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DROUGHT EFFECTS ON PHYSIOLOGICAL PARAMETERS OF DURUM AND BREAD WHEAT

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SUMMARY

The present research discusses the dynamics of changes in the surface of assimilation organs of different durum and bread wheat genotypes differing in the maturation period due to drought conditions. Under drought conditions, the soil water potential decreases, and in the later stages of the plants, the turgor pressure decreases, the stomata close, and a sharp decrease in photosynthetic activities. The situation creates stress in the crop plant, and various biochemical, physiological, and molecular reactions arise to overcome and protect itself from stress, allowing the plant to develop resistant mechanisms to adapt to the external environment. The existent research aimed to determine drought effects on assimilating surface areas and productivity traits of durum and bread wheat genotypes differing in their maturation periods grown under various climatic and soil conditions, with the comparison of the physiological indices. The experiments proceeded on wheat genotypes with contrasting maturation periods (early, medium, and late) during 2021–2022 at the Research Institute of Crop Husbandry, Absheron, Azerbaijan. The assimilating surface area of various organs underwent comparative studies in two durum (Garagylchyg-2 and Alinja-84) and two bread wheat (Nurlu-99 and Gobustan) cultivars under normal water supply and drought conditions. Post anthesis water stress caused a 34% and 27% reduction in grain yield and 1000-grain weight, respectively, while no significant effect on the grains per spike and spikes per m^2. The averages of grain yield and 1000-grain weight of different wheat cultivars in the controlled condition showed 696±36 g/m^2 and 43.1±0.8 g/m^2, respectively, while under water-stress conditions, these values significantly decreased to 452±57 g/m^2 and 31.6±1.4 g. The significant reduction in grain yield due to post-anthesis water stress might be due to a reduction in photo-assimilates production.

Keywords: wheat genotypes, the drought factor, duration of ripening, assimilation area

Key findings: Resistant cultivars' determination resulted from the effect of drought on productivity indicators against the background of changes in the main physiological characteristics of durum and bread wheat genotypes that differ in terms of maturity.

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INTRODUCTION

Recent global climatic changes have caused destructions in the ecological balance, and the development of stress factors, such as, drought and salinity, lead to serious issues in satisfying the population's demands for food. Verified facts state that biotic (pathogen and competition with other organisms) and abiotic (drought, salinity, radiation, and high and low

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temperatures) stresses cause drastic changes in the physiological activities of crop plants, attenuate biosynthesis in cells, disturb normal vital functions, and eventually destroy the crop plants (Fischer and Maurer, 1978; Abdoli and Saeidi, 2013; Tamrazov and Khudayev, 2020). In this regard, one of the main issues researchers face consists of the creation of new, highly productive, and stress-tolerant cultivars using plant genotypes grown under unfavorable climatic conditions, tolerant to various stresses, including drought and salt-tolerant plant genotypes (Blum and Jordan, 1985; Aliyev, 2000; Ahmadizadeh *et al.,* 2011).

Enhancing plant tolerance to stress factors requires more physiological studies to reveal tolerance mechanisms and determine physiological and genetic changes occurring in plants under stress (Moral *et al.,* 2002). Physiological investigations can facilitate the establishment of stress tolerance-associated genes in wheat genotypes. Notably, the establishment of genes tolerant to stress factors, as well as, their use in the hybridization process as donors, indicates one of the most important issues facing modern plant breeding (Abdoli and Saeidi, 2013; Ahmadizadeh *et al.,* 2011).

In crop plants, the role of assimilating organs (leaf, stem, and spike) is crucial in the proceeding of photosynthesis and the formation of the product. Therefore, measuring assimilating surface area during vegetation and analyzing the obtained data occurred. Stress resistance links with the reconstruction of the genetic systems of plant cells and, as a consequence, with changes in some physiological and biochemical processes (Aliyev, 2000; Gürel and Avcıoğlu, 2001). Therefore, the collection of fertile plant resources of Azerbaijan, especially crops and their wild forms, and their morphological, genetic, physiological, and other studies, prove of great scientific and practical importance. As a result of such research, it is possible to identify valuable gene sources from which it is possible to obtain resistant and high-yielding forms of plants, using them as donors in various genetic combinations (Kuzmin, 1986; Tamrazov *et al.,* 2016; Almeselmani *et al.,* 2011).

From a biological point of view, stress is any change in the external environment that impairs or adversely affects the normal development of a plant. Plants growing naturally and in the field are always under stress (Fischer and Maurer, 1978; Gholamin and Khayatnezhad, 2010). However, some environmental factors (sudden changes in the weather) cause stress for a few minutes, but for others, it can last longer. Even some factors, such as minerals, can cause stress months and years later. Plants can compete in a limited range with one or more adverse conditions. This situation creates stress in the plant body, and various biochemical and physiological mechanisms begin to overcome the stress and protect the plant life. Therefore, the study of ways to increase plant resistance to various stress factors is of great scientific and practical importance (Kuzmin, 1986; Tamrazov, 2016; Tamrazov and Khudayev, 2020).

The state of the chlorophyll-protein complex of plastids and the number of pigments determine the drought resistance in plants. Scientific research uses experiments and observations to develop theoretical foundations, as well as, practical ways to increase yields and improve the quality of crops (Abdoli and Saeidi, 2013; Tamrazov *et al.,* 2016; Tamrazov and Khudayev, 2020). The main task of the field experiment is to determine the difference between the variants of the experiment, quantify the influence of vital factors, and study the influence of growing conditions and methods of growing plants on their production and quality. Based on researchers' past experiments on different cultivars of wheat in the field, observation showed that dry conditions did not significantly affect productivity elements - spike length, spikelets, and the number of grains, but significantly affected the grain size, grain weight, and eventually grain yield (Tamrazov, 2016; Tamrazov and Khudayev, 2020).

Many factors affect the productivity of crop plants studied in practice, as well as, the crop products' quality (Abdoli and Saeidi, 2013; Aliyev, 2000). Along with agrotechnical measures, the weather conditions, the phases of plant development and even the biological characteristics (resistance to lodging, disease, frost, salinity, and drought) of the variety itself influence the yield of a crop variety. Therefore, all these factors must be taken into account and carefully studied in the field breeding experiments. Owing to the study of indicators and signs of photosynthetic activity, morpho-physiological and agronomic features, real and potential capabilities of wheat genotypes together with environmental factors, the principles determining the high productivity of the ideal wheat type have been developed (Abdoli and Saeidi, 2013).

The concept of an "ideal" wheat type resulted from the stability of leaf parameters, which along with the optimal height of the trunk and the vertical orientation of the leaves, provides a favorable placement of leaves in space and creates an excellent architecture for planting. Thus, an ensured efficient use of solar energy, and the formation of vegetative and economic organs, even during rich nitrogen nutrition and abundant irrigation, occurs. The possibility of inheriting these useful traits becomes the scientific basis of the author's selection work (Kuzmin, 1986; Gholamin and Khayatnezhad*,* 2010; Abdoli and Saeidi, 2013). The main aim of the latest research work sought to determine drought effects on assimilating surface areas and productivity elements of durum and bread wheat genotypes differing in their maturation periods, grown under various environmental and soil conditions.

MATERIALS AND METHODS

The experiments proceeded during 2021–2022 at the Research Institute of Crop Husbandry, Absheron, Azerbaijan. Five durum wheat genotypes (Garagylchyg-2, Alinja-84, Vugar, Barakatli-95, and Tartar), and seven bread wheat genotypes (Gobustan, Nurlu-99, Giymatli-2/17, Gyrmyzygul-1, Azamatli-95, Guneshli, and Tale-38), underwent the study. Each genotype sown in both irrigated and rainfed conditions comprised three replications. Irrigated plots gained watering at stem elongation, flowering, and grain-filling stages. The fertilization consisted of 120:60:60 kg NPK ha^{-1}. The 30% nitrogen application began at planting time and the rest at the beginning of stem elongation.

The research material used different genotypes of durum and bread wheat with different ripening periods. Since the studied cultivars have different ripening dates, they got divided into three groups, i.e., early-ripening, mid-ripening, and late-ripening cultivars. Genotypes tolerant to soil and water deficiency and able to provide high production were considered to be drought tolerant. The cultivars received regular phenological observations.

Data recorded and statistical analysis

An automatic device, AAS-400 (Aliyev, 2000; Abdoli and Saeidi, 2013), measured the assimilating surface area. Using the device, 10 plant samples of each genotype achieved measurements at different growth phases. In laboratory conditions, the plants underwent cutting into separate parts (leaf, stem, and spike). These plant parts were placed in the apparatus, with their assimilation area reflecting on the device screen.

It is important to conduct statistical analysis to determine the dependence between various parameters studied during the said research. The data recorded for the various parameters showed mean values (n = 10), standard error (Sx), and correlation (r) analysis. Statistical analysis employed the Excel and Statistica (v.7.0) software packages.

RESULTS AND DISCUSSION

Measurements proceeded with four samples of each group. However, the existing manuscript only presents data on two durum and two bread wheat genotypes. Maturing duration is known to be the most important factor in plant growth. With the differences in climatic and soil conditions in the regions of the country, such factor requires study. In this point of view, early and late-maturing cultivars need more preference. In general, early maturing wheat genotypes suit more with the characteristic of regions where spring-summer drought onsets early. Then again, the main part of the genotypes exhibit medium maturing, requiring consideration in wheat cultivation in most regions (Tamrazov, 2016; Tamrazov and Khudayev, 2020).

The assimilating surface area of various organs took comparative studies in two durum (Garagylchyg-2 and Alinja-84) and two bread wheat (Nurlu-99 and Gobustan) cultivars under normal water supply and drought conditions (Table 1). The assimilating surface area measurement in leaves of durum cultivar Garagylchyg-2 took place on the third day of March. The maximum value, obtained in the middle of the vegetation, began to decline until the end of vegetation, attributed to the increase in the surface of other assimilating organs—stem and spike as a result of leaf senescence. In the leaves, observing the maximum values usually occurred during the earing-flowering phase. In the durum cultivar Garagylchyg-2 leaf, the assimilating surface area showed at 66,800 and 51,800 m^2/ha in optimum irrigated and drought conditions, respectively, however, the variants differed by 22.4% (Tamrazov and Khudayev, 2020).

The maximum values for assimilating surface area revealed in the leaves of the bread wheat cultivar Gobustan during the earing-flowering phase on the first day of May (Aliyev, 2000; Blum and Jordan, 1985;

Table 1. Dynamics of the assimilating surface area of the early-maturing wheat genotypes (thousand m^2/ha).

Genotype	Variant	Organs	March	April			May			June
			III	I	II	III	I	II	III	I
Garagylchyg-2	Irrigated	Leaf	40.5	52.6	63.2	66.2	60.1	57.3	44.3	40.3
		Stems	29.8	32.3	41.8	53.8	57.5	68.5	60.2	55.4
		Spike	-	-	-	-	20.3	29.5	29.0	28.5
	Drought	Leaf	38.2	42.8	46.4	50.2	48.2	41.2	33.5	22.4
		Stems	25.4	30.7	40.7	49.8	52.8	55.8	50.6	40.8
		Spike	-	-	-	-	16.5	19.3	19.5	18.7
Alinja-84	Irrigated	Leaf	38.5	46.4	62.6	62.0	54.5	48.3	39.4	33.2
		Stems	27.6	35.3	58.6	63.2	68.3	59.2	50.3	48.3
		Spike	-	-	-	-	18.3	26.3	25.9	25.0
	Drought	Leaf	36.7	40.6	45.7	48.2	46.1	40.3	30.2	20.1
		Stems	21.8	28.4	43.4	47.5	53.8	57.2	54.2	44.3
		Spike	-	-	-	-	16.4	18.7	19.5	17.6
Nurlu-99	Irrigated	Leaf	40.1	49.2	55.3	60.2	63.4	60.1	53.2	40.1
		Stems	28.4	33.4	40.1	53.1	55.2	65.2	63.1	52.1
		Spike	-	-	-	-	19.1	26.2	28.1	27.3
	Drought	Leaf	36.3	40.1	45.3	49.2	47.1	40.3	31.2	21.4
		Stems	23.4	29.2	38.5	46.3	53.7	50.2	46.3	37.3
		Spike					17.6	21.2	25.4	23.0
Gobustan	Irrigated	Leaf	35.5	41.2	60.2	62.1	60.2	56.2	41.2	38.3
		Stems	24.8	32.6	56.3	63.7	68.4	63.5	60.1	56.2
		Spike	-	-	-	-	19.6	28.7	28.0	27.5
	Drought	Leaf	30.6	39.4	48.2	58.3	59.0	55.4	40.8	36.2
		Stems	21.2	30.1	45.1	58.0	63.2	61.2	59.1	53.2
		Spike	-	-	-	-	16.2	20.3	22.4	20.5

Figure 1. Plantation area of early-maturing wheat genotypes.

Ahmadizadeh *et al.,* 2011). Thus, in the well-watered and drought-exposed genotypes, the noted values displayed 64,200 and 61,200 m^2/ha, respectively, with a 4.6% difference between variants. In the durum cultivar Garagylchyg-2, the assimilating surface area of the stem reached maximum values on the second day of May, and in well-watered and drought-exposed genotypes, the values indicated 66,800 and 56,700 m^2/ha, respectively, with 15.1% difference between the variants (Tamrazov and Khudayev, 2020).

A similar situation took notice in the bread wheat genotype Gobustan. The stem assimilation surface area reached maximum values on the first and second days of May, and in well-irrigated and drought-exposed genotypes, the values displayed 69,700 and 61,200 m^2/ha, respectively, with a 12% difference between the variants. Dynamics of the increase in the spike surface of the durum cultivar Garagylchyg-2 showed as follows, i.e., during the maturation phase at the end of May and at the beginning of June, 31,200 and 20,900 m^2/ha, in the watered and drought-exposed plants, respectively, with a 33% difference between the variants. Such a sharp variation correlates to the intensification of drought at the end of vegetation (Table 1, Figure 1).

In bread wheat cultivar Gobustan, the values for the said index exhibited at 28,600 and 23,400 m^2/ha under well-irrigated and drought-exposed variants, respectively, and the difference between the variants was 18%. The dynamics of the changes in productivity indices were determined in two genotypes of each group (durum and bread genotypes). However, one genotype of each group was analyzed.

The indicators of mid-season wheat cultivars (Vugar, Giymatli-2/17, Azamatli-95, and Guneshli) grown in both variants at different vegetation phases appear in Table 2. Thus, the cultivar Vugar, like durum wheat, has a leaf surface area at 66,300 and 46,400 m^2/ha, in the stem at 70,200 and 56,100 m^2/ha, and in the spike at 27,400 and 19,800 m^2/ha. In bread wheat variety Giymatli-2/17, the said values show in m^2/ha: for leaf area at 63,500 and 57,000, stem at 81,200 and 70,300, and ear at 40,300 and 33,700. In the other bread wheat cultivar Azamatli-95, the area of the assimilation surface of the leaves was 64,200 and 63,700), in stems at 75, 400 and 71,300, and the spike at 28,500 and 25,600 m^2 ha^{-1}. In the cultivar Guneshli, the values show as follows in m^2/ha: leaves - 61,800 and 56,800; stem -70,300 and 63,300; and spike - 28,600 and 23,400. According to the difference between the variants in the cultivar Vugar for leaves (30%), for the stem (19.6%), and the spike (27.7%), while in bread wheat cultivar Azamatli-95, the said values were 5.5% for the leaf, 5.4% for the stem, and 10.1% for spike (Table 2, Figure 2) (Abdoli and Saeidi, 2013; Tamrazov *et al.,* 2016).

The dynamics of changes in the area of the assimilation surface of late-ripening wheat genotypes display in Table 3. This group includes two cultivars of durum wheat (Barakatli-95 and Tartar) and two cultivars of bread wheat (Gyrmyzy gul-1 and Tale-38). According to the data, the maximum value of the assimilation area of the leaf surface was recorded in the cultivar Barakatli-95 during the third day of April, at 63,500 and 41,200 m^2/ha, in stems on the second and third day of May (70,200 and 56,300 m^2/ha), and in the spike on the third day of May (30, 700 and 22,600 m^2/ha). In another durum wheat variety Tartar, the maximum leaf yield came out on the third day of April and the first day of May (65,400 m^2/ha), in contrast with the fertile variety-95 at 48,400 m^2/ha, with a stem of 71,800 m^2/ha on the second day of May; 59,300 m^2/ha, and in the spike on the second and third days of May, 32,600 and 31,300 m^2/ha, respectively.

Bread wheat cultivar Gyrmyzy gul-1, similar with other cultivars, revealed on the third day of April and the first day of May for the leaf (58,700 and 46,200 m^2/ha); the maximum value in the stem was 66,800 m^2/ha on the third day of April and the first day of May (50,300 m^2/ha), and on the second day of May for spike (18,400 and 15,700 m^2/ha). In other cultivars of bread wheat, Tale-38 showed the maximum leaf area on the third day of April and the first day of May (64,500 and 60,500 m^2/ha), in the stem on the second day of May (82,100 and 70,400 m^2/ha), and on the second and third days of May for spike (38,700 and 37,400 m^2/ha). Based from the data, the maximum values displayed in the cultivars Tartar and Tale-38 (Table 3 and Figure 3).

The leaves revealed a maximum value mainly in the period before trumpeting and in the stem and spike during the period from maturation to ripening (Tamrazov and Khudayev, 2020). Considering the difference between the variants, notably, the cultivar Tartar variants showed 25.7% in the leaves, 17.4% in the stem, and 2.5% in the spike, whereas for bread wheat cultivar Tale-38, it was 6.2% in leaves, 14.3% in stems, and 3.4% in spikes. Summarizing the differences

Table 2. Dynamics of the assimilating surface area of the middle-maturing wheat genotypes (thousand m^2/ha).

Genotype	Variant	Organs	March	April			May			June
			III	I	II	III	I	II	III	I
Vugar	Irrigated	Leaf	40.3	54.2	63.3	66.3	59.1	55.3	41.4	37.8
		Stems	29.4	34.8	48.2	53.7	58.5	70.2	62.4	52.8
		Spike	-	-	-	-	20.3	27.4	26.2	25.8
	Drought	Leaf	39.8	42.7	48.5	46.4	42.7	39.6	28.3	20.2
		Stems	28.3	32.4	40.7	51.2	55.3	56.1	51.2	40.7
		Spike					18.2	19.8	19.7	19.5
Giymatli-2/17	Irrigated	Leaf	47.5	61.2	64.3	63.5	59.5	56.2	47.8	44.3
		Stems	34.8	37.7	57.4	53.7	69.7	81.2	77.8	73.2
		Spike	-	-	-	-	25.5	32.7	38.3	35.2
	Drought	Leaf	37.6	48.2	57.3	54.2	53.2	38.5	32.3	28.2
		Stems	30.3	38.2	61.3	65.2	68.3	70.3	64.2	53.7
		Spike	-	-	-	-	26.4	39.7	38.2	33.4
Azametli-95	Irrigated	Leaf	38.2	48.3	55.7	64.2	59.3	52.8	40.7	36.3
		Stems	28.6	37.3	49.8	59.7	70.3	75.4	62.3	50.7
		Spike	-	-	-	-	21.2	28.4	28.5	26.3
	Drought	Leaf	39.7	45.4	56.8	63.7	56.2	50.8	39.7	33.2
		Stems	28.5	38.2	50.8	60.2	71.3	64.7	59.3	49.7
		Spike	-	-	-	-	20.3	24.7	25.6	22.4
Guneshli	Irrigated	Leaf	36.2	43.4	50.8	60.7	61.8	55.4	43.8	35.7
		Stems	34.2	38.3	48.2	58.5	69.7	70.3	68.6	50.1
		Spike	-	-	-	-	20.3	27.5	28.6	27.4
	Drought	Leaf	34.3	42.8	51.7	63.4	60.8	50.2	41.7	34.2
		Stems	31.2	40.3	45.4	56.7	63.8	69.2	60.1	48.2
		Spike	-	-	-	-	18.6	26.5	27.4	26.2

Figure 2. Plantation area of middle-maturing wheat genotypes.

Table 3. Dynamics of the assimilating surface area of the early- and late-maturing wheat genotypes (thousand m^2/ha).

Genotype	Variant	Organs	March	April			May			June
			III	I	II	III	I	II	III	I
Barakatli-95	Irrigated	Leaf	41.6	50.5	56.7	63.5	58.2	50.9	38.7	35.2
		Stems	34.2	38.3	54.6	56.2	63.5	70.2	60.1	47.3
		Spike	-	-	-	-	19.5	31.2	30.7	28.6
	Drought	Leaf	32.6	37.3	38.3	41.2	39.4	33.6	21.2	17.6
		Stems	31.3	33.8	40.2	46.7	48.3	56.3	43.2	30.4
		Spike	-	-	-	-	20.1	21.4	22.6	19.8
Tartar	Irrigated	Leaf	42.4	51.8	58.2	65.4	59.7	52.6	43.5	37.6
		Stems	35.3	41.2	48.4	56.2	62.5	71.8	64.2	48.3
		Spike	-	-	-	-	20.8	32.6	31.4	30.3
	Drought	Leaf	34.2	38.6	43.5	48.4	38.6	35.7	28.4	24.2
		Stems	32.6	35.4	41.7	53.8	56.7	59.3	50.1	42.2
		Spike	-	-	-	-	18.9	27.6	31.3	26.3
Gyrmyzygul-1	Irrigated	Leaf	36.3	42.4	52.5	58.7	54.7	48.2	32.6	28.4
		Stems	31.8	39.2	63.3	66.8	52.7	44.3	40.2	32.6
		Spike	-	-	-	-	15.2	18.4	17.6	16.2
	Drought	Leaf	30.3	35.2	37.8	38.1	46.2	40.8	30.4	25.2
		Stems	24.7	36.5	43.7	46.8	50.3	45.7	35.4	24.2
		Spike	-	-	-	-	13.6	15.7	14.8	13.4
Tale-38	Irrigated	Leaf	46.7	58.2	60.3	64.5	57.2	46.1	33.2	27.4
		Stems	36.2	38.4	53.8	57.5	66.4	82.1	75.3	73.2
		Spike	-	-	-	-	25.8	33.3	38.7	36.2
	Drought	Leaf	38.2	44.3	55.8	54.7	60.5	42.6	33.2	21.4
		Stems	31.3	37.4	52.6	61.7	70.4	68.2	46.4	41.0
		Spike	-	-	-	-	33.2	39.4	36.7	32.1

Figure 3. Plantation area of late-maturing wheat genotypes.

between the options for each group, the most resistant variety in terms of drought resistance in group I pointed to the durum wheat cultivar Garagylchyk-2, and in bread wheat the cultivar Gobustan, while in group II the durum wheat cultivar Vugar and bread wheat cultivar Azamatli-95. For group III, the durum wheat cultivar Barakatli-95 and in bread wheat the cultivar Gyrmyzy gul-1 was observed (Tamrazov *et al.,* 2016).

The results obtained from the mean comparison analysis of yield and its components appear in Table 4. Post-anthesis water stress leads to a 34% and 27% reduction in yield and 1000-grain weight on average, respectively. It had no significant effect on the grains per spike and spikes per m^2. The averages of yield and 1000-grain weight of different cultivars in the controlled condition were 696±36 g/m^2 and 43.1±0.8 g/m^2, respectively. Under water stress, these values significantly decreased to 452±57 g/m^2 and 31.6±1.4 g. The significant reduction in yield due to post-anthesis water stress might be due to a reduction in the photo-assimilates production, the sink power to absorb photo-assimilates, and the grain-filling duration (Abdoli and Saeidi, 2013; Tamrazov *et al.,* 2016). Therefore, the grain weight and yield reduction under post-anthesis water deficiency may reflect more from the lack of photo-assimilates supply for grain filling (Table 4, Figure 4).

Table 4. Mean comparisons of grain yield and its components, and some morphological traits of wheat cultivars under post-anthesis water stress.

Cultivars	Yield (g m^2)		R^c	Biomass (g m^2)		Harvest index (%)	
	Irrigated	Drought	%	Irrigated	Drought	Irrigated	Drought
Early mature wheat genotypes							
Garagilchyg-2	750±28	472±35	-37.01	1614±92	1255±82	46.5±1.0	37.6±1.5
Alinja-84	672±39	440±75	-34.5	1620±98	1186±75	41.5±0.4	37.1±2.8
Nurlu-99	725±43	497±52	-31.4	1590±82	1144±83	45.6±1.8	43.4±1.2
Gobustan	728±33	446±63	-38.7	1485±80	1056±100	49.0±0.9	42.2±1.7
Middle mature wheat genotypes							
Vugar	500±35	385±35	-11	1360±90	1152±112	36.8±1.2	33.4±1.8
Giymatli-2/17	725±37	448±50	-38.2	1670±100	1124±92	43.4±2.2	39.9±1.9
Azametli-95	780±45	497±70	-36.3	1655±102	1189±98	47.1±2.8	41.8±1.2
Guneshli	670±25	415±25	38.05	1419±85	1082±100	47.2±2.6	38.4±1.0
Late mature wheat genotypes							
Barakatli-95	750±62	515±74	-31.3	1685±95	1285±88	44.5±2.1	40.1±1.2
Tartar	685±40	470±68	-35.8	1785±105	1198±100	38.4±1.0	39.2±1.2
Gırmızıgul-1	700±18	400±70	-42.9	1452±38	1085±89	48.2±1.7	36.9±1.1
Tale-38	675±26	415±65	-38.5	1560±47	1145±92	43.2±1.2	36.2±1.0
Means	696±36	452±57	-	1574±84.5	1158.4±92.6	44.3±1.6	38.9±1.5
Decrease(%)	-33.9		-	-26.4		-12.2	

Figure 4. Formation period of the crop of studied wheat genotypes.

Table 5. Correlation between yield parameters and assimilatory surface area of leaves.

Parameters	Assimilative surface area of leaves	Spike weight	Weight of grain per spike	Grain yield
Assimilative surface area of leaves	-	0.58	0.57**	0.72**
Spike weight		-	0.55**	0.41*
Weight of grain per spike			-	0.68**

Harvest index can be expressed as the ability of plants to allocate photosynthetic assimilates to produce economic yield. A significant variation was noted among the cultivars for the said trait under well-watered and post-anthesis water stress conditions. Post-anthesis water stress significantly decreased the harvest index in most wheat cultivars (Abdoli and Saeidi, 2013; Blum and Jordan, 1985; Tamrazov *et al.,* 2016).

Thus, a correlation between the main productivity indicators has been established (Table 5). Correlation analysis showed no significant difference between the samples for physiological and productivity indicators. Past studies also revealed that superiority of these two mentioned signs is due to compensatory effects on each other (Ahmadizadeh *et al*., 2011). According to the existing results, wheat varieties with high biological productivity and yield index should have high grain productivity under water stress and control conditions. Thus, the possibility to emphasize the maturity period of genotypes, the disease infection factor, and the drought factor play an important role in the comparison of changes of the spike elements. Factually also, the delay in the ripening period during the vegetation contributes to the formation of the grains.

CONCLUSIONS

Drought affects various physiological parameters of wheat and reduces the assimilation surface area. Thus, the decrease in leaf area during drought proves one of the main reasons for the increase in yield. The research based on various physiological parameters helped identify several wheat genotypes with corresponding morpho-physiological characteristics. The use of the studied cultivars, in combination with the studied photosynthetic properties concerning the area of the assimilation surface of leaves and the biological productivity of plants, made it possible to create new promising cultivars. An extension of these studies has shown that chloroplasts of high-yielding genotypes get characterized by high rates of electron transport and phosphorylation.

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