

## Phenotypic Diversity among Fennel (*Foeniculum Vulgare*) Germplasm of Pakistan

Shumaila Khalil

*National Agricultural Research Centre, Islamabad, Pakistan, arifakhan149149@gmail.com*

Shazia Erum

*National Agricultural Research Centre, Islamabad, Pakistan*

Mahrine Rashid

*National Agricultural Research Centre, Islamabad, Pakistan*

Arifa Khan

*National Agricultural Research Centre, Islamabad, Pakistan, arifakhan149149@gmail.com*

Asif Javaid

*National Agricultural Research Centre, Islamabad, Pakistan*

*See next page for additional authors*

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### Cover Page Footnote

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### Authors

Shumaila Khalil, Shazia Erum, Mahrine Rashid, Arifa Khan, Asif Javaid, Areej Abbasi, and Irum Raza

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## PHENOTYPIC DIVERSITY AMONG FENNEL (*FOENICULUM VULGARE*) GERMPLASM OF PAKISTAN

SHUMAILA KHALIL<sup>1</sup>, SHAZIA ERUM<sup>1</sup>, MAHRINE RASHID<sup>1</sup>, ARIFA KHAN\*<sup>1</sup>, ASIF JAVAID<sup>1</sup>,  
AREEJ ABBASI<sup>1</sup>, AND IRUM RAZA<sup>1</sup>

<sup>1</sup>National Agricultural Research Centre, Islamabad, Pakistan

\*Corresponding author's email: arifakhan149149@gmail.com

### ABSTRACT

Fennel is facing continuous challenge with reference to biotic and abiotic stresses that can be solved with the knowledge of available germplasm of fennel in the country or worldwide. Selection of fennel genotype on the basis of research interest can never been accomplished without gene pool. The aim of the present study was to explore the phenotypic diversity among selective fennel accession and identify lines having high yielding potential. In the present study thirty fennel accessions were sown in PGRI, NARC. Irrigation practice was carried out during the growing period. Data was recorded during different growth stages and after harvesting. Nine morphological parameters under study include plant height, number of umbels/plant, umbel diameter, rays produced/umbel, fruits produced/umbel, fruit color and fruit shape. Statistical analysis was performed using ANOVA, Tukey Honest Significance Test and Multivariate cluster Analysis using Minitab Software version 20.0. High diversity was observed among the quantitative traits of thirty accessions. Qualitative traits of accessions from similar region had considerable resemblance. Fennel germplasm collected from Punjab gives outstanding performance with reference to phenotypic traits. Accessions were identified as potential sources including: 21293 (maximum plant height, Punjab, Jhang, Chiniot), 21209 ( great height, Punjab, Faisalabad), 21737 (short height, Punjab, Layyah, Karore Chak-84) 21699 (maximum number of rays/umbel, Punjab, Pakpattan) and 21722 (maximum number of umbels , Punjab, Narowal, Talwandi Bhandran in short 21722 due to high yield was identified as potential sources to be included in future breeding programs for the improvement of fennel varieties.

**Key words:** Phenotypic diversity, quantitative traits, germplasm.

### INTRODUCTION

Fennel (*Foeniculum vulgare*) is an annual, biennial or perennial herb, native to Mediterranean region and grown throughout Asia, North America and Europe. A cosmopolitan species, Fennel is commonly cultivated from the plains to 2000 m and has a wide distribution. It was grown by romans for its aromatic fruits and edible fleshy gardens (Soleymani and Shahrajabian, 2012; Abubacker, 2011). Principal fennel producing countries include India, Argentina, China, Indonesia, Russia, Japan and Pakistan (Volak and Stodola, 1998). India is leading producer of fennel followed by Syria, Egypt,

Turkey, Germany, Spain and Pakistan. Fennel is not cultivated on commercial scale in Pakistan but the farmers almost all over Pakistan grow on a small scale for their domestic use only (Ayub et al., 2008). Fennel has wide range of health benefits and is used for treatment of abdominal pains, antiemetic, aperitif, arthritis, cancer, colic in children, conjunctivitis, constipation, depurative, diarrhea, dieresis, emmenagogue, fever, flatulence, gastralgia, gastritis, insomnia, irritable colon, kidney ailments, laxative, leucorrhea, liver pain, mouth ulcer, and stomachache. Phytoconstituents derived from fennel are known to exhibit insecticidal activity (Rather et al., 2016).

Excellent efficacy of essential oil of fennel against *M. Persicae* indicates high prospects of environmentally safe insecticide against aphids (Pavela, 2018). Aqueous extracts of fennel exhibit bactericidal activity against *Enterococcus faecalis*, *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Salmonella typhimurium*, and *Shigella flexneri* (Kooti et al., 2015). Supplementing chicken feed with fennel boosts poultry health and productivity and protects against several infectious diseases (Khan et al., 2022). Despite diverse uses of fennel, it is not a commonly grown crop in Pakistan as fennel is facing continuous challenge with reference to insufficient variety information and availability, biotic and abiotic stresses which can be solved with the knowledge of available germplasm of fennel in the country or worldwide. Selection of genotype on the basis of research interest can never be accomplished without gene pool. Therefore, aim of present study is to explore phenotypic diversity among selective fennel accession and identify lines having yielding potential and adapted to agro-environmental condition of Pakistan.

## MATERIAL AND METHODS

Thirty fennel accessions obtained from Gene Bank, NARC (National Agriculture Research Centre) Islamabad Pakistan which were previously collected from the different agro-ecological zones of Pakistan, 5 accessions from KPK (Accession No. 020553, 021020, 21027, 021731, 021742), three accessions from Sindh (Accession No. 021761, 021760, 021758), twenty accessions from Punjab (Accession No. 020568, 020861, 020899, 021140, 21209, 021254, 021277, 021293, 021358, 021384, 021426, 021689, 021694, 021699, 021710, 021710, 021722, 021725, 021737, 021739) and one accession from

Baluchistan (Accession No. 020968) were used in this study. The experiment was conducted at PGRP, PGRI (Plant Genetic Resource Institute) NARC, Islamabad, during (2021-2022) located at 33°67'72" E longitude and 73°13'96" N latitude where the mean annual temperature fluctuates between 10 °C And 12 °C with a mean annual rainfall up to 1500 mm. The experiment was conducted at green house. The layout was Randomized Complete Block Design with three replications. The soil was amended by adding compost to depth of 3-4 inches. Seeds were sown manually with 18 inches spacing between rows and 6 inches between plants in a row. Plants were irrigated during different growth stages. Morphology of all fennel accession was characterized by eight agronomic traits on three randomly selected plants per accession. The traits measured were plant height, number of umbel/plants, diameter of umbel, number of rays/umbel, number of fruits/ umbel, weight of thousand fruits, fruit color and fruit shape. Descriptive stats is used to measure the differences in the means and standard error of each agronomic trait between accessions by applying analysis of variance and Tukey Range tests whereas, Minitab 20.0 software package was used to estimate the phylogenetic relationship between accessions through Multivariate cluster analysis.

## RESULTS AND DISCUSSION

Phenotypic characterization of thirty accessions of *Foeniculum vulgare* was conducted at NARC. Results were recorded on quantitative and qualitative parameters. Quantitative trait parameter under study were plant height, number of umbels/plant, diameter of umbel, rays/umbel, fruits/umbel and weight of 1000 fruits. Qualitative trait parameters include fruit color, fruit shape and fruit splitting (Table 1 to Table 5).

**Table 1: Mean values of quantitative traits of *Foeniculum vulgare*.**

Code no.	Accession Number	Origin	Plant Height	Umbels/ Plant	Diameter Of Umbel	Rays /Umbel	Fruits /Umbel	Weight of 1000 Fruits
1	20553	Haripur, KPK	47.66 <sup>B</sup>	45.33 <sup>CD</sup>	6.33 <sup>FGHIJK</sup>	12 <sup>BCDEFG</sup>	56.33 <sup>IJ</sup>	6.1 <sup>IJKL</sup>
2	20568	Faisalabad, Punjab	39 <sup>CDEF</sup>	19 <sup>HIJK</sup>	9.33 <sup>CDE</sup>	6.3 <sup>HI</sup>	13.67 <sup>KL</sup>	12.2 <sup>BCD</sup>
3	20861	Attock, Punjab	44 <sup>BC</sup>	10.66 <sup>JKL</sup>	3 <sup>L</sup>	5.33 <sup>I</sup>	36.33 <sup>JK</sup>	10.2 <sup>DEF</sup>
4	20968	Quetta, Baluchistan	34.33 <sup>DEFG</sup>	23.66 <sup>FGHIJ</sup>	8.33 <sup>DEFG</sup>	13.66 <sup>BCDE</sup>	250.66 <sup>BC</sup>	4.6 <sup>KL</sup>
5	21027	Mansehra, KPK	35 <sup>DEFG</sup>	16.33 <sup>HIJK</sup>	10.83 <sup>BCD</sup>	11 <sup>CDEFGH</sup>	130.33 <sup>EF</sup>	11.4 <sup>BCDE</sup>
6	21140	Faisalabad, Punjab	42.66 <sup>BCD</sup>	14.66 <sup>FGHI</sup>	5.16 <sup>IJKL</sup>	8.1 <sup>FGHI</sup>	95.33 <sup>GH</sup>	8.4 <sup>FGHI</sup>
7	21209	Faisalabad, Punjab	49.96 <sup>B</sup>	22.66 <sup>GHIJ</sup>	6.16 <sup>GHIJK</sup>	9.33 <sup>EFGHI</sup>	65 <sup>HIJ</sup>	9.2 <sup>EFGH</sup>
8	21254	Jhang, Punjab	47.9 <sup>BC</sup>	19 <sup>HIJK</sup>	13.76 <sup>A</sup>	14.66 <sup>BCDE</sup>	283 <sup>B</sup>	9.6 <sup>EFG</sup>
9	21277	Jhang, Punjab	38.66 <sup>CDEF</sup>	11.66 <sup>JKL</sup>	8.16 <sup>EFGH</sup>	15.33 <sup>ABCD</sup>	156 <sup>DEF</sup>	13.06 <sup>ABC</sup>
10	21293	Jhang, Punjab	61 <sup>A</sup>	14.33 <sup>FGHI</sup>	11.66 <sup>ABC</sup>	7.33 <sup>GHI</sup>	127.33 <sup>EF</sup>	7.7 <sup>GHIJ</sup>
11	21358	Layyah, Punjab	42 <sup>BCDE</sup>	14.66 <sup>FGHI</sup>	7.66 <sup>EFGHI</sup>	10.66 <sup>CDEFGHI</sup>	38.33 <sup>JK</sup>	5.1 <sup>JKL</sup>
12	21426	Attock, Punjab	45.33 <sup>BC</sup>	7.6 <sup>KL</sup>	4.33 <sup>KL</sup>	10 <sup>DEFGHI</sup>	45 <sup>IJK</sup>	7.4 <sup>GHIJK</sup>
13	21689	Bahawalnagar, Punjab	35 <sup>DEFG</sup>	15 <sup>FGHI</sup>	6.16 <sup>FGHIJK</sup>	13 <sup>BCDEF</sup>	152.67 <sup>DEF</sup>	7.5 <sup>GHIJK</sup>
14	21694	Okara, Punjab	28.33 <sup>I</sup>	13.33 <sup>IJK</sup>	12.56 <sup>AB</sup>	14.66 <sup>BCDE</sup>	171.33 <sup>D</sup>	9.56 <sup>EFG</sup>
15	21699	Pakpattan, Punjab	42 <sup>BCDE</sup>	15.66 <sup>IJK</sup>	12.6 <sup>AB</sup>	20.33 <sup>A</sup>	422.33 <sup>A</sup>	9.43 <sup>EFG</sup>

16	21710	Pakpattan, Punjab	32.33 <sup>FGH</sup>	29 <sup>EFGH</sup>	6.5 <sup>FGHIJK</sup>	12.33 <sup>BCDEFG</sup>	224.33 <sup>C</sup>	13.4 <sup>AB</sup>
17	21721	Sialkot, Punjab	33.66 <sup>EFGHI</sup>	36.33 <sup>DEF</sup>	7.4 <sup>EFGHI</sup>	11.33 <sup>BCDEFGH</sup>	143.66 <sup>DEF</sup>	9.8 <sup>DEFG</sup>
18	21739	Bahawalpur, Punjab	34.33 <sup>DEFG</sup>	15 <sup>FGHI</sup>	5.9 <sup>GHIJK</sup>	12.66 <sup>BCDEFG</sup>	134.33 <sup>EF</sup>	13.4 <sup>AB</sup>
19	21758	Nawab Shah, Sindh	35.33 <sup>DEFG</sup>	16 <sup>HIJK</sup>	5.23 <sup>IJKL</sup>	15 <sup>ABCD</sup>	256 <sup>BC</sup>	15.33 <sup>A</sup>
20	21761	Sukkur, Sindh	41.66 <sup>CDE</sup>	25 <sup>EFGHI</sup>	6.66 <sup>FGHIJK</sup>	16 <sup>ABC</sup>	124 <sup>EF</sup>	13.16 <sup>AB</sup>
21	35859	Jhang, Punjab	45.33 <sup>BC</sup>	32.33 <sup>DEFG</sup>	6.7 <sup>FGHIJK</sup>	16 <sup>ABC</sup>	132 <sup>EF</sup>	10.6 <sup>CDEF</sup>
22	20899	Lahore, Punjab	35 <sup>DEFG</sup>	0 <sup>L</sup>	0 <sup>M</sup>	0 <sup>J</sup>	0 <sup>L</sup>	0 <sup>M</sup>
23	21384	Muzaffargarh, Punjab	28.33 <sup>I</sup>	0 <sup>L</sup>	0 <sup>M</sup>	0 <sup>J</sup>	0 <sup>L</sup>	0 <sup>M</sup>
24	21725	Bahawalnagar, Punjab	0 <sup>K</sup>	0 <sup>L</sup>	0 <sup>J</sup>	0 <sup>J</sup>	0 <sup>L</sup>	0 <sup>M</sup>
25	21020	Mansehra, KPK	0 <sup>K</sup>	-0 <sup>L</sup>	0 <sup>M</sup>	0 <sup>J</sup>	0 <sup>L</sup>	0 <sup>M</sup>
26	C1 21722	Narowal, Punjab	25.66 <sup>HIJ</sup>	120.667 <sup>A</sup>	6.46 <sup>FGHIJK</sup>	11.33 <sup>BCDEFGH</sup>	148.667 <sup>DEF</sup>	13 <sup>ABC</sup>
27	C2 21731	D.I Khan, KPK	30.66 <sup>FGHI</sup>	50.667 <sup>C</sup>	5.6 <sup>HIJK</sup>	16.67 <sup>AB</sup>	158 <sup>DE</sup>	9 <sup>EFGH</sup>
28	C3 21737	Layyah, Punjab	17.66 <sup>J</sup>	65 <sup>B</sup>	4.8 <sup>JKL</sup>	11 <sup>CDEFGH</sup>	77.33 <sup>HI</sup>	9.5 <sup>EFG</sup>
29	C4 21742	D.I Khan, KPK	29.66 <sup>GHI</sup>	51.667 <sup>C</sup>	8.9 <sup>DEF</sup>	11.33 <sup>BCDEFGH</sup>	95.33 <sup>GH</sup>	6.8 <sup>HIJKL</sup>
30	C5 21760	Mirpurkhas, Sindh	23 <sup>IJ</sup>	37.330 <sup>DE</sup>	7.26 <sup>EFGHIJ</sup>	13 <sup>BCDEF</sup>	91 <sup>H</sup>	5.96 <sup>JKL</sup>

### *i. Height*

Out of 30 accessions, 21293 had the maximum plant height (61 inches) that was collected from Jhang, Pakistan while the least height was observed in case of accession number 21737 (17.66 inches) which was collected from Layyah, Punjab. While the average height observed in 30 accessions was found 34.8 inches (Figure 1).

### *ii. Diameter of Umbel*

Diameter of umbel was measured using scale and least diameter was measured in case of accession no 20861 (3cm) which was obtained from Attock Punjab while the maximum diameter was measured in case of accession No 21254 (13.76) which was collected from Okara, Punjab while, the average diameter of 30 accession was observed as 6.5 cm.



Figure 1: Growth stages of *Foeniculum vulgare* , a. Vegetative growth stage of Fennel, b. stem and leaves at vegetative growth stage, c. flowering stage, d. compound umbel, e. fruit setting, f. fruit formation, g. fruit maturation, h. fennel fruit after harvesting

### *iii. Number of Umbels*

Maximum number of umbels were recorded as 45 umbels/plant in case of accession number 21722 (120 umble/plant) which was obtained from Haripur while the least number of umbels were recorded as 12 umbels /plant in case of accession number 21277 which was obtained from Jhang while, the average number of umbels/plants in 30 accession was recorded as 25 (Figure 2).

### *iv. Number of Rays*

Maximum number of rays/umbel were recorded as 20 rays/umbel in case of accession number 21699 which was obtained from Pakpattan, Punjab while the

least number of rays were observed in case of accession number 20861 which collected from Attock, Punjab and was recorded as 5 rays/umbel. Average number of rays/umbels in 30 accessions was recorded as 11 rays/umbels (Figure 2).

### *v. No of Fruits/Umbel*

Maximum number of fruits were recorded in case of accession number 21699 (422.33 fruits/umbel) acquired from Pakpattan, Punjab while the least number of fruits were recorded in case of accession number 21358 i.e., 36 fruits/umbel and was collected from Layyah. While the average number of fruits in 30 accessions (Figure 2) were recorded as 120 fruits/umbels.

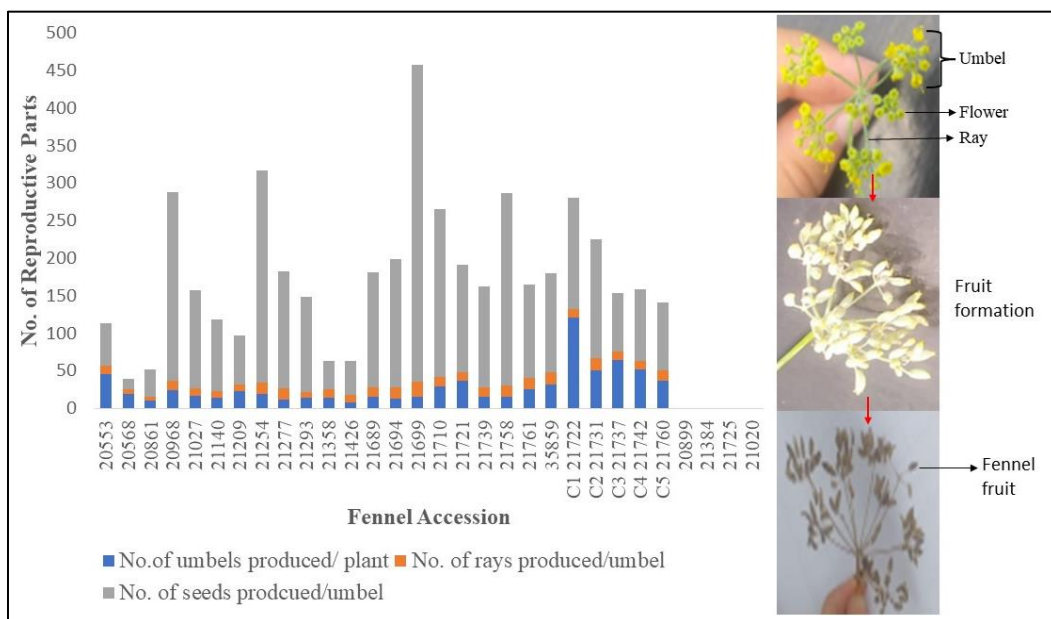


Figure 2: Mean Number of umbels/plant, number of rays and fruits/umbel in fennel.

vi. *Weight of 1000 Fruits*

Weight of 1000 fruits of 30 accessions was measured 20553 obtained from Quetta, Baluchistan had least weight 4.6 g/1000 fruits while accession 21758 obtained from Nawab shah had maximum weight that 15.33g/1000 fruits. While the average weight to 1000 fruits in 30 accession was recorded as 8.3 g (Table 1).

Dendrogram of cluster analysis grouped the genotypes into four major clusters (Figure 4). Cluster 1 consists of 13 observation and contains accession 1, 7, 3, 11, 12, 28, 29,30, 2, 22, 23, 24 and 25 which belonged to Haripur, Faisalabad, Attock, Layyah, D.I Khan, Mirpur Khas, Faisalabad, Lahore, Muzaffargarh and Bahawalnagar. Cluster 2 includes the genotypes 4, 19, 16 and that were collected from Quetta, Nawab Shah, Pakpattan and Jhang. Cluster 3 includes the genotypes 5, 18, 20, 21, 10, 6, 9, 13,14,17 and 26 that were collected from Mansehra, Bahawalpur, Sukkur, Jhang, Faisalabad, Bahawalpur, Okara, Sialkot, D.I Khan and Narowal respectively. While the cluster 4 includes genotype 15 that was collected from Pakpattan.

Centroid is multi-dimensional average of a cluster (Table 2). Means heights of clusters ranged from 30.9 inches to 42 inches with cluster 4 depicting the maximum mean height whereas cluster 1 depicted the least mean height. Similarly highest mean diameter of umbel (12.6) and fruit produced/ umbel (422.33) were depicted by cluster 4. Cluster 3 depicted the highest mean umbels/plant (30 umbels/plant). Highest mean weight of thousand fruits was observed in case of cluster 2.

The distances between cluster centroids measures how far apart the centroids of the clusters in the final partition are from one another. A larger distance generally indicates a greater difference between the clusters and less similarity (Table 3). Cluster 1 is closest to cluster 3 followed by cluster 2. Whereas cluster 2 lies in close proximity to cluster 3 (distance 114.35) followed by cluster 4 (distance169.18). Cluster 3 has least distance with cluster 1(100.62) and maximum with cluster 4(283.4). Cluster 4 lies closest to cluster 3 at a distance of 169.187.



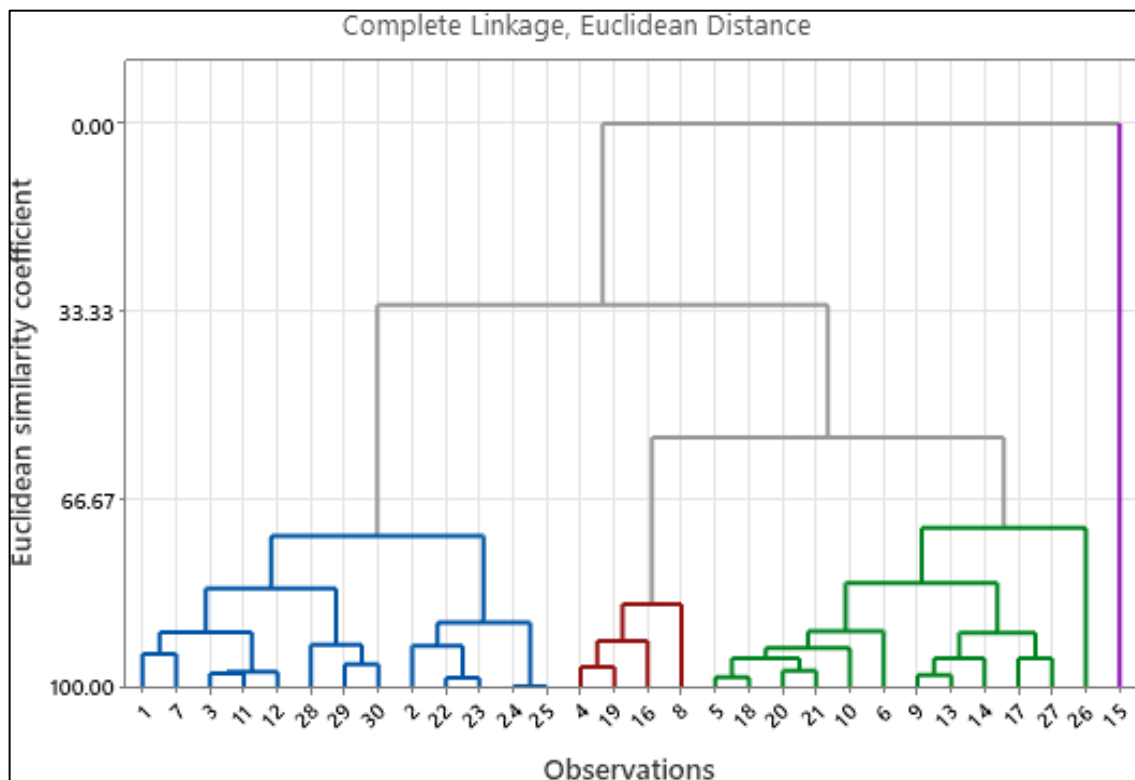


Figure 3: Dendrogram of quantitative characteristics of 30 genotypes of *Foeniculum vulgare* based on Euclidean distance

Table 2: Cluster centroid of Quantitative traits

Variable	Cluster1	Cluster2	Cluster3	Cluster4	Grand Centroid
Plant Height	30.9205	37.475	37.667	42.000	34.862
No. of Umbels Produced/ Plant	21.0769	21.917	30.444	15.667	24.756
Diameter of Umbel	4.4462	8.458	7.775	12.600	6.584
Rays Produced/Umbel	6.8462	13.917	12.786	20.333	10.614
Fruits Produced/Umbel	39.8718	253.500	139.472	422.333	120.944
Weight Of Thousand Fruits	5.5910	10.742	10.561	9.433	8.394

Table 3: Distances between Quantitative Traits Cluster Centroids

	Cluster1	Cluster2	Cluster3	Cluster4
Cluster1	0.000	213.947	100.621	383.004
Cluster2	213.947	0.000	114.354	169.187
Cluster3	100.621	114.354	0.000	283.424
Cluster4	383.004	169.187	283.424	0.000

**i. Qualitative Traits**

Dendrogram of cluster analysis of qualitative traits of fennel groups the genotypes into four clusters (Figure 4). Cluster

1 includes genotypes 1,2,3,5,6,9,10,12, 15, 16, 18, 19, 21, 26, 27, 28, 29 and 30 that were collected from Haripur, Faisalabad, Attock, Mansehra, Faisalabad, Jhang, Layyah, Bahawalnagar, Okara, Pakpattan, Bahawalpur,

Nawab shah, Bahawalnagar, Mansehra, Narowal, D.I Khan and Layyah respectively. Cluster 2 includes 4 genotypes that showed a clear division into two subgroups, subgroup includes 2 genotypes collected form Okara and Sukkur, whereas subgroup b contains genotypes collected from and Jhang and Sialkot. Cluster 3 includes genotype 11 and 14 collected form Jhang and Layyah whereas cluster 4 includes genotype 22, 23, 24 and 25 collected from Lahore, Muzaffargarh, Bahawalnagar and Mansehra.

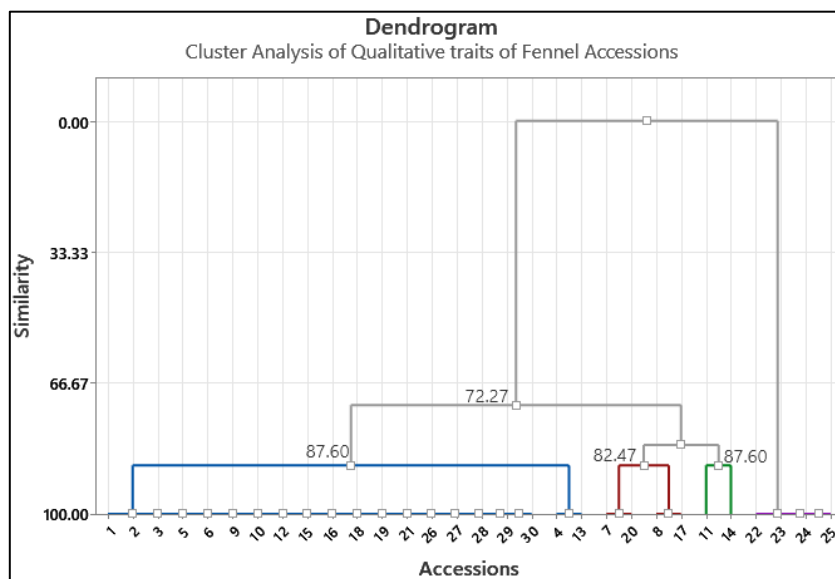
The shortest distance was observed between cluster 1 and 3 with a distance of 1.0 confirming the high similarity between qualitative traits of genotypes of cluster 1-3. The greatest dissimilarity was observed

between cluster 3 and 4 with a distance of 7.8264 (Table 5).

All accessions grew well except for accession 21725 and 21020 which did not germinate and were collected from Bahawalnagar and Mansehra. Whereas accession 20899 and 21384 collected from Lahore and Muzaffargarh respectively exhibited vegetative growth and attained height up to 35 and 28 inches respectively but did not carry reproductive growth. Subsequently did not produce umbels, rays and fruits. Highest height was observed in case of accession 21293 whereas number of umbels produced/ plant and rays/ umbels were below average.

**Table 4: Qualitative traits of 30 genotypes of *Foeniculum vulgare***

Code No.	Accession Number	Origin	Fruit Shape	Fruit Color
1	20553	Haripur, KPK	Oblong	Green
2	20568	Faisalabad, Punjab	Ellipsoid	Brown
3	20861	Attock, Punjab	Oblong	Green
4	20968	Quetta, Baluchistan	Ellipsoid	Brown
5	21027	Mansehra, KPK	Oblong	Green
6	21140	Faisalabad, Punjab	Ellipsoid	Brown
7	21209	Faisalabad, Punjab	Oblong	Brown
8	21254	Jhang, Punjab	Oblong	Green
9	21277	Jhang, Punjab	Ellipsoid	Brown
10	21293	Jhang, Punjab	Ellipsoid	Brown
11	21358	Layyah, Punjab	Ellipsoid	Brown
12	21426	Attock, Punjab	Ellipsoid	Brown
13	21689	Bahawalnagar, Punjab	Ellipsoid	Brown
14	21694	Okara, Punjab	Ellipsoid	Brown
15	21699	Pakpattan, Punjab	Ellipsoid	Brown
16	21710	Pakpattan, Punjab	Ellipsoid	Brown
17	21721	Sialkot, Punjab	Oblong	Green
18	21739	Bahawalpur, Punjab	Ellipsoid	Brown
19	21758	Nawab Shah, Sindh	Ellipsoid	Green
20	21761	Sukkur, Sindh	Ellipsoid	Green
21	35859	Jhang, Punjab	Ellipsoid	Brown
22	20899	Lahore, Punjab	-	-
23	21384	Muzaffargarh, Punjab	-	-
24	21725	Bahawalnagar, Punjab	-	-
25	21020	Mansehra, KPK	-	-
26	C1 21722	Narowal, Punjab	Ellipsoid	Brown
27	C2 21731	D.I Khan, KPK	Ellipsoid	Brown
28	C3 21737	Layyah, Punjab	Ellipsoid	Brown
29	C4 21742	D.I Khan, KPK	Ellipsoid	Brown
30	C5 21760	Mirpur khas, Sindh	Ellipsoid	Green



**Figure 4:** Dendrogram of qualitative characteristics of 30 genotypes of *Foeniculum vulgare* based on Euclidean distance

**Table 5:** Distances between Cluster Centroids of Qualitative Traits

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Cluster 1	0.00000	1.07703	2.03961	5.88303
Cluster 2	1.07703	0.00000	1.00000	6.94622
Cluster 3	2.03961	1.00000	0.00000	7.82624
Cluster 4	5.88303	6.94622	7.82624	0.00000

Fruit production/ umbel was a little above the average value indicating the plant as with a robust stature but medium yield. Whereas, accession 21209 from Okara and 21254 from Jhang ranged in top 10 % of most heighted accessions. Lowest height was observed in case of accession 21731. Fruit production/ umbel were below average, however number of umbels/plant and number of rays /umbel was above average implying the plant as short heighted plant with medium yield.

Number of umbels/plants was recorded highest in accession 21722, both ray/umbel and fruit /umbel were recorded above mean values whereas height was recorded below mean value. Data implies the accession as a high yielding accession with relatively very short height.

Cosge et al., (2009) also confirmed the direct effect of inflorescence on seed

yield of fennel. Umbel/plant was lowest in accession 21277 but its height, diameter, rays/umbel and fruits/umbel were above average.

Diameter and ray/umbels were lowest in accession 201861 and fruit/umbels were very low in comparison to average, however has above average height, with data suggesting it as a robust plant with low yield which is in contrast with Bahmani et al., (2015) result that stated seed yield in fennel is positively associated with plant height. Diameter was highest in case of accession 21254 from Jhang with above average height, rays/umbel and fruits/umbel. Ray/umbel and fruits/umbel were highest in case of accession 21699 from Pakpattan, with above average height and diameter of umbel as well as weight of fruits indicating accession as high yielding with medium stature. Highest weight/1000 fruits were

observed in accession 21758 with above average height, ray and fruit production whereas lowest weight/1000 fruits were observed in case of accession 20968 from Quetta with below average plant height and number of umbels, however above average rays/umbel and fruits/umbels producing plant suggesting it as a small stature plant with small fruit size, however relatively high yielding plant.

Zahid et al., (2009) explore the genetic diversity of fennel germplasm of Pakistan. Fifty fennel accessions were collected from different parts of Pakistan and evaluated (RAPD analysis) for seed germination %, days to initiation of flowering, plant height, stem girth, nodal distance, umbel diameter, days to 50 % maturity, days to harvesting, seed yield per row, weight of 100 seeds, Harvest index (%). Similar findings of Zahid et al., (2009) proved outstanding performance for understudy fennel accessions collected, 3 from NWFP, one from Baluchistan, seven from Punjab and one from Northern Areas of Pakistan. RAPD could resolve genetic variation among crop germplasm, identification of cultivars and for estimating genetic relationship (Silva et al., 2005a; 2005b).

As on the basis of cluster analysis, accessions were grouped into 4 clusters. Cluster 4 that included accession from Pakpattan had highest mean plant height, diameter, rays/umbel and fruits/umbel and the result are in agreement with previous studies, Where significant differences were found for the various agro morphological traits in the different fennel landraces (Bahmani et al., 2015).

Whereas cluster 1 included accessions having lowest mean height, diameter of umbel, rays/umbel, fruits/umbel and weight/1000 fruits. All the regions in cluster 1 have hot climate ranging from humid subtropical to semi-arid climate in Faisalabad to desert climate in Layyah.

Cluster 1 is closest to cluster 3 as suggested by data and can be predicted

considering the close climatic conditions of areas. Hence relatively similar are the characteristics of accession from these areas and is in congruence with the study of Lopes et al., (2010) who stated that some accessions clustered together collected at similar longitude and altitude.

Cluster analysis of qualitative traits groups accession into 4 clusters, cluster 1 includes accessions from Haripur, Faisalabad, Attock, Mansehra, Faisalabad, Jhang, Layyah, Bahawalnagar, Okara, Pakpattan, Bahawalpur, Nawab shah, Bahawalnagar, Mansehra, Narowal, D.I Khan. Climate in cluster 1 varies from temperate in Mansehra to desert climate in Layyah. while the cluster two diverges into two subgroups with subgroup a containing accession from Okara and Sukkur whereas subgroup b consisting of accessions from Jhang and Sialkot and climate ranges from humid subtropical in Sialkot to hot desert climate in Sukkur. Cluster 3 includes climate ranges from subtropical dry semi-arid in Jhang to desert climate in Layyah whereas cluster 4 includes accession from Lahore, Muzaffargarh, Bahawalnagar and Layyah. Data indicates that there is no similarity on the basis of climatic zones or area of origin of accession in case of qualitative trait clustering which is in accordance with the studies of (Lopes et al., 2010) which stated that no clear relationship was found between geographic coordinates (altitude, latitude and longitude) and accessions clustering.

## CONCLUSION

High diversity exists among the morphological parameters of thirty accessions of fennel collected from different agroecological zones of Pakistan. Accession 21293 and 21209 had robust height, whereas accession 21737 had short stature, 21699 and 21722 due to high yield could be interesting accessions for the future breeding programs. Their yield traits combined with height, number of umbels and raying could be used for improvement of fennel varieties.

Therefore, diversity within genotypes could facilitate the selection of genotype for distinct traits.

Diversity of Punjab fennel germplasm showed that it has a potential source of gene pool. Phenotypic variation may promote population persistence because it buffers against selection in changing environments and enables adaptations to novel and changing conditions.

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## AUTHORS CONTRIBUTION

Shumaila khalil Principal author, conceived the idea, conducted the research and Areej abassi prepared the 1st draft. Mahrin Rashid, Planned and supervised the research and experiments. Shazia Erum, Co-supervised the research. Asif Javaid provided samples of fennel. Irum Raza help in data analysis. Arifa Khan, guided in write up and helped in data recording.

## CONFLICT OF INTEREST

The authors have no conflict of interest.

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