected to ANOVA analysis. A percentage of 67% of the studied genotypes contains fruits with a diameter exceeding 2 cm, belonging to the genus P. ixocarpa and P. philadelphica, 16.5% fall in the typical form of the Colombian ecotype of 1.85 cm, and 16.5% are small fruits, with a diameter below 1.5 cm. Accession A7 obtained a yield of 3.9 kg/plant and accessions A4 and A3 have small fruits, but with a higher content in soluble substances.

Key words*: Tomatillo, cape gooseberry, diversity, germplasm variability, husk tomato.*

INTRODUCTION

Physalis is the fifth largest genus of Solanaceae family and embrace over 90 native species in America, and the greatest richness is concentrated in Mexico, which hosts 65 species (Martinez et al., 2017; Saavedra et al., 2019; Lagunovschi et al., 2016). Some of the Physalis species such as *P. divaricata*, *P. alkekengi* L. occur jointly in America and Asia (Mozaffarian, 2013; Sayadi and Mehrabian, 2016). *Physalis alkegengi* was distributed in wild flora of southern Europe (Filipovic et al., 2019). *Physalis alkekengi* is a perennial plant with preferences for limestone areas and can be found in the forests of Romania, from the plains to the hillsides.

The plant is completely toxic, except for fruits. The fruits contain citric acid, mineral substances and have a pleasant bitter-sour taste (Pârvu C., 2006). In traditional medicine references, Physalis is known as effective in treatment of several disorders such as: jaundice, asthma and shortness of breath, tissue necrosis, liver, kidney and bladder dysfunctions, wounds, haemorrhoids and helminths diseases (Mirzaee, 2019). *Physalis peruviana* L., *P. ixocarpa* L. and *P. philadelphica* L. are very little cultivated plants in Romania, but once with the promotion of fruit and vegetable consumption for a healthier diet, Physalis sp. it began to be required in the market.

At the moment, in the Official Catalogue of Romanian Crop Plants does not have a Physalis variety, which is the reason why the Vegetable Research and Development Station Buzau undertook a breeding program for this species. The aim of this study was to evaluate the germplasm collection, from which seven accessions are the subject of this work and to select valuable genotypes suitable for cultivation in the pedoclimatic conditions of southern part of Romania.

MATERIALS AND METHODS

The Breeding and Biodiversity Laboratory from Vegetable Research Development Station Buzau, Romania, holds a valuable germplasm collection, structured on several stages of breeding, of which seven stable genotypes were retained. The studied genotypes were: two genotypes belonging to *P. philadelphica* (tomatillo), two genotypes of *P. peruviana (cape gooseberry)*, two genotypes of *P.*

ixocarpa (husk tomato) and one genotype of *Physalis alkekengi*.

There are some studies referring that *P. philadelphica* and *Physalis ixocarpa* are synonyms, but despite the morphological similarities, these are different species. Fernandes (1974) and Hanelt and IPK (2001) - states that the *P. ixocarpa* has relatively smaller flower and fruit and also a capitate stigma.

Geographic location and conditions of the experiment

The evaluation process was carried out in the field. The temperature has registered a maximum of 37.3°C (middle of August) and a minimum of 6.4°C (late September), and relative humidity had recorded a maximum of 95.0% and a minimum of 23.0%.

The soil was clay-sandy, with a pH of 6.8 and with a content of organic matter of 6%, a phosphorus value of 106 mg kg^{-1} and exchangeable potassium, 320 mg kg^{-1}.

Agronomic management

The seedlings were obtained by sowing in alveolar pallets with 70 cubes with a volume of 50 mL/cubes. The planting was made after 56 days after germination, using the planting scheme: 70 cm between rows and 40-50 between plants cm. The seedlings were planted in a completely randomized distribution. The special care works were the usual one: manual and mechanical hoeing, dripping water and fertilization.

Throughout the plant season, no chemical treatments were applied for management of diseases and pest. So far, no pathogens have been identified to endanger the crop.

During the vegetation period, phenological and biometric observations were made for 30 qualitative descriptors and 16 quantitative descriptors according to UPOV Guidelines.

The agronomic variables were established according to studies of Arbelaez and Mora (1990), Lagos (2006), Bonilla et.al (2008) and Herrerra et al. (2012); Drăghici (2014); Panayotov et al. (2015); Panayotov (2018); Ozturk et al. (2017) were focused on fruit quality and yield.

The qualitative traits targeted in the study can be found in Table 1.

Table 1. Qualitative characters

Descriptors	Polymorphism
Plant habit (PH);	1.upright 3.semi-upright 5.prostrate
Stem: anthocyanin coloration of internodes (SAC)	1.absent 9.present
Stem: intensity of anthocyanin coloration of internodes (SIC)	3.weak 5.medium 7.strong
Stem: pubescence of internodes (SP)	1.absent 9.present
Leaf blade: shape (LS)	1.narrow elliptic 2.medium elliptic 3.broad elliptic
Leaf blade: dentation of margin (LM)	1.absent or weak 2.medium 3.strong
Leaf blade: colour (LC)	1.yellowish green 2.green 3.purplish green
Leaf blade: intensity of green colour (LIC)	3.weak 5.medium 7.strong
Petiole: attitude (PA)	1.semi-erect 2.intermediate 3.drooping
Flower: attitude of pedicel (FP)	1.erect 3.intermediate 5.drooping
Flower: number of anthers (FNA)	1.five 2.more than five
Fruit: shape in longitudinal section (FSLS)	1.oblate 2.circular 3.cordate 4.triangular
Fruit: shape in cross section (FSCS)	1.elliptic 2.circular 3.angular
Fruit: depth of stalk cavity (FDSC)	1.absent or very shallow 3.shallow 5.medium 7.deep
Fruit: shape of apex (FSA)	1.pointed 2.rounded 3.depressed
Fruit: main colour (at harvest maturity) (FMC)	1.white 2.green 3.yellow 4.orange 5.purple
Fruit: intensity of main colour (at harvest maturity) (FIMC)	1.light 2.intermediate 3.dark
Fruit: main colour (at physiological maturity) (FMCP)	1.white 2.green 3.yellow 4.orange 5.purple
Fruit: intensity of main colour (at physiological maturity) (FIMP)	1.light 2.intermediate 3.dark
Fruit: colour of flesh (FCF)	1.white 2.yellow 3.greenish yellow 4.green 5.purplish green 6.purple
Fruit: predominant number of locules (FPNL)	1.two 2.three 3.four 4.five 5.more than five
Fruit: adherence of calyx (FAC)	3.weak 5.medium 7.strong
Fruit: enclosure of calyx (FEC)	1.fully enclosed 2.slightly open 3.widely open
Calyx: pubescence (CP)	1.absent 9.present
Calyx: ribbing (CR)	1.absent 9.present
Calyx: anthocyanin coloration (CC)	1.absent 9.present
Calyx: intensity of anthocyanin coloration (CIAC)	1. very weak 3.weak 5.medium 7.strong 9. very strong
Fruit: firmness (FF)	3.soft 5.medium 7.firm
Fruit: number of seeds (FNS)	3.few 5.medium 7.many
Seed: colour (SC)	1.yellow 2.brown yellow

The quantitative characters targeted in the study were: plant height (cm), height at first bifurcation (cm), internode length in first order branches (cm), leaf length (cm), petiole length (cm), flower diameter (cm), fruit mass (g), fruit mass without calyx (g), equatorial diameter of fruit (cm), polar diameter of fruit (cm), fruit shape, fruit size, total soluble solids (°Brix), potential yield (g/plant) and number of fruits per plant.

Measurements of equatorial and polar diameter fruit where made with standardized electronic digital caliper. The fruit were measured with electronic scale, with accuracy +/- 0.0005 g and the total soluble solids content was measure using refractometer.

For statistical analysis, ANOVA was used, followed by the Tukey test.

RESULTS AND DISCUSSIONS

Descriptive analysis of the evaluated traits

For a better understanding of general behaviour of the accessions in relation with each trait, a basic descriptive analysis for quantitative (Table 2) and qualitative (Table 3) characteristics was carried out.

Tabel 2. Means and standard deviation of quantitative traits

Variable	A1	A2	A3	A4	A6	A7
Plant height (cm)	67.45 ±5.59d	43 ±3.9b	87.1 ±1.8e	**28.25** ±3.46a	54.1 ±1.83c	**107.05** ±5.16f
Height at first bifurcation (cm)	**18.4** ±0.28f	14.5 ±0.11e	10.25 ±0.07c	**1.6** ±0.14a	8.7 ±0.14b	13.05 ±0.35d
Internode length in first order branches (cm)	6,35 ±0.21c	**4.25** ±0.21a	**7.7** ±0.14d	6.375 ±0.04c	5.525 ±0.11b	7.465 ±0.05d
Leaf length (cm)	5.7 ±0.14b	**4.25** ±0.07a	**16.97** ±0.18f	8.70 ±0.15d	9.71 ±0.13e	6.475 ±0.03c
Leaf width (cm)	2.37 ±0.03a	**2.35** ±0.07a	**10.4** ±0.28c	4.865 ±0.05b	4.85 ±0.06b	2.79 ±0.02a
Petiole length (cm)	2.04 ±0.08bc	**1.15** ±0.07a	**6.35** ±0.35d	2.6 ±0.14c	2.65 ±0.07c	1.53 ±0.04ab
Flower diameter (cm)	2.3 ±0.14b	2.27 ±0.03b	2.15 ±0.07b	**0.775** ±0.03a	2.11 ±0.01b	**2.65** ±0.07c
Fruit mass (g)	17.15 ±0.21c	20.3 ±0.99d	3.55 ±0.07b	**1.55** ±0.07a	16.35 ±0.77c	**29.3** ±0.81e
Fruit mass without calyx (g)	16.55 ±0.49b	19.76 ±1.04c	3.11 ±0.01a	**1.05** ±0.07a	15.75 ±0.91b	**28.75** ±0.8d
Equatorial diameter of fruit (EDF) (cm)	3.82 ±0.11c	3.6 ±0.14c	1.75 ±0.07a	**1.29** ±0.01a	3.05 ±0.21b	**3.92** ±0.1c
Polar diameter of fruit (PDF) (cm)	2.75 ±0.18cd	3.04 ±0.08d	1.915 ±0.02ab	**1.375** ±0.05a	2.4 ±0.3bc	**3.22** ±0.09d
Fruit shape (EDF/PDF) (cm)	**1.39** ±0.05c	1.18 ±0.01b	**0.91** ±0.02a	**0.91** ±0.02a	1.27 ±0.06bc	1.21 ±0.08b
Fruit size (EDF+PDF)/2	3.29 ±0.14c	3.32 ±0.11c	1.83 ±0.04a	**1.33** ±0.03a	2.72 ±0.24b	**3.57** ±0.09c
Total soluble solids of fruits (TSS) °Brix	8.7 ±0.14c	7.2 ±0.14b	**13.55** ±0.07e	11.25 ±0.07d	**5.15** ±0.08a	8.75 ±0.21c
Yield (g/plant)	2177 ±143b	2989±6 9.3c	661.6 ±29.5a	**359.8** ±6.6a	2271 ±38.7b	**3957** ±239d
Number of fruits per plant	**127.2** ±9.97a	148.1 ±10.3a	187.1 ±12.3b	**232.9** ±14.5c	139.4 ±4.46a	135.1 ±4.2a

The quantitative traits were subject to analysis of variance followed by Tukey test and almost all evaluated traits have showed significant differences. Means follow by the same letter do no differ significantly according to Tukey test (Table 2).

The plant height values varied from A4 with a height of 28.25 cm to 107.05 cm at A7. The height at first bifurcation was taller at *P. philadelphica* (A1 and A7) with a mean value varying from 14.5 cm to 18.4 cm and the smaller one was recorded by *P. peruviana* (A4) with a mean value of 1.6 cm. Leaf length, leaf width and petiole length had the highest value on A3 and the smallest one was recorded by A2. Flower diameter had the smallest record on A4 with only 0.775 cm, and the highest was record by A7. Accordingly, the fruit mass, fruit mass without calyx, polar diameter of fruit, fruit size and yield followed the same pattern. A percentage of 67% of the studied genotypes contains fruits with a diameter exceeding 2 cm, belonging to the genus *P. ixocarpa* and *P. philadelphica*, 16.5% fall in the typical form of the Colombian ecotype of 1.85 cm, and 16.5% are small fruits, with a diameter below 1.5 cm. The maximum number of fruits per plant was 232.9 fruits and was registered by A4 and the minimum was registered by A1 with 127.2 fruits. Regarding the total soluble solids, the highest value was recorded by A3, followed by A4 and the lowest value was obtained by A5.

The quality characteristics can be found in Table 3.

Table 3. Quality characters and their variations in relation to studied accessions

Descriptors	A1	A2	A3	A4	A5	A6	A7
PH	1	1	3	5	1	3	3
SAC	9	9	9	9	9	9	9
SIC	7	5	5	3	3	7	5
SP	1	1	9	9	1	1	1
LS	2	2	3	2	3	2	1
LM	1	2	3	3	3	3	3
LC	1	1	2	3	2	2	2
LIC	3	3	5	5	5	5	5
PA	2	1	2	2	1	3	3
FP	3	3	3	3	1	3	5
FNA	1	1	1	1	1	1	1
FSLS	2	2	2	2	2	2	2
FSCS	2	2	2	2	2	2	2
FDCS	3	3	1	3	5	1	1
FSA	2	2	2	2	2	2	2
FMC	1	1	4	1	4	5	2
FIMC	1	1	1	1	3	2	2
FMP	3	3	4	3	4	5	5
FIMP	1	1	1	1	3	2	2
FCF	3	3	4	3	2	4	3
FPNL	3	1	1	3	3	2	1
FAC	3	3	3	3	3	3	3
FEC	2	2	1	1	1	3	3
CP	1	1	9	9	1	1	1
CR	9	9	9	9	9	9	9
CC	1	1	1	1	1	9	1
CIAC	1	1	1	1	1	5	1
FF	7	7	7	5	5	7	7
FNS	3	3	7	5	5	3	5
SC	1	1	1	1	1	1	1

Plant habit had an upright position on three genotypes, semi-upright position was on three genotypes and one genotype had prostrate habit (A4). All the studied accessions had anthocyanin coloration of internodes, but the intensity of coloration varied from weak (A4 and A5) to medium (A2, A3, A7) and strong (A1, A7). The pubescence of the internodes was present in 28.6% of accessions and absent

on 71.4%. Leaf shape varied from narrow elliptic on one accession (A7), to medium elliptic on four accessions (A1, A2, A4, A6) and broad elliptic to two accessions (A3, A5).
Dentation of margin was weak on A1, medium on A2 and strong on the rest of studied genotypes.
Leaf blade had a yellowish green colour on 28.6 genotypes, 57.1% had a green colour and 14.3% genotypes had purplish green colour. Intensity on green colour was weak on 28.6% genotypes and medium on 71.4%.
Petiole attitude was: semi-erect (A2, A5), intermediate (A1, A3, A4) and drooping (A6 and A7). Flower attitude of pedicel was semi-erect on 14.3% accessions, intermediate on 57.1% accessions and drooping in 14.3% accessions. Number of anthers was five on all genotypes. Fruit shape in longitudinal section and fruit shape in cross section was circular on all studied accessions.
Depth of stalk cavity of fruit was absent or very shallow on A3 and A7, shallow on A1, A2 and A4 and medium on A5. Shape of fruit apex was rounded on all studied genotypes.
Main colour of fruit at harvest maturity was white on 3 genotypes (A1, A2, A4), green on one genotype A7, orange on A3 and A5 and purple on A6.
Intensity of the main colour fruit at harvest maturity was light on A1, A2, A3, A4; intermediate on A6, A7 and dark on A5.
Fruit colour of flesh was yellow on genotype A5; greenish yellow on four accessions (A1, A2, A4, A7); and green on two accessions A3 and A4.
The predominant number of locules in fruit had a value of two on A2, A3, A7; three locules on A6; and four locules on A1, A4 and A5.
The fruit adherence of calyx was weak on all studied accessions. The enclosure of fruit calyx was fully enclosed on A3, A5, A5; slightly open on A1, A2; and widely open on A6 and A7. Pubescence of calyx was absent on 71.4% of genotypes and 28.6% was present.
Ribbed calyx was present on all studied genotypes. Anthocyanin coloration of calyx was present on 14.3% genotypes (A6) and absent on 85.7% genotypes. Firmness of fruit was firm on five accessions and medium on (A4, A5). The number of seeds in fruit was few (A1, A2, A6), medium (A4, A5, A7) and many on A3. The colour of seeds was yellow on all studied accessions.

Accessions summary

Physalis philadelphica - A1 (Figure 1)
Plant has indefinite growth, with erect habit and with an average internode length. The leaves have an average length of 5.8 cm and a width of 2.4 cm

Figure 1. A1 crop detail and fruits images

The flowers have a diameter of 2.4 cm. The fruits have a low adhesion of calyx and at maturity the calyx is slightly open. The fruits have a yellowish green colour and an average weight of 17.3 g, the total soluble content has a value of 8.8 º Brix.

Physalis ixocarpa - A2 (Figure 2)
Plant has an erect habit and with a height of over 50 cm, the height of the stem to the first branch and the length of internodes is 20% lower than A1. The anthocyanin coloration of internodes is medium. The leaves are shorter by 27% compared to A1. The genotype is noted for its earliness, its fruit reaching maturity 74 days after germination period.

Figure 2. A2 crop detail and fruits images

The fruits are yellow-green and average in size, with an average value of 21.2 g and a content of total soluble of 7.3º Brix.

Physalis peruviana - A3 (Figure 3)
Plant has an indefinite growth, with erect habit and a plant height of over 1 m. The height of the stem to the first branch is 10.1 cm. The length of the internodes is short at the base of the plant, only 4.5 cm, and the distance increases as the plant grows in height, reaching a length of internodes of 16.3 cm. The plant has strong pubescence and medium anthocyanin coloration of internodes. The leaves are long, with an average length of 17.2 cm and weakly purple veins.

Figure 3. A3 crop and fruits images

The fruits are orange and pubescent in colour and the calyx completely closes the fruit. The small fruits, when are immature, have anthocyanin coloration on the calyx, but at maturity is no longer present. The fruits have the highest total soluble content, in average, 13.56º Brix, the fruits are small (4g/fresh fruit), tasty and aromatic.

Physalis peruviana A4 (Figure 4)
Plant has an indefinite growth, with semi-erect habit (crawling to semierect). The height of the stem to the first branch is below 1 cm. The leaves are up to 50% narrower than those in genotype A3, and the main veins of the lower leaflets have higher anthocyanin intensity than at A3.
The fruit closure of the calyx is completely closed, and the calyx has a superficial pubescence. Compared to A3, the colour of the pulp is greenish-yellow compared to orange on A3. A4 is productive; it forms a very large number of fruits, but with a low weight (1.6 g/fruit) and with a high TSS content, 11.19º Brix.

Figure 4. A4 crop and fruits images

Physalis alkekengi - A5 (Figure 5)
The plant has a height of over 40 cm, and the stem has up to the first branch, on average, 1.9 cm.

Figure 5. A5 crop detail

The length of internodes is short, and anthocyanin coloration at internodes is weak. The flower differs from the other genotypes, being white and with an average diameter of 2.2 cm. A5 is late variety, its fruit reaching maturity in 124 days after germination period.

Physalis ixocarpa - A6 (Figure 6)
Genotype has a semi-erect habit and average plant height of 52.3 cm. The height of the stem to the first branch is, on average, 8.8 cm, and the length of internodes is 5.4-6.2 cm. The flowers have a diameter of about 2 cm, with erect attitude.

Figure 6. A6 crop and fruits images

Genotype has a calyx with anthocyanin colouring (green with purple vein) when fruits are immature, but it loses once the fruits reach maturity. The closure of the calyx on is wide open; the calyx is smooth, without pubescence. The average weight of the fruit is 16.9 g and has the lowest content in TSS, of only 5.8º Brix from all studied genotypes.

Physalis philadelphica - A7 (Figure 7)
Accession 7 recorded the shortest period from germination to flowering, but its fruits have reached maturity after 102 days.

Figure 7. A7 crop and fruits images

The plant with an erect habit and a height of over 105 cm, the length of the internodes is average, and the leaves have strong edge ripples, the flowers are large, over 2.6 cm, 13% more than the L6. The length of the internodes increases with the height of the plant. The fruits do not have anthocyanin colour on the calyx.

CONCLUSIONS

The researches were completed with a valuable germplasm collection, out of which seven accessions were the subject of this study. The accessions were evaluated in terms of phenotypic expressivity, finding that they have different phenological and phenotypic behaviour. The best results regarding yield potential was obtained by A7 with 3957 g/plant, and the highest total soluble content was obtained by A3 with a value of 13.56º Brix, the fruits were small (4 g/fresh fruit), tasty and aromatic In summary, the agronomic assessment of the accessions using descriptive analysis for quantitative and qualitative traits facilitated a better identification and documentation of the variability between accessions. Also, helped for establishment of a valuable genetic resource for *Physalis* species, which will be useful in future breeding programs.

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