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Determination of Interrelationships and Hierarchical Clustering Analysis among Yield Attributing Biometrical Traits of Okra [*Abelmoschus esculentus* (L.) Moench] in Coastal Ecosystem

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ABSTRACT

Background: Okra [*Abelmoschus esculentus* (L.) Moench] is India's major vegetable crop accounting for 60% of exports. The present study aims the determination and utilization of character association analysis and Wards hierarchical cluster analysis for genetic divergence to identify segregants for genetic improvement in okra.

Methods: In the field investigation were carried at Sivapuri Village, Chidambaram, Tamil Nadu, India, in the summer of 2020-2021. The observations for 20 biometrical traits were recorded on five randomly selected plants and recorded data from each replication was subjected to statistical analysis.

Result: The improvement in fruit yield plant^{-1} will be efficient if the selection is based on fruiting period, plant height, No. of branches plant^{-1}, first fruiting node, fruit length, No. of fruits plant^{-1}, No. of marketable fruits plant^{-1}, No. of pickings plant^{-1} and average fruit weight based on character association analysis. Wards hierarchical cluster analysis grouped the 60 genotypes into 10 clusters and among that cluster IV contains highest number (15) of genotypes followed by cluster VI (13). cluster VIII recorded the highest mean values for all the fruit yield related characters.

Key words: Correlation analysis, Genetic divergence, Okra, Path analysis, Wards hierarchical cluster analysis.

INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench], is a prominent and nutritious vegetable crop in India that belongs to the Malvaceae family (Muluken *et al*., 2016). Additionally, it is a dicotyledon, warm-season annual vegetable crop with a 90-100 days growth season that grows in tropical and subtropical areas of the world (Bagwale *et al*., 2016; Reddy *et al*., 2013) on sandy to clayey soil, mostly in Africa and Asia (Oppong-Sekyere *et al*., 2011). Yield is a complex quantitative trait that is influenced by a number of genes that interact with the environment (Saleem *et al*., 2018). Breeding success is affected by three main objectives: how much useful variability there is in the population, how many traits you want to pass down and how much you know about how traits are linked together (Badiger *et al*., 2017). Information on crop genetic diversity is critical for the identification and breeding of unique accessions, which is critical for gene bank administrators for germplasm conservation (Aminu *et al*., 2016). The hierarchical cluster analysis (HCA) is an appropriate method for determining family relationship and genetic affinity *i.e*., to determine the extent of genetic diversity of genotypes from each other. Wards hierarchical clustering method is used for clustering the okra genotypes.

Through the application of proper selection indices, awareness of such association between fruit yield and its contributing components may considerably increase the efficiency of an okra breeding programme (Reddy *et al*., 2013). Correlation studies are often used to compare inter-relationship between the dependent and independent traits is necessary as improvement is proportional to its magnitude of genetic variability present in the genotypes (Prasad and Sharma, 2012) and also extremely useful in selecting the elite genotypes. Component breeding may work better if the primary yield parameters are connected. Simultaneous selection is difficult to use with unrelated traits. To build selection indices for genetic yield enhancement, path analysis may help determine a trait's cause-and-effect connection. The path coefficient analysis shows each characteristic's indirect and direct contribution to the yield (Aminu *et al*., 2016). Breeders may evaluate genetic components by their influence. Direct selection of superior genotypes from separate genetic groups requires path analysis. In this inquiry, utilized correlation and path coefficient analysis to find important okra production traits.

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MATERIALS AND METHODS

Description of study area

The experimental study was done at Sivapuri Village, Chidambaram, Cuddalore District, Tamil Nadu, India, in the summer of 2020-2021.

Experimental material and design

The experiment included 60 distinct genotypes of Okra raised in a three-replication randomized complete block design. 2 to 3 seeds per hill were dibbled with a spacing of 60 cm between row and 30 cm among plants in a row. Thinning was done on the tenth day, leaving one vigorous and robust seedling per hill.

Observations recorded

Observations on yield-attributing parameters were noted while border plants were left in each replication. Five plants were randomly selected from each entry of genotype of replications and labelled for data collection. Data for 20 biometrical characteristics, including first flowering node (FFrN), days to first flower (DFFr), days to 50% flowering (D50%Fr), days to first fruit harvest (DFFuH), fruiting period (FuP), plant height (PtH)(cm), internodal length (InL)(cm), peduncle length (PuL)(cm), No. of branches plant^{-1} (NB/Pt), stem diameter (SeD) (mm), No. of nodes plant^{-1} (NN/Pt), first fruiting node (FFuN), fruit length (FuL)(cm), fruit diameter (FuD)(mm), No. of locules fruit^{-1} (NL/Fu), No. of fruits plant^{-1} (NF/Pt), No. of marketable fruits plant^{-1} (NMF/Pt), average fruit weight (AFuW)(g), no. of pickings plant^{-1} (NP/Pt) and fruit yield plant^{-1} (FY/Pt)(g).

Statistical analysis

Genotypic correlations were computed using variance and co-variances as suggested by Miller *et al.* (1985). Path coefficient analysis was performed as suggested by Dewey and Lu (1959). Ward (1963) method of hierarchical cluster analysis was used to assess the genetic diversity between the genotypes. The data were computed by using R software (Rstudio) with package variability, factoextra and FactoMineR.

RESULTS AND DISCUSSION

Correlation coefficient analysis

Information on the relationship between various components of fruit yield is required for establishing an effective plant breeding program based on selection and for simultaneously improving yield components. As a result, such data may be collected by examining genotypic and phenotypic correlation coefficients between yield and yield contributing traits. Yield is a dependent character that is the product of a number of component characteristics, but direct selection for yield is required to bring about a reasonable improvement in the desirable traits. Correlation coefficient analysis assesses the relational link between several plant characteristics that may be used to guide selection for yield improvement (Thulasiram *et al.*, 2017).

The matrix of genotypic correlation coefficients between twenty characteristics has been calculated and is shown in Table 1. A total of 112 significant genotypic correlations ($p>0.05$) were observed, with 27 being negatively and 85 being positively significant. In the current research, the characteristics of earliness in okra include first flowering node, days to first flower, days to 50% flowering, days to first fruit harvest and first fruiting node. Early flowering not only results in earlier pickings and higher yields, but it also enhances the plant's fruiting period. Flowering and fruiting at lower nodes assist in increasing No. of fruits plant^{-1} and obtaining early yields.

First fruiting node was shown to have a significant positive correlation with first flowering node, days to first flower, days to 50% flowering, days to first fruit harvest, fruiting period, plant height, internodal length, No. of branches plant^{-1}, No. of nodes plant^{-1}, fruit length, No. of Fruits plant^{-1}, No. of marketable fruits plant^{-1}, No. of pickings plant^{-1} and fruit yield plant^{-1}. The positive significant association with first fruiting node were also found by Tudu *et al.* (2021) for days to first flower, days to 50% flowering and days to first fruit harvest; Singh *et al.* (2017) for first flowering node, fruit length and plant height; Sood *et al.* (2016) for internodal length and Reddy *et al.* (2013) for No. of branches plant^{-1}.

Fruit-related features in okra include fruit length, fruit diameter, average fruit weight, no. of fruits plant^{-1}, no. of marketable fruits plant^{-1} and no. of pickings plant^{-1}. fruit length associated positively with first flowering node, plant height, internodal length, no. of branches plant^{-1}, no. of nodes plant^{-1}, first fruiting node, no. of fruits plant^{-1}, no. of marketable fruits plant^{-1}, average fruit weight, no. of pickings plant^{-1} and fruit yield plant^{-1}, whereas days to first fruit harvest and no. of locules fruit^{-1} correlated negatively. Archana *et al.* (2015) found a positive association between fruit length with plant height and no. of nodes plant^{-1}; Kumari *et al.* (2017) for average fruit weight and fruit yield plant^{-1}; Reddy *et al.* (2013) for no. of fruits plant^{-1} and no. of marketable fruits plant^{-1}.

Fruit diameter demonstrated a strong and positive correlation with fruiting period, no. of branches plant^{-1}, no. of locules fruit^{-1} and average fruit weight, whereas stem diameter, no. of fruits plant^{-1} and no. of marketable fruits plant^{-1} had a significant negative correlation. Fruit diameter was shown to have a substantial positive correlation with average fruit weight and no. of locules fruit^{-1} by Kerure *et al.* (2017), no. of branches plant^{-1} by Saryam (2012) and fruiting period by Ashraf *et al.* (2020).

No. of locules fruit^{-1} had a significant and positive genotypic correlation with fruiting period, no. of branches plant^{-1} and fruit diameter and a negative association with no. of locules fruit^{-1} was observed for fruit length, no. of fruits plant^{-1}, no. of marketable fruits plant^{-1} and fruit yield plant^{-1}. Saryam (2012) reported a similar positive association between no. of locules fruit^{-1} with fruiting period and a negative with no. of fruits plant^{-1}; Karri and Acharyya (2012) found a negative association for fruit length.

Table 1: Genotypic correlation coefficients among 20 characters in okra.

Traits	First Flowering Node	Days to first flower	Days to first 50% flowering	Days to first fruit harvest	Fruiting period	Plant height	Internode length	Peduncle length	No. of branches plant^{-1}	Stem diameter	No. of nodes plant^{-1}	First fruiting node	Fruit length	Fruit diameter	No. of locules fruit^{-1}	No. of fruits plant^{-1}	No. of Marketable fruits plant^{-1}	Average fruit weight	No. of pickings plant^{-1}	Fruit yield plant^{-1}
FFrN	1.00	0.218**	0.336**	0.148*	0.298**	0.228**	0.062	-0.269**	0.161*	0.06	0.392**	0.958**	0.286**	0.144	0.097	0.183*	0.174*	0.146	0.084	0.195**
DFFr		1.00	0.819**	0.950**	-0.101	0.051	0.295**	-0.112	-0.231**	0.144	-0.127	0.253**	-0.115	-0.056	0.066	-0.163*	-0.158*	0.071	0.046	-0.137
D50%Fr			1.00	0.850**	0.124	-0.002	0.168*	-0.063	-0.257**	-0.168*	-0.068	0.374**	0.126	-0.139	-0.11	0.039	0.037	0.193**	0.296**	0.057
DFFuH				1.00	-0.169*	0.010	0.245**	-0.200**	0.001	0.037	-0.269**	0.199**	-0.279**	-0.013	0.053	-0.232**	-0.238**	-0.274**	-0.196**	-0.263**
FuP					1.00	0.173*	0.101	0.334**	0.235**	-0.079	0.262**	0.176*	0.134	0.321**	0.328**	0.134	0.112	0.539**	0.206**	0.231**
PtH						1.00	0.686**	0.268**	0.239**	0.311**	0.550**	0.275**	0.416**	0.108	0.059	0.437**	0.436**	0.029	0.235**	0.407**
InL							1.00	0.339**	0.216**	0.288**	0.290**	0.147*	0.159*	0.133	0.089	0.322**	0.305**	-0.034	-0.206**	0.297**
PuL								1.00	-0.447**	-0.093	0.075	-0.219**	0.053	0.07	0.006	0.094	0.083	0.057	-0.109	0.105
NB/Pt									1.00	-0.14	0.323**	0.182*	0.375**	0.259**	0.218**	0.187*	0.168*	0.019	0.128	0.160*
SeD										1.00	0.137	0.04	-0.058	-0.194**	-0.054	0.138	0.151*	-0.105	-0.181*	0.112
NN/Pt											1.00	0.439**	0.384**	0.011	0.051	0.523**	0.518**	0.285**	0.258**	0.536**
FFuN												1.00	0.320**	0.122	0.022	0.303**	0.292**	0.108	0.125	0.296**
FuL													1.00	0.01	-0.299**	0.578**	0.551**	0.536**	0.619**	0.631**
FuD														1.00	0.743**	-0.152*	-0.149*	0.363**	0.025	-0.078
NL/Fu															1.00	-0.356**	-0.337**	0.121	-0.051	-0.315**
NF/Pt																1.00	1.001**	0.251**	0.112	0.980**
NMF/Pt																	1.00	0.224**	0.074	0.974**
AFuW																		1.00	0.637**	0.434**
NP/Pt																			1.00	0.224**
FY/Pt																				1.00

The trait No. of fruits plant^{-1} had significant and positive correlation with first flowering node, plant height, internodal length, No. of branches plant^{-1}, no. of nodes plant^{-1}, first fruiting node, fruit length, no. of marketable fruits plant^{-1}, average fruit weight and fruit yield plant^{-1}, whereas days to first flower, days to first fruit harvest, fruit diameter and no. of locules fruit^{-1} had significant and negative correlation. Similar findings were reported by Reddy *et al*. (2013) for plant height, no. of marketable fruits plant^{-1} and fruit yield plant^{-1}; Prasath *et al*. (2017) for fruit length; Thulasiram *et al*. (2017) for no. of branches plant^{-1} and no. of nodes plant^{-1}; and Vinithra *et al*. (2019) for average fruit weight, who observed a positive association with no. of fruits plant^{-1}. Negative association with no. of fruits plant^{-1} was reported by Ashraf *et al*. (2020) and Vinithra *et al*. (2019) for days to first fruit harvest; Thulasiram *et al*. (2017) for days to first flower; and Saryam (2012) for no. of locules fruit^{-1}.

No. of marketable fruits plant^{-1} had a significant and positive correlation with first flowering node, plant height, internodal length, no. of branches plant^{-1}, stem diameter, no. of nodes plant^{-1}, first fruiting node, fruit length, no. of fruits plant^{-1}, average fruit weight and fruit yield plant^{-1}, whereas days to first flower, days to first fruit harvest, fruit diameter and no. of locules fruit^{-1} had a significant and negative correlation. Similar findings were reported by Reddy *et al*. (2013) for plant height, fruit length, no. of fruits plant^{-1} and fruit yield plant^{-1}, which observed a positive association with no. of marketable fruits plant^{-1}.

Average fruit weight displayed a positive significant association with days to 50% flowering, fruiting period, no. of nodes plant^{-1}, fruit length, fruit diameter, no. of fruits plant^{-1}, no. of marketable fruits plant^{-1}, no. of pickings plant^{-1} and fruit yield plant^{-1} and a negative significant genotypic association with days to first fruit harvest. no. of pickings plant^{-1} was found to display significant positive relationships with days to 50% flowering, fruiting period, plant height, no. of nodes plant^{-1}, fruit length, average fruit weight and fruit yield plant^{-1}. days to first flower, days to first fruit harvest, internodal length, stem diameter and no. of locules fruit^{-1} with No. of pickings plant^{-1} all showed negative significance.

Fruit yield plant^{-1} displayed a positive significant genotypic association with first flowering node, fruiting period, plant height, internodal length, no. of branches plant^{-1}, no. of nodes plant^{-1}, first fruiting node, fruit length, no. of fruits plant^{-1}, no. of marketable fruits plant^{-1}, average fruit weight and no. of pickings plant^{-1} and a negative significant genotypic association with days to first fruit harvest and no. of locules fruit^{-1}. Reddy *et al*. (2013) recorded a similar positive association of fruit yield plant^{-1} for no. of fruits plant^{-1}, no. of marketable fruits plant^{-1} and fruit length; Thulasiram *et al*. (2017) for no. of branches plant^{-1}, plant height and no. of nodes plant^{-1} and Archana *et al*. (2015) for fruiting period. While negative association on fruit yield plant^{-1} with days to first fruit harvest were reported by Thulasiram *et al*. (2017) and Tudu *et al*. (2021) in okra crop.

Positively correlated characteristics between desirable traits are beneficial to plant breeders since they assist in the development of both characters at the same time. A negative correlation, on the other hand, will make it difficult to represent both characters with high values at the same time. In such a case, an economic compromise must be negotiated. Strong selection on the character that is genetically associated with the dependent character might result in genetic improvement in the dependent character.

In general, negative relationships occur between the two key yield components in all vegetable crops. Especially in okra, no. of fruits plant^{-1} and fruit length. In such cases, results in characteristics associated with negative relationships, breeders have a tendency to disrupt these unfavourable negative relationships between yield components. Unwanted linkages between such traits may emerge as a result of genetic reshuffling and dissociation of such linkages may be achieved by bi-parental intermingling in early segregating populations.

Path coefficient analysis

The breeder's immediate objective is to solve individual defects while maximising production potential. Yield is a complicated characteristic that combines multiple features. Some of them are major components that directly affect yield, while others indirectly impact yield by influencing the behaviour and growth of other components. So, it's better to know how other factors affect yield both directly and indirectly (Rathava *et al*., 2019). Path analysis is used to figure out how important each attribute is and to cut down on the number of attributes in selection programs. Path analysis at the genotypic level was used to figure out how direct and indirect effects work together to show how different plant parts work together to provide food.

The estimates of the path coefficient matrix are furnished in Table 2. At the genotypic level, days to first flower, days to 50% flowering, fruiting period, no. of branches plant^{-1} and fruit length exhibited negligible positive direct effects on fruit yield per plant, while internodal length, peduncle length, stem diameter, no. of nodes plant^{-1}, fruit diameter and no. of locules fruit^{-1} had a negligible negative direct effect on fruit yield per plant. Plant height had a low positive direct effect, whereas days to first fruit harvest and no. of pickings plant^{-1} exhibited a low negative direct effect. First fruiting node is the only character that obtains a highly negative direct effect on fruit yield plant^{-1}, whereas, first flowering node, no. of fruits plant^{-1}, no. of marketable fruits plant^{-1} and average fruit weight obtained highly positive direct effect on fruit yield plant^{-1}. The positive direct effect results are similar to those of Al-Juboori (2021) for plant height, no. of fruits plant^{-1}; Reddy *et al*. (2013) for no. of marketable fruits plant^{-1} and no. of branches plant^{-1}; Tudu *et al*. (2021) for days to first flower and Ranga *et al*. (2021) for days to 50% flowering and fruit length. Negative direct effects are conformity with the findings of Tudu *et al*. (2021) for first flowering node; Sharma and Prasad (2015) for days to first fruit harvest and Al-Juboori (2021) for no. of nodes plant^{-1}.

The residual factor indicates how successful the casual factors contributed to the variability of the dependent

Table 2: Genotypic path matrix (diagonal and bold are direct effects and off diagonal are indirect effects) for fruit yield plant^{-1} in okra.

Traits	First Flowering Node	Days to first flower	Days to first 50% flowering	Days to first fruit harvest	Fruiting period	Plant height	Internode length	Peduncle length	No. of branches plant^{-1}	Stem diameter	No. of nodes plant^{-1}	First fruiting node	Fruit length	Fruit diameter	No. of locules fruit^{-1}	No. of fruits plant^{-1}	No. of Marketable fruits plant^{-1}	Average fruit weight	No. of pickings plant^{-1}
FFrN	-0.404	0.020	0.017	-0.024	0.022	0.028	-0.003	0.012	0.009	-0.001	-0.021	0.387	0.002	-0.008	-0.006	-0.062	0.196	0.045	-0.012
DFFr	-0.088	0.090	0.041	-0.156	-0.007	0.006	-0.013	0.005	-0.012	-0.003	0.007	0.102	-0.001	0.003	-0.004	0.055	-0.178	0.022	-0.007
D50%Fr	-0.136	0.074	0.050	-0.139	0.009	0.000	-0.007	0.003	-0.014	0.003	0.004	0.151	0.001	0.007	0.007	-0.013	0.042	0.059	-0.043
DFFuH	-0.060	0.086	0.042	-0.164	-0.012	0.001	-0.011	0.009	0.000	-0.001	0.015	0.081	-0.002	0.001	-0.003	0.079	-0.268	-0.084	0.028
FuP	-0.120	-0.009	0.006	0.028	0.073	0.022	-0.004	-0.014	0.013	0.002	-0.014	0.071	0.001	-0.017	-0.019	-0.046	0.126	0.166	-0.030
PtH	-0.092	0.005	0.000	-0.002	0.013	0.125	-0.029	-0.012	0.013	-0.006	-0.030	0.111	0.002	-0.006	-0.004	-0.148	0.491	0.009	-0.034
InL	-0.025	0.027	0.008	-0.040	0.007	0.086	-0.043	-0.015	0.012	-0.006	-0.016	0.059	0.001	-0.007	-0.005	-0.109	0.343	-0.010	0.030
PuL	0.109	-0.010	-0.003	0.033	0.024	0.033	-0.015	-0.043	-0.024	0.002	-0.004	-0.089	0.000	-0.004	0.000	-0.032	0.094	0.018	0.016
NB/Pt	-0.065	-0.021	-0.013	0.000	0.017	0.030	-0.009	0.019	0.054	0.003	-0.018	0.074	0.002	-0.014	-0.013	-0.063	0.189	0.006	-0.019
SeD	-0.024	0.013	-0.008	-0.006	-0.006	0.039	-0.012	0.004	-0.008	-0.019	-0.007	0.016	0.000	0.010	0.003	-0.047	0.170	-0.032	0.026
NN/Pt	-0.158	-0.012	-0.003	0.044	0.019	0.069	-0.012	-0.003	0.017	-0.003	-0.054	0.178	0.002	-0.001	-0.003	-0.177	0.583	0.088	-0.037
FFuN	-0.387	0.023	0.019	-0.033	0.013	0.034	-0.006	0.009	0.010	-0.001	-0.024	0.404	0.002	-0.006	-0.001	-0.103	0.329	0.033	-0.018
FuL	-0.116	-0.010	0.006	0.046	0.010	0.052	-0.007	-0.002	0.020	0.001	-0.021	0.130	0.005	-0.001	0.018	-0.196	0.620	0.165	-0.089
FuD	-0.058	-0.005	-0.007	0.002	0.023	0.013	-0.006	-0.003	0.014	0.004	-0.001	0.049	0.000	-0.053	-0.044	0.051	-0.168	0.112	-0.004
NL/Fu	-0.039	0.006	-0.005	-0.009	0.024	0.007	-0.004	0.000	0.012	0.001	-0.003	0.009	-0.002	-0.039	-0.059	0.121	-0.379	0.037	0.007
NF/Pt	-0.074	-0.015	0.002	0.038	0.010	0.055	-0.014	-0.004	0.010	-0.003	-0.028	0.122	0.003	0.008	0.021	0.339	1.126	0.077	-0.016
NMF/Pt	-0.070	-0.014	0.002	0.039	0.008	0.054	-0.013	-0.004	0.009	-0.003	-0.028	0.118	0.003	0.008	0.020	-0.339	1.126	0.069	-0.011
AFuW	-0.059	0.006	0.010	0.045	0.039	0.004	0.001	-0.002	0.001	0.002	-0.015	0.044	0.003	-0.019	-0.007	-0.085	0.252	0.307	-0.092
NP/Pt	-0.034	0.004	0.015	0.032	0.015	0.029	0.009	0.005	0.007	0.004	-0.014	0.051	0.003	-0.001	0.003	-0.038	0.084	0.196	-0.145

Residual Effect =0.00657.

variable, in this example, fruit yield per plant. The residual effect was 0.00657 respectively, of negligible and insignificant. The significantly correlated and path positively direct characteristics reveals true relationship between them and would be included in a selection procedure for future okra improvement. Thus, no. of fruits plant^{-1} and fruit length have a cumulative effect on okra fruit yield. Okra breeders should pay close attention to these two characteristics. They must be worked on collaboratively in order to produce an ideotype.

Path coefficient analysis's positive direct effect on fruiting period, plant height, internodal length, no. of branches plant^{-1}, first fruiting node, no. of fruits plant^{-1}, no. of marketable fruits plant^{-1}, no. of pickings plant^{-1} and average fruit weight was almost comparable to their positive genotypic association with fruit yield plant^{-1}. Therefore, correlation indicates the underlying link between those features and direct selection based on these attributes will be beneficial. The genotypic path coefficient study demonstrated that days to first fruit harvest and no. of locules fruit^{-1} had a negative direct influence on fruit yield plant^{-1}, despite their strong negative correlation association. Under these conditions, a limited simultaneous selection model should be used, which means that limits should be placed on the undesired indirect effects through any other qualities in order to employ the direct impact. Although the genotypic correlation coefficients of first flowering node, no. of nodes plant^{-1} and fruit length with fruit yield plant^{-1} were positive, their direct path impact was negative. In this case, the indirect effects seem to be the source of the association and hence the indirect causal variables must be examined concurrently for selection.

Hierarchical cluster analysis (HCA)

Ward's minimum variance method is a type hierarchical cluster analysis and is a special case of the objective function approach originally presented by Ward (1963). Ward suggested a general agglomerative hierarchical clustering procedure, where the criterion for choosing the pair of clusters to merge at each step is based on the optimal value of an objective function. The hierarchical cluster analysis between sixty okra genotypes for yield and yield related traits under the study were grouped into ten major clusters (Table 3) and presented through a dendrogram using Ward's method (Ward, 1963) as an amalgamation rule and squared Euclidean distance as the measure of proximity between samples (Prasad and Sharma, 2012). The clustering was not based on a similar geographical origin. This indicated there was no association between clustering pattern and eco-geographical distribution of genotypes, which was supported by the previous studies of Ramya and Senthilkumar (2009) and Koundinya *et al.* (2016).

Among ten clusters, cluster I, II, IX and X was accommodated with single genotypes each, cluster IV with 15 genotypes and having highest number of genotypes in the cluster, cluster V with 12 genotypes, cluster VI with 13, cluster III and VII with 6 and cluster VIII with 4 genotypes (Table 3 and Fig 1). Cluster analysis is applied to place similar genotypes in one group as it determines the genotype by far or nearness on the basis of variation present between them (Sajad-Bokaei *et al.*, 2008). The differentiation of genotypes into distinct clusters proposed existence of genetic diversity in the genotypes screened in the present study suggesting that this material may serve as good source for selecting the diverse parents for hybridization program. In cluster analysis, there is no prior information about the group or cluster membership for any objects (Ranga *et al.*, 2021). Similar finding also reported by Prasad and Sharma (2012) for 19 okra genotypes into four clusters and Ranga *et al.* (2021) for 15 okra genotypes into two clusters by applying wards HCA.

Cluster-wise mean values of various characters were presented in Table 4. Cluster VIII had highest mean values for all the important yield components like no. of nodes plant^{-1}, no. of fruits plant^{-1}, no. of marketable fruits plant^{-1}, no. of pickings plant^{-1} and fruit yield plant^{-1} and lower values for earliness characters like days to flowering and harvesting.

Table 3: Distribution of 60 genotypes into different clusters based on wards method in okra.

Cluster	No. of genotypes	Name of genotypes
I	1	IC014026
II	1	EC359637
III	6	VarshaUphar, Rani-792, V-4, NOL-1307, Maharani, RajaLocal, MaduraiLocal
IV	15	ArkaAnamika, ArkaAbhay, HisarUnnat, HinaRCH, MH310, Pusa-A4, VRO-4, Ruchi, Ajeet-121, Anima, Harika, Ankur-40, SC-55, DHANVI-66, ChidambaramLocal
V	12	Punjab-8, Punjab-7, Punjabno.13, BS-51, AKO-111, Lushgreen, Hyveg-155, VRO-6, AKO-102, HisarNaveen, NOL-303+, Ankur-41
VI	13	PusaSawani, PusaMakhmali, VRO-22, MDU-1, V-4, HariPari, TS-102, LS-11, NRB-208, Superladylock, KiranLocal, BambeshwariLocal, DanteshwariLocal
VII	6	Pusa-5, Mahyco777, HariKranti, Superanamika, SugunaA-51, AKO-107
VIII	4	VRO-3, Salkeerthi, Gold-207, Palamkomal
IX	1	HoshiarpurLocal
X	1	EC305798

Table 4: Cluster wise mean values of 20 characters in 10 clusters of okra.

Characters	Clusters									
	I	II	III	IV	V	VI	VII	VIII	IX	X
First flowering node	3.60	5.33	4.44	5.49	4.86	5.58	5.89	5.32	5.97	6.60
Days to first flower	38.00	39.33	38.72	39.93	37.08	37.26	38.83	37.83	39.00	38.00
Days to first 50% flowering	40.33	41.67	43.17	43.78	40.58	41.77	43.28	41.42	43.00	41.67
Days to first fruit harvest	49.33	49.00	48.39	49.29	46.97	47.08	48.78	47.33	48.33	48.00
Fruiting period	50.00	60.33	59.72	58.07	59.56	57.56	58.28	59.33	62.00	63.67
Plant height	60.01	74.65	82.85	84.16	89.40	84.12	101.37	99.46	101.47	104.68
Internode length	5.30	5.87	6.38	5.94	6.03	5.71	6.98	7.32	8.73	7.40
Peduncle length	2.17	2.30	2.39	2.28	2.54	2.26	2.26	2.37	3.03	2.17
No. of branches plant^{-1}	3.40	3.60	3.90	3.63	3.77	3.71	4.11	3.83	2.73	5.53
Stem diameter	17.12	15.96	15.71	16.22	16.33	15.89	17.42	16.78	15.35	16.46
No. of nodes plant^{-1}	13.80	16.93	16.99	17.41	17.83	17.94	19.04	19.82	17.47	17.80
First fruiting node	3.60	5.53	4.77	5.80	5.17	5.88	6.31	5.64	6.60	6.27
Fruit length	7.37	9.43	14.13	14.24	14.21	14.60	14.38	14.85	14.90	16.33
Fruit diameter	14.02	20.88	15.98	16.43	16.35	16.07	15.53	16.85	16.76	20.16
No. of locules fruit^{-1}	5.00	7.40	5.18	5.13	5.23	5.16	5.20	5.10	5.27	5.93
No. of fruits plant^{-1}	16.40	16.73	23.40	26.02	26.91	25.83	28.42	31.48	26.80	25.00
No. of Marketable fruits plant^{-1}	15.40	15.80	21.30	23.86	24.71	23.57	25.93	28.95	24.53	22.67
Average fruit weight	10.77	13.26	13.41	13.46	13.36	13.33	12.83	13.46	13.14	13.92
No. of pickings plant^{-1}	11.13	12.93	13.77	14.07	13.89	14.38	13.86	13.35	12.40	15.53
Fruit yield plant^{-1}	176.40	221.47	313.91	349.86	358.64	342.52	364.43	418.22	352.33	347.80

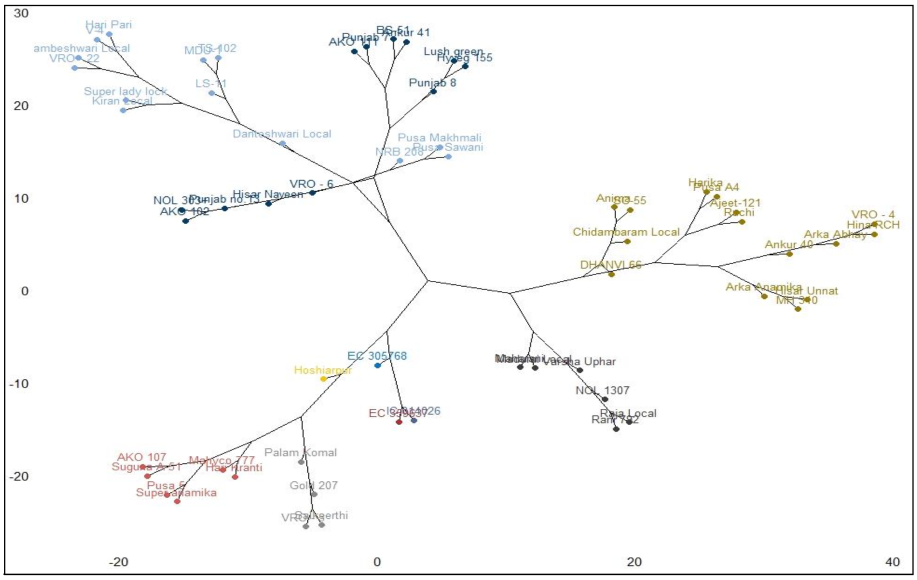

Fig 1: Phylogenetic tree dendrogram showing genetic relationship among 60 okra genotypes based on 20 biometrical traits using Ward's method

Cluster I recorded the lowest mean values for number of fruits plant^{-1}, average fruit weight, fruit length and fruit yield plant^{-1} and late maturity.

CONCLUSION

From the study it is concluded that, the association analysis of twenty biometrical traits revealed a strong association among the growth, earliness and fruit yield parameters of the okra under study. Based on the interrelationships, okra breeding improvement in fruit yield plant^{-1} will be efficient if the selection is based on fruiting period, plant height, no. of branches plant^{-1}, first fruiting node, fruit length, no. of fruits plant^{-1}, no. of marketable fruits plant^{-1}, no. of pickings plant^{-1} and average fruit weight. Wards hierarchical cluster analysis grouped the 60 genotypes into 10 clusters and among that cluster IV contains highest number of genotypes.

cluster VIII recorded the highest mean values for all the fruit yield related characters. The genotypes from cluster VIII are selected for further improvement in okra breeding programme. Based on whole results in the research the characters from interrelationships and parents from hierarchical clustering analysis shown variation has to be taken for further breeding programme to obtain high heterosis.

Conflict of interest: None.

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