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ORIGINAL ARTICLE

Influence of planting schemes and time of tubers on some photosynthetic parameters in potato plants

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The paper presents studies on the influence of tubers' planting schemes and planting time on some photosynthetic parameters in different potato plant varieties. We found that depending on the planting scheme and planting time of different potato varieties, the growth dynamics of the leaf area and the accumulation of total dry biomass do not differ significantly. However, the maximum value of these indices in both varieties pertains to the flowering phase of plants. Then, with the wilting of the above-ground mass of potato plants, the leaf size and area and the total dry biomass sharply decrease. In addition to those mentioned above, the planting time and scheme of potato tubers have a noticeable effect on the leaf area of Amiri-600 and Sevindge varieties. According to the indicators, the Amiri-600 variety exceeds the Sevindge variety for the entire growing season. The minimum leaf area is observed in April and at the end of June, strictly in the phases of tillering budding and the biological maturity of tubers. The third variant differs in the size of the leaf area, where potato plants were planted in the 70 × 30 cm scheme (except for the flowering phase in the Amiri-600 variety, whereas the maximum leaf area for this variety is noted in the 70 × 25 cm scheme-37.5 thousand m^2/ha). A similar situation is observed in the dynamics of accumulation of total dry biomass, but without exception, which is indicated in the case of leaf area. We found that the value and variability of the photosynthetic potential in the studied varieties significantly change depending on their characteristics and the planting time and schemes of potato tubers. The maximum value of the photosynthetic potential in both varieties (Amiri-600 and Sevindge) was observed in the 3rd variant (where the plants are placed in the 70 × 30 cm scheme). The minimum value was observed in the 4th variant (where the potato tubers were planted on February 14-15). We also found that the average value of net photosynthetic productivity in plant ontogenesis in all five variants was higher in the Amiri-600 variety (7.5-10.1 g/m^2 per day) than in the Sevindge variety (6.3-8.5 g/m^2 per day).

Keywords: Planting scheme and time, photosynthetic indicators, photosynthetic potential, net productivity of photosynthesis, total dry biomass, and leaf area.

Introduction

The development of the scientific base of potato yield increase is one of the main tasks of modern agrarian science. Achieve the solution of this problem requires the elucidation and deep understanding of the physiological and biochemical processes underlying the high productivity of potato plants. It is known that the main factor determining the level of productivity is the power of photosynthetic potential (PP) of plants (Agaev, F.N., et al., 2021; Eyvazov, A.G., 2017; Yusifov M.A., 2004). PV is considered a derivative of the leaf surface area based on the assimilation of solar radiation energy. The optimal value of leaf area and the dynamics of its formation in plant ontogenesis is of great importance in the accumulation of crop yield (Gaplaev, M.Sh. 2014; Yusifov, M.A., 2001). It should be noted that high yields of vegetable crops, including potatoes, can be obtained only in crops (plantings), dynamically forming the optimal leaf area, capable of active work during a long growing season (Agaev, F.N., et al., 2021; Yusifov, M.A., 2001).

Materials and Methods

Varieties of early maturing Sevindge and medium maturing Amiri-600, zoned in the Azerbaijan Republic, were research objects.

Experiments were laid in the Apsheronsky subexperimental farm of the Research Institute of Vegetable Industry. Soils in the experimental station were gray-brown, humus content 1.3-1.5%, total nitrogen 0.15%, hydrolyzable nitrogen ranged from 1.7 to 3.0 mg per 100 g of soil, and the amount of labile phosphate (according to Machigin) was 1.8-2.2 mg P_2O_5 per 100 g of soil. Total potassium content (by Protasova) K_2O is 25-30 mg ha, 100 g of soil. The reaction of soil solution is neutral or slightly acidic, RH=6.5-7.0. Soil poor in nutritious elements was taken into account when 20 t of manure and 2/3 of mineral fertilizer P60 K60 (at the rate of the active substance) were applied during autumn tillage and in early spring during bush formation (at the phase of 4-5 true leaves) and when flowering, nitrogen N60 (at the rate of the active substance) and the rest of PK were applied as a top

dressing. Mineral fertilizers were used: nitrogen in ammonium nitrate, phosphorus-granulated double superphosphate, and potassium sylvinite.

The area of the recording plot is 126 m^2. The repeatability of the experiment was three times. Vegetable samples were taken from the moment of appearance of the 5th-6th true leaf every 14-15 days. Field experiments were accompanied by the necessary biometric measurements in compliance with the requirements of field experiment methodology in vegetable growing (Litvinov, S.S. 2011). In some parts of potato varieties, the dry matter content was determined by the thermostat weight method at 1050C (Ermakov, A.I. 1987), which was used to determine the total dry biomass. Determination of leaf area was carried out with a portable apparatus L - 3000 C. The obtained figures for one plant were recalculated to m^2/ha, considering the number of plants per 1 hectare of crop. Photosynthetic potential (PV) was calculated by multiplying the leaf area of plants (m^2/ha) Led by the number of days of leaf activity period (Tv)

TP = Ler × Tv (1)

The following formula determined partial photosynthetic productivity (PSP) in potato plants:
PPF (2)

where B1 and B1 are the dry mass of plants at the beginning and at the end of the reference period, (B2 - B1) is the growth of dry biomass in n days, L1 and L2 is the leaf area at the beginning and the end of the reference period, m^2; ½ (L1+L2) is the average working area of leaves during the reference period, n is the period between two observations, days. Thus, NPF is the increase in dry weight of plants in grams during a specific time (day), referred to as a unit of leaf surface (m^2) and expressed as g/m^2 days (4).

The following variants were used in the experiment:

Potato tuber planting patterns.
1. 70 × 20 cm, number of plants per ha-67,143
2. 70 × 25 cm, number of plants per ha-53,714
3. 70 × 30 cm, number of plants per ha-44,762

Terms of planting potato tubers (under the scheme 70 × 25 cm)
4. February 14-15
5. February 20-26

Results

The results on the dynamics of leaf area growth of different potato varieties depending on the scheme and timing of planting are presented in Table 1.

Table 1. Dynamics of leaf area growth and photosynthetic potential during the growing season in different potato varieties depending on the scheme and terms of planting (2016-2019).

Variants	**Leaf area (thousand m^2/ha)**						**Photosynthetic potential, million m^2 × days/ha**
	April		**May**		**June**		
	14-16	**28- 30**	**12-14**	**26-27**	**9-11**	**23-25**	
	Amiri-600-The vegetation period is 110 days						
1	6.2	10.5	20.0	31.7	18.0	14.0	1.104
2	6.4	10.9	21.0	37.5	20.0	15.5	1.224
3	6.8	11.2	23.2	34.0	21.5	16.7	1.247
4	5.4	9.5	18.0	27.0	14.0	9.0	0.967
5	5.8	10.2	19.2	29.0	16.2	10.2	1.007
	Sevindge-The vegetation period is 102 days						
1	5.4	9.6	18.0	25.7	16.0	12.0	0.884
2	5.6	10.8	20.5	27.6	17.2	13.2	0.968
3	6.0	11.9	21.2	29.2	18.1	14.5	1.029
4	4.8	8.4	15.6	23.5	13.2	8.0	0.750
5	5.4	9.5	17.8	24.7	14.3	9.2	0.825

From these data, it is clear that the schemes and terms of planting potato tubers have a noticeable influence on the growth dynamics of leaf area of varieties Amiri-600 and Sevindge. During the period of vegetation by this indicator, the mid-season variety Amiri-600 exceeds the early-season variety Sevindge. Despite this difference, in both varieties, the maximum value of leaf area is observed at the end of May, during flowering, when the plants are fully formed and the intensive period of growth and an increase in tuber size begins. After that, with the yellowing and dying off of the above-ground part of the potato varieties, the leaf area decreases sharply, and this phenomenon continues until the end of the growing season. It should be noted that the lowest value of this indicator is observed at the beginning of the growing season, i.e., in the phase of tillering in both varieties studied (in the variety Amiri-600 5.4-6.8 thousand m2/ha, and in the variety Sevindge 4.8-6.0 thousand m2/ha). As the table shows, the plants are placed according to the scheme 70x30 cm in size. It is explained that in this variant, potato plants are sufficiently at a high level provided with nutrients; as a result, the foliage improved, the growth and development of plants accelerated.

According to the literature data, the planting PF correlates with both biomass and economic productivity of plants. The study of this indicator provides the necessary information about the development of the plant organism and the future yield of the crops under study (Bedenko, V.P., 1980; Morgun, V.V., et al., 2014). In experiments with watermelon plants, M.A. Yusifov revealed that FP is closely correlated with leaf area and yield (respectively, C_2=0.98 and C_2=0.95) (Yusifov M.A., 2004). Our research depending on the scheme and timing of planting showed that the value of photosynthetic potential has a varietal character. Mid-ripening variety Amiri-600, both in the growth of the leaf surface area, and the value of FP exceeded the early-ripening variety Sevindge (respectively, 1.007-1.247 million m².days/ha. and 0.790-1.029 million m² days/ha). The high value of FP was observed in both varieties in the 3rd variant (in the variety Amiri-600 1.247, and in the variety Sevindge 1.029 mln m² days/ha). At the same time, the lowest value of FP was observed in the 4th variant, as in the variety Amiri-600, the value of this indicator was 0.967, and in Sevindge 0.750 million m² days/ha, which is explained by the low soil temperature at early planting and delayed formation of the assimilation surface, as well as by the life span of the newly formed leaves.

In addition to the indicators mentioned earlier, we also studied the dynamics of accumulation of total dry biomass in different potato varieties depending on the scheme and timing of planting. As can be seen from the data shown in Table 2, the total dry biomass in both varieties, starting from the tillering phase and to the mass flowering (i.e., until June 10), is continuously increasing and reaches a maximum at this phase (respectively, in the variety Amiri 600 49.4-57.0 c/ha, and in the variety Sevindge, 47.0-53.9 c/ha), the transition to the phase of technical and biological maturity of tubers is characterized by decreasing the value of this indicator. A decrease in the dry biomass in all variants is explained by the drying and dying of the plant's above-ground mass. The lowest value of dry biomass in both varieties is noted in the leaf surface area, in the tillering phase (respectively, in the variety Amiri-600 2.4-3.0, and variety Sevindge 1.8-2.2 c/ha).

LPF, as it is known, represents the accumulation of dry biomass to a unit leaf area per unit time (Ivanova, L.A., et al., 2002; Yusifov M.A., 2004) and characterizes the average efficiency of leaf photosynthesis of a crop, weakly correlates with the final yield, and is a complex parameter determined by the intensity of not only photosynthesis but also plant respiration. With the same rate of these processes out of the two varieties, NFR will be higher in the one with a more significant contribution of above-ground (photosynthetic) organs in the mass of the whole plant (Ivanova, L.A., et al., 2002; Morgun, V.V., et al., 2014).

Table 2. Dynamics of total dry biomass accumulation in different potato varieties depending on the scheme and timing of planting, c/ha (2016-2019).

Variants	**April**		**May**		**June**		**July**
	14-16	**28-30**	**12-14**	**26-27**	**9-11**	**23-25**	**7-8**
	Amiri-600						
1	2.5	9.0	18.0	32.0	52.6	45.2	40.3
2	2.8	10.3	20.3	34.0	54.5	48.0	42.0
3	3.0	11.2	22.4	36.3	57.0	49.0	43.0
4	2.4	8.6	17.0	27.8	49.4	35.6	28.5
5	2.7	9.3	18.8	30.3	52.0	37.0	30.3
	Sevindge						
1	1.9	8.0	16.0	30.0	49.5	40.5	35.4
2	2.0	9.2	18.1	32.1	51.6	42.3	36.8
3	2.2	10.2	20.2	34.3	53.9	43.8	37.9
4	1.8	7.5	16.0	26.5	47.0	32.0	26.0
5	1.9	8.4	17.1	27.9	49.8	33.4	28.7

Since there is an inverse relationship between NEF and leaf surface area, the study of the dynamics of this indicator in ontogenesis has both theoretical and practical significance in evaluating the photosynthetic activity of plants. The data obtained in our study

show that although the course of dynamics of this index has no varietal specificity, quantitative differences of varieties are revealed (Table 3). Since in both varieties the value of MTF is the highest before budding, i.e., during the merging of plants in rows in all variants (respectively, the variety Amiri-600 14.9-18.2, and in the variety Sevindge-12.5-15.1 g/m² day), after this phase is a decrease in the value of MTF, in the transition to the phase of flowering somewhat increases the value of MTF. We found that it is not very noticeably, and from the phase of mass flowering to the end of the growing season, the value of NFR decreases sharply; even in the variety Amiri-600 in the first and third variant, there is a negative value in the value of NFR, which is explained by a sharp decrease in dry biomass in the phase of biological ripeness tubers than in the phase of technical ripeness.

However, along with the above, it should be noted that the average value of MTF during the growing season in all years of the study in all variants of the medium-early variety Amiri-600 was higher (7.5-10.1 g/m² day) than the early maturing variety Sevindge (6.3-8.8 g/m² day).

Table 3. Net photosynthetic productivity in different potato varieties depends on the planting scheme and timing, g/m²/day (2016-2019).

Variants	April		May		June		July	Mean during the vegetation
	14-16	28-30	12-14	26-27	9-11	23-25	7-8	
				Amiri-600				
1	9.0	16.0	12.3	6.4	6.8	6.2	-2.0	7.8
2	12.0	17.0	14.0	7.2	8.0	4.2	-1.0	8.8
3	14.0	18.2	15.1	8.1	9.0	5.0	1.0	10.1
4	8.5	14.9	11.9	5.9	6.4	3.8	1.0	7.5
5	9.2	15.4	12.6	6.0	7.0	4.2	1.0	7.9
				Sevndge				
1	8.0	13.0	10.5	5.4	6.4	2.8	1.0	6.7
2	10.0	14.2	11.2	6.3	7.1	3.4	1.5	7.7
3	12.3	15.1	12.8	7.2	8.1	4.2	1.8	8.8
4	7.2	12.5	10.1	5.0	6.1	2.4	0.8	6.3
5	8.4	13.6	11.2	6.0	7.2	2.9	1.0	7.2

The highest value of NFR in both studied varieties was observed in the third variant (respectively, in the variety Amiri-600 10.1, and in the variety Sevindge 8.8 g/m² day), and the lowest value in the variety Amiri-600 in the first (-2.0 g/m² day), and the variety Sevindge-in the fourth variant (0.8 g/m² day). It should be noted that the timing of planting tubers had almost the same effect on the value of NFR; as a rule, in the late planting, the value of NFR was slightly higher than in the early planting.

Conclusions

Depending on the scheme and timing of planting in different potato varieties, the course of the dynamics of growth of leaf area and accumulation of total dry biomass does not differ significantly, as, in both varieties, the maximum value of these indicators falls on the phase of flowering of plants. Then with the yellowing and dying away of the above-ground mass of potato plants, the value of both the leaf area and the total dry biomass sharply decreases.

Schemes and terms of planting potato tubers have a noticeable influence on the growth of the leaf area of varieties Amiri-600 and Sevindge. During the whole vegetation period, the variety Amiri-600 exceeds the variety Sevindge according to the specified indicator. The minimum value of leaf area is observed in April and at the end of June, i.e., in the phases of tillering, budding, and biological ripeness of tubers. The third variant differs in the value of the leaf area, where the potato plants are placed under the scheme 70 × 30 cm (except the phase of flowering in the variety Amiri-600, as the maximum value of the leaf area in this variety is noted in the scheme 70 × 25 cm-37.5 thousand m²/ha). A similar situation is found in the dynamics of accumulation of total dry biomass, but without exception, which is revealed in the leaf area.

The magnitude and course of the variability of photosynthetic potential in the studied varieties vary significantly depending on their varietal characteristics, scheme, and planting potato tubers. The maximum value of photosynthetic potential was observed in both varieties in the 3rd variant (where plants were placed under the scheme 70 × 30 cm). The minimum value was observed in the 4th variant (where potato tubers were planted on February 14-15).

The average value of net productivity of photosynthesis in plant ontogenesis in all studied five variants was higher (7.5-10.1 g/m² per day) in the mid-early variety Amiri-600 than in the variety Sevindj (6,3 - 8,8 g/m² per day). The highest value of NPF in both studied varieties was observed in the third variant during the merging of bushes of plants in rows (respectively, in the variety Amiri-600 18.2, and the variety Sevindge 15.1 g/m² day). As a rule, the value of the studied photosynthetic indices was slightly higher in late plantings than in early ones.

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