RESEARCH ON THE INFLUENCE OF SOME TECHNOLOGICAL FACTORS ON PRODUCTION IN PLASTIC TUNNEL TOMATO CULTIVATION

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Abstract. *Tomatoes (Lycopersicon esculentum Mill.) are native to Central and South America. The comparative experiments with the two tomato varieties took place in the period 2022-2023 and were organized in a 160 m^2 plastic tunnel from the Lovrin Research and Development Station, Timiș County, Romania. The experimental variants were placed according to the model of bifactorial experiments with subdivided plots, in 3 repetitions, namely: factor A (genetic factor – variety) with two gradations: a_1 – 'Elisabeta' and a_2 – 'Ruxandra', respectively factor B (technological factor) with two gradations: b_1 – unmulched and b_2 – mulched. To evaluate the production capacity, observations were made at the time of harvesting in terms of the number of fruits in each inflorescence and fruit weight, using current work techniques and precision equipment. The combined influence of genetic and technological factors highlights a distinctly significant difference in the average production per plant in the case of the tomato variety 'Ruxandra' grown on soil mulched with polyethylene film in the plastic tunnel. Soil mulching, as an experimental technological factor, causes a 20-25% increase in production, compared to the control variant.*

Keywords*: tomato, plastic tunnel, variety, mulched, unmulched.*

INTRODUCTION

Tomatoes (*Lycopersicon esculentum* Mill.) are native to Central and South America. The currently cultivated varieties originate in the species *Lycopersicon esculentum* var. *cerasiforme*. Originating in Peru and Ecuador, tomatoes spread to the valley of Teotihuacan-Mexico, where they were used as decorative and medicinal plants 200 years B.C.E. and later for vegetable consumption (Apahidean Al. S., Apahidean Al. I., 2016; Vînătoru C. et al., 2019).

The nutritional value of tomato fruits is due to their vitamin content (A, B, B2, B6, C), minerals (K, P, Fe, Ca, I, Mg), and organic acids (0.5-1.5%) (Ciofu Ruxandra et al., 2004). Tomato fruits are recommended in asthenia, chronic intoxication, vascular diseases, rheumatism, enteritis, and other conditions. The active principles contained in the berries work as a remineralizer, revitalizer, and blood alkalinizer (Vînătoru C. et al., 2019).

According to FAOSTAT data (2021), the total area cultivated with tomatoes in Romania reached 34.700 hectares, which represents 7.66% of the area allocated to this crop in Europe, and from this point of view, our country occupies the third place, after Italy (71.217 hectares) and Spain (34.100 hectares). In terms of produced crops, 18.099,000 tonnes of tomatoes were harvested in Europe, while Romania reported a production of 497.300 tons, which represents approximately 2.74% of the total production obtained on a European level. According to statistical data, the average annual consumption of vegetables per inhabitant in Romania is around 158.5 kg, of which 38.4 kg are tomatoes, which represents 24.22%. The main goals of the strategy devised in this sector consist in the reorganization of the vegetable production system in Romania for the purpose of making effective use of the country's special pedoclimatic conditions, along with the improvement of the socio-economic level of rural areas, which contributes to ensuring food safety and security. (https://www.fao.org/statistics/en/; https://commission.europa.eu/index_en).

MATERIAL AND METHODS

The comparative experiments with the two tomato varieties took place in the period 2022-2023 and were organized in a 160 m^2 plastic tunnel (45°58'15"N, 20°47'04"E), from the Lovrin Research and Development Station, Timiș County, Romania.

The research carried out during 2022-2023 aimed to evaluate the influence of agrotechnological factors on the production of plastic tunnel tomatoes, based on the following morphological characteristics: the number of fruits in the inflorescence, average fruit weight, average production per plant and per unit surface, which were analyzed comparatively on two agrofunds (a mulched and an unmulched surface).

The existing eco-pedological conditions in the area where the experiments took place may be described as follows:

• the soil belongs to the black soil class, lighly glazed, medium clay-clay, rich in humus on the surface, being representative of the Banat Low Plain;

• the pH has lower values (6.60) in the treated layer and slightly acidic reaction, which indicates a slight process of removing the bases from the colloidal complex of the soil;

• the average annual temperature in the period January 2022-September 2023 was 12.4 °C, higher by 1.6 °C compared to the multiannual average over the last 70 years, with significant deviations from the average reported in the spring and autumn months;

The biological material used in the research consisted of two tomato varieties; their description according to the companies that created and approved them will be presented below. The tomato variety 'Elisabeta' has an indeterminate plant growth type and falls into the category of semi-early maturity, being intended for plastic tunnel and field crops. The plants are vigorous and well balanced in terms of leaf area-fruit production ratio. The fruit is large, weighing 230-250 grams, deep red in color, round and smooth. Comparatively, the tomato variety 'Ruxandra' is an early genotype, the plant displays indeterminate growth; it is recommended for cultivation in plastic tunnel or fields. The fruit is medium to large and weighs 180-210 grams on average, displaying a round shape and intense red color (https://agrosel.ro/seminte-profesionale/tomate).

The experimental variants were placed split – plot design, in 3 repetitions, namely: factor A (genetic factor – variety) with two gradations: a_1 – 'Elisabeta' and a_2 – 'Ruxandra', respectively factor B (technological factor) with two gradations: b_1 – unmulched and b_2 – mulched. Mulching consists of covering the soil with 30-micron thick polyethylene film, which has one white side and the other black, with the aim of maintaining constant moisture in the soil and fighting weeds.

The production of the biological material intended for experimentation was carried out in the propagation greenhouse, by direct sowing, one seed at a time in an alveolus measuring 5x5x5 cm. When planted, the seedling was 30-35 days old, the height of the plant was 20-25 cm and it displayed 4-5 leaves. The nutrient substrate used for the production of seedlings was white peat moderately decomposed (0-5 mm), pH value (H_2O, v/v 1:2.5) 6.0, fertilizer level 1.0 g / l, nutrients added (nitrogen 140 mg N / l, phosphorus 100 mg P_2O_5 / l, potassium 180 mg K_2O / l, magnesium 100 mg Mg / l + all necessary trace elements iron added as EDTA chelate) (Klasmann-Deilmann®), mixed with horticultural perlite which is a granular inorganic material containing 74-77% of amorphous silicon dioxide; the product is natural, ecological, and extremely light (Gramoflor). Due to its granular and porous structure, it can aerate the soil and absorb water, releasing it over time into the substrate (Berar V., Poșta Gh., 2011).

The preparation of the land to establish the plastic tunnel tomato culture consisted of fertilization with manure (40-60 t/ha) which was incorporated along with the mobilization of the soil at a depth of 30 cm. The planting was carried out manually according to the location scheme when temperatures above 15 °C were recorded in the culture space, at a depth of 8-10 cm in the soil, which roughly corresponds to the period March 20-April 5. The planting scheme was positioned in equidistant rows with 90 cm between rows and 35 cm between plants per row (Poșta Gh., 2008).

The experimental culture was subjected to the following steps: palisading (supporting) the plants with strings up to a height of 2 m; fertilization during the vegetation period (foliar application and by drip irrigation system); ensuring the optimal level of moisture in the soil and phytosanitary protection of the tomato culture. Ecologically certified products from the category of polynutrients containing macroelements (nitrogen, phosphorus, potassium), mesoelements (calcium, magnesium, sulfur), and microelements (iron, zinc, copper, manganese, molybdenum, boron) were used for fertilization. Calcium deficiency causes the stagnation of plant growth and the appearance of a physiological disease (rot towards the base of the fruit); magnesium influences fruit quality, resistance to transport and storage; boron and manganese influence the synthesis of carbohydrates and the evolution of fruiting organs (Marinescu Gh., 2006). The total amount of fertilizers applied per surface unit was calculated considering a production potential of 80 t/ha and nutrient consumption per fruit ton (s.a. – active substance) which is 5.0 kg s.a. N; 0.7-1.0 kg s.a. P_2O_5; 4.7-5.0 kg s.a. K_2O; 4.0 kg s.a. CaO and 0.7 kg s.a. MgO (Agriplant® 1; Agriplant® 2; Agriplant® 3; Agriplant® 4; Agriplant® 6 – 100-200 g / l00 L water). During the vegetation period, 10-12 waterings were carried out through the drip irrigation system, to ensure an optimal humidity level between 65-70% of the IUA (Active Humidity Interval). Also, palisading was implemented periodically at intervals of 7-10 days (supporting the plant stem next to the string by means of clips), pruning (removal of young lateral shoots from the insertion of the leaf), phytosanitary treatments (to combat diseases and pests) (Marinescu Gh., 2006), and defoliation towards the end of the vegetation period (removal of exhausted leaves from the base of the plant) (Poșta Gh., 2008; Marinescu Gh., Enoiu I., Nanu Șt., 2020). Harvesting was carried out in stages as the fruits reached maturity. From the point of view of fruit quality, they had to display good storage capacity for 3-5 days (Rózsa S. et al., 2021).

To evaluate the production capacity, determinations were made at the time of harvesting in terms of the number of fruits in each inflorescence and fruit weight, using current work techniques and precision equipment. The valorization of the experimental results was carried out according to the multiple comparison method, based on variance analysis and the F test. The significance of differences was expressed based on letters, considering as significant the differences between variants with different letters (Ciulca S., 2006).

RESULTS AND DISCUSSIONS

Over time, in addition to the creation of tomato genotypes displaying superior productivity and quality characteristics adapted for plastic tunnel protected culture, research has been implemented to improve the culture technology by using inputs specific to conventional and non-conventional vegetable cultivation (Stoian L., 2005).

Achieving superior productions from a quantitative point of view, but more importantly qualitatively, requires the optimization of the technological factors of using nutrients and water from the soil, by means of mulching (Chen J. et al, 2013; Hong M. et al., 2022). Also, the adoption of an effective phytosanitary protection program for plastic tunnel tomato culture contributes substantially to obtaining healthier products for food consumption.

The production capacity of a genotype is determined by the fundamental physiological processes (photosynthesis, respiration, and utilization of assimilates) and morphological characteristics (Savatti M. et al., 2004). The influence of calcium assimilation and soil mulching with polyethylene film or organic mulch on the morphological characteristics that determine tomato production capacity have been research objectives in continuous development (Azad Md.A.K. et al., 2019; Sekara Agnieszka et al., 2019; Yana D., Rahima A., 2023).

To determine the production capacity, observations were made regarding the total number of flowers per inflorescence, respectively the number of fruits displayed in each inflorescence (table 1).

Table 1. The average values of the morphological features analyzed in plastic tunnel tomato culture

The morphological feature analyzed	Variance (combination of factors)	The inflorescence					Average per inflorescence
		I	II	III	IV	V	
Total number of flowers per inflorescence	a_1 x b_1 ('Elisabeta' x unmulched)	6.33	6.33	6.00	5.33	4.66	5.73
	a_2 x b_1 ('Ruxandra' x unmulched)	6.33	6.33	5.66	5.33	5.00	5.73
	a_1 x b_2 ('Elisabeta' x mulched)	8.00	6.66	7.00	6.00	4.66	6.46
	a_2 x b_2 ('Ruxandra' x mulched)	8.00	6.66	6.66	6.33	6.00	6.73
Total number of flowers per inflorescence	a_1 x b_1 ('Elisabeta' x unmulched)	5.33	5.33	5.00	4.66	4.33	4.93
	a_2 x b_1 ('Ruxandra' x unmulched)	4.66	3.66	4.66	4.66	3.66	4,26
	a_1 x b_2 ('Elisabeta' x mulched)	6.33	5.66	5.66	5.00	4.33	5.39
	a_2 x b_2 ('Ruxandra' x mulched)	6.66	5.00	5.66	5.33	4.66	5.46

Based on the data presented in the table above, it may be observed that mulching the soil with polyethylene film has a real influence on the number of fruits formed, especially in the first two inflorescences, but also in the fifth one. The influence of soil mulching on the number of fruits per inflorescence is also highlighted in table 2, by the significantly positive value displayed in the F sample.

Table 2. Variance analysis of in the case of the total number of fruits per plant

Source of variation	SS	DF	MS	F
Varieties	9.75	1	9.75	62.19
Technology	36.75	1	36.75	24.20 **
Varieties x Technology	0.03	1	0.03	0.02
Replications	3.57	2	1.78	
Varieties x Replications	0.31	2	0.15	
Technology x Replications	1.06	2	0.52	
Varieties x Technology x Replications	5.01	2	2.50	
Erorr varieties	0.31	2	0.15	
Erorr technology	6.07	4	1.51	
Total	56.50	11		

Table 3. The unilateral influence of the variety on the number of fruits per plant in plastic tunnel tomato culture

The genetic factor (Variety)	The number of fruits per plant	The relative number of fruits per plant (%)	Difference from control	Significance
a_0 (Average)	25.65	100.00	0.00	Control
a_1 ('Elisabeta')	26.55	103.50	0.90	-
a_2 ('Ruxandra')	24.75	96.50	-0.90	-

$LSD_{(p\ 5\%)} = 0.98$
$LSD_{(p\ 1\%)} = 2.27$
$LSD_{(p\ 0.1\%)} = 7.23$

Table 4. The unilateral influence of the technological factor on the number of fruits per plant in plastic tunnel tomato culture

Technological factor	The number of fruits per plant	The relative number of fruits per plant (%)	Difference from control	Significance
b_1 (unmulched)	23.90	100.00	0.00	Control
b_2 (mulched)	27.40	114.60	3.50	**

$LSD_{(p\ 5\%)} = 1.98$
$LSD_{(p\ 1\%)} = 3.27$
$LSD_{(p\ 0.1\%)} = 6.12$

Table 5. The combined influence of the experimental factors on the number of fruits per plant in plastic tunnel tomato culture

The combination of factors	The number of fruits per plant	The relative number of fruits per plant (%)	Difference from control	Significance
b_1 x a_1 (unmulched x 'Elisabeta')	24.86	100.00	0.00	Control
b_2 x a_1 (mulched x 'Elisabeta')	28.25	113.60	3.39	*
b_1 x a_2 (unmulched x 'Ruxandra')	22.94	100.00	0.00	Control
b_2 x a_2 (mulched x 'Ruxandra')	26.55	105.70	3.61	*

$LSD_{(p\ 5\%)} = 2.80$
$LSD_{(p\ 1\%)} = 4.63$
$LSD_{(p\ 0.1\%)} = 8.66$

The experimental data presented in the previous table indicates that mulching the soil with perforated 30-micron thick polyethylene film makes a significantly positive differences in the case of both tomato varieties tested, on the number of fruits per plant.

Table 6. Analysis of variance in the case of average fruit weight per plant

Source of variation	SS	DF	MS	F
Varieties	192.88	1	192.88	133.12 *
Technology	1363.84	1	1363.84	41.21 **
Varieties x Technology	41.03	1	41.03	1.24
Replications	17.48	2	8.74	
Varieties x Replications	2.89	2	1.44	
Technology x Replications	123.56	2	61.78	
Varieties x Technology x Replications	8.80	2	4.40	
Erorr varieties	2.89	2	1.44	
Erorr technology	132.37	4	33.09	
Total	1750.51	11		

The analysis of the experimental results presented in table 6 reveals that the technological factor has a distinctly significant positive influence on the weight of the tomato fruit, obtained in plastic tunnel culture.

Table 7. The unilateral influence of the variety on the weight of the fruit per plant in plastic tunnel tomato culture

The genetic factor (Variety)	Average fruit weight per plant (g)	Relative fruit weight per plant (%)	Difference from control (g)	Significance
a_0 (Average)	234.27	100.00	0.00	Control
a_1 ('Elisabeta')	238.28	101.70	4.01	*
a_2 ('Ruxandra')	230.26	98.30	-4.01	○

$LSD_{(p\ 5\%)} = 2.99$ g
$LSD_{(p\ 1\%)} = 16.90$ g
$LSD_{(p\ 0.1\%)} = 21.96$ g

Table 8. The unilateral influence of the technological factor on the weight of the fruit per plant in plastic tunnel tomato culture

Technological factor	Average fruit weight per plant (g)	Relative fruit weight per plant (%)	Difference from control (g)	Significance
b_1 (unmulched)	223.61	100.00	0.00	Control
b_2 (mulched)	244.93	109.50	21.32	**

$LSD_{(p\ 5\%)} = 9.23$ g
$LSD_{(p\ 1\%)} = 15.28$ g
$LSD_{(p\ 0.1\%)} = 28.60$ g

The comparative analysis of the results presented in the table above shows that mulching the soil in plastic tunnel grown tomatoes generates a significantly positive difference in fruit weight, compared to the non-mulched version.

Table 9. The combined influence of experimental factors on fruit weight per plant in plastic tunnel tomato culture

The combination of factors	Average fruit weight per plant (g)	Relative fruit weight per plant (%)	Difference from control (g)	Significance
b_1 x a_1 (unmulched x 'Elisabeta')	229.47	100.00	0.00	Control
b_2 x a_1 (mulched x 'Elisabeta')	247.09	107.07	17.62	*
b_1 x a_2 (unmulched x 'Ruxandra')	217.76	100.00	0.00	Control
b_2 x a_2 (mulched x 'Ruxandra')	242.77	111.50	25.02	**

$LSD_{(p\ 5\%)}$ = 13.06 g
$LSD_{(p\ 1\%)}$ = 21.61 g
$LSD_{(p\ 0.1\%)}$ = 40.44 g

The combined influence of genetic and technological factors on the average weight of the tomato fruit reveals a distinctly significant difference in the case of the variety 'Ruxandra', mulched with polyethylene film, compared to the variety 'Elisabeta'.

Table 10. Variance analysis in the case of average fruit production per plant

Source of variation	SS	DF	MS	F
Varieties	1.146	1	1.146	103.942 *
Technology	5.550	1	5.550	37.951 **
Varieties x Technology	0.022	1	0.022	0.153
Replications	0.276	2	0.138	
Varieties x Replications	0.022	2	0.011	
Technology x Replications	0.236	2	0.118	
Varieties x Technology x Replications	0.348	2	0.174	
Erorr varieties	0.022	2	0.011	
Erorr technology	0.584	4	0.146	
Total	7.602	11		

Table 11. The unilateral influence of the variety on fruit production per plant in plastic tunnel tomato culture

The genetic factor (Variety)	Average fruit production per plant (kg)	Relative fruit production per plant (%)	Difference from control (kg)	Significance
a_0 (Average)	6.03	100.00	0.00	Control
a_1 ('Elisabeta')	6.34	105.10	0.31	*
a_2 ('Ruxandra')	5.72	94.90	-0.31	○

$LSD_{(p\ 5\%)}$ = 0.26 kg
$LSD_{(p\ 1\%)}$ = 0.60 kg
$LSD_{(p\ 0.1\%)}$ = 1.92 kg

The analysis of the experimental results presented in the previous table indicates that the tomato variety 'Elisabeta' records a significantly higher average production per plant, compared to the other genotype tested in the plastic tunnel.

Table 12. The unilateral influence of the technological factor on fruit production per plant in plastic tunnel tomato culture

Technological factor	Average fruit production per plant (kg)	Relative fruit production per plant (%)	Difference from control (kg)	Significance
b_1 (unmulched)	5.35	100.00	0.00	Control
b_2 (mulched)	6.71	125.40	1.36	**

$LSD_{(p\ 5\%)}$ = 0.61 kg
$LSD_{(p\ 1\%)}$ = 1.02 kg
$LSD_{(p\ 0.1\%)}$ = 1.90 kg

Also, the mulching of the soil with polyethylene film causes a distinctly significant difference in the average production per plant in the case of the two tomato varieties grown in the plastic tunnel.

Table 13. The combined influence of experimental factors on fruit production per plant in plastic tunnel tomato culture

The combination of factors	Average fruit production per plant (kg)	Relative fruit production per plant (%)	Difference from control (kg)	Significance
b_1 x a_1 (unmulched x 'Elisabeta')	5.71	100.00	0.00	Control
b_2 x a_1 (mulched x 'Elisabeta')	6.98	122.30	1.27	*
b_1 x a_2 (unmulched x 'Ruxandra')	5.00	100.00	0.00	Control
b_2 x a_2 (mulched x 'Ruxandra')	6.45	128.90	1.45	**

$LSD_{(p\ 5\%)}$ = 0.87 kg
$LSD_{(p\ 1\%)}$ = 1.44 kg
$LSD_{(p\ 0.1\%)}$ = 2.69 kg

The productive potential or production capacity represents the maximum level of economically useful biomass that a genotype can achieve under optimal growth and development conditions (nutrition, water, microclimate) and in an environment free from diseases and pests (Grozeva Stanislava et al., 2021; Donoso A., Salazar Erika, 2023). Ensuring an optimal space for the growth and development of plants by adopting an appropriate planting scheme for the tomato culture represent essential technological aspects to achieve efficient production (Huda Md. Nurul et al., 2022).

Table 14. Variance analysis in the case of average tomato production per surface unit

Source of variation	SS	DF	MS	F
Varieties	1119.149	1	1119.149	104.128 *
Technology	5419.559	1	5419.559	37.949 **
Varieties x Technology	22.143	1	22.143	0.156
Replications	269.138	2	134.569	
Varieties x Replications	21.495	2	10.747	
Technology x Replications	230.601	2	115.300	
Varieties x Technology x Replications	340.648	2	170.324	
Erorr varieties	21.495	2	10.747	
Erorr technology	571.250	4	142.812	
Total	7422.736	11		

Table 15. The unilateral influence of the variety on production in plastic tunnel tomato culture

The genetic factor (Variety)	Average production (t/ha)	Relative production (%)	Difference from control (t/ha)	Significance
a_0 (Average)	62.85	100.00	0.00	Control
a_1 ('Elisabeta')	66.07	105.12	3.22	*
a_2 ('Ruxandra')	59.63	94.87	-3.22	○

$LSD_{(p\ 5\%)}$ = 2.71 t/ha
$LSD_{(p\ 1\%)}$ = 6,26 t/ha
$LSD_{(p\ 0.1\%)}$ = 19,93 t/ha

Table 16. The unilateral influence of the technological factor on production in plastic tunnel tomato culture

Technological factor	Average production (t/ha)	Relative production (%)	Difference from control (t/ha)	Significance
b_1 (unmulched)	55.77	100.00	0.00	Control
b_2 (mulched)	69.94	125.40	14.17	**

$LSD_{(p\ 5\%)}$ = 6.39 t/ha
$LSD_{(p\ 1\%)}$ = 10.58 t/ha
$LSD_{(p\ 0.1\%)}$ = 19.80 t/ha

Mulching the soil with perforated 30-micron thick polyethylene film causes a significantly positive increase in production per surface unit (+14.17 t/ha), compared to the non-mulched version.

Table 17. The combined influence of the experimental factors on production in plastic tunnel tomato culture

The combination of factors	Average production (t/ha)	Relative production (%)	Difference from control (t/ha)	Significance
b_1 x a_1 (unmulched x 'Elisabeta')	59.44	100.00	0.00	Control
b_2 x a_1 (mulched x 'Elisabeta')	72.70	122.30	13.26	*
b_1 x a_2 (unmulched x 'Ruxandra')	52.10	100.00	0.00	Control
b_2 x a_2 (mulched x 'Ruxandra')	67,17	128.92	15,07	**

$LSD_{(p\ 5\%)}$ = 9.04 t/ha
$LSD_{(p\ 1\%)}$ = 14.96 t/ha
$LSD_{(p\ 0.1\%)}$ = 28.00 t/ha

The combined influence of the experimental factors determines a distinctly significant positive difference in the production per surface unit in the case of the tomato variety 'Ruxandra' grown in the plastic tunnel and mulching the soil with perforated polyethylene film.

CONCLUSIONS

Based on the experimental results obtained following the determination of the elements that define the production capacity of the plastic tunnel tomato culture under the influence of some technological factors, we may draw the following conclusions:

- the two tomato varieties 'Elisabeta' and 'Ruxandra' with indeterminate plant growth can be used with good results for plastic tunnel cultivation, both in terms of production capacity and tolerance to adverse environmental factors (diseases and pests);
- mulching the soil with perforated 30-micron thick polyethylene film determines significant differences in the number of fruits per plant, in the case of the tomato varieties used in the experiments;
- also, mulching the soil around tomato plants grown in the plastic tunnel system causes a distinctly significant positive difference in the weight of the fruit, compared to the non-mulched version;
- the combined influence of genetic and technological factors highlights a distinctly significant difference in the average production per plant in the case of the tomato variety 'Ruxandra' grown on soil mulched with polyethylene film in the plastic tunnel;
- soil mulching, as an experimental technological factor, causes a 20-25% increase in production, compared to the control variant;
- we recommend the use of perforated polyethylene film for mulching tomato crops in the plastic tunnel because it is a preventive measure for plant protection and weed control, which also ensures a constant level of moisture in the soil and determines a significant increase in production;
- we also recommend cultivating the two tomato varieties over a longer vegetation period, as far as seven inflorescences.

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