

UDC 633.111«324»:575.222.2:581.1.032.3:631.55

4.1.3. Agrochemistry, agro-soil science, plant protection and quarantine

**EVALUATION OF 23 WHEAT GENOTYPES (*TRITICUM AESTIVUM L.*) FOR WATER STRESS BASED ON PHYSIOLOGICAL INDICES AND GRAIN YIELD**

Malek Hubaish Walli

Postgraduate student, department of Agrobiotechnology, Institute of Agriculture

ORCID identifier: <https://orcid.org/0000-0002-4884-6481>

e-mail: [malek\\_h88@yahoo.com](mailto:malek_h88@yahoo.com)

Tel +79891527633

Fatima Duksi

Postgraduate student, department of Agrobiotechnology, Institute of Agriculture

ORCID: <https://orcid.org/0000-0002-7353-7816>

e-mail: [f.duksi@gmail.com](mailto:f.duksi@gmail.com)

*RUDN University, 117198 Moscow, Russia*

Water scarcity is one of the consequences of global climate change, and it has a negative impact on crop growth and productivity, including wheat. Therefore, breeding programs to select genotypes tolerant to water stress are considered one of the most important strategic challenges. Wheat is one of the most common and widely used crops due to its nutritional and economic value. This study aimed to evaluate 23 wheat varieties under the influence of water stress levels of (control) 90%, 60% and 30% of field capacity. Based on physiological indicators and stress tolerance index (STI), the genotypes were classified into four clusters according to their tolerance to water stress: cluster (A) highly tolerant, Dujela (UD), Abo Ghurayb (SA), Buhuth22 (TB) genotypes; cluster (B) moderately tolerant, Latifiya (CL), Faris (NF), Baraka (AB) genotypes; cluster (C) moderately sensitive (EU, RA, KA, DB, VN, BW, QA, WA, LB) genotypes; and cluster (D) sensitive (FS, OT, PB, HB, MB, JB, GF, IB) genotypes. As for the effect of water stress levels on yield, it caused a loss of up to 50% of the grain yield (g/m<sup>2</sup>) at a stress level of 30%. Tolerant genotypes maintained high concentrations of antioxidant enzyme activity, such as catalase (CAT), while continuing to reduce the accumulation of oxidising materials such as hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>)

Keywords: BREAD WHEAT, GENETIC VARIATION, PHYSIOLOGICAL INDICATORS, WATER STRESS, GRAIN YIELD

<http://dx.doi.org/10.21515/1990-4665-217-001>

УДК 633.111«324»:575.222.2:581.1.032.3:631.55

4.1.3. Агрохимия, агропочвоведение, защита и карантин растений

**ОЦЕНКА 23 ГЕНОТИПОВ ПШЕНИЦЫ (*TRITICUM AESTIVUM L.*) НА УСТОЙЧИВОСТЬ К ВОДНОМУ СТРЕССУ НА ОСНОВЕ ФИЗИОЛОГИЧЕСКИХ ПОКАЗАТЕЛЕЙ И УРОЖАЙНОСТИ ЗЕРНА**

Малик Хубайш Валли

Аспирант кафедры агробиотехнологии Института сельского хозяйства

ORCID: <https://orcid.org/0000-0002-4884-6481>

Эл. почта: [malek\\_h88@yahoo.com](mailto:malek_h88@yahoo.com)

тел. +79891527633

Фатима Дукси

Аспирант кафедры агробиотехнологии Института сельского хозяйства

ORCID: <https://orcid.org/0000-0002-7353-7816>

Эл. почта: [f.duksi@gmail.com](mailto:f.duksi@gmail.com)

*РУДН, Москва, 117198, Россия*

Дефицит воды является одним из последствий глобального изменения климата и оказывает негативное влияние на рост и продуктивность сельскохозяйственных культур, включая пшеницу. Целью данного исследования была оценка 23 сортов пшеницы при воздействии различных уровней водного стресса: 90% (контроль), 60% и 30% от полевой влагоемкости. На основе физиологических показателей и индекса толерантности к стрессу (STI) генотипы были классифицированы на четыре кластера в соответствии с их устойчивостью к водному стрессу: кластер (А) высокоустойчивые генотипы Dujela (UD), Abo Ghurayb (SA), Buhuth22 (TB); кластер (В) умеренно устойчивые генотипы Latifiya (CL), Faris (NF), Baraka (AB); кластер (С) умеренно чувствительные генотипы (EU, RA, KA, DB, VN, BW, QA, WA, LB); и кластер (D) чувствительные генотипы (FS, OT, PB, HB, MB, JB, GF, IB). Что касается влияния уровней водного стресса на урожайность, то он вызвал потерю до 50% урожая зерна (г/м<sup>2</sup>) при уровне стресса 30%. Устойчивые генотипы поддерживали высокую активность антиоксидантных ферментов, таких как каталаза (CAT), при этом при одновременном снижении накопления окислительных агентов, таких как перекись водорода (H<sub>2</sub>O<sub>2</sub>)

Ключевые слова: МЯГКАЯ ПШЕНИЦА, ГЕНЕТИЧЕСКАЯ ИЗМЕНЧИВОСТЬ, ФИЗИОЛОГИЧЕСКИЕ ИНДИКАТОРЫ, ВОДНЫЙ СТРЕСС, УРОЖАЙНОСТЬ ЗЕРНА

## **Introduction**

Irregular rainfall patterns have led to increased drought worldwide. By 2040, 40% of the world's wheat-growing area is expected to suffer from severe water scarcity [1].

Drought and rising temperatures negatively impact wheat production, posing a significant threat to global food security. Therefore, the primary task of plant breeders was to select tolerant genotypes for water stress. Genotypes are diagnosed using various indicators, including morphological, physiological, biochemical, and molecular markers [2].

The impact of water stress on plant growth stages and the decrease in crop features, like the number of grains per spike and the amount of grain produced per square metre, have been identified [3]. Phenotypic indicators can accurately predict variety differences in productivity, biomass, and tolerance to stress conditions [4].

In our previous study [5], the feasibility of using physiological indicators alongside morphological traits and their relationship to stress tolerance indicators was proven sufficiently to be used as a selection tool in breeding tolerant wheat varieties. With the aim of improving and expanding wheat cultivation and maintaining wheat productivity in arid and semi-arid regions, our research was conducted to evaluate and select genotypes that are tolerant to water stress.

## **Materials and Methods**

This study is part of the first researcher's thesis, which will be submitted for defence to the Peoples' Friendship University of Russia (RUDN) in Moscow.

The study included 23 genotypes of bread wheat (*Triticum aestivum* L.) in Table 1 and included new varieties such as Dujaila , Faris, and Buhouth 22, which showed tolerance to other environmental variables. Genotypes were collected from the Iraqi Gene Bank and the accredited

research centres of the Iraqi Ministry of Agriculture, the College of Agriculture at Al-Muthanna University and the Russian Peoples' Friendship University (RUDN).

Table 1 – Genotypes sources used in the study

	Genotypes	Sample	Pedigree	Genetics arises	Source
1	Baraka	AB	IARI × STD	Hybridization	Iraq
2	Wafia	BW	-	-	France
3	Latifiya	CL	Australian breed × Aras	Hybridization	Iraq
4	Binakal	DB	BISU/3/YAV79/ALOI/ALTARS4/CD93683.7Y.040M-03 OY-LPAP.B	-	Spanish
5	Uruk	EU	Inia 66 (Rad) Irradiation of seeds of Enya 66	Irradiation	Iraq
6	Sham	FS	W-3018-A/JUPATECO-73	Irradiation	Iraq
7	Fateh	GF	MixPac × Aras	Hybridization	Iraq
8	Buhuth 10	HB	Abaa 95 × Abaa 99	Hybridization	Iraq
9	Buhuth 158	IB	119-S2/57-S2. Cr7.S2	Irradiation	Iraq
10	Babul 113	JB	MEXIPAK/R23	Irradiation	Iraq
11	Al Iraq	KA	Irradiation of Mexipac seeds with full cobalt 60 doses and 10 kilos rad, Max. (Rad)	Irradiation	Iraq
12	Bwru	LB	H31/Trapf21 / Enesco	Hybridization	Italy
13	Baghdad	MB	MX105-6MVL40 / BNSN	Hybridization	Iraq
14	Faris	NF	STAR/TR77/773/SLMS	Irradiation	Iraq
15	Tammuz	OT	Exposing the resulting hybrid (Maxipac x Saber Beek) to radiation	Hybridization and irradiation	Iraq
16	Buhuth	PB	118//S2/57-S2-CR7-S2	Hybridization	Iraq
17	Abaa 95	QA	Veery eer (CIMMYT)	Hybridization	Iraq
18	Abaa 99	RA	Ures/Bow's//Pollmer's (CIMMYT and ICARDA)	Hybridization	Iraq
19	Abo Ghurayb	SA	Ajeeba × Lian 12 × Mexico24	Hybridization	Iraq
20	Buhuth 22	TB	CMSS96Y03236M-050M-040M-020M-050Sy-020sy-IM-0Y	Irradiation	Iraq
21	Dujela	UD	8409644HS2-6H	Irradiation	Iraq
22	Nemchinovka	VN	-	-	Russia
23	Abo Raghif	WA	Inia 66 / 2 * Mexipak	Hybridization	Turkey

Experimental Design–The split-plot design, across three plots (replications). Levels of water stress treatments at 90% (control), 60%, and 30% of field capacity (FC), with each main plot containing subplots for 23

genotypes. The seeds were planted in November 2022-2023 and 2023-2024. The drip irrigation method was adopted in the experiment to control the distribution of the amount of irrigation water added in an organised manner. Treatments of water stress were carried out gradually after germination until the required treatment level was achieved and continued until harvest.

Chlorophyll content in the flag leaf – After 80–100% of the plants reached the flowering stage, 10 plants were selected from each experimental unit to measure the chlorophyll content (Chlo-SPAD), which was measured using an SPAD device [6].

Estimation of relative water content (RWC) – RWC was calculated using the formula [7]:  $RWC (\%) = (FW - DW)/(TD - DW) \times 100$ , fresh weight (FW), dried weight (DW), and turgid weight (TW).

Estimation of physiological enzyme parameters – Fresh leaves collected in the morning were placed in plastic tubes with ice and transported to the laboratory at the College of Pure Sciences, Al-Muthanna University, where their oxidative enzymes were evaluated using specific methods.

Estimation of hydrogen peroxide ( $H_2O_2$ ) activity in leaves –The concentration of  $H_2O_2$  was ascertained by evaluating the titanium-hydroperoxide complex at a wavelength of 415 nm, according to the study [8]. We used a standard curve with a range of 100 to 1000 nanomoles to determine the amount of  $H_2O_2$  present.

Estimation of Catalase (CAT) enzyme activity (EC:1.11.1.6) – Enzyme CAT activity was determined according to the method of [9], the equation:  $Catalase \text{ activity (unit)} = (\Delta abs/min \times \text{Reaction volume}) / 0.001$ .  $\Delta abs$  = the difference between absorbance (first absorbance - second absorbance), min = reaction time, and reaction volume = 2.04 ml, at a wavelength of 240 nm.

The grain yield ( $g/m^2$ ) was calculated by harvesting all plants from a one-square-metre area in each subplot (experimental unit) and weighing them by using an electronic balance.

Stress Tolerance Index (STI) by using the equation Fernandez [10]:  $STI = Y_s \times Y_p / \bar{Y}_p^2$ ,  $Y_s$  = weight of grain yield ( $\text{g}\cdot\text{m}^{-2}$ ) of cultivar under stress,  $Y_p$  = weight of grain yield ( $\text{g}\cdot\text{m}^{-2}$ ) of cultivar under normal conditions and  $\bar{Y}_p$  mean yield of cultivar under normal conditions.

Statistical Analyses. The data were analysed using *Statistix 8.1* to assess variance according to the experiment's design. The dendrogram was created based on the standard Euclidean distance matrix between 23 genotypes using the Ward (1963) method in IBM SPSS Statistics, after standardizing the trait data into standard data of mean and standard deviation [11]. The less significant difference (*LSD*) test compared the means at significance levels of 0.05.

## Results and Discussion

Water stress levels had a significant impact on chlorophyll content, as shown in Table 3 and Figure 1. The chlorophyll content was highest at the control level (47.65 SPAD units) compared to the highest water stress (30%) level (26.11 SPAD units). The UD variety had the highest chlorophyll content (45.53 SPAD units), while the FS variety had the lowest (32.66 SPAD units) and was more affected by water stress. The results indicated the effect of severe stress on the chlorophyll content in the plant, leading to a decrease in photosynthetic efficiency and thus affecting the growth and production of wheat [12].

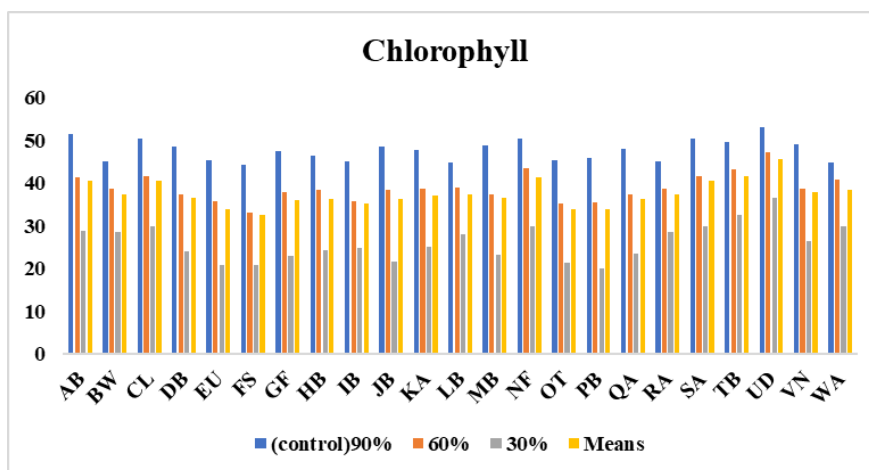


Figure 1. Evaluating the chlorophyll content of the flag leaf.

Table 3 and Figure 2 showed a highly significant effect of water stress on the genotypes and RWC trait at the significance level of 0.05. The mean of RWC decreased significantly at the 30% of field capacity level, reaching 50.01%, compared to a higher average value of 83.45% at the control level (90% FC). This decrease in RWC was attributed to the reduced absorption of the required amount of water, in addition to the increased loss due to transpiration under water stress. As for the genotypes, the UD variety showed a significant superiority over all genotypes in the stress level (84.58%). Genotypes that have reduced water loss in explant leaves are thought to be more water stress tolerant and less affected by water loss through evaporation and transpiration, and thus able to maintain their water content [13]. [14] found that epicuticular wax might be an important attribute in water stress-tolerant genotypes because they developed more epicuticular wax on leaves, which reduced the loss of water from the plant leaf surface (Figure 3).

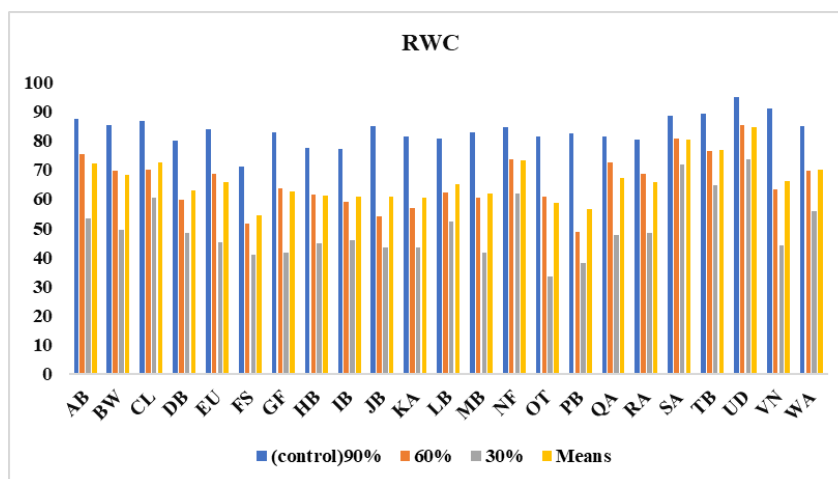


Figure 2. Evaluating of the Relative Water Content (RWC) of the plant



Figure 3. Waxy layer on the leaf surface of the UD genotype.

Table 2 showed that the concentration of  $H_2O_2$  increases with the increase in the severity of water stress; the  $H_2O_2$  concentration increased to  $4.02 \mu\text{mol. g}^{-1}\text{fw}$  at the highest stress level at 30% FC and was  $2.45 \mu\text{mol. g}^{-1}\text{fw}$  at the control level. Comparing the averages at the LSD at a significance level of 0.05, the genotypes FS, PB, and OT ( $3.95$ ,  $3.80$ , and  $3.75 \mu\text{mol. g}^{-1}\text{fw}$ ) contained the highest concentration of  $H_2O_2$ . The accumulation of  $H_2O_2$  in plants is considered an indicator of their sensitivity to stress. Despite the high antioxidants in the study varieties, the  $H_2O_2$  content remained high, but this varied according to the type of stress, its severity, and the genotype. Our findings, together with those of other researchers [15,16].

In Table 2, CAT activity at the control level (90% FC) was 42.486 units.mg<sup>-1</sup>fw, while at the level of 30% FC, CAT enzyme activity increased to 67.483 units.mg<sup>-1</sup>fw. Comparison of the genotypes' averages in LSD test at a significance level of 0.05 showed that the UD, TB, SA, NF, and CL varieties showed the highest enzyme activity: 79.8, 70.93, 70.3, 65.7, and 65.55 units.mg<sup>-1</sup>fw, respectively. The results confirm the effectiveness of the CAT in protecting biofilms and reducing the damage caused by stresses.

In this study, the activity of the CAT enzyme increased under these stresses, and the index of the difference in stress levels in expression is given to the tolerant varieties that recorded the highest enzyme concentration in fresh weight, as mentioned [15,16].

Table 2 – Evaluation of the hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) and catalase (CAT) enzyme of the plant

varieties	H2O2				CAT			
	(control) 90%	60%	30%	Means	(control) 90%	60%	30%	Means
Baraka (AB)	2.66	2.08	3.48	2.74	52.25	78.66	63.52	64.81
Wafia (BW)	2.26	3.06	4.1	3.14	41.8	51.17	75.49	56.16
Latifiya (CL)	1.88	2.62	3.48	2.66	51.62	80.56	64.47	65.55
Binakal (DB)	2.59	3.15	4.23	3.32	44.97	52.44	60.61	52.67
Uruk (EU)	2.29	3.1	4.16	3.18	42.12	52.76	69.79	54.89
Sham (FS)	3.05	4.79	4.01	3.95	33.88	40.72	56.49	43.7
Fateh (GF)	2.78	3.45	4.53	3.58	32.3	52.12	66.94	50.46
Buhuth10 (HB)	2.62	3.28	4.32	3.41	38.32	49.91	65.04	51.09
Buhuth158 (IB)	2.87	3.49	4.53	3.63	31.98	50.86	67.26	50.03
Babul 113 (JB)	2.73	3.41	4.49	3.55	33.57	49.27	69.16	50.67
Al Iraq (KA)	2.5	3.15	4.23	3.29	38	54.66	65.68	52.78
Bwru (LB)	2.1	2.97	4.06	3.05	44.02	61.31	67.89	57.74
Baghdad (MB)	2.6	3.26	4.23	3.36	40.28	51.17	63.78	51.74
Faris (NF)	2.62	2.03	3.29	2.65	54.34	74.86	67.96	65.72
Tammuz (OT)	2.98	3.72	4.54	3.75	35.15	45.47	65.68	48.77
Buhuth (PB)	3.03	3.72	4.66	3.8	27.55	43.26	60.29	43.7
Abaa 95 (QA)	2.27	3.07	4.1	3.15	35.78	60.04	72.01	55.94
Abaa 99 (RA)	2.36	3.14	4.16	3.22	42.12	57.51	64.41	54.68
Abo Ghurayb (SA)	1.92	2.44	3.29	2.55	52.25	86.26	72.39	70.3
Buhuth 22 (TB)	1.89	2.41	3.23	2.51	59.22	80.88	72.71	70.93
Dujela (UD)	1.88	2.39	3.11	2.46	65.55	94.49	79.36	79.8
Nemchinovka (VN)	2.27	3.1	4.13	3.17	39.9	53.07	74.23	55.73
Abo Raghif (WA)	2.15	3.05	4.1	3.1	40.22	62.26	66.94	56.47
Means	2.45	3.08	4.02	3.18	42.49	60.16	67.48	56.71
LSD.05	<i>T=0.143</i>	<i>V=0.263</i>	<i>TXV</i>	<i>0.456</i>	<i>T=1.611</i>	<i>V=3.054</i>	<i>TXV</i>	<i>5.289</i>

Table 3 and Figure 4 showed that there were significant differences between the genotypes affected by water stress, as the 30% FC level gave the lowest mean in yield trait, 306.4 g.m<sup>-2</sup>, compared to the control level, which gave the highest mean of 611.78 g.m<sup>-2</sup>, and the 60% FC level, which provided 445.61 g.m<sup>-2</sup>. The UD genotype gave the highest average of 738.1 g.m<sup>-2</sup>, while the lowest average was 244.38 g.m<sup>-2</sup> for the PB genotype. A decrease in the number of grains per spike and the number of spikes per plant leads to a decrease in yield. Generally, these stresses significantly affect wheat production by impacting stem growth and development and the plant's aerial dry weight. Tolerant wheat varieties showed a lower decrease in the number of productive branches and yield compared to sensitive varieties under stress conditions [17].

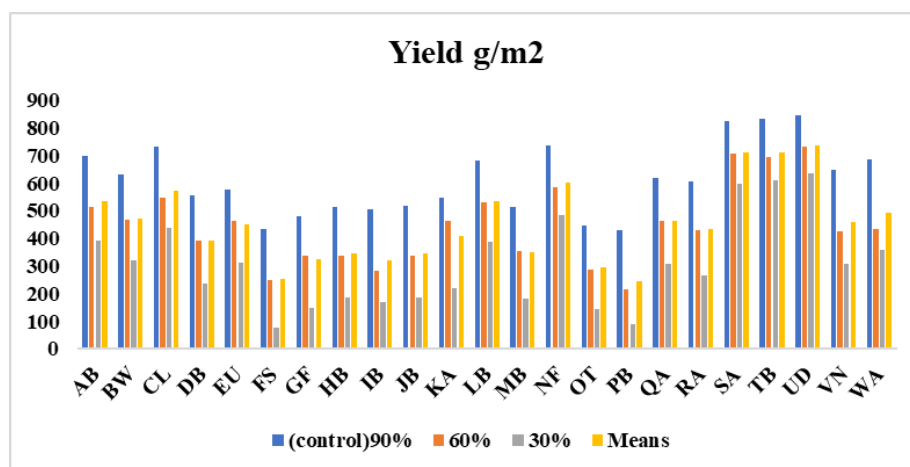


Figure 4. Evaluating of yield (g.m<sup>-2</sup>)

Table 3 and Figure 5 show that the genotypes UD, TB, SA, NF, and CL have the highest stress tolerance index STI values (1.68, 1.59, 1.57, 1.19, and 1.12) when compared to genotypes FS and PB, which have the lowest values of 0.31 and 0.30, meaning they are sensitive to drought; therefore, the genotypes with higher values may be considered drought-tolerant. These results was consistent with [10].

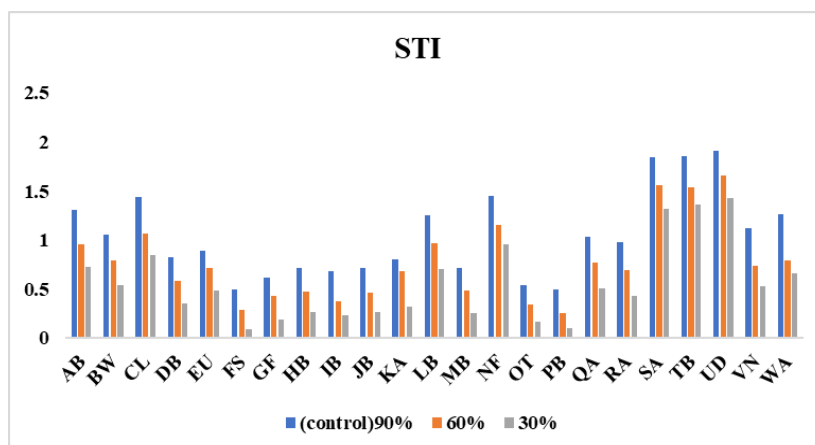


Figure 5. Stress Tolerance Index of genotypes.

Table 3 – Analysis of variance (ANOVA) of study traits and water stress treatments (T) and varieties (V) by using LSD test to means at significance level 0.05

Traits / Treatments		Control (90%)	60%	30%	Mean	LSD.05
<b>Chlorophyll (SPAD)</b>	Mean	47.65	38.89	26.11	37.55	T X V
	LSD.05	T=0.82			V=1.7	2.94
<b>RWC (%)</b>	Mean	83.45	65.76	50.01	66.41	T X V
	LSD.05	T=1.01			V=3.7	6.38
<b>Yield (g.m<sup>2</sup>)</b>	Mean	611.78	445.61	306.4	454.6	T X V
	LSD.05	T=13.8			V=26.1	45.14
<b>STI</b>	Mean	1.04	0.77	0.55	0.79	T X V
	LSD.05	T=0.024			V=0.08	0.14

Figure 6 shows the classification of 23 genotypes into four clusters based on the morphological and physiological indicators, yield components, and sensitivity indices for water stress: cluster (A), water stress-tolerant, included genotypes (UD, SA, TB); cluster (B), moderately water stress-tolerant, included genotypes (CL, NF, AB); cluster (C), moderately water stress-sensitive, included genotypes (EU, RA, KA, DB, VN, BW, QA, WA, LB), which is considered the largest cluster of genotypes that showed sensitivity to water stress at a level of 60% FC; and cluster (D), water stress-sensitive, included genotypes (FS, OT, PB, HB, MB, JB, GF, IB), which showed sensitivity to water stress levels through the traits of plant height, biomass, and grain yield.

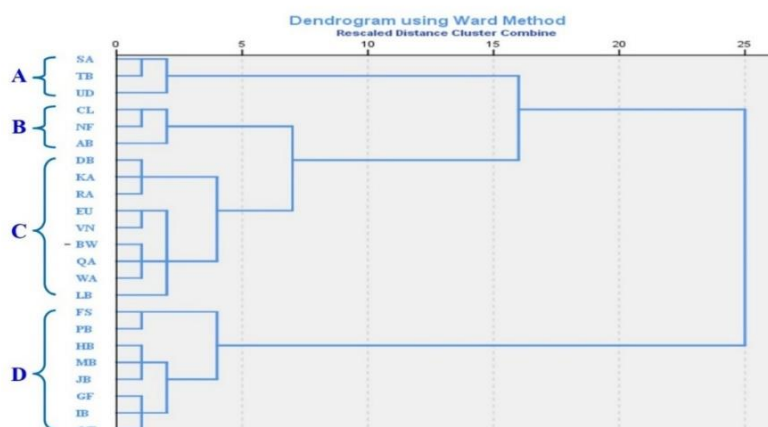


Figure 6. Dendrogram of genotypes based on morphological and physiological indicators.

The tolerant genotypes were registered on the NCBI platform after obtaining their sequences from the GenBank and identifying the locations of the genes responsible for tolerance to water stress. In our other study, the genotypes Baraka (AB), Latifiya (CL), Faris (NF), Abo Ghurayb (SA), and Buhuth 22 (TB) had been 99% sequence-similar to the *DRF1* gene of *Triticum turgidum* and GenBank accession numbers PP873665 to PP873669; the genotypes Latifiya (CL), Faris (NF), Abo Ghurayb (SA), Buhuth 22 (TB), and Dujela (UD) were 100% similar to the NAC20L gene of *Triticum aestivum* and GenBank accession numbers PP873670 to PP873674; and the genotypes Faris (NF), Dujela (UD), Abo Ghurayb (SA), and Buhuth 22 (TB) showed 100% sequence similarity to the *microsatellite* sequences of *Triticum turgidum* and had GenBank accession numbers PP873642 to PP873645.

## Conclusion

In this study, it was found that the effect of water stress, especially at the level of 30% FC, resulted in a 50% loss of yield compared to the control level. Based on the study's indices, the genotypes can be classified into four clusters

according to their tolerance to water stress: cluster (A), tolerant, Dujela (UD), Abo Ghurayb (SA), Buhuth22 (TB) genotypes; cluster (B), moderately tolerant, Latifiya (CL), Faris (NF), Baraka (AB) genotypes; cluster (C), moderately sensitive (EU, RA, KA, DB, VN, BW, QA, WA, LB) genotypes; and cluster (D), sensitive (FS, OT, PB, HB, MB, JB, GF, IB) genotypes. Tolerant genotypes maintained the grain's moisture, gluten, and protein content. Tolerant genotypes maintained high concentrations of antioxidant enzyme activity, such as catalase (CAT), while continuing to reduce the accumulation of oxidising agents such as hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>).

## References

1. Movahhedi-Dehnavi, M. Salicylic Acid Mitigates the Effects of Drought and Salinity on Nutrient and Dry Matter Accumulation of Linseed / M. Movahhedi-Dehnavi, Y. Behzadi, N. Niknam, R. Mohtashami // *Journal of Plant Process and Function*. — 2019. — Vol. 8, № 31. — P. 31–44.
2. Al-Ashkar, I. Morphological and genetic diversity within salt tolerance detection in eighteen wheat genotypes / I. Al-Ashkar, A. Alderfasi, W. B. Romdhane [et al.] // *Plants*. — 2020. — Vol. 9, № 3. — Art. 287.
3. Rao, S. D. Effect of drought stress on phenological and yield attributes in Wheat (*Triticum aestivum* L.) / S. D. Rao, M. Raghavendra, P. Gill [et al.] // *Journal of Eco-friendly Agriculture*. — 2022. — Vol. 17, № 1. — P. 65–71.
4. Paul, K. Co-occurrence of Mild Salinity and Drought Synergistically Enhances Biomass and Grain Retardation in Wheat / K. Paul, J. Pauk, A. Kondic-Spika [et al.] // *Frontiers in Plant Science*. — 2019. — Vol. 10. — Art. 501.
5. Walli, M. H. Selection of Salinity-Tolerant Wheat (*Triticum Aestivum* L.) Lines to Improve Production Yields Under Climate Change / M. H. Walli, F. Duksi, Y. D. K. Alasadiy [et al.] // *International Journal of Environmental Science*. — 2025. — P. 2112–2126.
6. Kamarianakis, Z. Design and Implementation of a Low-Cost Chlorophyll Content Meter / Z. Kamarianakis, S. Panagiotakis // *Sensors*. — 2023. — Vol. 23, № 5. — Art. 2699.
7. Din, A. Drought Tolerance Screening in Thirty Common Wheat (*Triticum aestivum* L.) Genotypes / A. Din, M. Ahmad, F. M. Watto [et al.] // *Sarhad Journal of Agriculture*. — 2020. — Vol. 35, № 1. — P. 168–177.
8. Mukherjee, S. P. Implications of water stress-induced changes in the levels of endogenous ascorbic acid and hydrogen peroxide in *Vigna* seedlings / S. P. Mukherjee, M. A. Choudhuri // *Physiologia Plantarum*. — 1983. — Vol. 58, № 2. — P. 166–170.
9. Aebi, H. Catalase in Vitro / H. Aebi // *Methods in Enzymology*. — 1984. — Vol. 105. — P. 121–126.
10. Fernandez, G. C. J. Effective Selection Criteria for Assessing Plant Stress Tolerance / G. C. J. Fernandez // *Adaptation of food crops to temperature and water stress*. — 1992.

11. Matković Stojšin, M. Assessment of Genotype Stress Tolerance as an Effective Way to Sustain Wheat Production under Salinity Stress Conditions / M. Matković Stojšin, S. Petrović, B. Banjac [et al.] // Sustainability. — 2022. — Vol. 14, № 12. — Art. 6973.
12. Shah, S. Response of Chlorophyll, Carotenoid and SPAD-502 Measurement to Salinity and Nutrient Stress in Wheat (*Triticum aestivum* L.) / S. Shah, R. Houborg, M. McCabe // Agronomy. — 2017. — Vol. 7, № 3. — Art. 61.
13. Sallam, A. Drought stress tolerance in wheat and barley: Advances in physiology, breeding and genetics research / A. Sallam, A. M. Alqudah, M. F. A. Dawood [et al.] // International Journal of Molecular Sciences. — 2019. — Vol. 20, № 13.
14. Paudel, H. Response of Wheat to Different Abiotic Stress Conditions: A Review / H. Paudel, R. Bhandari, A. Dhakal [et al.] // Science Heritage Journal. — 2023. — Vol. 7, № 1. — P. 27–31.
15. Mehmood, M. Impact of Drought, Salinity, and Waterlogging on Wheat: Physiological, Biochemical Responses, and Yield Implications / M. Mehmood, Z. A. Khan, A. Mehmood [et al.] // Phyton. — 2025. — Vol. 94, № 4. — P. 1111–1135.
16. Seleiman, M. F. Salinity Stress in Wheat: Effects, Mechanisms and Management Strategies / M. F. Seleiman, M. T. Aslam, B. A. Alhammad [et al.] // Phyton. — 2022. — Vol. 91, № 4. — P. 667–694.
17. Kumar, A. Impact of water deficit (salt and drought) stress on physiological, biochemical and yield attributes on wheat (*Triticum aestivum*) varieties / A. Kumar, S. K. Sharma, C. Lata [et al.] // Indian Journal of Agricultural Sciences. — 2018. — Vol. 88, № 10. — P. 1624–1632.

### Список литературы

1. Моваххеда-Дехнави, М. Салициловая кислота смягчает воздействие засухи и засоления на накопление питательных веществ и сухого вещества льна [Текст] / М. Моваххеда-Дехнави, Ю. Бехзади, Н. Никнам, Р. Мохташами // Журнал функций и процессов растений. — 2019. — Т. 8, № 31. — С. 31–44.
2. Аль-Ашкар, И. Морфологическое и генетическое разнообразие при определении солеустойчивости восемнадцати генотипов пшеницы [Текст] / И. Аль-Ашкар, А. Алдерфаси, В. Б. Ромдхан [и др.] // Растения (Plants). — 2020. — Т. 9, № 3. — Ст. 287.
3. Рао, С. Д. Влияние стресса от засухи на фенологические показатели и урожайность пшеницы (*Triticum aestivum* L.) [Текст] / С. Д. Рао, М. Рагхавендра, П. Гилл [и др.] // Журнал экологически чистого сельского хозяйства. — 2022. — Т. 17, № 1. — С. 65–71.
4. Пауль, К. Одновременное воздействие умеренного засоления и засухи синергетически усиливает замедление роста биомассы и зерна пшеницы [Текст] / К. Пауль, Й. Паук, А. Кондич-Шпики [и др.] // Границы растениеводства (Frontiers in Plant Science). — 2019. — Т. 10. — Ст. 501.
5. Валли, М. Х. Отбор солеустойчивых линий пшеницы (*Triticum aestivum* L.) для повышения урожайности в условиях изменения климата [Текст] / М. Х. Валли, Ф. Дукси, Я. Д. К. Аласадий [и др.] // Международный журнал экологических наук. — 2025. — С. 2112–2126.
6. Камарианакис, З. Разработка и внедрение недорогого измерителя содержания хлорофилла [Текст] / З. Камарианакис, С. Панагиотакис // Датчики (Sensors). — 2023. — Т. 23, № 5. — Ст. 2699.

7. Дин, А. Скрининг тридцати генотипов мягкой пшеницы (*Triticum aestivum L.*) на толерантность к засухе [Текст] / А. Дин, М. Ахмад, Ф. М. Ватто [и др.] // Сархадский сельскохозяйственный журнал. — 2020. — Т. 35, № 1. — С. 168–177.

8. Мукерджи, С. П. Последствия изменений уровней эндогенной аскорбиновой кислоты и перекиси водорода, вызванных водным стрессом, у проростков вигны [Текст] / С. П. Мукерджи, М. А. Чоудхури // Физиология растений (*Physiologia Plantarum*). — 1983. — Т. 58, № 2. — С. 166–170.

9. Аэби, Х. Каталала *in vitro* [Текст] / Х. Аэби // Методы энзимологии. — 1984. — Т. 105. — С. 121–126.

10. Фернандес, Г. С. Х. Эффективные критерии отбора для оценки стрессоустойчивости растений [Текст] / Г. С. Х. Фернандес // Адаптация продовольственных культур к температурному и водному стрессу. — 1992.

11. Маткович Стойшин, М. Оценка стрессоустойчивости генотипов как эффективный способ поддержания производства пшеницы в условиях стресса от засоления [Текст] / М. Маткович Стойшин, С. Петрович, Б. Баняц [и др.] // Устойчивое развитие (*Sustainability*). — 2022. — Т. 14, № 12. — Ст. 6973.

12. Шах, С. Реакция хлорофилла, каротиноидов и измерений SPAD-502 на засоление и нехватку питательных веществ у пшеницы (*Triticum aestivum L.*) [Текст] / С. Шах, Р. Хоуборг, М. Маккейб // Агрономия (*Agronomy*). — 2017. — Т. 7, № 3. — Ст. 61.

13. Саллам, А. Толерантность к засухе у пшеницы и ячменя: достижения в области физиологии, селекции и генетических исследований [Текст] / А. Саллам, А. М. Алкудах, М. Ф. А. Давуд [и др.] // Международный журнал молекулярных наук. — 2019. — Т. 20, № 13.

14. Паудел, Х. Реакция пшеницы на различные абиотические стрессовые условия: Обзор [Текст] / Х. Паудел, Р. Бхандари, А. Дхакал [и др.] // Журнал «Научное наследие» (*Science Heritage Journal*). — 2023. — Т. 7, № 1. — С. 27–31.

15. Мехмуд, М. Влияние засухи, засоления и переувлажнения на пшеницу: физиологические, биохимические реакции и влияние на урожайность [Текст] / М. Мехмуд, З. А. Хан, А. Мехмуд [и др.] // Фитон (*Phyton*). — 2025. — Т. 94, № 4. — С. 1111–1135.

16. Селейман, М. Ф. Солевой стресс у пшеницы: эффекты, механизмы и стратегии управления [Текст] / М. Ф. Селейман, М. Т. Аслам, Б. А. Альхаммад [и др.] // Фитон (*Phyton*). — 2022. — Т. 91, № 4. — С. 667–694.

17. Кумар, А. Влияние дефицита воды (засоление и засуха) на физиологические, биохимические показатели и урожайность сортов пшеницы (*Triticum aestivum*) [Текст] / А. Кумар, С. К. Шарма, К. Лата [и др.] // Индийский журнал сельскохозяйственных наук. — 2018. — Т. 88, № 10. — С. 1624–1632.