

Evaluation of Genetic Divergence in Durum Wheat (*Triticum durum* L.) for Yield Improvement

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Abstract

For assessment of the genetic divergence among fifty durum wheat (*Triticum durum* L.) genotypes, the present investigation was carried out at Agricultural Research Station, Niphad (MS) during *rabi* 2023–24. Observations were recorded on nine important traits, and analysis of variance revealed highly significant differences among genotypes, indicating the presence of substantial genetic variability. Considerable variation was observed for days to heading and maturity, plant height, tiller number, spike length, spikelets spike⁻¹, grains spike⁻¹, 1000-grain weight, and grain yield plot⁻¹, suggesting good scope for genetic improvement through selection and breeding. Genetic divergence was estimated using Mahalanobis's D² statistics, and the fifty genotypes were grouped into nine clusters by Tocher's method. The clustering pattern revealed wide inter- and intra-cluster distances, confirming the existence of substantial genetic diversity and offering valuable opportunities for crop improvement. Cluster mean analysis further demonstrated significant differences among clusters for all studied traits, highlighting diverse genetic backgrounds. Among the genotypes, DDW-47, NIDW-1149, and HD-8381 exhibited superior performance for yield and yield-attributing traits, while Jay and GW-1339 were characterized as earliest maturing and shortest. These genotypes, being diverse and promising, can serve as potential parents in crossing programs aimed at enhancing yield potential and adaptability of durum wheat.

Key words : Durum wheat, Genetic divergence, Mahalanobis D², Tocher's method, Cluster analysis, Genetic variability, Yield components, Plant breeding.

Wheat is one of the world's most important cereal crops, with *Triticum aestivum* L. (2n = 42) and *Triticum durum* L. (2n = 28) being the major cultivated species in India. Durum wheat, a tetraploid species (2n = 4x = 28), originated from domesticated emmer around 7000 BC and is recognized as the hardest form of wheat, well adapted to semi-arid environments. Its predominantly self-pollinated nature, though capable of 0–6% cross-pollination, is supported by a chasmogamous floral structure. Morphologically, durum wheat is characterized by tall, sturdy culms, waxy leaves, and dense, prominently awned golden spikes. It exhibits considerable variability in key agronomic traits such as plant height, spike length, spikelet number, tillering, and thousand-grain weight, making it a valuable resource for breeding

programs targeting stress tolerance and grain quality improvement.

Durum wheat is widely used for producing semolina, pasta, macaroni, couscous, and unleavened bread due to its high protein, rich yellow pigment, and favorable gluten properties. It contains higher levels of protein, iron, copper, zinc, and B-complex vitamins than rice and bread wheat (Dodake *et al.*). Additionally, its low-molecular-weight glutenins enhance dough extensibility, and its antioxidant and anthocyanin content contribute to health benefits, though it lacks the Glu-D1 locus associated with superior bread-making quality (Saini *et al.*). India is the world's second-largest wheat producer, with 32.76 million hectares under wheat and 117.5 million tonnes of production during 2024-25. Durum wheat accounts for about 5-6% of this

area and production (Anonymous 1). The Malwa plateau of Madhya Pradesh is especially renowned for high-quality durum wheat (Sakuruet *al.*). In Maharashtra, wheat is grown on 10.40 lakh hectares with 19.42 lakh tonnes of production, of which durum contributes about 5-6% (Anonymous 2). Wheat yield is a complex quantitative trait influenced by multiple genes and environmental factors, making direct selection difficult. Therefore, understanding the relationship between yield and its component traits is essential for improving selection efficiency and plant architecture. Genetic divergence analysis using Mahalanobis D^2 statistics (Mahalanobis, 1936) is widely employed to identify diverse parents and quantify trait contributions, thereby supporting effective hybridization strategies in crop improvement.

Material and methods

The experiment entitled “Evaluation of Genetic Divergence in Durum Wheat (*Triticum durum* L.) for Yield Improvement” was conducted at the Agricultural Research Station, Niphad, during the Rabi 2023–24 season. Fifty durum wheat genotypes obtained from the Agricultural Research Station, Niphad, were used as the experimental material for the study. The list of genotypes is presented in Table 1.

The experiment was laid out in a Randomized Block Design (RBD) with 50 treatments and three replications. The crop was grown under timely sown irrigated conditions during the Rabi 2023–24 season. Each genotype was planted in a plot measuring $2.50 \times 0.40 \text{ m}^2$, consisting of two rows spaced 20 cm apart. A recommended fertilizer dose of 120:60:40 kg NPK per hectare was applied to ensure optimum nutrient availability. Observations were recorded on nine important quantitative traits, including days to 50% heading, days to maturity, plant height (cm),

spike length (cm), number of spikelets per spike, number of grains per spike, number of tillers per running meter, thousand-grain weight (g), and grain yield per plot (kg). The recorded data were analyzed using analysis of variance (ANOVA) appropriate for the Randomized Block Design, following the procedure outlined by Panse and Sukhatme (1967). The analysis of divergence was carried out by D^2 statistics of Mahalanobis' (1936) as described by Rao (1952). The fifty genotypes were classified into nine clusters using Tocher's method.

Result and discussion

Mean performance of genotypes : The mean performance of fifty durum wheat genotypes revealed substantial variability across all nine traits studied. Days to 50% heading ranged from 61.33 to 76.33 days, with GW-1339 and Jay being the earliest, while NIDW-1520 was the latest. Days to maturity varied between 106.33 and 123.33 days, with Jay and GW-1339 maturing earliest and UAS-415 taking the longest.

Table 1. Durum wheat genotypes used for the study

Genotype	Genotype	Genotype
AKDW 4021	Jay	NIDW 1561
AKDW 5012	MACS 3061	NIDW 1583
AKDW 5013	MACS 3949	NIDW 1584
AKDW 9147-16	MACS 4028	NIDW 1586
DDW 47	MACS 4058	NIDW 1590
DDW 48	MACS 4059	NIDW 1594
Gulab	MACS 4100	NIDW 295
GW 1339	Motia	PDW 291
GW 1346	MPO 1255	PDW 314
HD 4502	MPO 1336	PDW 485
HD 4672	NIDW 1149	UAS 415
HD 4728	NIDW 1499	UAS 428
HD 8381	NIDW 15	UAS 440
HD 8681	NIDW 1520	UAS 453
HI 8802	NIDW 1585	UAS 466
HI 8805	NIDW 1542	Vijay
HI 8826	NIDW 1557	

Table 2. Mean Performance of Fifty Durum Wheat Genotypes for Yield and Yield Attributing Characters

Genotype	Days to 50% heading	Days to maturity	Plant height (cm)	Spike length (cm)	No. of spike-lets spike ⁻¹	No. of grains spike ⁻¹	Tillers running ⁻¹ meter	1000 grain weight (g)	Grain yield plot ⁻¹ (kg)
	1	2	3	4	5	6	7	8	9
AKDW 4021	64.00	113.00	80.69	6.04	18.53	56.27	84.00	45.63	0.595
AKDW 5012	63.33	110.67	83.11	6.58	17.27	51.73	64.67	40.20	0.456
AKDW 5013	65.33	113.33	81.68	6.96	18.80	57.10	91.67	46.33	0.627
AKDW 9147-16	64.00	109.67	86.95	7.09	18.20	55.87	78.00	43.77	0.558
DDW-47	71.67	117.33	80.41	6.31	18.53	56.93	93.67	46.67	0.700
DDW-48	76.00	122.00	83.49	7.18	18.00	54.60	75.67	43.14	0.532
Gulab	64.67	110.67	99.38	7.63	17.33	51.08	64.67	40.25	0.457
GW-1339	61.33	106.33	91.14	9.33	17.07	49.83	61.67	37.97	0.427
GW-1346	64.33	109.67	107.00	7.14	18.67	56.40	88.00	45.93	0.609
HD-4502	72.00	121.33	81.67	6.57	16.57	48.20	61.00	38.10	0.360
HD-4672	63.67	109.00	92.15	6.77	17.60	52.60	72.00	42.34	0.510
HD-4728	65.00	111.33	88.34	5.89	17.53	52.20	68.67	41.40	0.498
HD-8381	70.00	118.33	81.17	6.77	18.80	57.20	91.67	46.39	0.649
HD-8681	69.33	116.33	86.35	6.79	18.20	55.60	78.00	43.73	0.550
HI-8802	74.67	122.33	118.50	8.36	18.27	55.93	78.00	43.80	0.568
HI-8805	71.33	119.00	108.43	7.72	18.33	56.00	78.67	44.13	0.574
HI-8826	65.33	110.33	92.01	7.99	18.53	56.23	83.67	45.37	0.591
Jay	61.33	106.33	89.46	6.61	17.13	50.53	62.33	39.43	0.446
MACS-3061	75.67	121.33	108.28	6.86	18.13	54.80	76.67	43.23	0.540
MACS-3949	65.33	111.67	76.04	7.35	18.13	54.87	77.67	43.37	0.548
MACS-4028	66.33	112.67	98.17	6.55	17.87	53.20	75.00	42.67	0.518
MACS-4058	63.67	108.67	124.75	7.93	17.40	51.87	66.33	41.23	0.481
MACS-4059	66.67	113.33	110.16	6.94	17.40	51.80	66.00	40.57	0.477
MACS-4100	65.67	111.33	77.93	6.89	18.07	53.60	75.33	42.77	0.527
Motia	66.33	112.33	97.23	7.09	17.33	51.47	65.00	40.33	0.477
MPO-1255	62.67	107.00	108.24	6.75	17.80	53.20	74.67	42.57	0.517
MPO-1336	68.33	115.33	95.34	6.76	17.60	52.40	69.33	42.13	0.506
NIDW-1149	65.67	111.33	88.48	8.31	18.87	57.27	93.00	46.23	0.680
NIDW-1499	68.33	115.67	85.04	6.93	16.67	49.30	61.00	37.90	0.397
NIDW-15	70.67	119.33	104.28	7.39	18.07	54.40	75.33	42.87	0.532
NIDW-1520	76.33	123.00	89.86	7.72	18.67	56.40	88.67	45.63	0.612
NIDW-1585	65.67	111.67	83.56	6.16	18.33	56.00	78.33	44.10	0.573
NIDW-1542	70.00	117.00	84.63	6.86	18.53	56.20	82.67	45.03	0.583
NIDW-1557	67.00	113.33	88.03	6.42	17.07	50.00	62.00	38.57	0.436
NIDW-1561	71.33	122.00	98.65	6.66	17.73	53.00	73.67	42.53	0.513
NIDW-1583	67.33	113.00	82.64	7.16	17.53	52.27	68.67	41.90	0.502
NIDW-1584	67.33	113.67	76.34	6.91	17.13	50.67	62.67	40.00	0.447
NIDW-1586	66.33	112.67	70.39	6.92	17.93	53.40	75.33	42.70	0.520
NIDW-1590	69.67	119.00	96.05	8.10	17.67	52.87	72.67	42.40	0.513
NIDW-1594	74.33	122.67	97.02	6.83	17.13	51.00	63.00	40.17	0.450
NIDW-295	74.33	121.67	94.88	6.13	17.47	52.20	68.67	41.30	0.497

Table 2. Contd.

Genotype	Days to 50% heading	Days to maturity	Plant height (cm)	Spike length (cm)	No. of spike-lets spike ⁻¹	No. of grains spike ⁻¹	Tillers running ⁻¹ meter	1000 grain weight (g)	Grain yield plot ⁻¹ (kg)
	1	2	3	4	5	6	7	8	9
PDW-291	71.67	119.67	81.83	7.47	17.07	50.53	62.33	38.69	0.440
PDW-314	70.33	118.33	88.64	7.39	17.40	52.00	67.67	41.01	0.487
PDW-485	71.33	119.67	85.47	8.14	18.40	56.20	80.67	44.40	0.580
UAS-415	76.00	123.33	81.87	6.79	17.60	52.47	70.33	42.23	0.507
UAS-428	70.67	118.33	89.58	7.22	18.33	56.20	81.00	44.60	0.580
UAS-440	66.00	112.67	93.72	6.75	18.73	56.60	91.67	46.10	0.616
UAS-453	73.00	121.33	80.46	6.23	18.73	56.60	92.00	46.23	0.620
UAS-466	65.33	112.00	86.43	5.88	18.53	56.27	85.67	44.47	0.609
Vijay	64.33	109.67	93.81	6.43	17.40	48.47	68.00	40.99	0.486
Mean	68.22	115.03	91.00	7.03	17.88	53.64	74.94	42.67	0.530
Range	61.33-76.33	106.33-123.33	76.00-124.75	5.88-9.33	16.57-18.87	48.20-57.27	61.00-93.67	37.90-46.67	0.360-0.700
S.E.	1.1912	2.0343	1.7033	0.1491	0.4915	1.2859	3.4945	1.9742	0.0307
C.D. at 5%	3.3430	5.7090	4.7803	0.4183	1.3792	3.6089	9.8070	5.5406	0.0860
C.V.	3.0243	3.0630	3.2422	3.6713	4.7602	4.1526	8.0766	8.0137	10.0256

Plant height showed wide variation (76.0-124.7 cm), with MACS-3949 being the shortest and MACS-4058 the tallest. Spike length ranged from 5.88 to 9.33 cm, with GW-1339 possessing the longest spikes. The number of spikelets per spike varied between 16.6 and 18.9, with NIDW-1149 recording the maximum. Grains per spike ranged from 48.2 to 57.3, with NIDW-1149, HD-8381, and AKDW-5013 being superior. The number of tillers per running meter varied from 61.00 to 93.67, with DDW-47 and NIDW-1149 showing the highest tillering ability. Thousand-grain weight ranged from 37.9 to 46.7 g, with DDW-47, HD-8381, and AKDW-5013 performing best. Grain yield per plot showed considerable variation (0.36-0.70 kg), with DDW-47, NIDW-1149, and HD-8381 emerging as the highest yielders. Overall, several genotypes such as DDW-47, NIDW-1149, AKDW-5013, and HD-8381 exhibited superior performance for multiple yield-contributing

traits, highlighting their potential use in breeding programmes.

Table 3. Analysis of variance for nine different characters in durum wheat

Characters	Mean sum of squares		
	Repli-cation (2)	Geno-type (49)	Error (98)
Days to 50% heading	5.420	50.729**	4.256
Days to maturity	37.686	72.241**	12.414
Plant Height (cm)	12.856	377.79**	8.704
Spike length (cm)	0.166	1.435**	0.066
No. of spike-lets spike ⁻¹	1.258	1.277*	0.724
No. of grains spike ⁻¹	9.060	19.884**	4.960
No. of tillers running ⁻¹ meter	65.940	289.470**	36.633
1000 grain weight (gm)t	2.406	18.173*	11.690
Grain yield plot ⁻¹ (kg)	0.004	0.015**	0.002

* and ** indicate significant at 5 and 1 per cent level respectively.

Note: Figures in the parenthesis indicates the degrees of freedom

Analysis of Variance : The analysis of variance (ANOVA) showed that the mean sum of squares due to genotypic differences was highly significant for all traits studied, indicating substantial genetic variability among the wheat genotypes. This variability was evident for days to 50% heading, days to maturity, plant height, number of tillers per running meter, spike length, number of spikelets per spike, number of grains spike⁻¹, 1000-grain weight, and grain yield plot⁻¹. Such variability suggests good scope for selection and genetic improvement in wheat. The mean sum of squares for various traits is presented in Table.3. Similar results were reported by Sen *et al.* (2022), emphasizing that systematic crossing in self-pollinated crops like wheat effectively generates useful variability in succeeding generations.

Genetic Divergence : Genetic divergence among the fifty durum wheat genotypes was assessed using the Mahalanobis D² statistic (Mahalanobis, 1936), based on nine quantitative traits. This analysis helps identify genetically diverse parents for effective hybridization and selection. Cluster analysis using Tocher's

method (Rao, 1952) grouped the genotypes into nine distinct clusters, indicating substantial genetic variability within the material studied, which can be exploited in future breeding programmes.

Cluster Formation : Using Tocher's method, the 50 genotypes were grouped into nine clusters. Cluster I was the largest, comprising 27 genotypes, followed by Cluster IV with 10 genotypes and Cluster II with 7 genotypes. Clusters III, V, VI, VII, VIII, and IX were monogenotypic, each containing a single genotype. The distribution of genotypes across clusters is presented in Table 4.

Intra-and Inter-Cluster Distance : The intra- and inter-cluster D² values are presented in Table 5. Among the multi-genotype clusters, the highest intra-cluster distance was recorded for Cluster IV (D² = 3.85), followed by Cluster II (D² = 3.71) and Cluster I (D² = 3.32), indicating greater genetic variability within these groups. Clusters III, V, VI, VII, VIII, and IX showed zero intra-cluster distance as they were monogenotypic. The highest inter-cluster divergence was observed between Cluster II and

Table 4. Distribution of 50 genotypes into different clusters

Cluster number	No. of genotypes included	Genotypes
1	27	HD 8681, NIDW 1542, UAS 428, AKDW 9147-16, NIDW 1583, MACS 4100, MACS 3949, AKDW 5013, HD 8381, NIDW 1585, UAS 440, HD 4672, PDW 314, MPO 1336, UAS 466, AKDW 4021, AKDW 5013, MACS 4028, HD 4728, NIDW 1557, Vijay, Jay, Motia, NIDW 1499, NIDW 1561, NIDW 1584, PDW 291
2	7	DDW 47, UAS 453, DDW 48, UAS 415, NIDW 1520, PDW 485, NIDW 1586
3	1	Gulab
4	10	HI 8805, NIDW 15, MACS 3061, MACS 4059, GW 1346, MPO 1255, NIDW 1590, NIDW 1594, NIDW 295, HI 8826
5	1	HD 4502
6	1	NIDW 1149
7	1	HI 8802
8	1	MACS 4058
9	1	GW 1339

Cluster VIII ($D^2 = 9.98$), followed by Cluster V–VIII ($D^2 = 9.75$) and Cluster V–VII ($D^2 = 9.34$). These cluster pairs represent the most genetically diverse combinations and may be useful for hybridization to maximize heterosis. The lowest inter-cluster distance occurred between Cluster III and Cluster IV ($D^2 = 3.37$), indicating close genetic similarity.

Cluster-wise comparisons further revealed that :

1. Cluster I was most divergent from Cluster VIII ($D^2 = 8.46$) and closest to Cluster V ($D^2 = 4.08$).
2. Cluster II showed maximum distance from Cluster VIII ($D^2 = 9.98$) and minimum from Cluster VI ($D^2 = 4.88$).

Table 5. Average intra and inter cluster D^2 and D values (in parenthesis) of 9 clusters from 50 genotypes of durum wheat

Cluster	I	II	III	IV	V	VI	VII	VIII	IX
I	11.02 (3.32)	19.00 (4.36)	17.13 (4.14)	23.23 (4.82)	16.64 (4.08)	29.48 (5.43)	64.96 (8.06)	71.57 (8.46)	42.77 (6.54)
II		13.76 (3.71)	33.52 (5.79)	33.75 (5.81)	24.60 (4.96)	23.81 (4.88)	69.55 (8.34)	99.60 (9.98)	51.26 (7.16)
III			0.00 (0.00)	11.35 (3.37)	25.80 (5.08)	28.62 (5.35)	30.58 (5.53)	26.41 (5.14)	17.97 (4.24)
IV				14.82 (3.85)	35.64 (5.97)	32.26 (5.68)	27.45 (5.24)	33.64 (5.80)	40.06 (6.33)
V					0.00 (0.00)	57.30 (7.57)	87.23 (9.34)	95.06 (9.75)	52.99 (7.28)
VI						0.00 (0.00)	46.64 (6.83)	73.78 (8.59)	26.83 (5.18)
VII							0.00 (0.00)	18.49 (4.30)	49.70 (7.05)
VIII								0.00 (0.00)	55.05 (7.42)
IX									0.00 (0.00)

Table 6. Clusters mean performance for 9 characters in durum wheat

Characters	Days to 50% heading	Days to maturity	Plant height (cm)	Spike length (cm)	No. of spike-lets spike ⁻¹	No. of grains spike ⁻¹	Tillers running ⁻¹ meter	1000 grain weight (g)	Grain yield plot ⁻¹ (kg)
Clusters	1	2	3	4	5	6	7	8	9
I	66.79	113.64	86.95	6.75	17.83	53.41	74.02	42.46	0.52
II	72.95	119.90	81.71	7.04	18.27	55.23	82.33	44.43	0.58
III	64.67	110.67	99.38	7.63	17.33	51.08	64.67	40.25	0.46
IV	69.50	116.33	102.64	7.18	17.92	53.89	74.73	42.85	0.53
V	72.00	121.33	81.67	6.57	16.57	48.20	61.00	38.10	0.36
VI	65.67	111.33	88.48	8.31	18.87	57.27	93.00	46.23	0.68
VII	74.67	122.33	118.50	8.36	18.27	55.93	78.00	43.80	0.57
VIII	63.67	108.67	124.75	7.93	17.40	51.87	66.33	41.23	0.48
IX	61.33	106.33	91.14	9.33	17.07	49.83	61.67	37.97	0.43
Mean	67.92	114.50	97.25	7.68	17.73	52.97	72.86	41.92	0.512

3. Cluster III was closest to Cluster IV ($D^2 = 3.37$).
4. Cluster IV showed high divergence with Cluster V ($D^2 = 5.97$).
5. Cluster V and Cluster VIII formed one of the most divergent pairs ($D^2 = 9.75$).
6. Cluster VII was highly distant from Cluster V ($D^2 = 9.34$) but closest to Cluster VIII ($D^2 = 4.30$).
7. Cluster IX exhibited maximum divergence with Cluster II ($D^2 = 7.16$) and minimum with Cluster III ($D^2 = 4.24$).

Similar patterns of genetic divergence and clustering in wheat have been reported by Barman *et al.* (2021), Bhattarai *et al.* (2017), Poddar *et al.* (2022), and Shyam *et al.* (2018), emphasizing that genetically diverse clusters serve as effective sources for selecting parents to generate wider variability in breeding programmes.

Cluster Means : The mean performance of clusters for the 15 traits studied (Table 6) revealed considerable variability among the genotypes. For days to 50% heading, the earliest flowering was observed in Cluster IX (61.33 days), followed by Cluster VIII (63.67 days), whereas Clusters VII, II, and V exhibited delayed flowering. A similar trend was noted for days to maturity, with Cluster IX (106.33 days) and Cluster VIII (108.67 days) maturing earliest, while Clusters VII, V, and II showed the latest maturity. Plant height varied widely across clusters, ranging from 81.67 cm in Cluster V to 124.75 cm in Cluster VIII, which, along with Cluster VII, contained the tallest genotypes. Spike length was highest in Cluster IX (9.33 cm) and lowest in Clusters V, I, and II. The maximum number of spikelets per spike was recorded in Cluster VI (18.87), followed by Clusters VII and II, while Clusters V and IX showed lower values.

Cluster VI also exhibited the highest number of grains per spike (57.27) and maximum tiller count per running meter (93.00), whereas Cluster V consistently recorded the lowest means for these traits. For 1000-grain weight, Cluster VI again showed superiority (46.23 g), followed by Cluster II, while the lowest values were found in Clusters IX and V. Grain yield per plot was highest in Cluster VI (0.68 kg) and lowest in Cluster V (0.36 kg). Overall, Cluster VI performed best for most of the yield-contributing traits, indicating its potential value in breeding programmes.

Per cent Contribution of Traits to Genetic Divergence :

The contribution of nine traits to the total genetic divergence among the genotypes is presented in Table 7. Plant height was the most influential trait, accounting for 45.80% of the total divergence, followed by spike length (26.78%), days to 50% heading (15.18%), and number of tillers per running meter (8.49%). Moderate contributions were observed from grain yield per plot (2.29%), number of grains per spike (1.06%), and days to maturity (0.41%). In contrast, number of spikelets per spike and 1000-grain weight showed no contribution to divergence. Notably, plant height and spike length together accounted

Table 7. Percent Contribution of different characters for divergence

Characters	No. of times appearing first in the ranking	Contribution %
Days to 50% heading	186	15.18
Days to maturity	5	0.41
Plant height (cm)	561	45.80
Spike length (cm)	328	26.78
Number of spike-lets spike ⁻¹	0	0.00
Number of grains spike ⁻¹	13	1.06
Tillers per running mete	104	8.49
1000 grain weight (gm)	0	0.00
Grain yield plot ⁻¹ (kg)	28	2.29

for 72.58% of the total divergence, indicating their major role in differentiating the genotypes and highlighting their importance in hybridization and selection strategies.

Conclusion

The assessment of fifty durum wheat genotypes demonstrated substantial genetic variability across all nine traits studied. Genotypes such as DDW-47, NIDW-1149, and HD-8381 performed exceptionally well for grain yield and its contributing traits, whereas Jay and GW-1339 were identified as the earliest maturing and shortest entries. The greatest inter-cluster divergence was observed between Clusters II and VIII, indicating their potential usefulness as parents in hybridization. The presence of genotypes from the same geographical origin in different clusters further confirmed that genetic divergence is not solely influenced by geographic distance. Overall, the genetically diverse and high-performing genotypes identified in this study offer valuable potential for inclusion in future breeding programmes aimed at improving durum wheat productivity.'

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