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Intra and Inter cluster studies for quantitative traits in Okra [*Abelmoschus esculentus* (L) Moench]

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Abstract
Genetic divergence of 18 okra genotypes was studied using Mahalanobis D^2 statistics revealed that considerable genetic diversity among genotypes in okra. Eighteen genotypes were grouped into 5 clusters following Tocher's method, 3 clusters were polygenotypic (cluster I was the largest cluster with 7 genotypes followed by cluster II with 5 genotypes while, cluster III comprised of 4 genotypes) while remaining two clusters were mono-genotypic for the summer season. Whereas, for rainy season the 18 genotypes were grouped into 5 clusters following Tocher's method, 3 clusters were poly-genotypic (cluster III was the largest cluster with 6 genotypes followed by cluster I and II both having 5 genotypes) while remaining two clusters were mono-genotypic. Cluster III showed maximum intra cluster D^2 value followed by cluster II and cluster I. Cluster IV and V were mono-genotypic hence, showed no intra cluster divergence for the summer season. Whereas, for rainy season Cluster III showed maximum intra cluster D^2 value followed by cluster II and cluster I. Cluster IV and V were mono-genotypic hence, showed no intra cluster divergence. The highest inter cluster divergence was observed between genotypes of cluster I and V, followed by cluster IV vs V and cluster II vs V for the summer season. Whereas, for rainy season the highest inter cluster divergence was observed between genotypes of cluster III and V, followed by cluster I vs III and cluster I vs IV. The character yield (qha^{-1}) contributed most towards genetic divergence followed by yield plant^{-1}, fruit diameter, stem girth at 30 DAS and yieldplot^{-1} for summer season. Whereas, for rainy season number of fruits plant^{-1} contributed most towards genetic divergence followed by yield (qha^{-1}), yieldplant^{-1}, leaf area at 60 DAS, leaf area at 30 DAS and number of leaves at 90 DAS. Crosses between the members of clusters separated by high inter cluster distance are likely to produce desirable segregants.

Keywords: Okra, genetic divergence, cluster, Mahalanobis D^2, genotypes

Introduction
Okra [*Abelmoschus esculentus* (L) Moench] is an important vegetable crop widely grown in the tropical and subtropical part of the world (Tindall, 1983) [11]. Okra is an annual and day neutral plant cultivated in both *zaid* and *kharif* season for its delicious tender fruits in one and other part of the country. It has important position among vegetables due to its multiple virtues like high nutritive, medicinal value, ease of cultivation, wider adaptability, yearround cultivation, good portability, good export potential and abundant returns (Reddy, 2010) [9]. Okra is rich source of vitamins and mineral and fresh okra fruit contains 35 calories, 89.6 g water, 6.4 g carbohydrate, 1.9 g protein, 0.2 g fat, 1.2 g fiber and minerals per 100 g of edible portion (Gopalan *et al.*, 2007) [2]. It is said to be very useful against genitor-urinary disorders, spermatorrhoea, and chronic dysentery (Nandkarni, 1927) [7]. It is an often cross pollinated crop, heterosis is being exploited in form of developing hybrid varieties. Hence, genetic divergence is an important tool while selecting the parents for hybrid breeding. Divergence analysis is more authentictool for systematic identification of the diverse genotypes for hybridization purposes (Mahalanobis, 1936) [5].
Genetic diversity is an important tool to develop high yielding varieties by selecting genetically diverse parents with high yield and wider adaptability in breeding programme. Progress of any breeding programmes largely depends to a great extent on the availability of genetic variability for desired traits in genotypes (Kumar *et al.*, 2013) [3]. Genetic diversity analysis is of utmost important to plant breeders in deciding the most appropriate breeding method to increase the genetic potentialities as well as to surpass the yield barrier (Langade *et al.*, 2013) [4]. Genetically diverse parents used in recombination breeding programme supposed to give maximum heterosis in $F_{1's}$ and also getting broad spectrum of variability for quantitative traits in segregating generations to select desirable recombinant. Therefore, for any successful breeding programme genetic diversity is prerequisites.

For improvement in yield and its component traits in okra, the information on genetic divergence of different genotypes for various quantitative traits is necessary. In this view, the present study was undertaken to investigate genetic divergence in 18 genotypes of okra to identify the diverse genotypes to be used in breeding programme.

Materials and Method

The genotypes were evaluated through a field experiment conducted in randomized block design with three replications at Vegetable Research Farm, B.U.A.T, Banda during summer and rainy season of 2019. Each variety was planted in three rows replicated thrice with spacing of 45 cm × 20 cm and 60 cm × 30 cm during summer and rainy season, respectively. Observations were recorded from five randomly selected plants from the middle row of each variety in each replication for twenty eight plant characters *viz.*, days to 50% germination, plant height (cm) at 30, 60 and 90 DAS, days to first flower, days to 50% flowering, days to first harvest, number of nodes at 30, 60 & 90 DAS, leaf area (cm^2) at 30, 60 & 90 DAS, number of leaves at 30, 60 & 90 DAS, number of primary branchesplant^{-1}, stem girth (cm) at 30, 60 & 90 DAS, node to first flower appear, number of fruitsplant^{-1}, fruit length (cm), fruit diameter (cm), pedicle length (cm), fruit yieldplant^{-1}(kg), fruit yield plot^{-1}(kg) and fruit yield (qha^{-1}). The genetic divergence among genotypes was estimated by using D^2 statistics (Mahalanobis, 1936) [5]. All the genotypes used were clustered into different groups by following Tocher's method (Rao, 1952) [8]. The average intra and inter cluster distances were calculated by the formulae suggested by (Singh and Chaudhary, 1985) [10].

Results and Discussion

Genetic divergence analysis

Germplasm is a reservoir of genetic diversity which is used to meet the changing needs for developing promising varieties. It is also important that sufficient variability should be there in the germplasm for economic characters for their profitable exploitation following recombination breeding. The need of optimum parental diversity to achieve superior genotypes for the recovery of transgressive segregates has also been emphasized repeatedly (Weinhues, 1960 [12]; Moll *et al.*, 1962 [6] and Arunachalam, 1981) [1]. Arunachalam (1981) [1] also noted that the more diverse the parents, the greater the probability of heterotic expression of F_1 and a wide range of variability in segregating generations. The quantitative assessment of genetic divergence has been studied using Mahalanobis D^2 statistics on 18 genotypes over 28 yield and yield contributing characters. Results are presented below:

Grouping of genotypes into different clusters

On the basis of D^2 values, the 18 genotypes were grouped into 5 clusters following Tocher's method, 3 clusters were polygenotypic (cluster I was the largest cluster with 7 genotypes followed by cluster II with 5 genotypes while, cluster III comprised of 4 genotypes) while remaining two clusters were mono-genotypic for the summer season. Whereas, for rainy season the 18 genotypes were grouped into 5 clusters following Tocher's method, 3 clusters were poly-genotypic (cluster III was the largest cluster with 6 genotypes followed by cluster I and II both having 5 genotypes) while remaining two clusters were mono-genotypic. Cluster wise distribution of genotypes is summarized in Table: 1&2.

Intra and inter cluster divergence D^2 values

The average intra and inter-cluster D^2 values estimated as per the procedure given by Singh and Choudhary (1985) are presented in Table 3 and 4 for summer and rainy season respectively. Cluster III showed maximum intra cluster D^2 value (D^2 =765.77) followed by cluster II (D^2 = 525.46) and cluster I (D^2 = 439.96). Cluster IV and V were mono-genotypic hence, showed no intra cluster divergence for the summer season. Whereas, for rainy season Cluster III showed maximum intra cluster D^2 value (D^2 = 539.72) followed by cluster II (D^2 = 382.16) and cluster I (D^2 = 288.31). Cluster IV and V were mono-genotypic hence, showed no intra cluster divergence.

The highest inter cluster divergence was observed between genotypes of cluster I and V (D^2= 18923.93), followed by cluster IV vs V (D^2 = 15721.30) and cluster II vs V (D^2 = 10121.93) for the summer season. Whereas, for rainy season the highest inter cluster divergence was observed between genotypes of cluster III and V (D^2 = 2022.88), followed by cluster I vs III (D^2 = 1900.01) and cluster I vs IV (1567.02).

Cluster mean showing importance of grouped characters:

As improvement in yield and other related traits is a basic objective in any breeding programme, hence cluster means for fruit yield per plant and its major components need to be considered for selection of genotypes.

Cluster I

This cluster showed least value for yield plant^{-1} (0.05), stem girth at 30 DAS (0.98), number of branches at final harvest (1.43). It also showed high cluster mean values for leaf area at 30 DAS (101.35), leaf area at 60 DAS (133.01), leaf area at 90 DAS (155.74) for summer season. Whereas, for rainy season this cluster showed least value for pedicle length (0.2), leaf area at 90 DAS (1.16), plant height at 60 DAS (1.63). It also showed high cluster mean values for number of fruits plant^{-1} (132.37), fruit length (172.13), fruit diameter (203.23).

Cluster II

This cluster showed least value for yield plant^{-1}(0.06), stem girth at 30 DAS (1.10), fruit diameter (1.28). It also showed high cluster mean values for leaf area at 30 DAS (106.31), leaf area at 60 DAS (136.78), leaf area at 90 DAS (159.78) for summer season. Whereas, for rainy season this cluster showed least value for pedicle length (0.23), leaf area at 90 DAS (1.21), plant height at 60 DAS (1.64). It also showed high cluster mean values for number of fruits per plant (1134.33), fruit length (176.27), fruit diameter (207.5).

Cluster III

This cluster showed least value for yieldplant^{-1} (0.08), stem girth at 30 DAS (1.02), fruit diameter (1.24). It also showed high cluster mean values for leaf area at 30 DAS (110.80), leaf area at 60 DAS (145.11), leaf area at 90 DAS (171.06) for summer season. Whereas, for rainy season this cluster showed least value for pedicle length (0.21), leaf area at 90 DAS (1.05), plant height at 60 DAS (1.7). It also showed high cluster mean values for yield plot^{-1} (116.88), fruit length (130.25), fruit diameter (164.19).

Cluster IV

This cluster showed least value for yield plant^{-1} (0.06), stem girth at 30 DAS (0.94), number of branches at final harvest

(1.21). It also showed high cluster mean values for leaf area at 30 DAS (105.96), leaf area at 60 DAS (144.45), leaf area at 90 DAS (170.05) for summer season. Whereas, for rainy season this cluster showed least value for pedicle length (0.25), leaf area at 90 DAS (1.13), plant height at 60 DAS (1.7). It also showed high cluster mean values for yieldplot^{-1} (133.58), fruit length (166.00), fruit diameter (203.00).

Cluster V

This cluster showed least value for yield plant^{-1} (0.09), stem girth at 30 DAS (0.90), fruit diameter (1.28). It also showed high cluster mean values for yield (qha^{-1}) (96.86), leaf area at 60 DAS (131.47), leaf area at 90 DAS (154.40) for summer season. Whereas, for rainy season this cluster showed least value for pedicle length (0.2), leaf area at 90 DAS (1.15), plant height at 60 DAS (1.57). It also showed high cluster mean values for number of nodes at 60 DAS (127.1), fruit length (181.17), fruit diameter (183.67).

Contribution of individual characters towards genetic divergence

The percentage contribution towards genetic divergence by all the characters during summer and rainy season are presented in Table:7 and 8 respectively. The character yield (qha^{-1}) contributed most towards genetic divergence (82.35%) followed by yieldplant^{-1} (12.42%), fruit diameter (1.96%), stem girth at 30 DAS (1.96%) and yield plot^{-1} (1.31%) for summer season. Whereas, for rainy season number of fruitsplant^{-1} contributed most towards genetic divergence (36.6%) followed by yield (qha^{-1}) (30.07), yield plant^{-1} (13.73%), leaf area at 60 DAS (7.84%), leaf area at 30 DAS (6.54%) and number of leaves at 90 DAS (5.23%).

Table 1: Distribution of okra genotypes in different clusters for summer season

Cluster	Number of genotypes	Genotypes
I	7	Kashi Vibhuti, Punjab Suhavani, PusaSawani, NDO-10, Kashi Kranti, Arka Abhay, Hisar Naveen
II	5	Azad Bhindi-1, Akola Bahar, Kashi Vardan, Pusa A-4, Arka Anamika
III	4	Arka Nikita, Hisar Unnat, Varsha Uphar, Phule Vimukta
IV	1	P-8
V	1	Kashi Pragati

Table 2: Distribution of okra genotypes in different clusters for rainy season

Cluster	Number of genotypes	Genotypes
I	5	Kashi Pragati, Kashi Vibhuti, P-8, NDO-10, Punjab Suhavani
II	5	Pusa A-4, Kashi Vardan, Hisar Unnat, Akola Bahar, Hisar Naveen
III	6	Kashi Kranti, Arka Anamika, Arka Abhay, Arka Nikita, Phule Vimukta, PusaSawani
IV	1	Varsha Uphar
V	1	Azad Bhindi-1

Table 3: Intra and inter-cluster divergence (D^2) for fruit field and associated traits in okra for summer season

Cluster number	I	II	III	IV	V
I	439.96	1867.51	9753.05	775.36	18923.93
II		525.46	3948.18	1185.45	10121.25
III			765.77	7586.29	2078.05
IV				0.00	15721.30
V					0.00

Table 4: Intra and inter-cluster divergence (D^2) for fruit field and associated traits in okra for rainy season

Cluster number	I	II	III	IV	V
I	288.31	684.29	1900.01	1567.02	376.54
II		382.16	1335.48	584.34	641
III			539.72	991.79	2022.88
IV				0	1126.61
V					0

Table 5: Cluster mean values for different yield and associated characters in okra for summer season

Traits/ Cluster		I	II	III	IV	V
Days to 50% germination		**9.48**	**7.40**	**7.08**	**7.33**	**6.33**
Plant height	30 DAS	9.69	10.12	10.47	13.06	10.80
	60 DAS	30.53	31.29	32.23	32.38	30.33
	90 DAS	53.90	54.43	56.30	54.80	55.62
Days to first flower		54.53	51.17	47.22	51.19	44.15
Days to 50% flowering		58.05	55.58	49.83	57.07	46.67
Days to first harvesting		61.57	58.50	53.78	60.35	50.90
Number of nodes	30 DAS	6.55	6.86	7.33	8.24	7.32
	60 DAS	13.33	14.33	13.58	14.50	11.13
	90 DAS	20.26	21.10	19.91	21.62	17.85
Leaf area	30 DAS	101.35	106.31	110.80	105.96	92.10
	60 DAS	133.01	136.78	145.11	144.45	131.47
	90 DAS	155.74	159.78	171.06	170.05	154.40
Number of leaves	30 DAS	7.81	7.89	8.16	10.97	6.83
	60 DAS	17.06	18.03	19.23	20.87	14.13
	90 DAS	24.67	24.57	25.74	27.90	21.25
Number of branches at final harvest		1.23	1.39	1.40	1.21	1.29
Stem girth	30 DAS	0.98	1.10	1.02	0.94	0.90
	60 DAS	1.43	1.49	1.44	1.37	1.46
	90 DAS	1.90	1.96	1.78	1.87	1.97
Node to flower appear		3.46	3.12	3.48	4.20	3.17
Number of fruits per plant		4.62	5.60	6.31	4.79	7.25
Fruit length (cm)		10.55	10.31	10.55	10.27	9.82
Fruit diameter(cm)		1.30	1.28	1.24	1.27	1.28
Pedicle length (cm)		1.91	1.71	2.02	1.75	1.96
Yield/plant (kg)		0.05	0.06	0.08	0.06	0.09
Yield/plot(kg)		1.49	1.89	2.33	1.84	2.58
Yield (q/ha)		54.39	68.35	85.59	68.11	96.86

Table 6: Cluster mean values for different yield and associated characters in okra for rainy season

Traits/ Cluster		I	II	III	IV	V
Days to 50% germination		6.13	6.13	6.22	7	8.33
Plant height	30 DAS	10.98	10.4	11.07	12.36	10.13
	60 DAS	1.63	1.64	1.7	1.7	1.57
	90 DAS	44.6	42.33	43	39	46.33
Days to first flower		47.82	72.68	46.11	41.48	49.83
Days to 50% flowering		53.22	49.98	51.6	47.48	55.83
Days to first harvesting		22.76	23.18	22.11	23.75	22.6
Number of nodes	30 DAS	82.68	89.08	83.19	92.35	91.81
	60 DAS	115.62	119.83	113.18	125.27	127.1
	90 DAS	7.08	7.55	6.64	7.25	6.83
Leaf area	30 DAS	16.97	18.2	16.79	19.73	18.1
	60 DAS	23.54	23.76	22.91	25.52	24.56
	90 DAS	1.16	1.21	1.05	1.13	1.15
Number of leaves	30 DAS	1.94	2.08	1.98	2.26	1.81
	60 DAS	3.26	3.43	3.24	3.35	2.95
	90 DAS	5.83	5.62	5.47	5.83	6.5
Number of branches at final harvest		3.12	3.58	3.11	2.58	2.58
Stem girth	30 DAS	2.34	1.95	2.3	2.3	1.83
	60 DAS	13.42	13.83	13.29	12.33	11.92
	90 DAS	24.33	25.63	23.77	23.73	20.64
Node to first flower appear		33.31	35.91	34.03	32.28	31
Number of fruits per plant		132.37	134.33	98.63	132.83	138
Fruit length (cm)		172.13	176.27	130.25	166	181.17
Fruit diameter(cm)		203.23	207.5	164.19	203	183.67
Pedicle length		0.2	0.23	0.21	0.25	0.2
Yield/plant (kg)		6.05	6.9	6.64	7.38	6.38
Yield/plot (kg)		107.57	123.41	116.88	133.58	112.18
Yield (q/ha)		17.2	18.72	19	21.27	17.69

Table 7: Contribution of fruit yield and ancillary characters towards divergence in okra (%) (Summer season)

Traits	Days taken to 50% germination	Plant height (30 DAS)	Plant height (60 DAS)	Plant height (90 DAS)	Days to first flower	Days to 50% flowering	Days to first harvesting	No of nodes (30 DAS)	No of nodes (60 DAS)	No of nodes (90 DAS)	Leaf Area (30 DAS)	Leaf Area (60 DAS)	Leaf Area (90 DAS)	No of leaves (30 DAS)	No of leaves (60 DAS)	No of leaves (90 DAS)	No of primary branches per plant	Stem girth (30 DAS)	Stem girth (60 DAS)	Stem girth (90 DAS)	Node to first flower appear	Number of fruits per plant	Fruit length (cm)	Fruit diameter (cm)	Pedicle length (cm)	Yield/plant (kg)	Yield/plot (kg)	Yield (q/ha)
Times 1st rank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**3**	--	--	--	--	--	**3**	--	--	**2**	**126**
Contribution (%)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**1.96%**	--	--	--	--	--	**1.96%**	--	--	**1.3%1**	**82.35%**

Table 8: Contribution of fruit yield and ancillary characters towards divergence in okra (%) (Rainy season)

Traits	Days taken to 50% germination	Plant height (30 DAS)	Plant height (60 DAS)	Plant height (90 DAS)	Days to first flower	Days to 50% flowering	Days to first harvesting	No of nodes (30 DAS)	No of nodes (60 DAS)	No of nodes (90 DAS)	Leaf Area (30 DAS)	Leaf Area (60 DAS)	Leaf Area (90 DAS)	No of leaves (30 DAS)	No of leaves (60 DAS)	No of leaves (90 DAS)	No of primary branches per plant	Stem girth (30 DAS)	Stem girth (60 DAS)	Stem girth (90 DAS)	Node to first flower appear	Number of fruits per plant	Fruit length (cm)	Fruit diameter (cm)	Pedicle length (cm)	Yield/plant (kg)	Yield/plot (kg)	Yield (q/ha)
Times 1st rank	--	--	--	--	--	--	--	--	--	--	**10**	**12**	--	--	--	**8**	--	--	--	--	--	**56**	--	-	--	**21**	--	**46**
Contribution (%)	--	--	--	--	--	--	--	--	--	--	**6.54%**	**7.84%**	--	--	--	**5.23%**	--	--	--	--	--	**36.6%**	--	-	--	**13.73%**	--	**30.07%**

Conclusions
The D^2 cluster analysis grouped 18 genotypes into five distinct clusters during both the season. This indicated existence of high degree of genetic diversity in the germplasm. Therefore, these germplasms may serve as valuable source for selection of diverse parent in the present study.The five clusters in divergence analysis contained genotypes of heterogenous origin thereby indicating no parallelism between genetic and geographic diversity. Therefore, crosses between the members of clusters separated by high inter cluster distance are likely to produce desirable segregants. In this context, cluster pairs exhibiting maximum inter-cluster distance were between genotypes of cluster I and V followed by cluster IV vs V and cluster II vs V for the summer season. Whereas, for rainy season the highest inter cluster divergence was observed between genotypes of cluster III and V followed by cluster I vs III and cluster I vs IV.

Hence, the importance of selection for divergent parents based on these characters will be useful for heterosis breeding in okra.

Apart from the above findings it can be concluded that, selection and hybridization of genotypes from high divergent clusters I (Kashi Vibhuti, Punjab Suhavani, PusaSawani, NDO-10, Kashi Kranti, Arka Abhay and Hisar Naveen) and V (Kashi Pragati)& cluster IV (P-8) and cluster V (Kashi Pragati) during summer season and during rainy season hybridization between cluster III (Kashi Kranti, Arka Anamika, Arka Abhay, Arka Nikita, Phule Vimukta and PusaSawani) and cluster V (Azad Bhindi-1) & cluster I (Kashi Pragati, Kashi Vibhuti, P-8, NDO-10 and Punjab Suhavani) and cluster III (Kashi Kranti, Arka Anamika, Arka Abhay, Arka Nikita, Phule Vimukta and PusaSawani) are expected to yield potential F1s and transgressive for further exploitation

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