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EVALUATION OF SOME PHYSIOLOGICAL PARAMETERS IN BREAD WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract

In this study, wheat genotypes with different characters were tested in different environments (arid, irrigated, waterlogging and KI application) and the responses of the genotypes to these conditions in terms of different parameters were determined. Altay 2000, Nacibey, Müfitbey, Gerek 79, Bezostaja-1 genotypes were used in the experiment. In the experiment, plant height, leaf area index, chlorophyll a, chlorophyll b, grain weight/spike, yield, grain yield, SOD, POD and proline measurements were made. Yield and yield components in wheat are largely under the influence of the environmental conditions. Bezostaja-1 and Altay 2000 genotypes were determined as stable and high performance cultivars best adapted to changing environmental conditions. While the most effective yield factors on grain yield were determined as plant height, chlorophyll a and b, grain weight/spike and LAI, SOD POD and proline were determined to be effective parameters in showing the effect of drought. It has been determined that KI application is a very effective method in identifying drought-resistant plants in irrigated conditions and gives very good results in imitating drought. In addition, drought and waterlogging are important inhibitory stress environments in plant growth. Besides, heritability of LAI, grain weight, chlorophyll a, chlorophyll b plant height, grain yield, SOD, POD and proline were found to be so low and under effect of environmental conditions.

Key words: Wheat, Drought, Potassium iodide, Irrigation, Waterlogging, Yield components, Broad sense heritability.

Introduction

The world populatıon is increasıng rapidly more and more, however the food resources to feed population are tremendously decreasing equally. It is estimated that the rapidly growing world population will experience famine related to major food insufficiency in the future. With the gradual decrease of the food resources in the world and inability to share the produced food equally will cause famine in the world (Thornton & Cramer, 2012). On the other hand, the decrease in water resources due to global warming and the rapid increase in drought naturally affect food production deeply. Therefore, it is becoming increasingly important to develop wheat genotypes, high yielding and quality, resistant to biotic/abiotic stress to serve adequate food for the increasing world population in the future.

Wheat in cereals is one of the most grown plants in the world, since it is a basic food source and simple to grow and store. Although this is the case, increasing biotic and abiotic stresses negatively affect wheat production and lead researchers to search for the development and production of high-yielding and high-quality genotypes that are more resistant to biotic and abiotic stresses.

A preferred registered genotype means a genotype with high yield, quality, resistance to biotic and abiotic stresses and high stability for yield components over the years and in different locations (Guzman *et. al*., 2016). Therefore, sufficient nutrition of population in the future is going to only be possible by developing wheat genotypes of plants resistant to biotic and abiotic stresses (Akcura & Kaya, 2008). The most important abiotic factors are drought and waterlogging, heat stress, and these issues are the main research topics of breeding programs carried out in recent years (Akcura & Kaya, 2008; Setter & Waters, 2003). Drought resistance is a topic that has been studied and conducted for a long time in breeding studies, and many studies have been carried out on this subject (Mohammadi & Abdulahi, 2017). In addition to the changes in the morphological and physiological characteristics of the plant in arid conditions, the biochemical changes in the plant were determined and how the plants responded to drought and their mechanisms were successfully revealed. It has been determined that the plant is very sensitive to drought, especially in the first development period and flowering period, and it needs water during these periods (Van Ginkel *et al*., 1998).

Similar to drought, the effect of waterlogging is increasing day by day and its damage is increasing significantly compared to the past. Therefore, it is necessary to develop novel genotypes, resistant to waterlogging conditions (Setter & Waters, 2003). Significant changes and decreases occur in metabolic activities when wheat expose waterlogging conditions, especially in hypoxia (decreased oxygen) and anoxia (lack of oxygen), conditions wheat get damaged at different level. Particularly first emergence and flowering periods are known as sensitive periods for crop growth in wheat. In such periods photosynthetic activities retards and ceases by accumulation of iron, copper, magnesium, molybdenum accumulated in the roots. It has been shown that the increased amount of components has toxic effects on the plant development (Romina *et. al*., 2017). KI application is new phenomena in wheat breeding programs for imitating drought conditions. 0.5-1% KI application at the beginning of flowering period in irrigated conditions is suggested to sellect drought resistant genotypes and it is well accepted to be used (Olgun *et al.*, 2006).

The aim of the study was to determine the effect of different applications (arid conditions, irrigated conditions, waterlogging conditions and KI application) in plant growth and the responses of Bezostaja-1 and Altay 2000 genotypes to such conditions in terms of plant height, LAI, chlorophyll a, chlorophyll b, seed weight per spike, seed yield, SOD, POD and proline.

Materials and Methods

This study was carried out in Eskişehir Osmangazi University, Faculty of Arts and Sciences, Department of Biology, Eskişehir, Turkey (89º 45' 00" N 30º 29' 21" E, altitude: 823 m) in 2016-2017, 2017-2018. In this experiment, Altay 2000, Naci Bey, Müfit Bey, Gerek 79, Bezostaja-1 genotypes were used and characteristic of them are given below:

Bezostaja-1: Bread wheat, awnless, winter habit, red hard grain, plant height 95-105 cm, 1000 grain weight 38-44 g, test weight 80-84 kg/hl, protein content 12-15%, resistant to yellow and brown rusts.

Altay 2000: Bread wheat, awned, winter habit, white hard grain, plant height 105-115 cm, 1000 grain weight 36-40 g, test weight 80-82 kg/hl, protein content 11-13%, resistant to yellow and brown rusts.

Müfitbey: Bread wheat, awned, winter and moderate early habit, white hard grain, plant height 110-115 cm, 1000 grain weight 38-42 g, test weight 78-82 kg/hl, protein content 13-14%, moderate resistant to yellow and brown rusts.

Nacibey: Bread wheat, awned, winter habit, red semi hard grain, plant height 100-110 cm, 1000 grain weight 37-42 g, test weight 79-80 kg/hl, protein content 12-14%, resistant to brown rust, yellow and brown rusts.

Gerek 79: Bread wheat, awned, altrdnative and early habit, white soft grain, plant height 100-110 cm, 1000 grain weight 30-48 g, test weight 76-80 kg/hl, protein content 11-13%, susceptible to brown rust, yellow and brown rusts (T.C. Tarım Orman Bakanlığı, 2021).

The seeds of the cultivars used in the experiment were sown in PVC (width 0,75 m, length 1 m and height 0,75 m) bags (32,7% sand, 38,3% silt and 27,0% clay) containing 80 kg capacity loamy sandy soil. The physical chemical structure of the soil used in the bags is given in Table 1. Chemical characteristics of soil were pH 7,68-,74, lime $CaCO_3$ 4,12%-4,45%, salinity 0,063-0,07%, P_2O_5 0,398-0,407, total N (%) 0,064-0,082 and organic matter 1,77-1,59% in 2016-2017 and 2017-2018.

Considering the climate data of the years 2016-2017 and 2017-2018, the precipitation (336,4mm) in 2016-2017 was lower than that of second year (349,1mm), but higher than long-term (1970-2018) precipitation (316,3). The average temperature (10,78 °C) in the first year was higher than the second year (7,64 °C). While the temperature in the second year was lower than the long-term temperature (8,61 °C, Table 2).

In the study, planting was made in the second week of October at 475 seeds/m². Seeds were sown in PVC containers (1 m width, 1 m length, and 0,75 m height) containing 80 kg of loamy textured soil (29,6% sand, 33,2% silt and 37,2% clay). Soil also had 0,37% $CaCO_3$, 311,4 mmol/kg P_2O_5, 407,4 mmol/kg K_2O, and 2,06% organic matter, 7,44 pH, and 2,81 dS/m electrical conductivity. When the plants reach the stage with three or four leaves, the bags are taken to open conditions and winter is ensured, and the plants are allowed to grow in ambient conditions. PVC bags are covered with a net to protect them from bird damage. Six kg of N da-1 (1/2 seed at sowing and 1/2 rooting stage) and six kg da-1 P_2O_5 (with sowing) were applied (ammonium sulfate for nitrogen, 21%; and triple superphosphate for phosphorus, 46%). The experiment was laid out as split-split-plot design in randomized complete block design with three replicates. The climatic date in 2016-2017 and 2017-2018 and long term (1970-2018) were given in Table 2.

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Table 1. The physical chemical structure of the soil used.

Years	Soil structure	pH	Lime (%$CaCO_3$)	Saltiness (%)	P_2O_5 (t/ha)	K_2O (t/ha)	Total N (%)	Organic matter
2016-2017	Loamy-Clay	7,68	4,12	0,063	0,398	27,713	0,064	1,77
2017-2018		7,74	4,45	0,07	0,407	24,98	0,082	1,59

Table 2. The climatic data in 2016-2017 and 2017-2018 and long term period.

	Months	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Tot/Mean
2016-17	Precipitation (mm)	0,3	72,2	19,0	70,3	17,6	36,2	40,1	30,9	18,5	31,3	**336,4**
	Mean Temp. (°C)	19,1	14,5	7,8	3,0	2,3	5,0	7,1	10,8	18,2	20,0	**10,78**
2017-18	Precipitation (mm)	7,1	64,0	0,1	42,4	52,4	46	50,2	23,7	50,6	12,6	**349,1**
	Mean Temp. (°C)	18,3	9,1	1,5	1,7	-2,5	-4,3	2,6	12,8	15,5	21,7	**7,64**
1970-2018	Precipitation (mm)	17,9	32,8	34	40,5	30,6	26,1	27,6	43,1	40,0	23,7	**316,3**

In the study, planting was made in the second week of October at 475 seeds/m². Seeds were sown in PVC containers (1 m width, 1 m length, and 0,75 m height) containing 80 kg of loamy textured soil (29,6% sand, 33,2% silt and 37,2% clay). Soil also had 0,37% $CaCO_3$, 311,4 mmol/kg P_2O_5, 407,4 mmol/kg K_2O, and 2,06% organic matter, 7,44 pH, and 2,81 dS/m electrical conductivity. When the plants reach the stage with three or four leaves, the bags are taken to open conditions and winter is ensured, and the plants are allowed to grow in ambient conditions. PVC bags are covered with a net to protect them from bird damage. Six kg of N da-1 (1/2 seed at sowing and 1/2 rooting stage) and six kg da-1 P_2O_5 (with sowing) were applied (ammonium sulfate for nitrogen, 21%; and triple superphosphate for phosphorus, 46%). The experiment was laid out as split-split-plot design in randomized complete block design with three replicates.

Four treatments were applied in the experiment (1-Arid, 2- Irrigated, 3-KI, potassium iodide, 4-Waterlogging). No irrigation was applied to the arid application. In the irrigated application, three irrigation applications were made; at planting, tillering (Feekes 6.0) and flowering period (Feekes 10.51). In KI application (Olgun *et al.*, 2006), a drought effect was created by applying 0,1% KI at one third of awn emergence period (Feekes scale 10.54). In the waterlogging application, when the plants reached at the flowering period (Feekes 10.51), 10-day-waterlogging was applied.

In the experiment, plant height, LAI, chlorophyll a, chlorophyll b, grain weight per spike, grain yield, SOD, POD and proline measurements were made (Sairam *et al*., 2002) SOD and POD analyses were made; dehydrated plant specimens were pulverized by treatment with liquid nitrogen; extracted by cold 0.1 mM phosphate (pH 7,8) containing 1 mM EDTA (ethylenediaminetetraacetic acid), 1 mM PMSF (phenylmethanesulfonylfluoride), and 0.5% PVP (polyvinylpyrrolidone). Measurements were made by using spectrophotometer (Sairam *et al*., 2002). Proline was made; crushed with liquid nitrogen and extracted with a pestle in an ice-cold mortar with 4.5 mL of 3% 5-sulfosalicylic acid and homogenated. Plant samples were filtered with a filte paper (#2) and the filtrate was used for the analysis. Proline content was determined spectrophotometrically at 520 nm (Bates, 1973).

Leaf area index was calculated by AAM-5, Hayashi-Denko, Tokyo device after the cutting flag leaves at the flowering period (Feekes 10.51) (Koç & Barutçular, 2000). Statistical analyses were made by Minitab v 17 ve SPSS 21 software programs.

Results and Discussion

The effect of different applications on wheat genotypes for yield components and physiological characteristics was given in Table 3. As seen in the table, the difference between years was found to be significant at 5%/1% in all measurements except the leaf area index. Moreover, the differences between applications and genotypes were found to be significant at the level of 5%/1% for all components, examined. Year x application interaction in LAI; year x application x genetic interaction in chlorophyll a and proline was found to be insignificant. In addition, all other interactions were found to be significant at 5%/1% in all components (Table 3).

Table 3. Variance analysis table of yield components and physiological characteristics of wheat genotypes tested in four different environments.

	D.F.	Plant height		LAI		Chlo. a		Chlo. b		Seed We./Spike	
		Mean SS	F value	Mean SS	F value	Mean SS	F value	Mean SS	F value	Mean SS	F value
Year	1	1020,833	97,843**	3,475	9,132**ns**	448,688	143,921**	17,534	263,894**	2,312	462,400**
$Error_1$	2	10,433		0,381		3,118		0,066		0,005	
Applications	3	5974,511	366,784**	36,427	209,371**	2134,951	394,757**	62,644	460,145**	4,614	587,419**
Ye. x Appl.	3	260,767	16,009**	0,795	4,568	173,522	32,084**	5,156	37,871**	0,896	114,118**
$Error_2$	12	16,289		0,174		5,408		0,136		0,008	
Genotypes	4	79,908	4,650**	5,896	61,473**	212,402	33,806**	19,767	181,952**	0,324	46,780**
Ye. x Gen.	4	145,417	8,463**	1,033	10,768**	27,148	4,321**	1,954	17,983**	0,067	9,639**
Appl. x Gen.	12	57,969	3,374*	0,746	7,780**	17,894	2,848**	0,921	8,479**	0,107	15,474**
Ye. x Appl. x Gen.	12	41,544	2,418**	0,298	3,110**	11,338	1,773**ns**	0,701	6,450**	0,073	10,573**
$Error_3$	64	17,183		0,096		6,283		0,109		0,007	
Mean	119	194,937		1,383		76,975		2,825		10,573	
C.V. (%)		**16,510**		**31,394**		**34,366**		**33,760**		**28,078**	

	D.F.	Seed yield		SOD		POD		Proline	
		Mean SS	F value	Mean SS	F value	Mean SS	F value	Mean SS	F value
Year	1	8,597	689,958**	4942,014	23,389*	25346,540	34,363*	1125,144	175,617**
$Error_1$	2	0,012		211,295		737,611		6,407	
Applications	3	50,636	2950,725**	18463,831	220,910**	53025,921	335,126**	6011,889	165,499**
Ye.xAppl.	3	3,188	185,793**	827,297	9,898**	2512,446	15,879**	310,068	8,536**
$Error_2$	12	0,017		83,581		158,227		36,326	
Genotypes	4	14,431	606,309**	11041,203	191,897**	4293,430	10,116**	868,820	10,789**
Ye.x Gen.	4	0,765	32,129**	3273,052	56,886**	2862,977	6,746**	88,528	1,099**ns**
Appl.x Gen.	12	3,112	130,770**	2460,136	42,757**	3097,509	7,157**	454,748	5,647**
Ye.xAppl.x Gen.	12	0,220	9,225**	943,878	16,405**	1969,470	4,641**	122,379	1,520**ns**
$Error_3$	64	0,024		57,537		424,409		80,529	
Mean	119	2,292		1397,547		2616,467		306,883	
C.V. (%)		**48,034**		**25,279**		**19,044**		**12,914**	

Table 4. In terms of the data examined, the differences between years, applications and genotypes and their relations with each other.

	Plant height	LAI	Chlo. a	Chlo. b	Seed We./ Spike	Seed yield	SOD	POD	Proline
					Years				
1.yıl	81,650 **b**	3,570	23,596 **B**	4,596 **B**	1,431 **B**	2,899 **B**	154,302 **a**	239,117 **a**	138,713 **A**
2.yıl	87,483 **a**	3,576	27,463 **A**	5,361 **A**	1,709 **A**	3,435 **A**	141,467 **b**	254,050 **b**	132,589 **B**
L.S.D. (%)	2,537		3,99	0,467	0,002	0,088	11,919	21,335	4,587
					Applications				
Arid	86,633 **B**	3,862 **B**	26,439 **B**	5,163 **B**	1,760 **B**	3,100 **B**	142,080 **B**	299,367 **A**	135,031 **B**
Irrigated	103,200 **A**	5,223 **A**	36,458 **A**	6,817 **A**	1,990 **A**	4,984 **A**	126,690 **C**	212,967 **C**	122,733 **D**
KI	70,233 **D**	2,649 **D**	16,206 **D**	3,332 **D**	1,087 **D**	1,956 **D**	183,733 **A**	302,833 **A**	155,502 **A**
Waterlogging	78,200 **C**	3,250 **C**	23,015 **C**	4,602 **C**	1,443 **C**	2,627 **C**	139,033 **B**	259,167 **B**	129,337 **C**
L.S.D. (%)	3,183	0,329	1,834	0,291	0,070	0,103	7,209	9,919	4,753
					Genotypes				
Altay 2000	84,500 **AB**	3,982 **B**	26,853 **B**	5,599 **B**	1,608 **B**	3,748 **B**	137,133 **C**	280,633 **A**	134,651 **BC**
Nacibey	84,792 **A**	3,747 **B**	26,861 **B**	4,627 **C**	1,641 **AB**	3,472 **C**	136,119 **C**	259,740 **B**	133,580 **BC**
Müfitbey	86,042 **A**	3,092 **D**	21,785 **C**	4,082 **D**	1,415 **D**	2,474 **D**	146,115 **B**	267,593 **AB**	137,468 **B**
Gerek 79	81,542 **B**	3,501 **C**	23,136 **C**	4,347 **C**	1,487 **C**	2,211 **E**	185,406 **A**	283,128 **A**	144,507 **A**
Bezostaja-1	85,958 **A**	4,408 **A**	29,012 **A**	6,237 **A**	1,699 **A**	3,929 **A**	134,648 **C**	251,863 **B**	128,049 **C**
L.S.D. (%)	3,177	0,237	1,921	0,253	0,064	0,118	5,814	15,789	6,878

In terms of the data examined, the differences between years, applications, genotypes and their relations with each other are given in Table 4. The values obtained from the second year in plant height were higher than the first year. Again, in applications where differences in stress environments were evaluated, the highest value was obtained from irigated conditions (103,200 cm), while the lowest value was obtained from KI application (70,233 cm). On the basis of genotypes, the highest plant height was obtained from Nacibey (84,792 cm), Müfitbey (86.042 cm), Bezostaja-1 (85,958 cm) and Altay-2000 (84,500 cm), while the lowest plant height was obtained from Gerek 79 (81,542 cm). Plant height is a factor that can be highly affected by environmental conditions and is highly affected by genetic-environment interaction (Hristov *et al*., 2011).

Therefore, more precipitation in the second year caused taller plants to be obtained. Studies have shown that plant height is highly dependent on the amount of precipitation, so there are differences in plant height depending on the amount of precipitation (Tonk *et al*., 2011). Studies revealed that as the amount of water available to the plant in the soil increases, plant development and growth increase to a certain extent depending on the genetic capacity (Mardeh *et. al*., 2006). Similarly, higher plant height was obtained in irrigated conditions in our study.

Leaf area is an important factor affecting photosynthetic capacity. With the increase in leaf area, mesophyll cells containing chlorophyll, the number of stomata increase, and the metabolic activities of the plant increase at that rate. In winter cereals, the upright and tightly developed leaf structure creates a strong photosynthetic activity and in this case requires more LAI. Therefore, more dry matter production is due to the increase in LAI, directly affecting photosynthesis (Bahar & Genç, 2017). Although it varies with genetic capacity, leaf development that is more affected by environmental conditions largely depends on the photosynthetic substances produced in vegetative growth and the adequacy of water and nutrients. Once the difference between years was found to be insignificant in our study, the highest LAI was obtained in aqueous conditions (5,223). The least LAI was obtained from the KI application (2,649). The genotype with the highest LAI yield was Bezostaja-1, while the least value was found in the Müfitbey genotype (3,092).

Chlorophyll a and chlorophyll b are essential components of chlorophyll and thus photosynthesis. Both are the main components of chlorophyll and affect the capacity and speed of its photosynthetic activities. Although both are active components, chlorophyll a has significant potential for light binding, energy acquisition and sugar production, especially in photosystem I and photosystem II (Sarieva *et al*., 2010). Again, both factors are under the influence of genetic and environmental interaction and are adversely affected by drought stress (Chovancek *et al*., 2019). Similarly, in our study, the amount of chlorophyll a and chlorophyll b were also affected positively and negatively depending on the amount of precipitation between years and the water stress in the applied conditions. While unfavorable conditions reduced chlorophyll a and b, more chlorophyll a and b were obtained from favorable conditions. More precipitation in the second year caused more chlorophyll a (27,463 µg/ml) and chlorophyll b (5,361 µg/ml) to be obtained. Again, in irrigated conditions, the highest chlorophyll a (36,458 µg/ml) and chlorophyll b (6,817 µg/ml) were obtained, while the lowest value was observed in KI application, chlorophyll a (16,205 µg/ml) and chlorophyll b (3,332 µg/ml). Again, on the basis of genotypes, the highest amount of chlorophyll a (2,012 µg/ml) and chlorophyll b (6,237 µg/ml) were obtained in Bezostaja-1 genotype, while the lowest values in chlorophyll a and b were obtained from from Altay-2000 (26,853 µg/ml) and Müfitbey (4,082 µg/ml) genotypes. Similar to literatures our results revealed that stress conditions negatively affect chlorophyll a and chlorophyll b.

In our study, grain weight per spike was highly affected by the differences between years and applications, and the difference between genotypes was also found to be very important. In fact, different responses between genotypes in different environments and years explain why the interactions of grain weight per spike are also important. Since grain weight per the spike is an element that is shaped by the dry matter produced, it is closely related to plant health and photosynthetic activity. Since environmental conditions affecting plant growth positively/negatively affect photosynthetic capacity and performance, they affect dry matter and thus grain weight in the ear. This component, that is higher in positive conditions, decreases considerably in negative conditions (Husain *et. al*., 2003). More precipitation in the second year caused a higher grain weight per spike (1,709 g). This component was maximum in irrigated conditions (1,990 g), while it is lowest (1,087g) in KI application. Bezostaja-1 genotype gave highest grain weight per spike (1,699 g), while the lowest value was obtained from Müfitbey genotype with 1,415 g.

Grain yield is one of the most important factors in plants, and it is a criterion that is taken into consideration in the evaluation of plants and revealing their importance (Stone & Savin, 1999). Efficiency for wheat means the criterion that is taken as the most fundamental basis and handled at the highest level in meeting the nutritional need in the world. Therefore, the increase and decrease in wheat yield production play the main role in the direction of food policies in the world. The amount of production in meeting the need of the geometrically increasing world population in terms of wheat production and the yield per unit area that determines this. High yield is only possible by producing high quality genotypes with high genotype capacity and meeting the breeding technique needs of these genotypes. Therefore, in the description of a high yielding genotype, genotype that is high yielding, high quality, resistant to biotic and abiotic stresses and stable in terms of these characteristics are taken into consideration. Breeding programs carried out for this purpose are carried out taking these issues into account. Genetic potentials for wheat are being challenged in the world, and increasing the yield will only be possible with the emergence of plants that are more resistant to biotic and abiotic stresses (Reynolds *et al*., 2011).

In our study, it has been tried to reveal how wheat genotypes are affected by conditions such as abiotic stresses, drought and waterlogging, and how well the plants perform under favorable conditions such as irrigated conditions. By testing different environments including stress conditions and positive conditions, the responses and interactions of wheat genotypes in terms of yield and yield components were tried to be determined. Considering these conditions for grain yield, it has been revealed how important the genotype-environment interaction is. Therefore, it has been tried to explain why interactions are important in terms of efficiency. When the grain yield obtained from the second year is taken into account in the second year with high precipitation, it is clearly seen why it gives more yield (3,435 t/ha). Similarly, it has been clearly demonstrated how high the grain yield (4,984 t/ha) obtained from irrigated conditions is compared to KI application (1,956 t/ha) and arid conditions (3,100 t/ha) and how vital water is here. When we look at the genotypes, the highest grain yield was obtained from the Bezostaja-1 genotype (3,929 t/ha), while the lowest grain yield was obtained from the Gerek 79 genotype (2,211 t/ha). This shows that grain yield is highly affected by environmental conditions as well as genetic potential, and it is clearly seen that the yield increases as the amount of water increases.

When plants are exposed to abiotic stress conditions, they form substances containing reactive oxygen species called ROS. These substances can cause detrimental effects on the DNA structure of the plant, proteins, lipids and carbohydrates, and may cause plants to be under oxidative stress. Plants also try to reduce the effect of stress by producing substances such as SOD, POD, CAT and proline in order to prevent this damage (Apel & Hirt, 2004). Considering the SOD values in this context, the highest amount of SOD was seen in the first year (154,302), while it remained lower in the second year (141,467). Less precipitation in the first year caused more SOD accumulation in wheat genotypes. Again, the highest SOD value (183,733) was obtained in KI application, which caused the most drought, while the lowest value was obtained from irrigated conditions (126,690). This situation reveals that the increased amount of SOD represents the severity of drought. As a matter of fact, studies have shown that SOD accumulates significantly in arid conditions compared to optimum conditions (Zaefyzadeh *et al*., 2009). When we look at the basis of genotypes, the highest value was seen in the Gerek 79 genotype (185,406), while the lowest value was seen in the Bezostaja-1 genotype (134,648). Considering both genotypes and applications, it reveals how sensitive genotypes are to genotype x environment interaction in terms of SOD. Likewise, the peroxidase enzyme, shortly called POD, emerges as a result of the plant's response to stress environments, like SOD. This response is an expression of both the defense and repair activities of the plant. POD is one of the most important stress response enzymes and can be named as the stress response of the plant exposed to stress. As it is known, plants immediately defend themselves in the stress environment and after showing resistance to stress, they engage in repair activities. Therefore, the high amount of POD enzyme indicates that the plant engages in repair activities as well as defense and how resistant it is to the stress environment. (Devi *et al*., 2012). In our study, when we look at the POD values in terms of years, the highest value was observed in the second year (254,050) with heavy rainfall, while lower values were observed in the first year (239,117). On the basis of trials, the highest POD value was observed in KI application (302,833), while the lowest value was observed in aqueous conditions (212,967). On the basis of cultivars, the highest value was seen in Gerek 79 genotype (283,128), while the lowest POD value was observed in Bezostaja-1 genotype (215,863).

Proline is an amino acid that accumulates in the cell against the plant's stress conditions and is important in terms of showing stress. Proline accumulation reveals the need to take precautions against drought in the plant in response to water stress due to lack of water. When the symptoms of stress conditions occur, proline accumulation begins in the plant and the plant activates the plant to reduce the anabolic activities of the plant, to form the defense mechanism and to increase the stress amino acids by increasing the accumulation of free calcium ions in the cell sap. In a study, it was revealed that the amount of proline increases significantly when the wheat plant encounters arid conditions, and in this case it especially increases, and in this case, the amount of abscisic acid and ethylene, which reduces wheat growth and activates the defense amino acids, increases and this causes a noticeable increase in the rate of dry matter transport to the grain (Johari-Pireivatlou, 2010). It has also been stated that earliness occurs at a rate of one third during the ripening period compared to normal wheat (Mwadzingeni *et al*., 2016). Finally, when the results of Proline values are examined, as seen in Table 4; On the basis of years, the highest value was seen as the first year (138,713), while the lowest value was seen as the second year (132,589). On the basis of applications, the highest Proline value was observed in KI application (155,502), while the lowest value was observed in aqueous conditions (122,733). Considering the Proline values on the basis of genotypes, the highest Proline value was seen in the Gerek 79 genotype (144,507), while the lowest value was seen in the Bezotoja-1 genotype (128,049).

The biplot graph of the variation, stability and genotypic performances of wheat genotypes tested in different environments in 2016-2017 and 2017-2018 in terms of the examined factors is given in Figure 1. As can be seen in the figure, the years 2016-2017 were quite different in terms of the components examined, and the second year was a more stable year in which the conditions were more suitable. Bezostaja-1 and Altay 2000 genotypes were determined as more stable and more performance genotypes compared to other genotypes, and were determined as new performance genotypes that respond better to changing growing environment conditions and different stress conditions. On the other hand, Gerek 79 and Müfit bey genotypes were determined as unstable lower performance genotypes. In terms of the examined components, LAI, grain weight per spike, chlorophyll a, chlorophyll b plant height and grain yield formed a group. In other words, these components were determined as genotypes that are closely related to grain yield. Biplot analysis explains that proline SOD and POD components are different from the other components, increasing under stress conditions and repair occurs especially when the yield components that affect yield decrease with stress conditions. Again, according to this analysis, the opposite of wet conditions was determined as KI application, and the opposite of dry conditions was determined as waterlogging. This means that KI applied in irrigated conditions creates excellent arid conditions and causes plants to respond as if they were in dry conditions. In other words, biplot analysis has shown that KI application can be a very important application in terms of determining the drought tolerance of plants in irrigated conditions. Again, stress of plants in dry conditions and waterlogging conditions reveals that plants are damaged in both applications and cause similar yield reduction, and both applications create stress conditions. Just as the roots are damaged in Waterloggin and the growth organs are left behind in the plant, the same is obtained in arid conditions with a different mechanism. Therefore, waterlogging presents itself as the opposite of arid conditions. Biplot analysis allowed obtaining sufficient results in revealing the performance of wheat genotypes in all conditions in this study. As a matter of fact, it has been stated that biplot analysis can be used safely in the evaluation of yield components in studies with biplot and in expressing plants and yield components together (Farshadfar *et al*., 2012). Again, it has been shown that biplot analysis gives important results and provides sufficient explanations in studies on wheat.

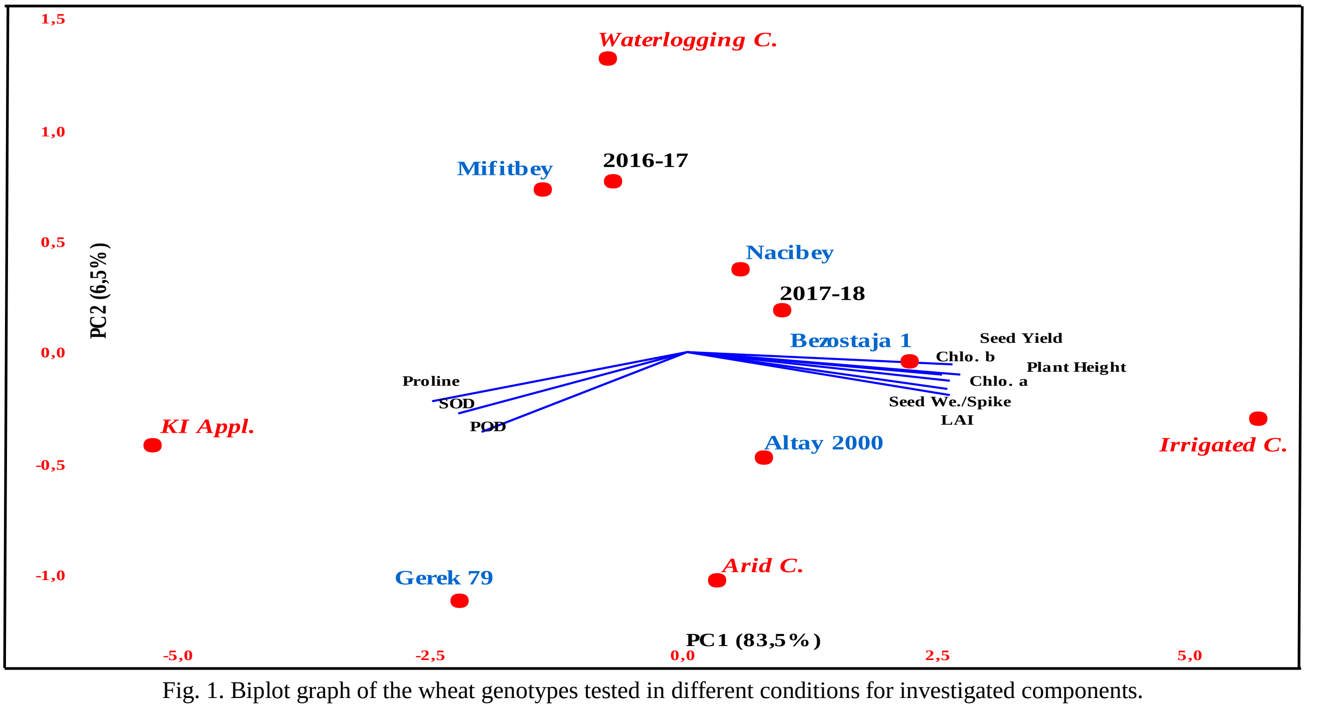
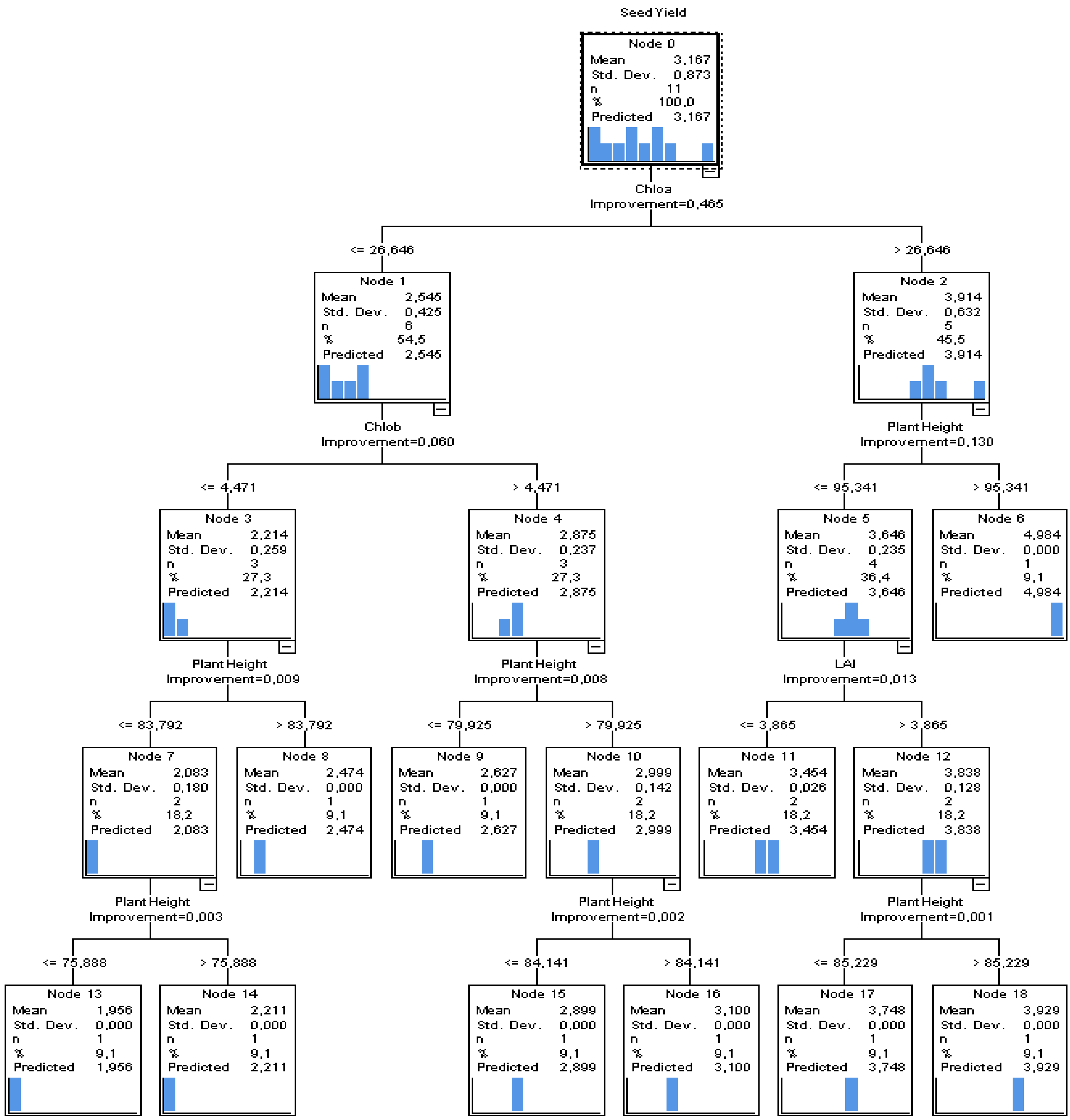


Fig. 1. Biplot graph of the wheat genotypes tested in different conditions for investigated components.



R^2: [1- $\frac{RiskEstimation}{\delta^2}$ **]:** $R^2 = 1 - \frac{0.518}{(0.873)^2}$: 0.68

Fig. 2. Decision tree showing the effect of the independent factors on the grain yield by accepting the grain yield as the dependent variable.

Besides, the decision tree could be used as a reliable analysis in determining the yield components that are considered independently on the dependent variable (Singh & Singh, 2017). In this study, the grain yield is accepted as the dependent variable and the decision tree showing the effect of the examined independent factors on grain yield is given in Figure 2. In the decision tree the most effective yield factor was determined as chlorophyll a. Chlorophyll b comes into play when chlorophyll a is lower than 26,646 µg/ml. It was determined that the yield was 2,214 t/ha when chlorophyll b was lower than 4,471 µg/ml and the grain yield was 2,875 kg when chlorophyll b was higher than 4,71. Again, when chlorophyll b is less than 4,471 µg/ml, the plant height is activated and the yield varies between 1,956 - 2,474 t/ha. When chlorophyll b is greater than 4,471 µg/ml, plant height also comes into play, varying between 2,627-3,100 t/ha. Plant height is activated when chlorophyll a is greater than 26,646 µg/ml, LAI is effective when plant height is higher than 95,341 cm, and the yield varies between 3,454 and 3,835 t/ha. When the LAI is greater than 3,866, the plant height comes into play and the yield varies between 3,748-3,929 t/ha. Again, when the plant height is more than 95,341 cm, the yield is determined as 4,984 t/ha. Briefly, if we write down the factors that affect grain yield from large to small, it can be expressed as chlorophyll a>chlorophyll b>Plant height>LAI. In other words, at high values of the factors affecting the yield, the factors in the lower unit come into play and can maximize the yield **(R^2: 0,68). (Residual: 0,32).**

If it is considered that wheat genotypes grown in different environments have different results in terms of various factors and that genotype-environment interaction has a significant effect on genotypes, stability studies and the heritability of genotypes should be calculated in order to reveal the behavior of genotypes in different environments. Many studies have been carried out on this subject for many years, and it has been revealed that determining how much of the examined characters are affected by the genotypic potential and how much is affected by the environment increases the chances of success in breeding programs and provides great benefit in determining the stability performance of the developed genotypes (De Vita *et al*., 2010). According to some researchers, it is important to examine the genotype x year x environment interaction (Ashraf *et al.*, 2001; Kılıç *et al*., 2003), while some studies have revealed that the genotype x environment interaction, which has greater variation, should be addressed. Broad sense heritabilities were varied as 0.35-0.60 in leaf area index, 0.30-0.50 in plant height, 0.20-0.50 in chlorophyll a and b, 0.30-0.65 in grain weight per spike, 0.40-0.60 in grain yield, varied between, 0.30-0.50 in SOD, 0.40-0.60 in POD and 0.20-0.50 in proline (Kafa, 1991).

In our study, broad sense heritability results calculation method is given in Table 5. Besides, for calculating broad sense heritability, the heritability level was found by taking the rate of the genotypic variance to the phenotypic variance calculated over the expected mean square of the analysis (Kafa, 1991).

When the number of years, y, the number of applications is p, the number of genotypes is g and the number of replicarions is r; **$(X)_{ikjr}$** value of **i**th genotype, in **k**th year, **j**th application and **r**th replication.
The value taken in the repeat is will be as follows:

$(X)_{ikjr}$: m ± gi ± yk ± pj ± (gy)ik ± (gp)ij ± (yp) kj ± (gyp) ikj ± (c) ikjr in formula:

As seen in Table 5, the broad-sense heritability obtained in our study was 0.35 at plant height, 0.40 in LAI, 0.20 in chlorophyll a, 0.25 in chlorophyll b, 0.36 in grain weight per spike, grain yield was 0.39, SOD 0.28, POD 0.45 and proline 0.23. The results obtained in our study are in accordance with the literature and it has been determined that the examined components have changed under the influence of environmental conditions in a broad sense and the genotypic effect remains in the minority.

Table 5. Broad sense heritability calculation method and heritability results in yield components.

M	: Grand mean
gi	: ith genotipe effect, (i= 1,2,.....,g)
yk	: kth year effect, (k = 1, 2, ..., y)
pj	: jth application effect, (j = 1,2,......p)
(gy)ik	: Effect of ith genotype x kth year interaction,
(gp)ij	: Interaction of ith genotype x jth applicaion,
(yp)kj	: Effect of kth year x jth application interaction,
(gyp)ikj	: Effect of interaction of ith genotype x kth year x jth application,
(c) ikjr	: Error

Source of variations	Degree of freedom	Observed means of SS	Expected means of SS
Genotype	(g-1)	V1	$\sigma^2e + r\sigma^2gyp + rp\sigma^2gy + ry\sigma^2gp + ryp\ \sigma^2g$
Gen. x Appl.	(g-1)(p-1)	V2	$\sigma^2e + r\sigma^2gyp + ry\sigma^2gp$
Gen. x Year	(g-1)(y-1)	V3	$\sigma^2e + r\sigma^2gyp + rp\sigma^2gy$
Gen. x Appl. x Year	(g-1)(p-1)(y-1)	V4	$\sigma^2e + r\sigma^2gyp$
Error	(yp)(g-1)(r-1)	V5	σ^2e

Variance of Genotype x Year x application	$\sigma^2gyp = (V4-V5)/r$	Genotypic variance	$\sigma^2g = [(V1-V2) – (V3 – V4)]/y.p.r$
Genotype x Year Variance	$\sigma^2gy = (V3-V4)/r.y$	Phenotypic variance	$\sigma^2f = \sigma^2g + \sigma^2gy/y + \sigma^2gp/p + \sigma^2gyp/yp + \sigma^2e/ pry$
Genotype x Application Variance	$\sigma^2gp = (V2-V4)/r.p$	Heritability	$H = \sigma^2g/\sigma^2f$

	Plant He.	LAI	Chlo. a	Chlo. b	Se.We./Spike	Seed yield	SOD	POD	Proline
Variance of Genotype x Year x Application	8,12	0,07	1,69	0,20	0,02	0,07	295,45	515,02	13,95
Genotype x Year Variance	2,90	0,55	11,86	0,94	0,00	0,41	1746,88	670,13	-25,39
Genotype x Application Variance	10,95	0,30	4,37	0,15	0,02	1,93	1010,84	752,03	221,58
Genotypic Variance	123,02	17,64	357,75	43,76	0,81	49,81	17211,75	3024,14	1045,42
Phenotypic Variance	354,76	44,15	1786,98	175,93	2,23	127,74	62518,93	6763,16	4479,23
Heritability	**0,35**	**0,40**	**0,20**	**0,25**	**0,36**	**0,39**	**0,28**	**0,45**	**0,23**

Conclusions

As a result, yield and yield components in wheat are largely under the influence of environmental conditions. Bezostaja-1 and Altay 2000 genotypes were determined as stable and high performance cultivars best adapted to changing environmental conditions. While the most effective yield factors on grain yield were determined as plant height, chlorophyll a and b, grain weight per ear and LAI, it was determined that SOD POD and proline were effective parameters in showing the effect of drought. KI application is a very effective method to identify drought-resistant plants in irrigated conditions and gives very good results in mimicking drought. Although drought and waterlogging are important inhibitory stress environments in plant growth, it was concluded that the heritability of the investigated LAI, grain weight per spike, chlorophyll a, chlorophyll b plant height, grain yield, SOD, POD and proline were so low. More detailed studies are needed on this subject, and conducting studies that determine the effect of drought will shed light on future studies.

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