Photosynthetic activity of *Triticum carthlicum* Nevski. (=*Triticum persicum* Vav.) variety samples in the forest-steppe zone of the Northern Trans-Urals

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Abstract. The studies of plants' assimilation activity of the *Triticum carthlicum* Nevski. (=*Triticum persicum* Vav.) tetraploid species' variety samples have been carried out in the subtaiga zone (Aromashevo) and the northern forest-steppe zone (Tyumen). The number of leaves on plants by zones varied from three to five. Measurements showed that the lamina length varied from 6.4-23.7% in the northern forest-steppe zone and from 0 to 21.9% in Aromashevo. The lamina area on the main shoot of the Triticum carthlicum Nevski variety samples in the northern forest-steppe zone amounted to 62.3 cm^2, which was 26 cm^2 less than in the subtaiga zone. Calculation of net photosynthetic productivity in northern forest-steppe zone showed that Triticum carthlicum Nevski variety samples formed from 10.864g*m^2/day to 20.764 g*m^2 /day, giving way to durum and soft wheat. In the subtaiga zone, PP_n of Triticum carthlicum Nevski wheat varied from 9.088 to 13.827 g*m^2/day, significantly yielding Bezenchukskaya 139 variety.

1 Introduction

Over a long period of cultivated plants' selection, their assimilation activity has evolved in a certain way and an increase in the yield of varieties is associated with a change in different elements of photosynthetic productivity depending on the agroecological selection backgrounds, the crops characteristics and directions of selection. According to several scientists, the enlargement of leaves in wheat evolution proceeded in parallel with the enlargement of seeds and ears. Playing a leading role in the ear supply, the flag leaf has received a particularly strong development, and the duration of its active life has increased during the period of grain swelling.

In plant selection, it is very important to increase the photosynthetic productivity of plants. In the process of long-term selection for productivity, forms with larger leaves first appeared. According to A.V. Kulakov [1], the main increase in the yield of modern spring wheat varieties of the Povolzhsky selection center in comparison with its old varieties and the original local variety Poltavka is associated with an increase in leaf surface, and the

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selection varieties exceeded Poltavka in this trait both in dry and especially in moist years. At the same time, it turned out that the upper leaves increased much stronger than the lower ones during the selection process. So, on average for 5 years, the area of the first (lower) leaf of Saratovskaya 29 was only 4% more than the corresponding Poltavka leaf, and the area of the flag leaf - by 44%. As a result of these measurements, the economic suitability coefficient (K_{ec}) of the best varieties increased to 45-46% versus 38-40% for Poltavka and old varieties.

The relationship between the top leaf area, its photosynthesis, the productivity of wheat varieties has been noted many times and can be used as a breeding trait for the selection of productive wheat forms [2, 3, 4]. This relationship is weaker in awned wheat and barley due to the higher value of ear photosynthesis in grain swelling [5, 6].

The aim of this research was to study the differences in the photosynthesis intensity in the *Triticum carthlicum* Nevski. (=*Triticum persicum* Vav.) tetraploid wheat species [7, 8] in comparison with modern varieties of tetraploid, and especially hexaploid wheat.

2 Materials and methods

The study of the leaf surface was carried out according to the method of P.P. Litun [9] in the earing phase in 1999–2000 in the zone of the northern forest-steppe (Tyumen) and in the subtaiga zone (Aromashevo village). Measurements were started from the first (bottom) leaf using a special millimeter ruler. The calculation of the leaf surface area was carried out according to the formula:

$$S=L/4(a_1 + a_2 + 1{,}5\ a_3) \quad (1)$$

Where: L - leaf length, cm

a_1, a_2, a_3 - leaf width at measurement points, mm

The photosynthesis productivity (PP) and net photosynthesis productivity (PP_n) were calculated by the method of A.A. Nichiporovich [10, 11] using the formula:

$PP = ½\ h * l\ m^2/day.$

$PP_n = Y_{Biol.}/PP(g*day/m^2)$, where

h – the leaf surface area on the day of measurement, (m^2)

l - duration of the growing period (days)

Y_{biol} - biological yield

For research, 8 Triticum carthlicum Nevski variety samples were taken: K-7885 var. *persicum*, K-11891 var. *rubiginosum*, K-13698 var. *stramineum*, K-14036 var. *stramineum* + *rubiginosum*, K-17555 var. *rubiginosum*, K-17687 var. *stramineum,* K-19726 var. *persicum,* K-29288 var. *persicum*. Tyumenskaya 80 soft wheat variety and Bezenchukskaya 139 durum wheat variety were used as the standard.

3 Results and discussion

The number of leaves on Triticum carthlicum Nevski plants varied from 3 to 5. Most of the plants had four leaves. An analysis plants' sampling in 1999 showed that only variety sample K-7885 had plants with three leaves. They accounted for 1.3% of all studied plants. The number of plants with five leaves ranged from 21.3% to 33.8% (Table 1). The maximum value was noted for Bezenchukskaya 139 durum wheat variety - 81.3%. In the studied varieties, the occurrence frequency of plants with three leaves in Aromashevo conditions was higher than in Tyumen.

Table 1. The number of plants with three and five leaves per stem, % (1999-2000).

It.No.	Variety samples	Tyumen, five leaves	Aromashevo	
			three leaves	five leaves
1	Tyumenskaya 80	27.5	7.5	20.0
2	K-7885	30.4	0	7.5
3	K-11891	33.8	0	5.0
4	K-13698	23.8	2.5	12.5
5	K-14036	21.3	5	7.5
6	K-17555	21.3	2.5	12.5
7	K-17687	30.0	2.5	7.5
8	K-19726	31.7	2.5	10.0
9	K-29288	26.3	0	15.0
10	Bezenchukskaya 139	81.3	0	10.0

Studies have shown that the lamina length in Triticum carthlicum Nevski plants in the northern forest-steppe zone (experimental field of the TSAA) varied in the first leaf from 17.9% to 23.7% (Figure 1). The variation coefficient of the second leaf length was 9.8-17.5%. The variation coefficient of the third leaf was higher (CV = 6.4% –18.9%). The length of the fourth leaf varied from 20 to 26 cm (CV = 10.5% –14.7%). The fifth leaf ranged from 14 cm (K-7885) to 19.1 cm (K-17555) in length (Table 2).

Table 2. The lamina length in the Triticum carthlicum Nevski variety samples, Tyumen 1999-2000.

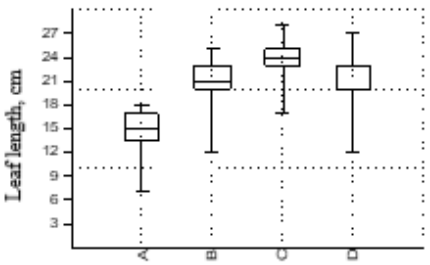
Cultivar, variety sample	I leaf		II leaf		III leaf		IV leaf		V leaf	
	L cm	CV%	L cm	CV%	L cm	CV%	L cm	CV%	L cm	CV %
Tyum80	13.9±0.42	27.2	19.4±0.37	16.9	20.9±0.5	21.4	26.1±0.49	11.8	11.4±0.73	29.9
K-7885	14.3±0.38	23.7	19.6±0.39	17.5	22.5±0.48	18.9	26.1±0.49	11.8	14.0±0.61	21.4
K-11891	13.5±0.29	19.7	19.7±0.26	11.6	23.3±0.32	12.3	20.7±0.31	13.3	16.8±0.52	16.3
K-13698	14.7±0.26	15.9	20.7±0.25	10.9	24.4±0.2	7.3	21.7±0.27	11.3	18.6±0.64	14.9
K-14036	15.1±0.27	15.9	20.6±0.22	9.8	24.1±0.17	6.4	21.1±0.25	10.5	16.7±0.81	19.9
K-17555	16.9±0.23	12.2	20.5±0.24	10.3	23.9±0.24	8.9	21.3±0.26	10.8	19.1±0.64	13.9
K-17687	15.3±0.32	18.9	19.6±0.24	11	23.3±0.23	8.7	21.3±0.26	10.8	18.3±0.43	11.5
K-19726	14.3±0.29	17.9	18.5±0.32	15.3	22.6±0.21	8.2	20.2±0.33	14.7	16.8±0.38	11.3
K-29288	14.1±0.32	20.3	17.9±0.33	16.5	21.9±0.28	14.2	19.9±0.38	16.9	17.1±0.51	13.7
Bezenchukskaya 139	16.0±0.29	16.4	21.0±0.32	13.8	24.2±0.26	9.5	21.6±0.4	16.7	16.5±0.33	16.2
LSD_{05}	1.42		1.35		1.39		1.57		2.37	

In Aromashevo conditions (subtaiga zone), the lamina length in Triticum carthlicum Nevski in terms of plant layers did not reliably exceed the leaf length of the Tyumenskaya 80 variety (Table 3). The smallest percentage of length variation was observed in Triticum carthlicum Nevski on the last (fifth, flag) leaf (0-7.4%).

Table 3. The lamina length in the Triticum carthlicum Nevski variety samples, Aromashevo 1999-2000.

Cultivar, variety sample	I leaf		II leaf		III leaf		IV leaf		V leaf	
	L cm	CV%	L cm	CV%	L cm	CV%	L cm	CV%	L cm	CV %
Tyum 80	15.1±0.7	27.9	23.2±0.6	14.9	25.4±0.6	15.1	25.7±0.5	11.9	27.3±0.5	5.5
K-7885	16.9±0.3	13	22.1±0.5	14.3	26.7±0.4	10.1	26.4±0.6	10.9	27.0±0.9	6.4
K-11891	16.8±0.4	14.2	21.8±0.5	14	26.5±0.4	10	26.3±0.5	10.9	28.5±0.5	2.5
K-13698	16.5±0.5	19.1	21.8±0.5	14.7	26.1±0.4	10.1	25.9±0.5	12.6	27±0.9	7.4
K-14036	16.4±0.5	20.1	22.6±0.6	16.3	26.7±0.5	11.2	26±0.6	12.8	26.3±0.9	5.8
K-17555	15.9±0.5	19.8	21.5±0.6	16.5	26.2±0.4	10.7	25.8±0.5	11.4	27.4±0.6	4.9
K-17687	17.1±0.5	18.9	22.5±0.5	14.5	26.2±0.5	11.1	25.8±0.6	13.7	28.0±0.1	0

K-19726	16.6±0.5	20	22.3±0.5	13.8	25.9±0.6	14.2	26.3±0.5	11.8	28.3±0.3	1.8
K-29288	14.9±0.5	21.9	21.8±0.6	17.6	25.7±0.4	13.6	25.7±0.4	10.1	26.7±0.4	3.9
Bezenchukskaya 139	15.9±0.6	21.9	21.8±0.6	16.2	25.8±0.7	17.8	26.1±0.5	11.8	28.4±0.4	3.1
LSD_{05}	2.29		2.42		2.35		3.49		3.33	



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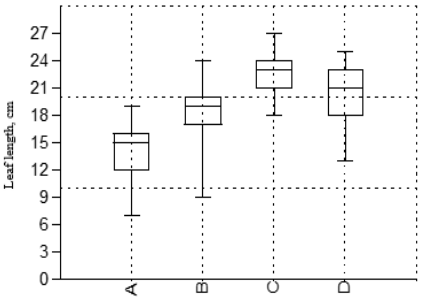

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Fig. 1. Diagram of the range of deviation in leaf length in the Triticum carthlicum Nevski variety samples: a - K-13698; b - K-19726. Note: * - A-first leaf, B-second leaf, C-third leaf, D-fourth leaf.

The length of the flag leaf in plants at two points of the study differed by varieties. In Aromashevo, the flag leaf of Triticum carthlicum Nevski plants was 7.3 cm longer than in Tyumen (Table 4). No significant differences were found between the variety samples in Aromashevo, the flag leaf length ranged from 25.9 to 26.5 cm. In Tyumen, the flag leaf of the soft wheat variety was shorter than that of the Triticum carthlicum Nevski variety samples and Bezenchukskaya 139 and had L = 14±0.39 cm.

Table 4. The length of the flag leaf in the Triticum carthlicum Nevski variety samples, 1999-2000.

Variety sample cultivar	Tyumen		Aromashevo	
	L, cm	CV, %	L, cm	CV, %
Tyumenskaya 80	14±0.39	25.2	26.2±0.46	11.5
K-7885	14.9±0.39	22.9	26.3±0.44	10.6
K-11891	18.9±0.35*	16.5	26.3±0.45	10.9
K-13698	20.6±0.29*	12.9	26±0.51	12.5
K-14036	19.8±0.31*	14.2	26.2±0.52	12.6
K-17555	20.4±0.25*	10.8	25.9±0.45	11
K-17687	19.4±0.23*	10.4	25.9±0.56	13.7
K-19726	18.4±0.28*	13.5	26.4±0.48	11.6
K-29288	17.9±0.46*	23.1	25.9±0.41	10.1
Bezenchukskaya 139	17.1±0.32*	16.8	26.5±0.49	11.9
LSD_{05}	1.50		1.83	

The lamina area on the main shoot of the Triticum carthlicum Nevski variety samples in the northern forest-steppe zone ranged from 54.6 cm^2 (K-7885) to 68.8 cm^2 (K-17555) and significantly exceeded the soft wheat variety Tyumenskaya 80 (Table 5). However, not a single variety sample has surpassed the durum wheat variety Bezenchukskaya 139 (79.5 cm^2) on this indicator. In the subtaiga zone, the leaf area of the Triticum carthlicum Nevski variety samples was almost twice as large as in Tyumen. For the standard, it amounted to 88.5 cm^2 and differed in a lower coefficient of variation (CV = 6.3%) in comparison with the Triticum carthlicum Nevski variety samples.

Table 5. Leaf surface area of the Triticum carthlicum Nevski variety samples, 1999-2000.

Variety sample, cultivar	Tyumen		Aromashevo	
	S, cm^2	CV, %	S, cm^2	CV, %
Tyumenskaya 80	48.6	14.5	88.5	6.3
K-7885	54.6	9.2	89.3	12.5
K-11891	59.4	5.7	88.4	12.5
K-13698	64.6	5.7	88.1	15.3
K-14036	62.2	5.1	88.7	11.4
K-17555	68.8	8.2	86.8	14.4
K-17687	67.8	6.9	89.4	10.8
K-19726	61.9	7.9	89.3	10.2
K-29288	59.1	12.6	86.4	16.3
Bezenchukskaya 139	79.7	9.2	86.6	10.5
LSD_{05}	5.5		15.6	

The leading role in the assimilants' supply to the ear belongs to the upper (flag) leaf, the size of which is strongly influenced by the growing conditions (%). Comparative analysis of Persian wheat variety samples indicates that the flag leaf area in the northern forest-steppe zone was significantly higher than the standard and amounted to 12.9-15.1 cm^2 (Table 6). The exception was the variety sample K-7885, which had the smallest flag leaf surface (CV = 19.9%). The surface of the flag leaf in the subtaiga zone was twice as large as in Tyumen, but no significant differences were found between the variety samples. The variation in the flag leaf area in the Persian wheat variety samples in Aromashevo ranged from 11.8 to 17.6%. While for the standard it amounted to CV = 8.3%.

Table 6. The leaf surface area of the flag leaf, 1999-2000.

Variety samples	Tyumen		Aromashevo	
	leaf S, cm^2	CV, %	leaf S, cm^2	CV, %
Tyumenskaya 80	7.2	26.6	27.8	8.3
K-7885	8.4	19.9	27.9	14.3
K-11891	12.9	10.8	28.0	14.2
K-13698	15.1	16.6	27.5	17.6
K-14036	14.2	13.5	27.9	15.3
K-17555	15.8	8.8	27.1	12.3
K-17687	15.0	10.2	28.2	14.3
K-19726	13.6	10.4	28.1	12.3
K-29288	13.9	16.3	27.2	11.8
K-49901	11.6	17.9	28.5	14.4
LSD_{05}	4.0		2.52	

Photosynthetic potential is an integral indicator of plant photosynthesis and an important yield-related trait. According to V.A. Kumakov (1980, 1985), the variation in yield over the years is associated with the variability of the leaf surface and photosynthetic potentials. The highest PP was formed in the northern forest-steppe zone in the K-17555 variety sample - 33.2 m^2 per day. While Tyumenskaya 80 soft wheat had low PP (22.6 m^2/day) and Bezenchukskaya 139 durum wheat had the highest - 39.05 m^2/day (Table 7). Under subtaiga conditions, no significant differences in photosynthetic potential were found between the Triticum carthlicum Nevski variety samples.

The net productivity of photosynthesis shows the specific productivity of the leaf apparatus. In the zone of the northern forest-steppe, it was the highest in the K-7885 variety sample (28.328 g*m^2/day) but did not exceed this indicator of Tyumenskaya 80 soft wheat –32.958 g*m^2 per day. In the subtaiga zone, PP_n of all variety samples was lower than in northern forest zone; a sharp decrease was observed in soft wheat - 19.203 g*m^2/day, while

the net photosynthetic efficiency of Triticum carthlicum Nevski variety samples was reduced by only 1,398- 6.968 g*m^2/day.

Table 7. Photosynthetic potential of Persian wheat plants' leaves, 1999-2000.

It.No.	Variety sample	Tyumen		Aromashevo	
		PP, m^2/day	PP$_n$, g*m^2/day	PP, m^2/day	PP$_n$, g*m^2/day
1	Tyumenskaya 80	22.605	32.958	42.020	13.755
2	K-7885	26.476	28.328	43.745	12.847
3	K-11871	28.493	18.601	42.893	12.986
4	K-13698	32.922	15.035	43.624	11.690
5	K-14036	30.474	14.635	44.372	10.772
6	K-17555	33.211	10.990	42.949	9.593
7	K-17687	32.218	10.864	43.352	9.088
8	K-19726	30.671	15.813	44.200	10.520
9	K-29288	28.680	20.746	42.337	13.817
10	Bezenchukskaya 139	39.045	22.538	42.001	15.833

4 Conclusion

The assimilation surface of leaves in the Triticum carthlicum Nevski variety samples in the northern forest-steppe zone varied from 54.6 cm ^{2} to 68.8 cm ^{2} significantly exceeding soft wheat but yielding in this indicator to the Bezenchukskaya 139 durum wheat variety (79.5 cm^2). In the subtaiga zone, the leaf area of the Triticum carthlicum Nevski variety samples was almost twice as large as in the northern forest-steppe zone, no significant differences between cultivars were found.

The greatest photosynthetic potential was formed in the zone of the northern forest-steppe in the variety sample K-17555 - 33.2 m^2 per day. Under subtaiga conditions, no significant differences in photosynthetic potential were found between the Triticum carthlicum Nevski variety samples.

The net photosynthesis productivity showed that the Triticum carthlicum Nevski variety samples did not exceed the standard varieties Tyumenskaya 80 and Bezenchukskaya 139.

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