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DROUGHT TOLERANCE OF WHEAT INTROGRESSIVE FORMS

In Kazakhstan the main limited factor for the wheat, growing up in arid lands is survival in the summer, which make the studies on wheat drought resistance are very importance. It is interesting for adaptation to environmental drought to be combined physiological and biochemical indicators with total grain yield and productivity of wheat. The objects of the study were 12 introgressive forms of winter wheat, obtained from the crossbreeding of the varieties of winter wheat (Triticum aestivum L.) with wild relatives – Triticum timopheevii, Triticum militinae, Triticum kiharae, Aegilops cylindrical, Aegilops triaristata, in the yield of 2015-2017.The drought tolerance of wheat genotypes in field experiments was judged by the absolute value of yield and the signs of productivity, as well as by the degree of decline in productivity under conditions of drought. Determination of drought tolerance in the laboratory was conducted by the detection of free proline. Phenotyping, determine biomass accumulation and photosynthesis was carried out on NDVI-technology. The experimental data were processed statistically and by cluster analysis.

Screening of the results allowed to: reveal wide variability of the studied indicators; detect a change in the standardized index of vegetation differences, determined by the accumulation of vegetative biomass and phenological development phases of the studied wheat forms as well as obtained the best genotypes with the maximum of the NDVI indexes. The genotypes promising in breeding for drought resistance that persistently retain a high level of free proline content have been identified. There were comparative analysis of the introgressive forms and varieties by total yield, identification of promising simples by individual indicators and overall productivity. The results contribute to deciphering physiological mechanisms of growth and resistance of grain crops, intensification of wheat breeding for adaptability to environmental stresses, and enrichment of the genetic resources of Kazakh wheat with a variety of prospective forms obtained from crossbreeding with wild relatives.

Key words: drought, wheat introgressive forms and wild relatives, NDVI-technology, free proline, productivity.

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Бидайдың интрузивті нысандарын құрғақшылыққа төзімділік

Қазақстанда аридті жерлерде бидай өсірудің шектеу факторы жазғы құрғақ жағдайларда өмір сүру болып табылады, бұл бидайдың құрғақшылыққа төзімділігін зерттеуге ерекше мән береді. Бидай және астық өнімділігі туралы деректермен бейімделудің физиологиялық және биохимиялық көрсеткіштерін салыстыратын құрғақшылық экологиясы бойынша жұмыстар қызығушылыққа лайық. Зерттеу нысандары ретінде 2015-2016 жж. егілген өнімдер барысында қысқы бидайдың (Triticum aestivum L.) сорттарын жабайы туыстарымен – Triticum timopheevii, Triticum militinae, Triticum kiharae, Aegilops cylindrical, Aegilops triaristata будандастырған кезде пайда болған қысқы бидайдың 12 интогрессивті нысандары алынды. Дала эксперименттеріндегі идай генотиптерінің құрғақшылыққа төзімділігі жалпы өнімділік және өнімділіктің белгілері, сондай-ақ құрғақшылық жағдайында дақылдардың өнімділігін төмендету дәрежесі бойынша бағаланды. Зертханада құрғақшылыққа төзімділікті анықтау бос пролинді анықтау арқылы жүзеге асырылды. Фенотиптеу, биомасса жинау және фотосинтезді анықтау NDVI технологиясы бойынша жүргізілді. Эксперименттік деректер статистикалық түрде өңделді және кластерлік талдау жүргізілді.

Нәтижелерді скринингтеу бойынша, зерттелген индикаторлардың кең ауқымдылығын анықтау, өсімдіктердің биомассасының жинақталуы және зерттелген бидай формаларының фенологиялық фазалары арқылы анықталған өсімдік айырмашылықтарының стандартталған индексінің өзгеруін анықтау және максималды NDVI көрсеткіштерімен перспективті үлгілерді алуға болады. Бос пролиннің жоғары деңгейін сақтайтын, құрғақшылыққа бейімделу барысында селекциялық құндылық болып табылатын генотиптер анықталды. Интрогрессивті нысандар мен сорттардың өнімділігіне салыстырмалы талдау жүргізіліп, жалпы өнімділік пен жеке көрсеткіштердің перспективалық үлгілері анықталды. Алынған нәтижелер астық дақылдарының өсуі мен тұрақтылығының физиологиялық тетіктерін, бидайдың іріктеуін экологиялық стресстікке бейімделуге ынталандыруға, сондай-ақ қазақстандық бидайдың генетикалық ресурстар жабайы туыстары арқылы өтетін әр түрлі перспективалы нысандармен байытуға ықпал етеді.

Түйін сөздер: құрғақшылық, бидайдың интрогрессивті нысандары және жабайы туыстары, NDVI технологиясы, бос пролин, өнімділік.

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Толерантность к засухе интрогрессивных форм пшеницы

В Казахстане лимитирующим фактором для выращивания пшеницы на аридных землях является выживание в условиях засушливого лета, что придает исследованиям засухоустойчивости пшеницы особую актуальность. Заслуживают интерес работы по экологии засухи, которые сопоставляют физиологические и биохимические индикаторы адаптации с данными по урожайности зерна и продуктивностью пшеницы Объектами исследования служили 12 интрогрессивных форм озимой пшеницы, полученных при скрещивании сортов озимой пшеницы (Triticum aestivum L.) с дикими сородичами – Triticum timopheevii, Triticum militinae, Triticum kiharae, Aegilops cylindrical, Aegilops triaristata, в урожае 2015-2017 гг. Толерантность к засухе генотипов пшеницы в полевых экспериментах оценивалась по величине общей урожайности и признакам продуктивности, а также по степени снижения продуктивности посевов в условиях засухи. Определение толерантности к засухе в лаборатории проводилось путем обнаружения свободного пролина. Фенотипирование, определение накопления биомассы и фотосинтеза осуществлялось по технологии NDVI. Экспериментальные данные обрабатывались статистически и кластерным анализом.

Скрининг результатов позволил: выявить широкую вариабельность изучаемых показателей, обнаружить изменение стандартизированного индекса различий растительности, определяемого по накоплению вегетативной биомассы и фенологическим фазам развития изучаемых форм пшеницы, а также получить перспективные образцы с максимальными значениями NDVI индексов. Были идентифицированы генотипы, представляющие ценность в селекции на адаптацию к засухе, которые устойчиво сохраняют высокий уровень содержания свободного пролина. Был проведен сравнительный анализ интрогрессивных форм и сортов по урожайности, выявлению перспективных образцов по отдельным показателям и общей продуктивности. Полученные результаты способствуют расшифровке физиологических механизмов роста и устойчивости зерновых культур, интенсификации селекции пшеницы на адаптивность к экологическим стрессам, обогащению генетических ресурсов казахстанских пшениц разнообразием перспективных форм, полученных от скрещивания с дикими сородичами.

Ключевые слова: засуха, интрогрессивные формы пшеницы и дикие сородичи, NDVI-технология, свободный пролин, продуктивность.

Introduction

In Kazakhstan, the main limited factor for the wheat growth in arid lands is survival in the summer, which make the studies on wheat drought resistance are very importance. It is important for growing wheat, that adaptation to environmental stresses be combined with grain yield and the productivity of crops.

The arid climate is a dry climate with high air temperatures, experiencing large daily fluctuations, and a small amount of precipitation, about 100-150 mm / year or their complete absence. Arid and semi-arid lands occupy more than half of the republic territory, where grain crops often suffer drought.

The strategy of biological adaptation to drought was considered through genetic, physiological, biochemical and morphoanatomical mechanisms (Fischer, 2011:96) .The idea of nonspecific and specific factors of plant resistance was advanced in the works of G.V. Udovenko, R.M. Hove, M. Bhave, P.A. Henkel (Udovenko, 1979; Hove, Bhave, 2011; Henkel, 1982: 162). The teachings of D.M. Grodzinsky on the functioning of plants' "reliability" systems revealed mechanisms of adaptive stability in an original way (Grodzinsky, 1983:29). The ability of plants in the process of growth and development to withstand changing environmental conditions and form a full-fledged off spring depends on their adaptive potential, which is an interconnecting function of programs of ontogenetic and phylogenetic adaptation (Zhuchenko, 2008:66). There are many contradictory data on the connection between physiological and biochemical indicators of plant metabolism and resistance to abiotic stresses. The most important resistance mediators are the intensity of growth processes in stressful conditions, the accumulation of green biomass and the content of chlorophyll providing photosynthetic activity, the level of free proline and others (Trethowan et al., 2002; Ivanov et al., 2013; Kuznetsov et al., 1999). The main economic-useful attribute of agricultural crops, in particular wheat, is yield. At the same time, the realization of high potential productivity of many varieties in production conditions often occurs only by 20-30%. R.A. Urazaliyev conceptually considers the same problem within the ecological adaptability of wheat, barley and other crops in creating varieties of specific agro-ecotypes (Urazaliyev et al., 2007:29). Papers works on the construction of models for deciphering the nature of the interaction effect "genotype-environment" in the study of the ecological and genetic organization of polygenic plant characteristics generated interest in the scientific community (Dragavtsev, 2005).

However, the narrow specificity of breeding, the tendency to a partial loss of fitness genes, induces wild species and varieties – donors of resistance to certain unfavorable factors of the environment – to be involved in the breeding of crops. Great perspectives are opening by using of wild species as an introgressive genetic material (Nevo, 2006; Ogbonnaya F.C. et al., 2013). It is known that introgression (introgression, latin *intro* – in, inside and *gressus* – approaching, crossing, attacking) means the inclusion of individual genes of one kind of organism in the gene pool of another species. This has been achieved by one of the traditional methods, such as trans-species hybridization, which makes it possible to obtain a highly plastic new genetically original source material for wheat breeding. Wild relatives of wheat are, as a rule, "records" of sustainability, because they were selected by nature. The series of trans-species crossings with wild types of wheat T.kiharae, T.timophevii, T.militinae and others, as sources of an immunity, stability and high content of protein in grain, were carried out in the Kazakh Scientific Research Institute Agriculture and Plant Growing within 20 last years (Kozhahmetov, Abugalieva, 2014).

The purpose of this work is study the physiological growth indicators and productivity of wheat with introgressive forms in arid climate conditions obtained from trans-species crossing of wheat varieties with wild species.

The tasks of our research are the search for informative physiological and biochemical criteria for drought tolerance; the intensification of wheat breeding for adaptability in arid lands; the enrichment of the gene pool of Kazakh wheat with a variety of prospective forms obtained from crossbreeding with wild relatives.

Materials and Methods

The objects of the study were 12 introgressive forms of winter wheat, formed from the crossbreeding of the cultivars of winter wheat (Triticum aestivum L.) of Kazakhstan breeding – Karlygash, Erythrospermum 350, Zhetysu, Steklovidnaya 24, Komsomolskaya 1 and widely zoned Bezostaya 1 with wild wheat – Triticum timopheevii, Triticum militinae, Triticum kiharae, Aegilops cylindrical, Aegilops triaristata. Breeder – Dr. K. Kozhahmetov. Experimental results were compared with wheat varieties and wild relatives by studied indicators.

Field and laboratory tests were used. Wheat genotypes were grown up in the experimental fields of the Kazakh Scientific Research Institute

Agriculture and Plant Growing in 2015-2017. The drought tolerance of wheat genotypes in field experiments was evaluated by total yield and the signs of productivity, as well as by the degree of decline in productivity under conditions of drought. Drought tolerance in the laboratory was onducted by the determination of free proline in the leaves of the seedlings according the method of L.S. Bates et al. (Bates et all, 1973).

Phenotyping, determine biomass accumulation and photosynthesis was carried out on NDVI-technology. NDVI-technology for measuring retro-reflectance in the red and near infrared spectrum to determine biomass accumulation on the Greenseeker instrument; N. TechInductries, USA (Verhulst N. et all, 2010); photosynthesis in the field was measured on a portable instrument FP 100 (PSI, Czech Republic).The experimental data were processed statistically and by cluster analysis.

The general scheme of experiments on screening the resource material of winter wheat for drought tolerance on the basis of morpho-physiological, physiological-biochemical and breeding-genetic indicators was shown in Figure 1.

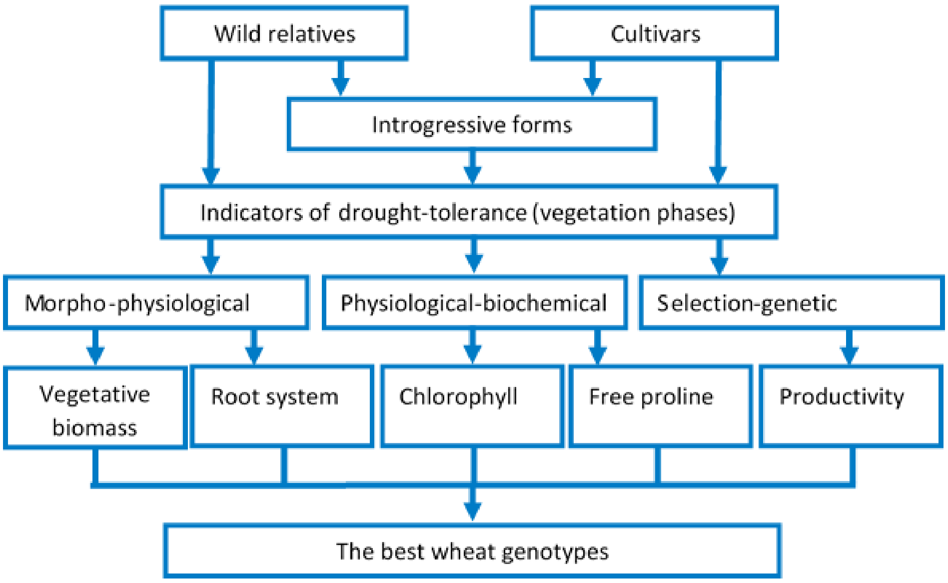

Figure 1 – Scheme of experiments on screening of winter wheat resource material for drought tolerance

Results and Discussion

Determination of biomass accumulation and detection of drought tolerance by the NDVI method

In our experiments, the NDVI technology was used to measure the accumulation of biomass during the growing season by the phenological phases of development in the field conditions. The data of indices of vegetative development on the best genotypes among introgressive forms of wheat were presented in Table 1.

It should be noted that in the phase of tillering and tubing, NDVI indexes of the introgressive forms were in the range of 0.28-0.77, with the subsequent increase in phases of earing-flowering to 0,86 – 0,88, followed by a decrease due to degradation of the chlorophyll complex and grain ripening. Genotypes with Ae. cylindrica, T.militinae and Erythrospermum 350, Bezostaya 1, as relative forms, were distinguished. The introgressive forms of winter wheat had a more powerful vegetative mass that corresponded to a high NDVI index, exceeding Almaly grade – standard.

In general, the data of three years of cultivation identified the variability of wild, cultural and introgressive forms according to the indicator of green development and higher indices of NDVI among introgressive genetic materials in comparison with wild relatives. The results consistently identified the best genotypes with the maximum value of NDVI indices: Erythrospermum 350 x T. militinae, Bezostaya 1 x T.militinae) x T. militinae-9, (Bezostaya 1 x T.militinae) x T. militinae-6. Maximum of NDVI indexes was determined during phase's earing – flowering. These genotypes have a high potential for productive development and are a valuable material for the breeding process, which is confirmed by works of other scientists on influence of a germplasm of wild relatives on improvements of qualities of agricultural plants (Davayan P.O.et al., 2003).

Table 1 – Genotypes of introgressive forms of winter wheat with a maximum index of NDVI in 2015-2017

Development phase	NDVI index value			Max NDVI indexed genotypes
	min	max	ave	
the beginning of tillering	0,28	0,45	0,37	Erythrospermum 350 x T. militinae Zhetysu x T. militinae Steklovidnaya 24 x Ae. cylindrica
full tillering	0,32	0,54	0,43	Erythrospermum 350 x T. militinae Zhetysu x T. militinae Bezostaya 1 x Ae. cylindrical
the beginig of tubing	0,40	0,62	0,54	Zhetysu xT.timopheevii Bezostaya 1 x Ae. cylindrical Erythrospermum 350 x T. militinae
tubing – earing	0,54	0,77	0,65	Bezostaya 1 x Ae. cylindrical Erythrospermum 350 x T. militinae Erythrospermum 350 x T.kiharae (Bezostaya 1x T.militinae) x T. militinae 9 (4)
earing	0,59	0,86	0,72	Erythrospermum 350 x T. militinae Bezostaya 1 x Ae. cylindrical (Bezostaya 1x T.militinae) x T. militinae 4 Erythrospermum 350 x T.kiharae
earing-flowering	0,66	0,88	0,77	Erythrospermum 350 x T.kiharae Bezostaya 1 x Ae. cylindrical Steklovidnaya 24 x Ae. cylindrica
flowering	0,64	0,78	0,71	Steklovidnaya 24 x Ae. cylindrica Erythrospermum 350 x T.kiharae Bezostaya 1 x Ae. cylindrical
grain filling	0,58	0,70	0,64	Zhetysu x T. militinae Erythrospermum 350 x T.kiharae Steklovidnaya 24 x Ae. cylindrica (Bezostaya 1 x T.militinae) x T. militinae-9
milky ripeness	0,28	0,45	0,37	Erythrospermum 350 x T. militinae Zhetysu x T. militinae Steklovidnaya 24 x Ae.cylindrica

2. *The chlorophyll content in plant leaves in field conditions*

The study of the relationship between the indexes of the photosynthetic apparatus of crops and the yield is of great importance both for understanding the patterns of the production process, for developing breeding criteria for high productivity and for forecasting yields in agrocenoses (Pryadkina G.A. et al., 2014).

The chlorophyll content in 2015-2017 was estimated in the field during the growing season by several measurements. During the tillering phase, the chlorophyll content was noted to be the maximum in vegetation and varied from 0.63 to 0.71. The tubing phase mostly proceeded under conditions of temperature stress (37-39 ° C) and the chlorophyll content decreased to the level of 0.34-0.62. The chlorophyll content stabilized at the level of 0.59-0.68 by the earing phase (Table 2). Wild relatives were characterized by a narrower interval of variability at the level of 0.53-0.59 in comparison with varieties 0.60-0.68 (grade-standard Almaly). Data on genotypes of winter wheat in comparison with the sort-standard Almaly, the chlorophyll content in leaves of which is accepted as 100%. The chlorophyll content in wild rrelatives and introgressive forms exceeded the Almaly standard by 1.1-1.3 times, Ae.cylindrica and Steklovidnaya 24 x Ae.cylindrica were on the leading positions.

In laboratory experiments on seedlings, the chlorophyll content was subject to a certain range of variability and exceeded the Almaly grade-standard for wild forms in the range of 1.3-1.5 times. Among the varieties and the introgressive forms there were samples that showed an almost 2-fold increase in the chlorophyll content, for example, Erythrospermum 350 x T. kiharae, Erythrospermum 350 and Bezostaya 1.

Table 2 – The chlorophyll content of wheat introgressive forms in FP 100 units

Development phase	Chlorophyll content			Genotypes
	min	max	ave	
the beginning of tubing	0,63	0,71	0,68	Erythrospermum 350 x T. militinae Bezostaya 1 x Ae. cylindrical (Bezostaya 1x T.militinae) x T. militinae-4 Zhetysu xT.timopheevii Steklovidnaya 24 x Ae. cylindrica
tubing – earing	0,54	0,62	0,47	Erythrospermum 350 x T.kihara Zhetysu x T. militinae
earing-flowering	0,59	0,68	0,64	Steklovidnaya 24 xAe. cylindrica Erythrospermum 350 x T.kihara
grain filling	0,53	0,68	0,61	Bezostaya 1 x Ae. cylindrical Zhetysu x T. militinae

Variability in the accumulation of chlorophyll, intrinsic to introgressive forms, was revealed through the study. However, the trend of exceeding its content compared with cultivars was quite clearly seen, which indicated an increased productive potential of introgressive genetic material of photosynthetic (Krupnov, 2011; Pryadkina et al., 2014).

3. Free proline of wheat introgressive form, wheat varieties and wild relatives

It was found that the content of proline during the flowering phase of cultivars varied from 29 to 38 mg %, with the highest amount of proline recorded in varieties Steklovidnaya 24 and Zhetysu, which are parental forms for the studied introgressive forms. The content of free proline in wild relatives significantly exceeded the cultivars by 1.8-2.0 times and was in the range of 43-58 mg %. Among the wild forms, genotypes T. kiharae and T. militinae can be distinguished by the level of free proline.

The introgressive forms showed variability by the content of free proline, the amount of amino acid in the leaves was 35-55 mg%, the largest number was observed in the forms: Steklovidnaya 24 x T. timopheevii (50 mg%), Erythrospermum 350 x T. kharae (52 mg%) and Zhetysu x T. militinae (55 mg%). With the increase of temperature occurring at the initial stages of the grain-filling phase, a distinct tendency of free proline amount increasing was observed in the leaves of the studied wheat plants. The proline content increased by an average of 33% for all forms of wheat. In 2017, wild relatives met the established range of variability of this indicator 54-66 mg% (51-68 mg% in 2015, 55-64 mg% in 2016), introgressive forms showed some decrease in proline content in leaves 66-80 mg%, but varied over a wide range (70 – 81 mg% in 2015, 76-85 mg% in 2016), and the proline content of the varieties was at the level of the previous years. The previously observed tendency for a proactive increase in the proline content of cultivars compared to wild and introgressive forms remained stable with drought continuous. It turned out that the mechanisms of adaptation of cultured wheat were more developed associated with the water-retaining capacity of proline. The introgressive forms showed the maximum level of accumulation of free proline in the range of 70-81%, which is lower compared to the data of 2016, 76-85 mg %. Genotype Erythrospermum 350 x T. kharae leaded by the accumulation of proline (81%), Table 3.

Considering that proline is a potential reserve metabolite that performs a protective, anti-stress role in plant metabolism, the level and variability in its accumulation can be sufficiently informative criteria for the adaptability of agricultural plants in arid lands. In this regard, a comparative analysis of free proline content in cultivars and wild relatives of wheat and their intragressive forms under drought conditions is very promising for assessing the level of manifestation of plant adaptation potentials in the development of hybrid combinations and in the breeding of valuable genotypes by a set of utility characteristics and properties (Fischer, 2011; Tazhibayeva, 2010).

Table 3 – Variability in the accumulation of free proline in leaves of wild, cultural and the introgressive forms in various phenological phases of wheat development, 2015-2017

Wheat genotypes	The variability range of free proline accumulation, mg%	The sample with the best result
Flowering phase		
Wild relatives	43-58	T.kiharae, T.militinae
Introgressive forms	35-55	Steklovidnaya 24 x T.timopheevii, Erythrospermum 350 x T.kiharae, Zhetysu x T.militinae
Varieties	29-38	Steklovidnaya 24, Zhetysu
Grain filling phase		
Wild relatives	51-68	Ae.cylindrica, T.kiharae
Introgressive forms	76-85	Erythrospermum 350 x T.kiharae, (Bezostaya1x T.militinae) x T.militinae
Varieties	46-60	Erythrospermum 350, Steklovidnaya 24

4. Productivity of wild, wheat varieties and the introgressive forms

The total productivity of all studied wheat forms by the results of the harvest of 2016 was slightly lower than in 2015, in 2017 – it was at the level of 2016. In terms of the specification “mass of 1000 grains”, most closely associated with drought tolerance (Dragavtsev, 2005), the largest value was recorded in the form of Steklovidnaya 24 x Ae.cylindrica (60.7 g in 2015 and 54.5 g in 2016), Erythrospermum 350 x T. kiharae (55.4 g in 2016 and 56.2 g in 2017), the smallest – (Bezostaya 1 x Ae.triaristata) x Karlygash (42.5 – 45.5 g in 2015-2017).

It should be noted that according to the main indicator for the characteristic of drought resistance, all tested genotypes with introgression of germplasm of wild relatives showed good results. According to the specification “mass of 1000 grains”, six introgressive forms exceeded the Almaly sort-standard (47.8 g), four introgressive forms out of which were higher than Karakhan sort-standard (50.7): Steklovidnaya 24 x Ae. cylindrica and Zhetysu x T. militinae, Erythrospermum 350 x T. kiharae. This indicator of crop productivity is, as a rule, accompanied by another – “the mass of grain in the main ear” that finds confirmation in our experiments. It turned out that these genotypes were characterized by maximum values in the accumulation of green mass and chlorophyll among the forms exhibiting higher plastic indices during vegetation. According to another characteristic of the crop structure “plant height,” introgressive forms varied in the range (106.9-131.3 cm).The genotype (Bezostaya 1 x T.militinae) x T. militinae-4 was distinguished in 2016, productive “bushiness” was at the level of 2015 and varied within the range of 3.6-5.1 pcs.

Studies by various authors with the participation of Professor Hisashi Tsujimoto have experimentally proved that the Chinese Spring wheat lines with the addition of chromosomes of alien genetic material possessed rich genetic resources to increase resistance to high temperatures and improve productivity (Caiyun Liu, 2015; Sohail Q., 2011).

Data on productivity of introgressive forms of winter wheat in reproductions of years 2015-2017 were presented in Table 4.

The studied forms exceeded the average yield of Almaly sort-standard by an average of 10 -15 cwt/ha, which indicated the genetic diversity of the introgressive material, its high yield potential. Steklovidnaya 24 x Ae.cylindrica, Zhetysu x T. militinae и Erythrospermum 350 x T.kiharae (62, 2 – 66, 6 cwt/ha respectively) were characterized by the highest amount. The obtained results were confirmed through the studies of other authors, who proved experimentally the expediency of transffering foreign genetic material for increasing the productivity and overall yield of cereals in conditions of drought and other stresses, as well as improving the economically valuable qualities of wheat (Davayan P.O., 2003; Sohail Q., 2011; Francis C., 2013).

Table 4 – Yield of wheat introgressive forms, 2015-2017

Wheat introgressive forms	Yield, cwt/ha
Almaly (standart)	41,3 ±0,9
(Bezostaya1 x Ae.triaristata) x Karlygash	53,3± 0,8
Erythrospermum 350 x T. militinae	57,5±0,9
Bezostaya1 x Ae. cylindrica	59,5±0,9
(Bezostaya1 x T.militinae) x T. militinae-6	51,1±0,5
(Bezostaya1 x T.militinae) x T. militinae-9	53,3±0,4
(Bezostaya1 x T.militinae) x T. militinae-4	51,1±0,7
Steklovidnaya 24 x T.timopheevii	57,7±0,8
Zhetysu x T.timopheevii	51,1±0,7
Steklovidnaya 24 x Ae. cylindrica	65,2±0,8
Erythrospermum350 x T.kihara	66,6±0,9
Zhetysu x T. militinae	64,6±0,9

5. *Final clusterization of wheat genotypes*

Clustering based on similarity-differences in wild, cultural and wheat introgressive forms for drought tolerance in field and laboratory tests combination with productivity and yield indicators revealed two clusters with uneven distribution of genotypes (Figure 2). There is a clear tendency to unite into the larger cluster the introgressive and wild, and the second cluster mainly represented by varietal diversity. The dendrogram confirms the results obtained by us that the introgressive forms gravitate according to their adaptive properties to wild relatives, and outweigh the parental varieties and the standard variety by economic-valuable traits.

Conclusion

The use of the following indicators for increasing wheat adaptation in arid conditions was theoretically substantiated and practically proved: the accumulation of biomass, the change in the chlorophyll content and the accumulation of free proline in seedlings, the analysis of the structure of the yield and productivity. Expansion of the norm of the reaction of genotypes during adaptation to drought was achieved by the involvement of germplasm of wild relatives in breeding process, the creation and testing of wheat introgressive forms.

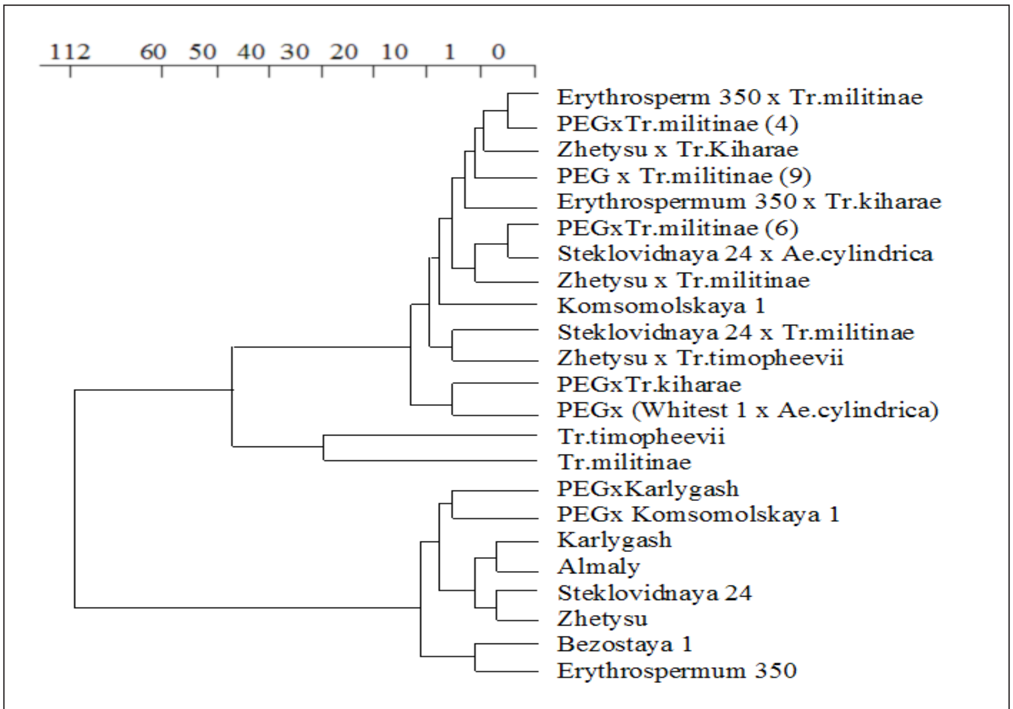

Figure 2 – Dendrogram of similarity-differences of wild, cultural and wheat introgressive forms on the complex of adaptive properties, productivity and total yield

Screening of the results obtained by the NDVI method on the accumulation of biomass, the chlorophyll and free proline content and productivity of wild, cultural and introgressive forms of wheat in the yield of 2015-2017 allowed to:

– reveal wide variability of the studied indicators;

– detect a change in the standardized index of vegetation differences, determined by the accumulation of biomass and phenological development phases of the studied wheat forms;

– differentiate wild, cultivars and wheat introgressive forms by accumulation of vegetative biomass as well as the chlorophyll and free proline content, identify promising samples;

– compare the introgressive forms and wheat varieties by total yield and productivity, identify promising patterns by individual indicators and overall productivity;

– characterize the drought tolerance of the introgressive forms and wheat varieties using productivity indicators such as "1000 grains" (main), "grain mass in the main ear" and others;

– identify promising genotypes combining drought tolerance, determined by the accumulation of vegetative biomass, the chlorophyll and free proline content, with indicators of productivity and yield;

– consider an integrated approach to determine the drought tolerance of wheat introgressive forms, using indicators such as accumulation of vegetative biomass using NDVI technology, chlorophyll content, "1000 grains mass" and other components of productivity.

It was established that resistance to drought declines in the series:

Wild relatives > Wheat introgressive forms > Cultivars.

Outstanding genotypes within each of the groups were distinguished, which are higher in resistance to a certain or group of abiotic factors, mean values.

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