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ROOT HABITUS AND PLANT PRODUCTIVITY OF SPRING BREAD WHEAT SYNTHETIC LINES IN WESTERN SIBERIA, AS CONNECTED WITH BREEDING FOR DROUGHT TOLERANCE

V.P. SHAMANIN[1], I.V. POTOTSKAYA[1], S.S. SHEPELEV[1], V.E. POZHERUKOVA[1], A.I. MORGOUNOV[2]

[1]*Stolypin Omsk State Agrarian University,* 1, Institutskaya pl., Omsk, 644008 Russia, e-mail: vp.shamanin@omgau.org (✉ corresponding author), iv.pototskaya@omgau.org, sergeyschepelew@mail.ru, ve.pozherukova@omgau.org;
[2]*International Maize and Wheat Improvement Center (CIMMYT),* P.K. 39 Emek, 06511, Ankara, Turkey, e-mail a.morgounov@CGIAR.ORG
ORCID:
Shamanin V.P. orcid.org/0000-0003-4767-9957
Pototskaya I.V. orcid.org/0000-0003-3574-2875
Shepelev S.S. orcid.org/0000-0002-4282-8725
Pozherukova V.E. orcid.org/0000-0001-8429-2167
Morgounov A.I. orcid.org/0000-0001-7082-5655
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Abstract

In Western Siberia, drought appears during the initial period of plant vegetation, and dryness in June and early July is increasing, as evidenced by the hydrothermal coefficients. Improvement of drought tolerance of wheat varieties is a breeding priority for ensuring crop stability over the years of warming and increasing frequency of dry years. This paper is the first our report of wide surveyed concerning the assessment of phenotypic differences in the main parameters of the root system between hexaploid synthetic wheat lines and their advantage over standard varieties due to the formation of the powerful root system penetrating into deep layers of the soil. The synthetic lines we studied in 2016-2017 in Western Siberia, were created in CIMMYT by crossing of durum wheat (*Triticum durum* Desf., genome AB) varieties Aisberg, Leucurum 84693, Ukr-Od 952.92, Ukr-Od 1530.94 (Odessa, Ukraine) and Pandur (Romania) with different entries of *Aegilops tauschii* Coss. (synonym *Ae. squarrosa,* genome D) from Caspian basin. Also, 15 synthetic wheat lines derived from Kyoto University (Japan) were also involved in studying. In total, we examines 126 lines of spring and winter types. Our screening revealed high variability of genotypes on the main parameters of root habitus in hybrid combinations with involving of different forms of the goat grass. The lines derived from hybrid combinations Aisberg/*Ae.sq.*(369), Ukr-Od 952.92/*Ae.sq.*(1031), Ukr-Od 1530.94/*Ae.sq.*(458) and Ukr-Od 1530.94/*Ae.sq.*(629) had high parameters of the root system development, i.e. the total root length was 73.9-141.1 cm, the root area was 16.6-25.3 cm^2, the number of root tips was 98-235, the root weight was 0.75-0.87 g. The lines with 5-6 germinal roots were mainly derived from the crosses when goat grass entries *Ae.sq.*(223) and *Ae.sq.*(310) of Gilan province, *Ae.sq.*(1031) of Zanjan province (Iran), and also *Ae.sq.*(409) from Dagestan (Russia) were the progenitors. The correlation coefficients between the main quantitative traits of plant productivity and the root system parameters calculated for the synthetic wheat lines showed that the plant height can be a marker for selecting genotypes with better parameters of root system, and therefore more drought-tolerant in Western Siberia. Synthetic lines No.No. 18, 28, 32, 38 of Aisberg/*Ae.sq.*(369), No. 37 of Ukr-Od 1530.94/*Ae.sq.*(310), No. 59 of Ukr-Od 30.94/*Ae.sq.*(1027), No. 61 of Pandur/*Ae.sq.*(409), and No. 36 of Aisberg/*Ae.sq.*(369)//Demir, selected for the elements of the spike productivity and a better root development may be involved in breeding for drought tolerance under conditions of Western Siberia.

Keywords: *Triticum durum* Desf., Aisberg, Leucurum 84693, Ukr-Od 952.92, Ukr-Od 1530.94, Pandur, *Aegilops tauschii* Coss., synthetic wheat, lines, parameters of the root system, drought tolerance

According to the information of FAO (Food and Agriculture Organization), the world population can reach 9-10 billion people by the middle of the 21st century. It will require the increase in the total yield of wheat from 650-700 million tons at present to about 1 billion tons (http://faostat.fao.org), for which the annual growth of grain wheat production is expected to be 2% in comparison

with the current 1.3%.

Targeted selection to increase the yield of commercial wheat varieties leads to the sharp decrease in their genetic diversity in resistance to abiotic stress factors. In the process of breeding, valuable adaptive alleles, accumulated for thousands of years in the local varieties of folk selection, were irretrievably lost [1].

Previously, a significant increase in the average minimum and maximum air temperature over the past 50 years in the Omsk Region was shown, and each second year was characterized by a shortage of precipitation during the vegetation period [2]. In the conditions of Western Siberia, drought is mainly manifested in the initial period of vegetation, and dryness in June—early July is increasing, as evidenced by changes in the hydrothermal coefficient. Due to the increasing frequency of dry years, increasing the drought resistance of wheat varieties becomes a priority for selection and the basis for increasing the yield of cultivated varieties in the Western Siberian region [3, 4].

Potential sources of drought hardiness genes are different kinds of goat grass growing in the arid regions. *Aegilops tauschii*, due to its wide adaptation in different ecogeographic zones (from Turkey in the West to Afghanistan and Central Asia in the East), is considered one of the donors of economically valuable genes for the expansion of the gene pool of soft wheat, which lost a wide polymorphism in the process of selection and cultivation [5-6]. About 400 samples of *Ae. tauschii*, found in the Caucasus region and the arid regions of Western Asia, were involved in the international program for Central Asia and Transcaucasia from the ICARDA (International Center of Agricultural Research) in the arid regions [7]. By now, CIMMYT (International Maize and Wheat Improvement Center) created about 1,300 synthetic hexaploids of spring and winter type, and 600 of them are based on *Ae. tauschii*. Numerous synthetic wheat lines have been successfully used in breeding and have proved their potential, in particular, when increasing resistance to biotic and abiotic stresses [8-11]. Increased drought resistance of synthetic wheat compared to varieties obtained by classical breeding methods was revealed by many researchers [12, 13]. In particular, it was noted that synthetic lines have larger habitus and longer root system length, which, with water deficiency, causes the formation of yield by 5-40% higher than that of soft wheat varieties [14]. The advantage of synthetic wheat and lines based on it is a better accumulation of dry weight of the roots and more productive use of moisture to increase the dry mass of the plant under water scarcity conditions due to better saturation of the soil with roots in the deep layers of the soil, whereas *Ae. tauschii* samples have higher indicators in the conditions of the optimal water supply of plants [15, 16].

Recent investigations have also proved a significant polymorphism of the synthetic wheat genome with *Ae. tauschii* on the morphology of the root system and drought resistance. The study of synthetic wheat lines with a lack of moisture in the soil revealed a close correlation between the water status of plants with biomass and root length [13, 17]. In some domestic works, it is noted that high productivity and drought resistance of plants are closely associated with a well-developed primary root system, due to which moisture from soil layers up to 1.5 m [18] is absorbed under drought conditions. The high heritability of the number of embryonic roots is proved, which indicates the possibility of a positive effect in the selection on this basis in breeding for drought hardiness [19].

QTLs that control the angle of the first root and the number of embryonic roots were revealed with the help of the mapping population of double wheat haploids. However, the relationship of genetic components with the physiological parameters of the water regime in dry conditions is not found [20, 21]. On the chromosomes 5B and 6D of spring wheat, QTLs, determining the signs

of water content, total root mass, and dry matter content in roots, were mapped. The coincidence of QTL localization, involved in the control of signs of water content and dry matter content in the roots, as well as water content, dry matter content in the roots and the water-holding capacity of the leaves, was noted; it indicates the relationship of physiological mechanisms that determine the water status of the above-ground part of the plant and the root system [22, 23].

Drought-resistant varieties created in the arid conditions are characterized by an increased length of roots and their total weight, which plays a crucial role in the formation of higher grain productivity with a moisture deficit [24-26].

It is also important to note that the previously obtained synthetic hexaploids did not exhibit significant polymorphism in the genome D; in this regard, the preliminary study and selection of samples of the *Ae. tauschii* is important for the creation of synthetic forms and hard wheat cultivars. The maximum genetic diversity of the *Ae. tauschii* forms, including rare and endemic ones, was found in the center of origin of this species. For example, the subspecies of *Ae. tauschii* ssp. *strangulata*, which is regarded as a potential donor of the genome D of *Triticum aestivum* [27, 28], grows in the geographically limited territory, i.e. in Transcaucasia (Armenia, Azerbaijan), as well as in the Northern provinces of Iran, the Golestan and Mazandaran [6, 29]. The greatest genetic diversity of the subspecies *Ae. tauschii* ssp. *tauschii* is concentrated on the South-West coast of the Caspian Sea, where the active forming process continues, which has great importance both for phylogenetic purposes and for practical breeding. In the NPGBI (National Plant Gene Bank of Iran), the collection of more than 180 samples of *Ae. tauschii*, growing in the territory of this country, is created; however, only 40 of them were used to create a collection of synthetics at the University of Kyoto [30-31]. In this regard, new synthetics from the University of Kyoto and CIMMYT, which were created by involving in the hybridization of unique samples of *Ae. tauschii* from the Caspian basin and drought-resistant hard wheat cultivars, represent a significant genetic resource for expanding the genotypic diversity of wheat in breeding for drought hardiness in the conditions of Western Siberia.

In this paper, we have revealed the breeding importance of synthetic wheat lines as sources for improving the characteristics of the root system in hybrid combinations involving different forms of goat grass and found that the height of plants can serve as a marker feature in the selection of genotypes with a better root system and, consequently, more drought-resistant in the conditions of Western Siberia.

The work objective is to analyze the morphometric parameters of the root system and the elements of productivity in the lines of hexaploid synthetic wheat for the selection of the parental material, promising for selection of drought hardiness of soft spring wheat in the conditions of Western Siberia.

Techniques. In the experimental field (the city of Omsk, 2016-2017), the synthetic lines were investigated; they were developed at CIMMYT by the hybridization of hard wheat cultivars Aisberg, Leucurum 84693, Ukr-Od 952.92, Ukr-Od 1530.94 (Odessa, Ukraine) and Randur, Romania (*Triticum durum* Desf., the AB genome) with various samples of *Aegilops tauschii* Coss. (synonym for *Ae. squarrosa*, *Ae.sq.*, genome D) from the Caspian basin area: from Iran *Ae.sq.*(310), *Ae.sq.*(369), *Ae.sq.*(629), *Ae.sq.*(1027), *Ae.sq.*(1031), the provinces Gilan, Zanjan, and Mazandaran; from Azerbaijan *Ae.sq.*(392), Shamakhi; from Russia *Ae.sq.*(409), Dagestan, of unknown origin *Ae.sq.*(458), *Ae.sq.*(511). Fifteen synthetic wheat lines obtained at the University of Kyoto (Japan) as a result of the hybridization of hard wheat cultivar Langdon (the USA) with *Ae. tauschii* samples were analyzed (Iran, Turkmenistan, Kyrgyzstan, India, China) [32, 33].

The *Ae. tauschii* samples (CIMMYT Germplasm Bank) referred to the subspecies of ssp. *tauschii*, var. typical (92 lines), ssp. *strangulate* (11 lines). A total of 126 lines of spring and winter type of development were investigated.

In 2016, 60 synthetic lines of spring type were sown in a single row of 1 m long; after every five numbers, the standards were alternately placed, No. 1 Pamyati Azieva (middle-early) and No. 2 Serebristaya (middle-late). The seeding rate was 25-30 grains per meter run. After harvesting, the structural analysis of the elements of productivity was carried out in the laboratory conditions. To analyze the root system development, 10 plants of each line and standards were dug from a depth of 25 cm; the root system was washed and scanned (Epson Expression 11000XL, Epson America, Inc., USA). In 2017, 47 lines of the winter type of development were investigated. Each of them was sown on the area of 1.4 m^2. The seeding rate was 25 g of grains per a working plot. After every 10 numbers, middle-early and middle-late standards No. 1 and No. 2 (the sorts of Pamyati Azieva and Serebristaya) were located alternately. The row width was 15 cm. Repetition was 4-fold, the placement of working plots in the experiment was randomized. To analyze the root system, 5 plants of each line and standards were dug from a depth of 25 cm in 4-fold repetition; the root system was washed and scanned as described above.

To process data on the root system state, the WinRhizo-2016 software package (Regent Instruments, Inc., Canada) was used. The following indicators were evaluated: root biomass, the number of embryonic roots, width, length, total length, root area, the average diameter of the root system, root volume, the number of root ends, the number of branches, the number of root intersections, fractal difference.

The statistical processing of the experimental data included the determination of the mean (*M*), standard error of the mean (±SEM), variation and correlation analyses. The comparison of synthetic lines and standards was carried out with the help of the analysis of variance; the reliability of differences was estimated by the smallest significant difference at the level of significance of 5% (LSD_{05}). The correlation coefficients (*r*) were calculated to determine the relationship between the studied features. To assess the significance of the correlation coefficient, table values of *r* were used at the significance levels $p = 0.05$ and $p = 0.01$. The correlation coefficients were considered reliable at $p < 0.05$. The indicators were calculated according to the description [34] using the Microsoft Excel statistical software application package and SPSS (PASW) Statistics 20.0 (IBM, USA).

Results. The weather conditions of the vegetation period of 2016 were characterized by high temperatures and lack of precipitation before the wheat sowing, which led to an acute early spring drought. For example, in May 2016, only 5 mm of precipitation fell, which was by 81% less than the average annual value (26 mm). In the first half of June, a large shortage of precipitation was observed as well. In the tillering phase, the common suppression of plants and reduction of growth processes were noted. In July, the moderately warm rainy weather, favorable for the development of plants, was the predominant one. In August, the weather was dry and warm. The maximum air temperature on some days in June, July, and August reached 32-35 °C. In 2017, an early summer drought, typical for the southern forest-steppe of Western Siberia, was observed. Since the 2nd ten-day period of June, for 3 weeks in critical periods of vegetation (the stooling stage and the formation of generative organs), the plants have experienced great stress due to atmospheric and soil drought. The hydrothermal coefficient in this period was 0.53, which characterizes the weather conditions as very dry. During the 2nd and 3rd ten-day periods of July, the conditions for plant growth and development were favorable in terms of water supply. In Au-

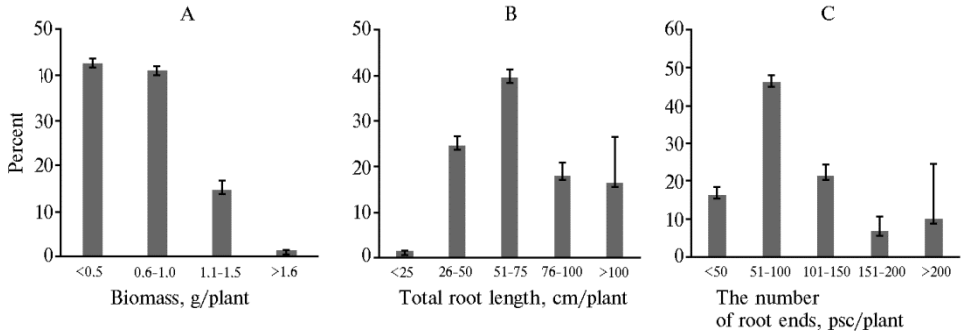
gust, the weather was dry and warm. The average daily air temperatures during the vegetation period slightly exceeded the average annual rates.

Significant polymorphism in the main parameters of the root system was observed in the lines obtained with the participation of different samples of *Ae. tauschii* (Table 1, Fig.). It is known that the D genome of *Ae. tauschii* has greater genetic variability compared to the genome of soft wheat.

1. The parameters of the root system among the studied synthetic wheat lines (at the average for hybrid combination, Omsk, 2016, microplot test)

Sample No. *Ae.sq.*, form	*n*	Perplant							
		A	B	C	D	E	F	G	H
Hard wheat cultivar Aisberg									
511	5	4	41.2	10.6	0.23	0.88	52	115	0.35
369	8	4	86.2	19.9	0.39	0.80	128	315	0.82
Hard wheat cultivar Leuc 84693									
409	1	4	51.1	11.3	0.21	0.78	39	85	0.38
Hard wheat cultivar Ukr-Od 952.92									
1031	3	5	73.9	16.6	0.32	0.83	98	233	0.75
Hard wheat cultivar Ukr-Od 1530.94									
310	3	5	66.2	13.6	0.24	0.73	89	160	0.56
392	3	4	52.8	11.5	0.21	0.75	69	142	0.40
458	3	4	78.1	16.9	0.31	0.78	114	221	0.85
629	3	4	141.1	25.3	0.38	0.62	235	356	0.87
1027	11	4	63.0	14.7	0.29	0.85	85	199	0.71
Hard wheat cultivar Pandur									
223	1	5	128.4	25.6	0.42	0.63	217	398	1.41
409	1	5	79.4	17.3	0.31	0.72	125	247	0.98
Hard wheat cultivar Langdon									
Forms from Japan	15	4	67.7	15.9	0.32	0.82	83	196	0.69
The synthetic line Aisberg/Ae. sq.(369)//Demir									
	1	6	128.2	28.4	0.52	0.73	151	329	1.06
Pamyati Azieva cultivar (middle-early standard)									
	1	4	50.9	13.9	0.33	0.97	73	155	0.63
Serebristaya cultivar (middle-late standard)									
	1	6	54.6	14.5	0.32	0.93	53	133	0.57
The variety range		3-6	15.3-213.2	5.1-35.9	0.15-0.67	0.56-1.36	28.5-366.8	37.5-624.4	0.19-1.85
LSD_{05}		0.22	2.56	0.58	0.01	0.03	3.78	10.1	0.10

Note. *n* — the number of lines in the hybrid combination of the spring type of development. A — the number of embryonic roots, pcs., B — the total length of the roots, cm; C — root area, cm^2; D — the volume of roots, cm^3; E — the average diameter of the roots, mm; F — the number of root ends, pcs.; G — the number of root branches, pcs.; H — root biomass, g.



The distribution of 47 studied wheat synthetic lines according to the root biomass (A)**, the total length of roots** (B) **and the number of root ends** (C) (Omsk, 2016, microplot test; vertical segments indicate the standard error of the mean).

The root biomass of some synthetics significantly ($p < 0.05$) exceeded the same indicator of standards by 0.4-0.9 g, and the total length of the roots exceeded 55-92 cm (Table 1). The increase in the root weight does not always increase their water absorption capacity; therefore, the main contribution to the productivity of plants is made by the total number of roots [12, 15].

In the combinations of Aisberg/*Ae.sq.*(369), Ukr-Od 952.92/*Ae.sq.*(1031), Ukr-Od 1530.94 92/*Ae.sq.*(458), Ukr-Od 1530.94/*Ae.sq.*(629), Ukr-Od 1530.94

92/*Ae.sq.*(1027), the representative differences between the synthetic lines and standards were identified by the following indicators: the total length of roots — 73.9-141.1 cm, roots area — 16.6-25.3 cm^2, the number of the root ends — 98-235 pieces, the root biomass — 0.75-0.87 g. In general, synthetics differed from the standards by a smaller diameter of roots (0.62-0.88 mm), which allowed them to extract moisture from the deeper layers of the soil. D. Eissenstat [35] notes that the smaller diameter of the root system reduces the nutrient costs of root formation and increases their area. The formation of embryo roots affects the productivity of varieties in the arid conditions and depends on the ecological origin of the variety. The primary root system has a strong influence on the growth and development of plants in the initial stages of ontogenesis, helping to survive in early drought [18, 19, 36].

The comparison of the number of embryonic roots of the studied lines of synthetics, created with the participation of different goat grass samples, has shown that 5-6-radicular samples are typical for the lines, obtained on the basis of the goat grass forms from Iran, i.e. *Ae.sq.*(223) and *Ae.sq.*(310) from the province of Gilan, and *Ae.sq.*(1031) from the province of Zanjanas well as the form from Dagestan *Ae.sq.*(409). The development of the primary root system was a moderately variable trait (*Cv* = 16.5%). Within the boundaries of each hybrid combination, a significant variation of the trait (from 3 to 6 roots), which indicates the possibility of selection, was observed.

2. Parameters of the root system among the best synthetic wheat lines on the spike productivity (at the average for hybrid combination, the city of Omsk, 2016-2017, microplot test)

№	Cultivar, line	A	B	C	D	E	F	G	H
18	Aisberg/*Ae.sq.*(369)	1.35^{a}	4.3	10.0^{ab}	109.3^{ab}	28.8^{ab}	384	768^{ab}	0,38
28	Aisberg/*Ae.sq.*(369)	1.40^{a}	3.3	11.3^{ab}	124.1^{ab}	32.3^{ab}	401	817^{ab}	$0,71^{ab}$
32	Aisberg/*Ae.sq.*(369)	1.39^{a}	3.2	12.1^{ab}	164.7^{ab}	41.9^{ab}	648^{ab}	1243^{ab}	$0,71^{ab}$
36	Aisberg/*Ae.sq.*(369)//Demir	1.52^{ab}	5.0^{ab}	11.6^{ab}	144.7^{ab}	35.3^{ab}	420	811^{ab}	$0,79^{ab}$
37	Ukr-Od 1530.94/*Ae.sq.*(310)	1.48^{ab}	5.5^{ab}	11.7^{ab}	151.2^{ab}	31.3^{ab}	579^{ab}	929^{ab}	$0,69^{ab}$
38	Aisberg/*Ae.sq.*(369)	1.30^{a}	3.6	11.2^{ab}	152.8^{ab}	40.2^{ab}	547^{ab}	1154^{ab}	0,59
59	Ukr-Od 1530.94/*Ae.sq.*(1027)	1.43^{ab}	4.1	11.2^{ab}	147.0^{ab}	38.9^{ab}	552^{ab}	1115^{ab}	0,66
61	Pandur/*Ae.sq.*(409)	1.49^{ab}	4.2	9.8	109.5^{a}	29.0^{ab}	701^{ab}	678	$0,72^{ab}$
Pamyati Azieva (middle-early standard)		1,21	4.3	9.2	93.4	19.4	380	601	0.46
Serebristaya (middle-late standard)		1,34	4.6	9.6	105.2	23.2	378	676	0.45
LSD_{05}		0,09	0.18	0.24	11.5	2.2	43.4	102.9	0.23

N o t e. A — the main spike mass, g; B — the number of embryonic roots, pcs.; C — the length of the largest root, cm; D — root area, cm^2; E — the number of root ends, pcs.; G — the number of root branches, pcs.; H — root biomass, g. The significant differences between lines and standards (LSD_{05}, $p < 0.05$) are marked with different Latin letters.

The weight of grain from the main spike is the most important feature in the assessment of the drought hardiness of varieties (Table 2). In studying this trait, we obtained the results that are consistent with the data from other researchers [18, 37]. In case of unfavorable moisture supply in the initial period of plant development in 2016 and in the conditions of early summer drought in 2017, the best synthetic forms had an advantage in the productivity of the main spike over the varieties of classical selection due to the formation of a powerful root system penetrating into the deeper layers of soil (10.0-12.1 cm), a larger total length (109.3-164.7 cm), a larger number of ends (384-701 pcs.) and branches (678-1,243 pcs.), a larger area (28.8-41.9 cm^2), and root biomass (0.59-0.79). As per root biomass (0.69-0.79 g), the following synthetics were distinguished: No. 28, 32 of Aisberg/*Ae.sq.*(369); No. 36 of Aisberg/*Ae.sq.*(369)//Demir; No. 37 of Ukr-Od 1530.94/*Ae.sq.*(310), and No. 61 of Pandur/*Ae.sq.*(409).

The length of the longest root significantly exceeded the standards for all lines except No. 61 Pandur/*Ae.sq.*(409). Lines with 5-6 embryonic roots, as a rule, were characterized by a greater total root length, increased productivity of the spike, and grain size. So, No. 36 Aisberg/*Ae.sq.*(369)//Demir and No. 37

Ukr-Od 1530.94/*Ae.sq.*(310) showed, at average over 2 years of research, the length of the roots of 145-150 cm, the productivity of the spike was 1.5 g and weight of 1000 grains of 44.1-45.8 g.

The most productive synthetics No. 32 Aisberg /*Ae.sq.*(369) and No. 61 Pandur/*Ae.sq.*(409), with the yield of 426-436 g/m^2 in 2017, had significantly high indicators of the area, number of ends, and root biomass. The results of the research indicate that just one or two backcrosses of the synthetic hexaploids with the best commercial varieties of wheat are enough for the allocation of the synthetic backcrossed lines with valuable introgressed components of plant productivity from *Ae. tauschii*.

For example, the line No. 36 obtained by crossing of the synthetic line Aisberg/*Ae.sq.*(369) with the cultivar of Turkish breeding Demir showed a noticeable improvement in the main agronomic indicators (productivity of the spike reached 1.52 g).

We calculated the correlation coefficients between the main quantitative characteristics of plants and the parameters of the root system of synthetic wheat lines (Table 3).

3. Correlation coefficients (*r*) between the indicators of root system development and some quantitative signs of productivity among 47 studied synthetic wheat lines (the city of Omsk, the average for 2016-2017, microplot test)

Trait	NER	RB	LLR	TLR	RA	RV	NRE	NRB
NER		0.12	0.28	0.34*	0.37*	0.37*	0.42**	0.41**
RB	0.12		0.26	0.26	0.31*	0.34*	0.10	0.17
LLR	0.28	0.26		0.88**	0.81**	0.71**	0.79**	0.79**
TLR	0.34*	0.26	0.88**		0.97**	0.89**	0.95**	0.97**
RA	0.37*	0.31*	0.81**	0.97**		0.97**	0.93**	0.97**
RV	0.37*	0.34*	0.71**	0.89**	0.97**		0.87**	0.92**
NRE	0.42**	0.10	0.79**	0.95**	0.93**	0.87**		0.98**
NRB	0.41**	0.17	0.79**	0.97**	0.97**	0.92**	0.98**	
PH	0.37*	0.18	0.56**	0.66**	0.67**	0.64**	0.68**	0.66**
PTC	0.35*	0.24	–0.28	–0.34*	–0.31*	–0.28	–0.39**	–0.36*
NGS	0.18	0.33*	0.46**	0.55**	0.55**	0.51**	0.50**	0.52**
GWS	0.32*	0.22	0.62**	0.73**	0.71**	0.66**	0.74**	0.72**
GWP	0.36*	0.28	0.47**	0.56**	0.55**	0.52**	0.57**	0.56**
1000GM	0.38*	0.11	0.58**	0.67**	0.63**	0.57**	0.75**	0.69**

N o t e. NER — the number of embryonic roots, RB — root biomass, LLR — the length of the longest root, TLR — the total length of roots, RA — roots area, RV — roots volume, NRE — the number of root ends, NRB — the number of root branches; PH — plant height, PTC — productive tilling capacity, NGS — the number of grains per spike, GWS — grain weight from a spike, GWP — grain weight from a plant, 1000GM — 1000 grains mass.
*, ** The critical value of *r* is 0.30 and 0.39, respectively.

M. Reynolds et al. showed [15] that the increase of root biomass does not affect the improvement of the water supply of plants in conditions of water deficit. The authors have found a weak positive relationship between the basic elements of spike productivity with the number of embryonic roots, and the biomass of roots (*r* varies from 0.18 to 0.38); therefore, it can be assumed that the main mechanism of adaptation of synthetic lines to drought under the conditions of Western Siberia is enhanced root growth in length, which allows plants to extract moisture from deeper soil layers.

For the length of the largest root and the total length of the roots, the authors found an average positive relationship with the main elements of productivity (r = 0.47-0.73). This information corresponds to the previously published results by the foreign researchers [38-40].

The synthetic wheat lines were characterized by the formation of a greater total length and a greater number of root branches. In the conditions of the early summer drought in 2017, the most productive lines No. 32 Aisberg/*Ae.sq.*(369) and No. 61 Pandur/*Ae.sq.*(409) showed better adaptation to drought due to the maximum total length of roots (232-239 cm), and the line

No. 38 Ukr-Od 1530.94/*Ae.sq.*(310) had the most developed root system (diameter 5.6 cm) at a depth of 18-20 cm.

Plant height had correlation coefficients higher than the average value for the following traits: for root length r = 0.56-0.66; for area and volume of roots, the number of ends and branches of roots r = 0.64-0.68. The revealed positive correlation indicates that the height of plants can serve as a marker sign in the selection of plants with good indicators of the formation of the root system and, consequently, more drought-resistant in conditions of Western Siberia. It should be noted that the opposite results were obtained in the United States in the study of the contribution of the root system to the drought resistance of spring wheat [41].

The length of the largest root and the total length of roots were poorly correlated with biomass (r = 0.26), because the inverse relationship between the diameter of roots and their length (r = –0.39) was found; it allowed roots with a smaller diameter to penetrate into the soil to a greater depth. The unproductively large outflow of assimilates to the formation of excessive root biomass can lead to the decrease in plant productivity and grain yield per unit of the area. According to the paper by B. Ehdaie et al. [42], the formation of a larger area of roots due to the spread of lateral roots in the horizontal direction increases the absorption capacity of the root system, which favorably affects the productivity of plants.

V. Nazem and A. Arzani [43] during the investigation of morphological features of the synthetic hexaploids, noted less intense leaf color, from light to gray-green with a well-developed wax coating, which also contributes to optimal stomatal regulation due to less heating of the leaf surface and reducing of the moisture consumption for transpiration. It can be assumed that the architectonics of the root system, in particular, the formation of a larger number of ends and branches, as well as the maximum development in the length of the main roots of a smaller diameter, maintain the positive water status of the synthetic lines in conditions of water scarcity. The obtained results show the relationship of the elements of productivity with the parameters of the root system, which can improve the efficiency of selection and indicate the prospects in the use of synthetic wheat lines in breeding for drought resistance.

Thus, combinations Aisberg/*Ae.sq.*(369), Ukr-Od 952.92/*Ae.sq.*(1031), Ukr-Od 1530.94 92/*Ae.sq.*(458), Ukr-Od 1530.94/*Ae.sq.*(629), Ukr-Od 1530.94 92/*Ae.sq.*(1027) show a significant polymorphism in the features of the root system development; it allows selection of the parental material for breeding for drought resistance. Standard varieties of spring wheat compared to the best synthetic lines have less root biomass and lower basic indicators of the root system biometric parameters. The positive correlation between the development of roots system and the height of plants is revealed; therefore, the height of the plant can be a marker trait in the selection of genotypes with an effective root system. The lines No. 18, 28, 32, 38 Aisberg/*Ae.sq.*(369), No. 37 Ukr-Od 1530.94/*Ae.sq.*(310), No. 59 Ukr-Od 30.94/*Ae.sq.*(1027), No. 61 Padur/*Ae.sq.*(409), and No. 36 Aisberg/*Ae.sq.*(369)//Demir, distinguished by the elements of the spike productivity and the parameters of the root system, can serve as parental material for inclusion in breeding programs to improve the drought hardiness of wheat varieties in different regions of Russia.

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