

EVALUATION OF GENETIC DIVERSITY: A STUDY ON MORPHOLOGICAL AND PHYSIOLOGICAL TRAITS OF LOCAL AND INTRODUCED DURUM WHEAT (*TRITICUM DURUM* DESF.) GENOTYPES

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Abstract. *Wheat is the most widely consumed staple food in the world and provides more nourishment for humans than any other food source. This study evaluated the genetic parameters of selected morphological and physiological traits using 77 durum wheat genotypes (8 local and 69 introduced). The research was conducted from 2022 to 2024 in the Field Laboratory of Grains and Legumes at Azerbaijan State Agrarian University. The wheat was cultivated in Ganja using a completely randomized design under winter wheat growing conditions. Phenological stages were recorded according to the Kuperman method, from emergence to full maturity. Morphological traits such as plant height (PH, cm) excluding awns, spike length (SL, cm), number of spikelets per spike (SNS), number of grains per spike (GNS), grain weight per spike (GWS), thousand kernel weight (TKW, g), and grain yield (GY, kg/m²) were measured. The longest SL was recorded as 12.10 cm in genotype GDP-647, and the shortest was 5.0 cm in genotype Ganja. Twenty-two genotypes showed superior SL performance compared to the check varieties. In the first year, Ganja-8 had 18 SNS, while in the second year it reached 25. The lowest SNS was 13 in genotype GDP-560. Ganja-1 had the highest GNS with 4.30, and GDP-682 had the lowest with 1.2. TKW ranged widely, from 55.30 g (GDP-669) to 31.30 g (GDP-457). The lowest spike density was found in GDP-597 (17.80), while the highest was 35.0 in Ganja-6 and Ganja-7. The study provided a comparative overview of phenological development in local and introduced genotypes, revealing a significant local adaptation effect in introduced genotypes. Among locals, Ganja-5 and Ganja-8 exhibited high phenological performance. Cluster analysis based on estimates grouped genotypes into four main clusters according to traits such as PH, SL, SNS, GNS, GWS, TKW, and spike density. Notably, local genotypes Ganja-5 and Ganja-8 demonstrated strong phenological development and adaptability, indicating their potential for breeding programs.*

Keywords: *durum wheat, genotype, grain quality, productivity, yield components*

INTRODUCTION

Wheat (*Triticum spp.*) is one of the most vital cereal crops worldwide, contributing significantly to global food security and human caloric intake. Among the wheat species, durum wheat (*Triticum durum* Desf.) plays a prominent role due to its unique grain hardness, high protein content, and superior end-use quality,

especially in pasta and semolina production [4]. As climate change, water scarcity, and emerging diseases increasingly threaten food systems, the improvement of durum wheat through genetic breeding has become a central goal of modern agriculture [6]. The success of any breeding program largely depends on the availability and use of diverse genetic material. Genetic diversity among durum wheat genotypes offers opportunities to select lines with superior traits such as yield potential, drought tolerance, disease resistance, and adaptability to specific agroecological zones [7]. Particularly in dryland regions like Azerbaijan, identifying genotypes that can thrive under fluctuating climatic conditions is vital for stabilizing grain production [5]. Comparing local landraces with introduced germplasm allows breeders to detect useful alleles for adaptive traits and provides insight into genotype \times environment (G \times E) interactions [3]. Local varieties often exhibit long-term adaptation to regional stress factors, while introduced lines may bring new traits or higher yield potential, albeit requiring careful evaluation in the target environments [1]. The evaluation of morphological and physiological traits such as plant height, spike length, grain weight, number of grains per spike, and thousand kernel weight (TKW) remains a critical step in selecting high-performing and resilient genotypes [6]. The integration of phenotypic evaluation with statistical methods such as cluster analysis enhances the identification of promising materials for durum wheat improvement [2]. This study evaluates the genetic diversity and agronomic traits of durum wheat genotypes under drought conditions in the Northern Great Plains (USA), which is essential for the development of drought-tolerant cultivars [8].

MATERIALS AND METHODS

The experiment was conducted during the 2022/2023- 2023/2024 growing season at the Field Laboratory of Grains and Legumes, Azerbaijan State Agrarian University, located in Ganja (468 m above sea level; 40°40'N latitude, 46°20'E longitude). The region has a temperate climate suitable for winter wheat cultivation. A total of 77 durum wheat genotypes were used, consisting of 8 local and 69 introduced lines. The experiment followed a completely randomized design (CRD). Each genotype was sown in one row (2 meters in length) with a row spacing of 25 cm. Standard agronomic practices were applied throughout the growing period. Phenological observations were conducted based on the Kuperman methodology, monitoring key development stages from emergence to full maturity. The following traits were recorded: Plant height (PH, cm): Measured (excluding awns) from 10 randomly selected plants per plot before harvest. Spike length (SL, cm): Measured just before harvest. Number of spikelets per spike (SNS). Number of grains per spike (GNS). Grain weight per spike (GWS)Thousand kernel weight (TKW, g):

Weight of 1000 grains. Grain yield (GY, kg/m²): Determined by weighing harvested grains from each plot.

RESULTS AND DISCUSSIONS

Sowing occurred in early November. Phenological observations showed dynamic development across all genotypes.

Table 1. Average values of agronomic and physiological traits of 77 durum wheat genotypes (2022-2024 growing seasons, Ganja, Azerbaijan).

№	Genbank number	Origin	PH (cm)	SL (cm)	SNS (no)	SPS (no)	GWS (g)	TGW (g)	SD (no)
1	GDP-023	EGY	93.00	6.00	16.50	43.00	3.00	36.00	27.40
2	GDP-044	ARG	105.5	7.00	18.00	40.00	1.80	44.00	26.40
3	GDP-049	ARG	102.0	7.30	21.50	51.00	1.70	41.10	29.70
4	GDP-57	ARG	75.00	8.00	17.50	39.00	2.00	41.30	26.90
5	GDP-078	ESP	82.00	6.50	18.00	53.00	2.40	46.00	28.30
6	GDP-115	CIMMYT	79.50	9.00	21.00	54.00	2.00	46.20	23.50
7	GDP-177	ICARDA	63.50	7.70	20.50	46.00	2.20	42.00	26.40
8	GDP-182	ICARDA	96.00	8.80	20.50	53.00	2.00	36.40	25.50
9	GDP-183	ICARDA	116.0	8.60	18.00	42.00	1.70	40.80	26.20
10	GDP-196	ICARDA	93.00	6.50	16.50	37.00	1.80	39.30	27.10
11	GDP-204	AUS	62.50	7.50	22.00	43.00	2.40	38.40	23.90
12	GDP-207	AUS	79.00	8.80	19.00	52.00	1.40	34.30	24.00
13	GDP-215	AUT	83.50	7.90	18.00	39.00	1.60	42.00	27.00
14	GDP-215	AUT	84.00	8.50	20.50	46.00	1.40	39.40	20.60
15	GDP-216	AUT	119.5	7.00	18.50	43.00	1.40	39.70	28.70
16	GDP-232	ITA	109.5	7.50	21.50	33.00	1.60	39.50	26.20
17	GDP-235	ITA	105.0	8.80	18.00	37.50	2.40	46.00	23.00
18	GDP-238	MAR	90.0	7.70	19.50	47.50	1.80	42.60	32.50
19	GDP-261	ICARDA	88.5	8.50	18.00	47.50	1.80	45.60	21.10
20	GDP-271	ICARDA	91.5	8.00	20.00	42.50	1.80	43.60	24.30
21	GDP-310	ESP	85.50	9.00	21.00	20.00	1.50	42.70	22.20
22	GDP-330	ESP	133.0	11.00	16.00	35.50	1.80	33.50	19.00
23	GDP-332	ESP	88.50	7.70	16.50	51.50	2.00	38.80	20.70
24	GDP-341	FRA	91.00	8.50	22.50	48.50	1.90	42.30	19.40
25	GDP-353	ITA	192.0	8.70	21.50	36.00	1.50	43.50	25.50
26	GDP-375	ITA	69.50	10.00	19.50	42.50	2.00	45.70	21.50
27	GDP-376	ITA	102.0	9.50	17.50	38.00	2.10	47.60	20.50
28	GDP-388	USA	68.50	8.00	20.50	41.00	1.70	41.40	22.10
29	GDP-395	ESP	87.00	8.30	18.00	42.50	1.30	53.70	22.80
30	GDP-397	IND	69.00	7.30	18.50	54.00	1.60	34.60	22.60
31	GDP-403	ALG	67.00	9.00	19.50	55.00	2.00	38.60	23.20
32	GDP-417	ICARDA	72.50	7.90	19.50	41.50	1.40	37.70	24.30
33	GDP-419	ICARDA	75.00	8.50	21.00	50.00	1.60	41.50	20.50

34	GDP-420	ICARDA	75.00	6.90	20.00	58.50	2.10	40.00	28.10
35	GDP-422	ICARDA	88.50	6.20	18.00	44.50	1.70	32.80	32.10
36	GDP-457	FRANCE	94.00	7.30	21.00	46.50	1.80	31.30	27.60
37	GDP-466	FRANCE	71.50	8.50	17.00	62.00	1.60	37.30	25.60
38	GDP-469	FRANCE	71.00	6.00	19.00	47.50	2.40	38.10	24.30
39	GDP-501	FRANCE	82.50	8.90	20.00	59.50	1.90	37.70	29.80
40	GDP-503	FRANCE	92.50	8.50	20.50	66.50	2.20	38.30	19.40
41	GDP-505	FRANCE	63.50	9.50	23.50	61.00	2.80	35.50	24.30
42	GDP-512	FRANCE	102.0	8.00	22.50	49.50	2.60	35.00	25.30
43	GDP-534	FRANCE	68.00	8.00	20.50	37.00	2.30	36.60	25.00
44	GDP-535	FRANCE	98.50	9.30	20.00	41.00	1.70	38.70	23.30
45	GDP-537	FRANCE	59.50	7.70	18.00	51.50	1.50	42.20	24.90
46	GDP-551	ETH	65.00	6.90	21.00	56.50	2.00	36.10	21.40
47	GDP-560	TUR	72.00	6.80	13.00	45.00	1.50	43.10	29.10
48	GDP-566	İSRAEL	78.00	6.80	20.50	38.50	1.60	46.80	25.90
49	GDP-574	KAZ	113.5	7.50	18.00	48.50	1.60	44.60	28.90
50	GDP-590	OMN	111.0	7.20	23.00	51.50	1.60	36.50	31.90
51	GDP-597	ESP	106.5	6.30	22.50	45.50	1.30	41.50	17.80
52	GDP-609	SYR	103.5	8.50	16.00	46.50	1.60	47.60	30.70
53	GDP-611	IRN	99.50	7.90	18.00	46.00	1.80	44.30	20.40
54	GDP-647	TUN	100.0	12.10	17.50	38.50	1.90	35.60	26.30
55	GDP-664	IRQ	85.50	10.00	22.00	37.20	2.30	38.90	23.80
56	GDP-669	PRT	109.5	7.70	18.00	53.50	1.50	55.30	18.40
57	GDP-671	TUN	94.00	8.70	18.50	43.00	1.30	34.90	25.20
58	GDP-682	ETH	90.00	9.00	18.50	47.00	1.20	42.60	20.00
59	GDP-684	CYP	102.0	9.50	18.00	47.00	2.10	45.90	22.60
60	GDP-694	TUN	60.00	9.80	17.50	38.00	1.70	44.10	19.30
61	GDP-700	IRQ	92.50	8.70	21.50	48.50	1.60	45.70	22.70
62	GDP-701	IRN	60.50	7.70	19.00	41.00	3.30	55.30	22.10
63	GDP-705	GRC	69.50	10.50	20.50	45.50	2.00	50.20	21.80
64	GDP-737	UZB	77.50	11.80	17.00	41.00	1.60	42.10	20.90
65	GDP-738	UZB	68.00	7.90	18.50	49.50	1.50	35.50	24.10
66	GDP-741	UZB	86.50	8.00	21.50	49.00	1.60	39.70	30.10
67	GDP-748	ITA	80.00	9.70	19.00	48.50	1.90	47.00	23.70
68	GDP-761	TUN	84.50	8.00	22.50	40.00	2.00	51.00	28.30
69	GDP-762	IRN	88.00	6.70	22.50	47.50	1.70	51.90	32.80
70	Ganja-1	GANJA	134.0	9.20	22.50	52.00	4.30	47.60	23.90
71	Ganja-2	GANJA	107.0	8.80	22.50	45.00	2.30	51.50	25.50
72	Ganja-3	GANJA	95.50	9.40	21.50	48.00	2.30	43.90	19.60
73	Ganja-4	GANJA	77.00	10.40	20.50	45.50	2.00	38.30	19.60
74	Ganja-5	GANJA	91.00	8.00	18.50	45.50	1.60	79.20	25.50
75	Ganja-6	GANJA	118.0	5.00	21.50	42.00	3.20	47.70	35.00
76	Ganja-7	GANJA	95.00	5.90	20.00	51.50	1.80	40.00	32.50
77	Ganja-8	GANJA	107.0	6.10	21.00	40.00	1.90	35.70	35.00

As observed in Table 1, the genotypes demonstrated wide variability across all examined traits, underlining significant genetic diversity within the panel. The tallest plant height was recorded in genotype GDP-353 (192.00 cm), an introduced Italian line, while the shortest was in GDP-537 (59.50 cm), indicating a near threefold difference in stature. Among local genotypes, Ganja-1 (134.00 cm) and Ganja-6 (118.00 cm) showed strong vertical growth. Spike length (SL) ranged from 5.00 cm (Ganja-6) to 12.10 cm (GDP-647), with 22 genotypes exceeding the check varieties in this trait. Notably, GDP-647 (Tunisia) exhibited exceptional performance, making it a promising candidate for increasing spike size in breeding programs. The number of spikelets per spike (SNS) varied considerably. Ganja-8 demonstrated a significant increase in SNS from 18 in the first season to 25 in the second, suggesting excellent environmental responsiveness. GDP-560 (Turkey) recorded the lowest SNS with 13, indicating potential limitations in reproductive structure development. Grain number per spike (GNS) was highest in Ganja-1 (4.30) and lowest in GDP-682 (1.20), highlighting strong reproductive efficiency in some local genotypes. Ganja-1 also had the highest grain weight per spike (GWS), reinforcing its potential as a high-yielding local cultivar. The thousand-kernel weight (TKW) varied from 31.30 g (GDP-457) to 55.30 g (GDP-669), indicating significant differences in grain filling capacity. GDP-669 (Portugal) and Ganja-2 showed superior kernel weights, which are important traits for grain quality and processing. Lastly, spike density (SD) ranged from 17.80 (GDP-597) to 35.0 (Ganja-6 and Ganja-8), with the local varieties displaying notably higher densities, indicative of their strong adaptability and yield potential in local agro-ecological conditions.

Principal Component Analysis

To better understand the interrelationships among the studied morphological and physiological traits, a Principal Component Analysis (PCA) was performed. The analysis identified key components explaining most of the variation in the dataset across 77 durum wheat genotypes. The results are shown in Table 2.

The PCA revealed that PC1 was dominated by plant height (PH), accounting for the largest proportion of total variance (78.46%). This suggests that height is a major distinguishing trait among the genotypes. PC2 was influenced by the number of spikelets per spike (SPS), indicating variation in reproductive structures. PC3 was mainly defined by thousand kernel weight (TKW), a critical indicator of grain size and quality. PC4 received high loadings from both spike density (SD) and number of grains per spike (SNS), suggesting an association between spike compactness and reproductive output. PC5 isolated spike length (SL) and PC7 isolated grain weight per spike (GWS) as relatively independent traits. The first three components collectively explained 96.06% of the total variance, underscoring their importance in the characterization of durum wheat genotypes.

Table 2. Principal Component Analysis (PCA)

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7
PH	0.9952						
SL						0.97765	
SNS					0.9981		
SPS		0.83262	0.54366				
GWS							0.99597
TGW			0.83757				
SD				0.97741			
Eigenvalue	432.61	53.81	43.23	16.09	4.00	1.21	0.44
% variance	78.46	9.76	7.84	2.92	0.73	0.22	0.08

These results can guide breeders in selecting trait-specific genotypes for further improvement and hybridization efforts.

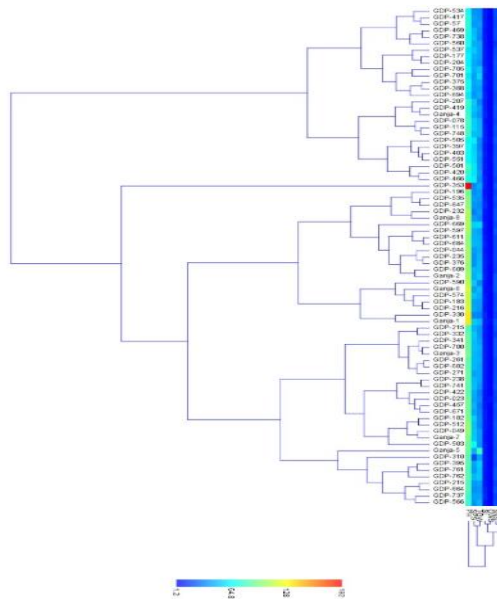


Figure1. Cluster analysis based on estimates grouped the genotypes into four major clusters:

*Cluster I: Subdivided into a and b, included both local and introduced genotypes, indicating shared traits.
 Cluster II: Contained only GDP-353 (Italy), distinguished primarily by its exceptional plant height. Clusters III and IV: Further divided into two subgroups each, consisting of 14 and 7 genotypes, respectively. These clusters were differentiated by traits such as spike density and grain number.*

CONCLUSIONS

This study revealed significant genetic variation among 77 durum wheat genotypes, including 8 local and 69 introduced lines, highlighting a rich genetic resource for durum wheat improvement under Azerbaijan's agro-climatic conditions. Among the local genotypes, Ganja-5 and Ganja-8 stood out with superior traits such as spike density reaching up to 35.0, grain number per spike up to 4.3, and plant height up to 134 cm, indicating their strong local adaptation and phenological stability. These genotypes represent valuable candidates for use as parental lines in breeding programs focused on enhancing yield and stress resilience. Introduced genotypes also showed remarkable traits: GDP-647 (Tunisia) exhibited the longest spike length of 12.10 cm, significantly exceeding the local varieties, while GDP-669 (Portugal) achieved the highest thousand-kernel weight of 55.30 g, a key indicator of grain quality and size. The wide range of trait variability observed—such as plant height ranging from 59.5 cm to 192 cm and thousand-kernel weight varying from 31.3 g to 55.3 g—underscores the extensive genetic diversity present in the panel. Cluster analysis effectively grouped genotypes into four main clusters, allowing for the identification of distinct phenotypic profiles and facilitating targeted breeding strategies. This grouping enables breeders to efficiently select genotypes with complementary traits to maximize genetic gains. The combination of locally adapted genotypes with superior yield components and promising introduced lines with desirable traits offers a robust framework for durum wheat improvement in Azerbaijan. Harnessing this genetic diversity will be critical to developing new varieties capable of thriving under local environmental challenges while meeting demands for productivity and grain quality.

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