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Research Article

Evaluation of The Tropical Cucurbit Chayote *Sechium edule* (Jacq.) Sw. var. *Albus spinosum* Under The Temperate Climate Conditions Of North Macedonia

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Abstract

The aim of this study was to evaluate some biological, morphological, productive and quality properties of the tropical cucurbit chayote *Sechium edule* (Jacq.) Sw. var. *albus spinosum* grown under temperate climate conditions in the Kochani region, North Macedonia during 2019 and 2020. The short day photoperiod resulted in long vegetative stage (143.25 ± 8.13 days). Flowering started in September, and the generative phase lasted 56.25 ± 4.60 days in average based on the harvest date. Average ripe fruit yield of 28.05 ± 18.67 kg/plant was obtained, with higher yield, number of fruits and fruit weight in 2020. The higher summer temperatures that resulted in a stressed growth, the later development of flowers and higher pest infestation with white fly and aphids may have contributed the lower yield in 2019. According to the ANOVA and LSD test results, 27 to 31 days were enough for fruit maturation. The fruit was 12.14 ± 0.01 cm long, 8,06 ± 0.06 cm wide and 7.30 ± 0.05 cm thick and had an average water content of 94.72 ± 0.13%, total soluble solids of 2.35 ± 0.21 %Brix and pH value of 6.39 ± 0.11.

Keywords
Phenology, Morphological, Productive properties, *Sechium edule* (Jacq.) Sw.

INTRODUCTION

The chayote, also known as mirliton squash *Sechium edule* (Jacq.) Sw. is a tropical plant from the cucurbit family (Cucurbitaceae) and originates from Mexico and Central America (Newstrom, 1990; Newstrom, 1991; Castillo-Martínez et al., 2013). It is most popular in Latin America and grown in the tropical and subtropical regions. A great diversity in genotypes and cultivars exist (Castillo-Martínez et al., 2013), with several varieties in cultivation (Cadena Iñiguez and Arévalo Galarza, 2010; Arévalo Galarza et al., 2011). The plant is edible in its entirety. Aside from the fruit, which is the main marketable product, the roots, leaves and tender stems are also edible (Castillo-Martínez et al., 2013). Recently, this species is gaining more attention due to its reported nutritional and bio-functional properties (Parra et al., 2018; Riviello-Flores et al. 2018; Vieira et al. 2019). In North Macedonia, this species is not well known, and is not cultivated as a commercial crop. So far, it is not listed in the National variety list published by the Ministry of Agriculture, Forestry and Water Economy of the Republic of North Macedonia (2008). In the Eastern part of the country, where the study took place (Kochani region) it was brought in the late 90's. Its cultivation is isolated and local, mainly as a garden plant by certain individuals. It is sometimes available on the local market. The available information for the performance of this tropical species in the temperate climate conditions of North Macedonia or the surrounding region, which is well outside its range of cultivation is scarce. Therefore, a study was conducted in order to investigate some biological, morphological and productive properties of this species. The study represents a preliminary evaluation of the chayote under the temperate continental sub-Mediterranean climate conditions of North Macedonia. It will also be of benefit for the wider region and give insight into the possibility of cultivation of this crop in regions with similar climate conditions.

MATERIALS and METHODS

The study was conducted in the Kochani region in North Macedonia during 2019 and 2020. The chayote investigated in this study originates from a local population of the *albus spinosum* variety (Figure 1), first introduced in the region during the 90's decade (author's notation). The study was performed in four replications. Each year, five chayote vines were grown on wire trellises. Four vines were used for the evaluation of the phenology, morphological and productive properties of chayote, where each vine represented a replication. The fifth vine was used to examine the effect of low temperatures on chayote at the end of the vegetative cycle in autumn and to determine the date of the first freeze injury.

Figure 1. *Sechium edule* (Jacq.) Sw. var. *albus spinosum*

The fruits were sprouted indoors during early spring and grown in pots until transplanting the young plants at the trial site on 1st of May. In absence of guidelines for fertilization in our conditions, the fertilization was done based on the author's previous experience with chayote. Table 1 presents an overview of the fertilizers used in the study and fertilizers dosage.

Table 1. Fertilizers used in the trial and fertilizer dosage. FER/ plant – quantity of applied fertilizer per plant; AI/ plant –quantity of applied active ingredient per plant. S- denotes application in soil. F – foliar application

Time of application	FER/ plant (g)	AI/ plant (g)
Before transplanting (S)	200 g NPK (15:15:15)	30 g (N); 30 g (P); 30 g (K)
Beginning of June (S)	200 g NPK (15:15:15)	30 g (N); 30 g (P); 30 g (K)
July (F)	1.5 g NPK (12:4:6)	0.18 g (N); 0.06 g (P); 0.09 g (K) + trace elements
August (F)	3.0 g NPK (12:4:6)	0.36 g (N); 0.12 g (P); 0.18 g (K) + trace elements
September (F)	3.0 g NPK (12:4:6)	0.36 g (N); 0.12 g (P); 0.18 g (K) + trace elements
Fruiting (F)	3.0 g Megagreen x 3 applications	1.02 g (Ca) + trace elements × 3
Fruiting (F)	3.0 g NPK (8:6:46) x 3 applications	0.24 g (N); 0.18 g (P); 1.38 g (K) × 3
Summary: Fertilizers (g/plant)		Active ingredients
400 g/plant NPK (15:15:15); 7.5 g/plant NPK (12:4:6); 9.0 g/plant NPK (8:6:46); 9.0 g/plant Megagreen		N: 61.62 g; P: 60.84 g; K: 64.59 g; Ca: 3.06 g + trace elements

Harvest was performed in November depending on the weather conditions, before the crop was damaged by frost and temperatures below 0 °C.

Phenology of chayote

The phenology of the chayote vines was observed and the following characteristics were determined in each plant: The length of the vegetative stage (days to flowering) was determined as number of days from transplanting date to the date when the first open flower of each plant appeared. The length of the reproductive stage was determined as number of days from the date when the first flower appeared to the harvest date. Life cycle length was determined based on the harvest date and the first frost date. Each year, four out of five chayote vines were examined for the productive and morphological properties. The dates when the first open female and male flowers in the trial appeared were recorded. The fruit maturation time was examined in 2019. Female flowers were labeled on the day of opening successively thru the reproductive stage (end of September to third week of October, Figure 2A). At harvest, fruits of different age were obtained. The fruit weight and dimensions of labeled fruits were measured. The results were grouped in three groups based on the fruit age: 27 to 31 days, 32 to 36 and 37 to 41 days from flowering to harvest. The results were analyzed with ANOVA and LSD test using Microsoft Excel, according to the statistical methods for agricultural research provided by Hadživuković (1973).

Morphological characteristics

The arrangement of male and female flowers was observed during the flowering period in autumn. The rest of the morphological properties were examined in November on fully developed fruiting vines. The plant length (PL) was determined at harvest. After harvesting the fruits, the vines were cut and the length from the base of the plant to the tip was measured. The leaf dimensions were determined on 10 random fully developed leaves per vine. The leaf surface area was measured using the tracing method described by Oloan and Jose (2011), using paper replicates of chayote leaves by the formula: Leaf surface (blade) area (cm^2) = Weight of paper replica (g) × 100 cm^2 / Weight of standard (g), where 100 cm^2 is the surface of the standard. The fruit dimensions (length, width and thickness) were measured with digital caliper on 10 mature fruits per plant. Fruit spine density was evaluated according to the rating scale by Oloan and Jose (2011). Descriptive characteristics of the stem, leaves, tendrils and fruit were evaluated according to the scale by UPOV (2011).

Productive Properties

At harvest, the fruits from each vine were harvested, the vines were cut and after the plant length was measured, the leaves were separated from the stems (Figure 2B). The fractions were measured on a balance. Each fruit was weighted individually, and the fruits were separated in two groups- ripe and unripe fruit. Unripe fruits were considered fruits with weight of 200 g or lower (200 g to 100 g). This characteristic was selected as a criterion after taking in consideration the characteristics of mature, fully developed fruits such as the weight, fruit dimensions and thorn firmness. The group of unripe fruits generally comprised of fruits developed later in the season which did not have the time or adequate weather conditions to obtain full maturity. Small, underdeveloped fruits with weight less than 100g were excluded from the study. The following properties were examined:

Biological yield (BY) and biological yield components per plant (BYC):

-Green mass yield (kg/ plant) = leaves (kg/ plant) + stems (including tendrils) (kg/ plant);

-Total fruit yield (kg/ plant) = mature fruit yield (kg/ plant) + unripe fruit yield (kg/ plant);

-Biological yield (BY) (kg/plant) = green mass yield (kg/ plant) + total fruit yield (kg/ plant).

-Total number of fruits (TNF), number of mature fruits (NMF) and number of unripe fruits (NUF) per plant.

The ripe fruits were also additionally classified in five classes based on the fruit weight – 201 to 300, 301 to 400, 401 to 500, 501 to 600 and over 600g.

Figure 2. A: Chayote fruit labeled at the date when the female flower opened; B: determination of the chayote biological yield and its components (separated leaves, stems (including tendrils) and fruits of chayote vine.

Chemical properties

The water content, total soluble solids and pH were determined in four replications, using 2 samples per replication. The water content was determined by drying the fruit samples at 105 °C to constant weight and was expressed as % of the fresh fruit weight. In order to measure the total soluble solids and pH, liquid samples were prepared by processing the fruits on a blender, after which the samples were strained to obtain liquid (fruit juice). The total soluble solids of the fruit were measured in %Brix using digital refractometer (Kruss). The pH was determined using digital pH-measuringinstrument (Testo).

Pests

The infestation of pests was rated according to the scale given by Oloan and Jose (2011).

Weather conditions

The trial site is situated in the temperate continental sub-Mediterranean region of North Macedonia (Filipovski et al., 1996). According to the new global maps of the Köppen-Geiger climate classification for the present-day (1980–2016) at 1-km resolution (Beck et al., 2018), the climate of this region is classified as BSk (steppe, arid, cold) climate. The meteorological data during the vegetation for the trial years 2019-2020 (Table 2) were obtained from the automated weather station in Kochani (http://agrometeo.mk).

Table 2. Meteorological data for the 2019-2020 period. Data for 11/2020 was available to 22.11.2020.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Vegetation average
Mean monthly temperatures (ºC)									
2019	12.99	16.00	22.47	23.64	25.66	20.37	14.86	12.67	18.58
2020	11.96	17.22	20.63	23.97	23.56	21.70	13.33	7.95	17.54
Mean monthly maximum temperature (ºC)									
2019	19.07	22.11	29.77	31.06	33.54	28.31	25.16	18.24	25.91
2020	18.59	24.71	28.20	30.91	31.26	28.78	20.44	15.08	24.75
Mean monthly minimum temperature (ºC)									
2019	6.48	9.48	15.52	15.37	16.49	12.10	5.04	7.60	11.01
2020	4.2	9.62	14.30	15.69	16.06	14.02	7.39	1.66	10.37
Average sunshine duration (h/day)									
2019	6.80	6.85	9.63	9.69	10.89	9.04	8.91	3.31	8.14
2020	8.15	7.19	8.29	10.85	10.47	9.09	6.33	5.67	8.26
Average relative humidity (%)									
2019	60.69	62.76	62.78	55.31	45.04	55.21	57.43	72.37	58.95
2020	58.44	58.20	61.07	55.30	61.86	53.87	71.83	73.75	61.79

RESULTS AND DISCUSSION

Phenological properties

Photoperiod and growth stages

Some important dates regarding the phenology of chayote and the length of the growth phases are given in Table 3. The chayote is a short day plant, meaning flowering is initiated at day length of 12 hours. In the climate conditions of Mexico, where chayote originates from, the photoperiod conditions flowering in 2.5 months after planting when the crop is planted from June to September, or 5 months if established from December to January (Cadena-Iñiguez et al., 2007). In the region of Kochani, North Macedonia (coordinates 41°55”N, 22°25”E), the chayote began flowering in short day conditions in September, near the autumn equinox (25.09.2019 and 11.09.2020). The day length on these dates was 12:03:11 hours in 2019 and 12:40:04 hours in 2020 (source: https://dateandtime.info/citysu nrisesunset.php?id=789403). The short-day photoperiod resulted in a long vegetative stage – 149 days to flowering in 2019 and 137.5 days to flowering in 2020. In comparison, Oloan and Jose (2011) reported 98 to 119 days to flowering in different chayote accessions form the Philippines. The generative phase (based on the harvest date) lasted 53 days in 2019 and 59.5 days in 2020. The total life cycle based on the harvest date was 202 days in 2019 and 196 days in 2020. Based on the first frost damage date, the life cycle lasted 210 days in 2019 and 203 days in 2020. The species is monoecious, bearing both female (pistillate) and male (staminate) flowers on the same plant. The first open flowers in both years were female. Earlier development of female flowers is in accordance with observations from previous years (author’s notation). There was a 10 days difference between the first opened female and male flower in the trial in 2019, while in 2020 this difference was 12 days. During this period, abortion of female flowers was observed due to lack of pollination. Also, small fruits, probably of parthenocarpic origin formed but failed to develop further. The critical flowering period for effective fruit set and maturation lasted from the last quarter of September in 2020 and first quarter of October in 2019 to the second quarter of October. Flowers pollinated in this period had enough time to develop mature fruits. The flowering period lasted until the end of the season (November), when the chayote was damaged by frost, however flowers pollinated later in the autumn season did not have enough time and favorable conditions to mature. The pollination was performed by insects – the honey bee.

Table 3. Phenology of chayote: important dates and duration of growth stages. *Vegetative stage excludes the propagation period of chayote which takes place in indoor conditions; DFM- days between first opened female and male flower

Important dates					
	Sowing date	First female flower	First male flower	Harvest	Frost damage
2019	01.05.2019	25.09.2019	05.10.2019	19.11.2019	01.12.2019
2020	01.05.2020	11.09.2020	23.09.2020	13.11.2020	20.11.2020

Duration of growth stages					
	Vegetative stage*	Reproductive stage	Days to harvest	Days to first frost damage	DFM
2019	149 ± 2.63	53 ± 2.63	202	210	10
2020	137.5 ± 3.11	59.5 ± 3.11	196	203	12
AVG	143.25 ± 8.13	56.25 ± 4.60	199 ± 4.24	206.5 ± 4.95	11 ± 1.41

Sensitivity to low temperatures

Although a perennial in tropical climates, in temperate regions chayote grows as an annual. In both years chayote was killed by the first freezing temperatures in autumn. The first signs of frost damage in 2019 occurred on 01.12.2019.

Figure 3. Chayote is extremely sensitive to low temperatures. Plant killed by light frost in 2019 after a night of temperature fluctuations between 0 °C to -2 °C: severe frost damage of chayote leaves, stems, flowers and fruit (a) and main stem (b).

Figure 3 shows frost damaged chayote branch and fruit on the early morning hours of 01.12.2019, when temperature at 0 °C to -2 °C for several hours caused complete die back of plants. From 00:00 to 08:00 AM the temperature ranged from + 0.5 to -0.2 °C with exception at 06:00 AM – 2.3°C at and 7:00 AM -1.4 °C (source: Automatic agrometeorological station in Kochani, information available at agrometeo.mk). Therefore, fruits should be harvested before freezing temperatures occur. The first frost damage in 2020 occurred on 20.11.2020, when the temperature dropped down to -1.7 °C. It can be concluded that even short duration of temperatures between -1 °C to -2 °C are enough to cause severe damage to chayote vines and fruit. These observations are in accordance with the frost sensitivity report by Cisneros Solano et al. (2011).

Fruit maturation time

Table 4 shows the fruit development (weight, length width and thickness) of the different maturation day groups. The mean squares of the weight, length, width and thickness of chayote fruits are presented in Table 5. According to Arévalo Galarza et al. (2011), the *albus spinosum* variety has a fruit length of 5.8 to 17.1 cm, 5.0 to 12.2 cm width and 3.6 to 9.7 cm thickness. As seen from the results, the fruit size of all 3 groups was within these limits. Significant difference in means was obtained only for the fruit length between the maturity groups of 27 to 31 and 37 to 41 days after flowering. The differences in width and thickness between the 3 groups were insignificant. Although the highest value for the average fruit weigh (352.29 g) was determined in the 32 to 36 days maturity group, the difference was insignificant in comparison to the other groups – 349.73 g in the 27 to 31 days group and 348.70 g in the 37 to 41 days group. Therefore, based on the results it can be argued that under good weather conditions 27 to 31 days are enough for the fruits to mature in temperate conditions. Oloan and Jose (2011) reported 21 to 31 days from flowering to maturity for different chayote accessions, while according to Stephens (1994), this period is 35 days from pollination.

Table 4. Weight, length, width and thickness of chayote at maturation period of 27 to 31, 32 to 36 and 37 to 41 days after flowering. DAF – days after flowering; LSD (0.05) and LSD (0.01): least significant difference at 0.05 and 0.01 level of probability; means with different letters significantly differ at 0.05 level of probability

DAF	Weight	Length	Width	Thickness
27 to 31	349.73 ± 72.09a	11.65 ± 1.49a	8.08 ± 0.61a	7.31 ±0.47a
CV	20.61	12.79	7.55	6.43
Min/max	198/ 477	8.96/ 15.08	6.56/ 9.02	61.52/ 82.09
32 to 36	352.29 ± 84.99a	12.16 ± 1.59ab	8.11 ± 0.68a	7.33 ± 0.42a
CV	24.13	13.08	8.38	5.73
Min/max	226/ 532	10.48/ 16.10	7.05/ 9.60	6.72/8.34
37 to 41	348.70 ± 65.87a	12.65 ± 0.91b	8.10 ± 0.58a	7.30 ± 0.39a
CV	18.89	7.19	7.16	5.34
Min/ max	198/ 471	9.59/ 14.03	6.46/ 9.13	6.27/7.95
AVG	350.24	11.87	8.10	7.31
LSD (0.05)	51.63	0.68	0.39	0.23
LSD (0.01)	78.21	1.03	0.59	0.35

Table 5. Mean squares of the weight, length, width and thickness of chayote fruits.

	Df	Weight	Length	Width	Thickness
Replication	3	617.38252	0.52304	0.03405	0.00983
Maturity	2	45.67797	1.01531	0.00141	0.00122
Error	6	890.22543	0.15485	0.05102	0.01768

Morphological Characteristics

The examined morphometric characteristics of chayote are presented in Table 6. The plant has a branched vine-like habit and had an average plant length of 8.41 ± 0.81 m. The stems are light green at young stage and yellow at mature stage. The pubescence is present on the nodes (many) and in the internode region (few). The leaves are alternately arranged. The petiole is glabrous, light green with green striate. The leaf blade is dark green in color with white venation, ovate to ovate-cordate, 5-lobed. The terminal lobe is acute, the upper lateral lobes are subobtuse, while the lower lateral lobes are subobtuse to obtuse. The abaxial surface is pubescent with many trichomes. Mucrones are few, present on the apex of lobes. The leaf blade had an average area of 333.03 ± 5.01 cm^2. The plant attaches to the provided support by tendrils. The tendrils are light green, with few striate, with a long main axis and 3 shorter lateral branches. The plant is monoecious, bearing both female and male flowers with cream-white corolla (tends to be lighter in female flowers) and green calyx. The arrangement of male and female flowers is pictured on Figure 4. Male flowers were grouped in raceme of 10-20. The female flowers were singular, or in inflorescence with a short pedicel bearing 2 to 4 female flowers. However, development of a combined inflorescence was also observed, of up to 10 female flowers and 10 to 15 male flowers that developed later in the bases of the female flowers. Usually, a node with single female flower also developed a male, female or combined inflorescence. Sometimes, a female flower was followed by two (male and female) inflorescences.

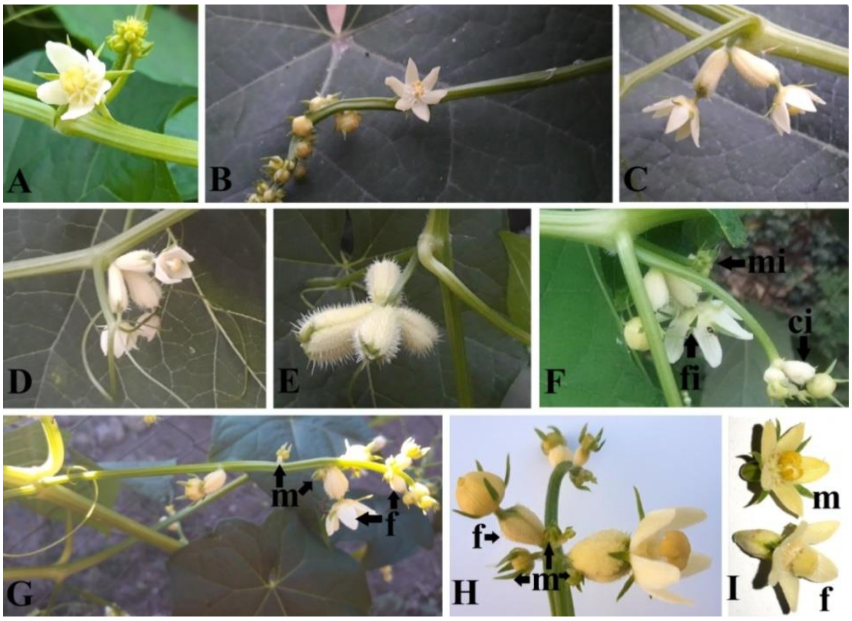

Figure 4. Arrangement of male and female flowers in chayote. Single female flower and male inflorescence developing at the same node (A); Male inflorescence (B); Female inflorescence of 2 flowers (C), 3 flowers (D) and 4 flowers (E); Female inflorescence (fi), male inflorescence (mi) and combined inflorescence (ci) developing at the same node (F); Combined inflorescence (G and H); Female and male flowers (I); f- female flowers, m-male flowers

The fruit is pyriform to pyriform-obovoid in longitudinal section and oval in cross section, with up to 5 slightly pronounced grooves. The fruit had an average length of 12.14 cm, width of 8.06 cm and thickness of 7.29 cm. The skin is yellowish-cream, with many spines (>100) distributed on the entire fruit surface. The flesh is white with few fibrous flesh. The seed is single, with a soft seed coat, flat with obovoid shape and cream color. Unlike in tropical regions, the chayote evaluated in the trial did not form tuberous roots, which are also edible.

Table 6. Some morphological characteristics of chayote. PL- plant length; TL- tendril length; BL- leaf blade length; BW- leaf blade width; LWR- blade length/width ratio; BA- leaf blade area; PL- petiole length; FL- fruit length; FW- fruit width; FT- fruit thickness

	2019	CV%	2020	CV%	AVG
PL (m)	7.83 ± 1.63	20.82%	8.98 ± 0.30	3.34%	8.41 ± 0.81
TL (cm)	41.80 ± 2.38	5.69%	42.18 ± 2.25	5.33%	41.99 ± 0.27
BL (cm)	24.08 ± 1.58	6.56%	24.35 ± 0.53	2.18%	24.22 ± 0.19
BW (cm)	20.99 ± 1.49	7.10%	21.20 ± 0.53	2.50%	21.10 ± 0.15
LWR	1.15 ± 0.01	0.87%	1.15 ± 0.01	0.87%	1.15 ± 0.00
BA (cm^2)	329.49 ± 43.37	13.16%	336.57 ± 17.62	5.24%	333.03 ± 5.01
PL (cm)	11.24 ± 2.28	20.28%	12.10 ± 2.44	20.17%	11.67 ± 0.61
FL (cm)	12.14 ±0.59	4.86%	12.13 ± 0.60	4.95%	12.14 ± 0.01
FW (cm)	8.10 ±0.23	2.84%	8.02 ± 0.12	1.50%	8.06 ± 0.06
FT (cm)	7.33 ± 0.17	2.32%	7.26 ± 0.09	1.24%	7.30 ± 0.05

Productive properties

Biological yield and components

The productive properties recorded in chayote (biological yield and yield components, number of fruits per plant, leaf/stem ratio) are presented on Table 7. In 2019 there was a severe drop in all of the examined productive properties as compared to 2020. The biological yield was 38.11 ± 17.11 kg/plant in 2019, as compared to 75.25 ± 19.32 kg/plant in 2020. In 2019, the average number of mature fruits per plant was 45.00 ± 10.17 with a yield of 14.85 ± 2.63 kg/plant. In 2020, increased number of mature fruits per plant was recorded (112.00 ± 26.00), which resulted in a higher yield (41.25 ± 9.09 kg/plant). The lower yield in the first trial year can be attributed mainly to the later start of flowering as compared to 2020, which postponed the reproductive stage later in the autumn season and shortened the critical flowering period for effective fruit set and maturation. Female flowers developed in the end of September were aborted due to lack of pollination, and pollinated flowers later in the season were unable to mature due to unfavorable conditions (low temperatures). The summer of 2019 had higher temperatures compared to 2020 (Table 2), which negatively affected the plant growth and development. In both years, frequent wilting and growth stagnation was observed during warm periods with day temperatures of around 35 ^{o}C or higher. This occurrence was more pronounced in 2019, with higher temperatures especially during August, and was reflected in the lower leaf, stem and total green mass yield per plant. In addition, a higher pest infestation levels were recorded in 2019. All of this factors may have contributed to the lower yield in 2019.

Table 7. Biological yield components (kg/plant) and number of fruits per plant in chayote. BY- biological yield; BYC- biological yield component; CBY- contribution of the components in the biological yield; LSR- leaf/ stem ratio; TNF/plant- total number of fruits per plant; NMF/plant- number of mature fruits per plant; NUF/plant- number of unripe fruits per plant.

	2019	2020	AVG
BY (kg/plant)	38.11 ± 17.11	75.25 ± 19.32	55.68 ± 26.26
Components (kg/plant)			
Green mass	21.95 ± 13.73	31.58 ± 8.27	26.77 ± 6.81
Leaves	11.40 ± 6.93	16.74 ± 4.55	14.07 ± 3.78
Stems	10.55 ± 6.96	14.84 ± 3.72	12.70 ± 3.03
Fruits (total)	16.15 ± 3.38	43.67 ± 11.05	29.91 ± 19.46
Fruits (ripe)	14.85 ± 2.63	41.25 ± 9.09	28.05 ± 18.67
Fruits (unripe)	1.31 ± 0.77	2.42 ± 1.96	1.87 ± 0.78
Number of fruits per plant			
TNF/plant	52.50 ± 16.49	127.50 ± 38.5	90.00 ± 53.03
NMF/plant	45.00 ± 10.17	112.00 ± 26.00	78.50 ± 47.38
NUF/plant	7.50 ± 6.35	15,5 ± 12,5	11.5 ± 5.66

The share of the biomass components (%) is shown on Figure 5. In 2019, the ripe fruits represented 38.97% of the total fresh biomass, while in 2020 their share was higher (54.82%).

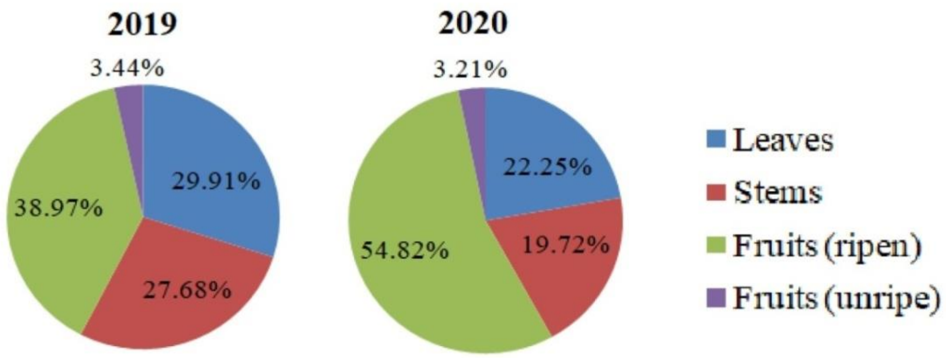

Figure 5. Biomass components – leaves, stems including tendrils, ripe and unripe fruits (%).

Evaluation of the fruit weight

Table 8 presents the results for the evaluation of the fruit weight in five groups: 201-300 g, 301-400 g, 401-500 g, 501-600 g and over 600 g. As seen from the results, in 2020 the average fruit weight (369.37 ± 6.51 g) was higher compared to 2019 (330.41 ± 11.21 g), as well as the average number of fruits per plant in each category. In 2019, the highest number of fruits per plant (18.50 ± 4.51) were within the group of 200 to 300 g, while in 2020 the highest number of fruits per plant (41.00 ± 5.23) were in the group within 300 to 400 g.

Table 8. Evaluation of the fruit weight of mature fruits during 2019-2020. Number of fruits per plant in each category and average fruit weight (g) per year

Weight category	2019	2020	AVG
201-300 g	18.50 ± 4.51	33.00 ± 11.37	25.75 ± 10.25
301-400 g	17.50 ± 3.70	41.00 ± 5.23	29.25 ± 16.62
401-500 g	8.50 ± 1.29	24.00 ± 5.89	16.25 ± 10.96
501-600 g	0.50 ± 0.58	12.00 ± 4.08	6.25 ± 8.13
>600 g	0	2.00 ± 1.83	1.00 ± 1.41
Total No. of fruits	45.00	112	78.50
Weight AVG (g)	330.41 ± 11.21	369.37 ± 6.51	349.89 ± 27.55

Chemical Parameters

Some chemical parameters of the fruit are given in Table 9. The fruit had an average water content of 94.72 ± 0.13%, total dry content of 5.28 ± 0.13, total soluble solids of 2.35 ± 0.21%Brix and pH value of 6,39 ± 0,11. While water content and the pH were similar to the reports from other regions, the total soluble solids obtained in North Macedonia were lower compared to reports by Ekanayake et al. (2007), Mishra and Das (2015), Oloan and Jose (2017) and similar to the results reported by Castro Rodríguez et al. (2015).

Table 9. Water content, total dry content (TDC), total soluble solids (TSS) and pH in chayote fruits.

	Water content (%)	TDC (%)	TSS (%Brix)	pH
2019	94.81 ± 0.33	5.19 ± 0.33	2.20 ± 0.42	6.47 ±0.11
2020	94.63 ± 0.36	5.37 ± 0.36	2.49±0.39	6.31 ±0.09
AVG	94.72 ±0.13	5.28 ± 0.13	2.35 ± 0.21	6.39 ± 0.11

Pests

The insects pest observed in chayote were the white flies and aphids (Figure 6). Pest infestation was higher in 2019 compared to 2020 (Table 10).

Table 10. Pest infestation in chayote. The infestation of pests was rated according to the scale given by Oloan and Jose (2017)

White flies		Black bean aphid	
2019	2020	2019	2020
3 (26%-50%)	1 (1%-25%)	1 (1%-25%)	0

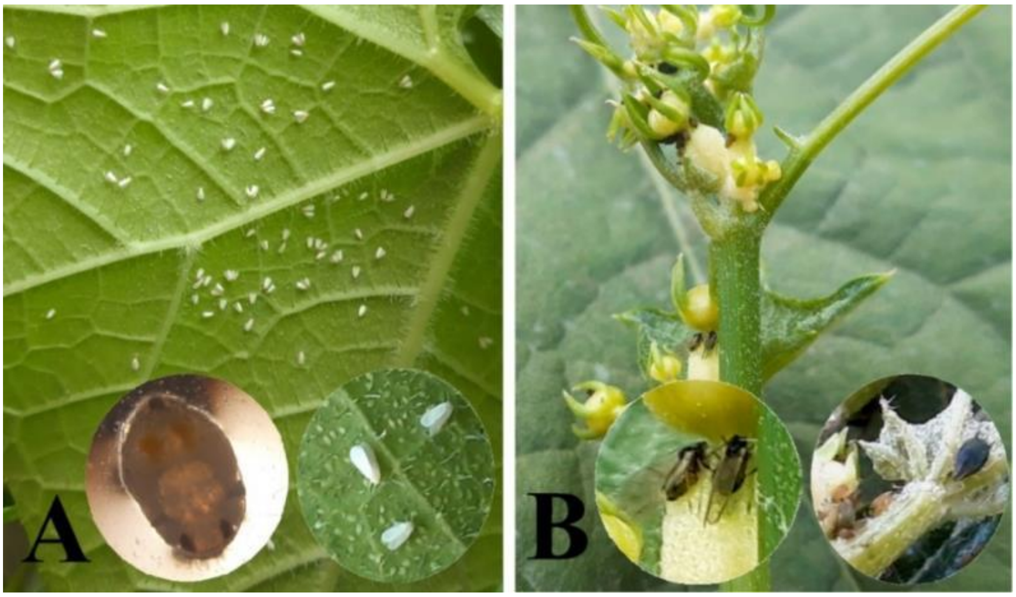

Figure 6. Pests recorded in chayote: white flies (A) and aphids (B).

CONCLUSIONS

Based on the results, it can be concluded that the short day photoperiod of this species which initiates late flowering, along with its frost sensitivity are the main limiting factors for its cultivation in temperate climate regions. In the temperate climate conditions of North Macedonia variable chayote yield was obtained. The species is worth further investigations in order to determine the best production practices and technology in regards to the optimal yield and fruit quality.

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