TEMPORAL PATTERNS OF VARIATION IN BIOMORPHOLOGICAL AND BIOCHEMICAL TRAITS AMONG PROMISING TOMATO CULTIVARS

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Abstract. This article focuses on the variability of biomorphological and biochemical indicators in promising tomato varieties depending on the stages of plant development. The main aim of the study was to examine the dynamics of changes in biomorphological and biochemical traits in tomato varieties that differ in ripening period, fruit shape, and resistance to environmental conditions, as well as to identify similarities and differences in these patterns across different growth phases.

The results showed that significant biomorphological changes in tomato varieties mainly occur during the seedling stage up to the formation of male flowers. A sharp increase in fruit mass in both varieties was observed during the technical maturity stage of the first fruits. After this stage, the growth rate decreased in the “Alsu ” variety, while in the “Damla ” variety this process continued until the full ripening of fruits.

It should be noted that during the period from seedling emergence to the formation of female flowers, plant height in the “Alsu” variety increased 5.1 times, the number of tiers 3.8 times, leaf weight 75.4 times, stem and petiole weight 107.5 times, and root weight 14.3 times. In the same period, the “Damla” variety showed increases of 6.2, 2.6, 101.8, 142.3, and 23.4 times, respectively.

It was determined that the dynamics of accumulation of dry matter, sugars, and extractive substances in the fruits of the studied tomato varieties follow a two-peak curve, with maximum values

observed during the stages of primary fruit formation and technical ripeness. The highest levels of these indicators were recorded at the stage of technical maturity of the first fruits.

It was also revealed that under conditions of high temperature and drought stress, metabolic processes in the fruits of promising tomato varieties are disrupted, leading to an increase in toxic substances. In particular, nitrate content exceeded the maximum permissible level by 1.44–2.57 times.

Key words: variety, biomorphological indicators, biochemical indicators, development stages, tomatoes.

1. Introduction

Tomatoes are a nutrient-rich food product with their nutritional value largely determined by their chemical composition. They consist predominantly of water (approximately 90%) and contain a wide range of vitamins, including vitamin E, PP (niacin), A, B1, B2, B5, B9 (folate), beta-carotene, and ascorbic acid (vitamin C). In addition, tomatoes provide essential microelements such as iron, silicon, zinc, iodine, copper, fluorine, and cobalt. They also contain mono- and disaccharides, organic acids (including citric, malic, and succinic acids), as well as both saturated and unsaturated fatty acids, and dietary fiber. Due to this complex composition, tomatoes are widely regarded as an important component of a balanced human diet [1].

The bioactive compounds present in tomatoes contribute to various physiological functions. They support immune system activity, help maintain normal nervous system function, promote digestive health, and contribute to the proper functioning of the cardiovascular and circulatory systems. Furthermore, regular consumption of tomatoes may support skin health, assist in the elimination of toxins, and promote overall cellular well-being [2].

Fruits rich in mono- and disaccharides serve as a valuable energy source and can positively influence mood. However, due to their sugar content, their consumption should be moderated by individuals with diabetes. The biochemical composition of tomato fruits is influenced by multiple factors, including soil and climatic conditions, temperature variations during the growing season, application of mineral and organic fertilizers, biological characteristics of the varieties, irrigation regimes, and the specific phases of plant growth and development. During the vegetation period, the accumulation of effective temperatures above 15°C determines the plant's heat requirements, which vary depending on varietal characteristics. At temperatures below 15°C, tomato development slows down; at around 10°C, assimilation processes are significantly reduced; near 1°C, growth ceases; and at sub-zero temperatures, plants may be severely damaged or die. At the same time, tomatoes are capable of tolerating relatively high temperatures, although excessive heat can negatively affect growth and fruit quality [3].

Tomato plants are sensitive to light conditions, particularly during early growth and flowering stages. Insufficient light or shading can delay flowering and reduce fruit set. Reduced sunlight intensity (for example, during prolonged cloudy weather) lowers the rate of photosynthesis, which in turn decreases the accumulation of dry matter and sugars in the fruits. High planting density may also delay fruit ripening and reduce overall yield.

Tomatoes respond well to fertilization. Organic fertilizers, such as well-decomposed manure, improve soil structure and fertility, especially in soils poor in organic matter, but should be applied in moderate amounts. Excessive application may delay fruit ripening, reduce quality, and increase susceptibility to diseases. Balanced use of mineral fertilizers, on the other hand, has a positive effect on plant development, yield, and fruit quality.

Tomato fruits are generally classified as climacteric, meaning they continue to ripen after harvest due to ethylene production. In addition to their nutritional value, tomato by-products also exhibit important biological activities, including antioxidant and antimicrobial effects, largely due to their bioactive compounds. Future research should focus on advanced breeding methods, including marker-assisted selection and the identification of genetic diversity among wild and cultivated tomato genotypes to ensure their sustainable use [4].

The aim of the present study is to investigate the dynamics of biochemical and biomorphological indicators in tomatoes depending on their growth and developmental stages, and to identify the patterns observed throughout this process [5].

2. Materials and Methods

The object of the study consisted of two promising tomato cultivars, Alsu and Damla developed at the Research Institute of Vegetable Growing. Biomorphological characteristics of the tomato genotypes and the biochemical composition of their fruits were investigated during the following developmental stages: the formation of 4–5 leaves, the appearance of male flowers, the formation of female flowers, fertilization, the development of the first fruits, the technical maturity of the first fruits, and changes in fruit mass during growth, as well as at the end of the vegetation period.

Field experiments were conducted on the soils of the Absheron Experimental Station of the Research Institute of Vegetable Growing. Since these soils are characterized by low humus content and limited mineral nutrients, 20 t/ha of organic manure and two-thirds of the planned dose of mineral fertilizers (excluding nitrogen), calculated as N80P80K60 in active ingredients, were applied during autumn plowing. Twenty days after planting and at the initial stage of fruit formation, the remaining portions of nitrogen, phosphorus, and potassium were applied in two split doses in the form of ammofoska (N20P20K20). The experimental plots consisted of rows 20 m in length and 2.8 m in width, with 70 cm spacing both between and within rows. The total plot area was 56 m^2, and the experiment was conducted in three replications.

The dry matter content in vegetative and generative organs, as well as in the fruits, was determined using the thermostat-weight method by drying samples at 105°C. The total sugar content of the tomato fruits was measured using an RA-130 refractometer (Japan), while extractive substances were determined with an RX-5000 CX refractometer (ATAGO, Japan). The nitrate content in the fruits was assessed using a SOEKS nitrometer.

3. Results

Observations and measurements were carried out on 12 morphological and productive parameters in tomato varieties, including plant height, number of leaf layers (i.e., number of leaves), and the biomass of leaves, stems and petioles, roots, flowers, and fruits. Additional parameters included the number of flowers and fruits, fruit length, diameter, and fruit index. It was found that the most pronounced biomorphological changes mainly occur during the transition from the seedling stage to the male flowering phase. From the onset of female flowering to the initial fruit set stage, the growth rate of all plant organs decreases. However, from initial fruit formation until the end of the growing season, the dynamics of the studied traits accelerate (Table 1).

For instance, in the Alsu tomato variety, the transition to the male flowering stage resulted in a 4.16-fold increase in plant height, a 2.5-fold increase in leaf number, a 65.5-fold increase in leaf mass, a 91.1-fold increase in stem and petiole mass, and a 14.3-fold increase in root mass. In contrast, in the Damla variety, the corresponding increases were 3.76, 1.8, 44.6, 66.6, and 7.70 times, respectively. This marked difference is explained by the fact that in Damla , intensive growth continues until the next developmental phase, namely female flowering. While growth in Alsu slightly slows with the appearance of female flowers, it continues to increase in Damla . The reduction in growth rate in Damla coincides with the fertilization and early fruit formation stage.

A sharp increase in fruit mass was observed in both varieties during the technical ripeness stage of the first fruits. After this stage, fruit mass accumulation slows in Alsu, whereas it continues in Damla until the mass ripening stage, after which growth declines toward the end of the growing season. During technical ripeness, fruit mass increased 19.13-fold in Alsu and 11.71-fold in Damla . During the transition to mass ripening, a different pattern was observed: the increase was 1.41-fold in Alsu and 3.71-fold in Damla. This difference is attributed to the fact that Alsu is an early-maturing variety, while Damla is mid-maturing.

In summary, most studied parameters—except fruit length, diameter, index, and flower mass—reached their maximum values by the end of the vegetation period. The highest flower mass in Alsu (20.62 g) was recorded during fertilization and early fruit set, whereas in Damla it was observed during mass ripening (10.71 g). In Alsu , maximum fruit length (185.0 mm) occurred at technical ripeness, while maximum fruit diameter (156.3 mm) was reached at the end of the growing period.

In contrast, in Damla , the highest values of these traits (100.35 mm and 109.75 mm, respectively) were recorded at the end of vegetation.

Interestingly, the fruit index remained nearly stable from technical ripeness to the end of the season in both varieties (1.120–1.194 in Alsu and 0.91–0.92 in Damla).

The results also indicate that dry matter content in leaves steadily increases up to the technical ripeness stage of the first fruits. However, in the mid-maturing Damla variety, the maximum level (34.4%) is reached at this stage, whereas in the early-maturing Alsu variety, the peak (32.8%) occurs during mass ripening (Table 2). In later stages, leaf dry matter decreases in both varieties, with a slightly stronger decline observed in Damla compared to Alsu.

The dynamics of dry matter accumulation in stems and petioles show a single-peak pattern in Damla , with a maximum value (12.5%) at the end of the growing season. In contrast, Alsu exhibits a double-peak pattern, with peak values recorded at both the technical ripeness stage of the first fruits (11.4%) and again at the end of vegetation (14.9%).

Table 1.Dynamics of changes in biomorphological indicators of perspective tomato varieties grown in open fields depending on growth and development phases (2021-2022)

Development phases	**Plant height, mm**	**Number of tiers, pieces**	**The mass of the leaves, g**	**The mass of the stem and petioles, g**	**The mass of the root, g**	**The number of flowers, pieces**	**The mass of the flowers, g**	**The number of fruits, pieces**	**The mass of the fruits, g**	**The length of the fruits, mm**	**The diameter of the fruits, mm**	**The fruit index**
Alsu												
Seedling phase(formation of 4-5 leaves)	17,8	4,8	1,41	1,58	0.44	-	-	-	-	-	-	-
Formation of male flowers	74,0	12,0	92,37	143.96	6,27	33	4,76	-	-	-	-	-
Formation of female flowers	91,0	18,0	106,34	169,86	6,25	39	5,13	-	-	-	-	-
Fertilization and the formation of the first fruits	105,0	20,0	124,77	205,1	11,75	142	20,62	2	175,45	59,95	50,78	0,18
Formation of the first fruits	112,5	22,0	185,42	295,88	15,57	66	1,80	2	214,24	65,43	80,30	0,81
Technical maturity of the first fruits	220,0	22,0	362,23	619,06	20,24	-	-	2	4097,18	185,0	155,0	1,194

Mass maturation	224,0	23.0	414,49	633,04	21,84	-	-	3	5756,66	174,0	155,3	1,120
End of vegetation	267,0	25,0	671,81	1322,92	23,12	>100	4,56	3	6026,66	176,0	156,3	1,126
Damla												
Seedling phase (formation of 4-5 leaves)	21,4	5,0	1,38	1,54	0,37	-	-	-	-	-	-	-
Formation of male flowers	80,5	9,0	61,52	102,27	2,85	29	2,64	-	-	-	-	-
Formation of female flowers	133,0	13,0	140,47	219,13	8,66	43	5,57	-	-	-	-	-
Fertilization and the formation of the first fruits	144,0	18,0	175,90	290,01	10,35	66	10,18	3	231,44	59,57	48,49	1,23
Formation of the first fruits	158,5	18,0	181,65	299,40	11,48	173	3,14	3	771,0	79,08	95,28	0,83
Technical maturity of the first fruits	166,0	23,0	225,04	490,72	14,44	-	-	7	2709,35	82,62	89,85	0.92
Mass maturation	188,0	25,0	317,50	619,25	31,24	234	10,71	5	5457,30	95,35	105,26	0,91
End of vegetation	190,0	28,0	398,89	765,48	33,79	>100	10,05	9	5727,33	100,35	109,75	0,91

Table 1 presents the dynamics of biomorphological indicators of two tomato varieties (Alsu and Damla) across different growth and developmental stages under open-field conditions (2021–2022). Overall, both varieties demonstrate a clear phase-dependent increase in all vegetative and generative traits, with the most intensive changes occurring during the transition from the seedling stage to flowering and early fruit development.

In both varieties, plant height, leaf number (tiers), and biomass of leaves, stems, and roots increased steadily across all developmental phases. The most pronounced growth acceleration was observed during the transition to male and female flowering stages, followed by a gradual reduction in vegetative growth during the early fruit formation stage. Thereafter, a second phase of intensified accumulation was observed during fruit development and maturation, particularly in fruit mass and related yield components.

In the Alsu variety, plant height increased from 17.8 mm at the seedling stage to 267.0 mm at the end of vegetation, while leaf mass rose sharply from 1.41 g to 671.81 g. Stem and petiole mass also showed a substantial increase, reaching a maximum of 1322.92 g. Root mass gradually increased throughout the growth cycle, reaching 23.12 g at the final stage. Flower production peaked during the reproductive phase, while fruit development intensified from the formation of the first fruits onward.

Fruit mass reached its maximum during mass ripening (5756.66 g), accompanied by stable fruit index values (~1.12–1.19) during later stages. Fruit dimensions also reached their maximum values toward the end of vegetation, with diameter reaching 156.3 mm.

In the Damla variety**,** a similar but more prolonged growth pattern was observed. Plant height increased from 21.4 mm to 190.0 mm, while leaf mass rose from 1.38 g to 398.89 g. Stem and root biomass also increased significantly, with root mass reaching a maximum of 33.79 g. Flower and fruit formation were more pronounced in later stages compared to Alsu, indicating extended generative activity. Fruit mass increased progressively, reaching a maximum of 5727.33 g at the end of vegetation. Fruit length and diameter also peaked in the final stage (100.35 mm and 109.75 mm, respectively). The fruit index remained relatively stable (0.91–0.92) during the later developmental phases.

Comparatively, Alsu showed earlier and more rapid biomass accumulation and fruit development, consistent with a more early-maturing growth pattern, whereas Damla **e**xhibited a slower but more prolonged accumulation of biomass and fruit yield, characteristic of a mid- to late-maturing variety. Overall, both varieties demonstrated that maximum vegetative and reproductive performance is achieved toward the end of the vegetation period, although the timing and intensity of these changes differ between genotypes [6].

Conclusions.

The conducted study revealed clear phase-dependent biomorphological and productive changes in tomato varieties (**Alsu** and **Damla**) grown under open-field conditions. It was established that the most intensive growth and developmental changes occur during the transition from the seedling stage to flowering, particularly at the male and female flowering phases. During this period, all vegetative parameters, including plant height, leaf number, and biomass accumulation of leaves, stems, and roots, increased sharply.

A subsequent reduction in vegetative growth was observed during the formation of flowers and early fruit set, followed by a renewed increase in growth dynamics during fruit development and maturation stages. Fruit-related parameters, especially fruit mass, showed the most significant increases during technical and mass ripening phases.

Comparative analysis indicated that the Alsu variety is characterized by earlier development, faster biomass accumulation, and earlier attainment of maximum fruit growth, confirming its early-maturing nature. In contrast, the Damla variety exhibited a more gradual but prolonged growth and productivity pattern, with peak values occurring later in the vegetation period, which corresponds to its mid- to late-maturing characteristics.

Overall, the study demonstrates that both genetic factors and developmental phases significantly influence the growth dynamics and yield formation of tomato plants. The obtained

results highlight the importance of selecting appropriate varieties based on maturity type and environmental conditions to optimize productivity under open-field cultivation systems.**References**

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