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Correlation and path coefficient analysis studies in okra (*Abelmoschus esculentus* (L.) Moench)

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Abstract
Correlation and path coefficient analysis studies were carried out in thirty six okra genotypes for fourteen traits *viz*., days to first flowering, days to 50 per cent flowering, plant height, number of branches per plant, internodal length, fruit length, fruit girth, fruit weight, number of fruits per plant, total phenols, peroxidase activity, polyphenol oxidase activity, per cent disease infection and yield per plant. The study revealed that yield per plant was positively correlated with fruit girth, fruit length, number of fruits per plant, plant height and fruit weight at genotypic level of correlation. Whereas the characters, per cent disease incidence, days to fifty per cent flowering, internodal length and days to first flowering were found to have negative correlation with single plant yield at genotypic level. The high positive direct effect on yield plant was contributed by fruit girth followed by plant height, fruit weight, fruit length and number of branches per plant. Hence, improvement in yield will be efficient if selection is based on fruit girth, fruit length, number of fruits per plant, plant height and fruit weight and short flowering period.

Keywords: Correlation, path coefficient, *Abelmoschus esculentus* L.

Introduction
Okra (*Abelmoschus esculentus* (L.) Moench) belong to the family Malvaceae and it is widely grown for its tender pods in tropical and sub-tropical parts of the world (Wammanda *et al*., 2010) [19]. It has various names such as Lady's finger and okra in English, bhendi in Hindi, gombo in French and ibisco in Italian. The exact origin of okra is unknown, but it is believed to have originated from West Africa. Ethiopia is considered to be its origin by Vavilov, 1951.
Tender and immature pods of okra are used as vegetable. It has a vital source of fat, carbohydrate, fiber, calcium, phosphorous, iron, ascorbic acid, carotene, thiamin and riboflavin (Benchasri, 2012) [2]. It is also rich in carbohydrates which is mainly present in the form of mucilage (Kumar and Yadav, 2009) [7]. The mucilage in okra has been used in Asian medicine as a protective food additive against irritating and inflammatory gastic diseases (Lengsfeld *et al*., 2004) [10]. Dried stems and roots of okra have been reported to be utilized for cleaning sugarcane juice from which molasses is prepared. Crude fibre is present in mature pods and stems which is utilized by the paper industry. It is also rich in iodine besides other nutritional benefits (Benchasri, 2012) [2].
Correlation and Path Analysis are considered to be important and efficient tools useful for getting information regarding association of various characters. This is beneficial for plant breeder in developing high yielding cultivar by determining the component traits on which selection can be based for improvement of yield. The present study was done to find out the association of different traits and their direct and indirect effects.

Materials and Methods
The present study was carried out at Department of Vegetable Crops, Horticultural and Research Institute, Tamil Nadu Agricultural University, Coimbatore during summer of 2019. The experimental material consist of thirty six okra hybrids developed from the crosses of twelve diverse okra genotypes in a Line x Tester mating design. The genotypes which were utilized as Lines were high yielding in nature *viz*., Pusa Sawani, Parbhani Kranti, Arka Abhay, Arka Anamika, AE 65 and 14/11. The genotypes used as testers were resistant/tolerant towards Yellow Vein Mosaic Virus (YVMV) disease *viz*., AE 64, AE 66, AE 17, 14/4, 14/5 and 14/10. Both lines and testers were selected based on screening studies for Yellow Vein Mosaic Virus (YVMV) disease conducted previously during the summer of 2018. The materials were obtained from National Bureau of Plant Genetic Resources and Department of Vegetable Crops, Horticultural and Research Institute, Tamil Nadu Agricultural University.
The selected genotypes were crossed in a Line x Tester mating design to yield thirty six cross combinations. (table 1).

The thirty six hybrids developed were evaluated and raised along with a YVMV resistant check cultivar Bhendi Hybrid CO 4 in randomized block design replicated twice with 25 plants in each replication following a spacing of 60 x 45 cm. In order to grow a successful crop, recommended package of practices by Tamil Nadu Agricultural University were followed. The observations were recorded from five randomly selected plants from each treatment and their average values were used for statistical analysis. Data was collected for fourteen traits *viz*., days to first flowering, days to 50 per cent flowering, plant height (cm), number of branches per plant, internodal length (cm), fruit length (cm), fruit girth (cm), fruit weight (g), number of fruits per plant, total phenol (mg/100g), peroxidase activity (Activity/min/g), polyphenol oxidase activity (Activity/min/g), per cent disease incidence and yield per plant (g). The genotypic correlation was worked out as per Singh and Chaudhary (1979) [16]. It provides information about relationship between a pair of variables and the direction of their relationship. Direct and indirect effects of yield attributes on yield through path analysis were also carried out.

Table 1: List of genotypes/hybrids used in the study

Genotypes			
1.	Pusa Sawani x AE 64	19.	Arka Anamika x AE 64
2.	Pusa Sawani x AE 66	20.	Arka Anamika x AE 66
3.	Pusa Sawani x AE 17	21.	Arka Anamika x AE 17
4.	Pusa Sawani x 14/4	22.	Arka Anamika x 14/4
5.	Pusa Sawani x 14/5	23.	Arka Anamika x 14/5
6.	Pusa Sawani x 14/10	24.	Arka Anamika x 14/10
7.	Parbhani Kranti x AE 64	25.	AE 65 x AE 64
8.	Parbhani Kranti x AE 66	26.	AE 65 x AE 66
9.	Parbhani Kranti x AE 17	27.	AE 65 x AE 17
10.	Parbhani Kranti x 14/4	28.	AE 65 x 14/4
11.	Parbhani Kranti x 14/5	29.	AE 65 x 14/5
12.	Parbhani Kranti x 14/10	30.	AE 65 x 14/10
13.	Arka Abhay x AE 64	31.	14/11 x AE 64
14.	Arka Abhay x AE 66	32.	14/11 x AE 66
15.	Arka Abhay x AE 17	33.	14/11 x AE 17
16.	Arka Abhay x 14/4	34.	14/11 x 14/4
17.	Arka Abhay x 14/5	35.	14/11 x 14/5
18.	Arka Abhay x 14/10	36.	14/11 x 14/10

Results and Discussion

It is necessary to study, assess and understand the relationship between yield and yield attributing traits before exercising selection. With this view in mind, correlation coefficients of different yield attributing traits with single plant yield were worked out and presented in Table 2

Genotypic correlation with yield per plant

The traits fruit girth (0.7803), fruit length (0.7414), number of fruits per plant (0.6884), plant height (0.6725) and fruit weight (0.6311) recorded significantly positive correlation with single plant yield at genotypic level. Whereas the characters, days to first flowering (-0.6868), internodal length (-0.6746), days to fifty per cent flowering (-0.5087) and per cent disease incidence (-0.2844) were found to have significantly negative correlation with single plant yield at genotypic level.

Inter correlation among yield and yield contributing traits

The inter correlation coefficients of days to first flowering with plant height (-0.8115), fruit length (-0.7566), fruit girth (-0.6512), fruit weight (-0.4973) and number of fruits per plant (-0.7661) was negative and significant. The inter correlation of days to first flowering was positive and significant with days to 50 per cent flowering (0.762) and internodal length (0.4128). The association of days to 50 per cent flowering was negative and significant with plant height (-0.7015), fruit length (-0.5704), fruit girth (-0.4179), fruit weight (-0.5754), number of fruits per plant (-0.668), whereas it was positive and significant with internodal length (0.4605). The trait plant height exhibited positive and significant intercorrelation with fruit length (0.8334), fruit girth (0.7105), fruit weight (0.6999) and number of fruits per plant (0.9504) The traits internodal length (-0.5121) and percent disease incidence (-0.2856) showed negative and significant intercorrelation with plant height**.** Number of branches per plant recorded significant and positive intercorrelation with fruit length (0.0649) and fruit weight (0.4166) and had no intercorrelation with other traits. Negative and significant association of internodal length was expressed by fruit length (-0.4429), fruit girth (-0.6068), fruit weight (-0.4439) and number of fruits per plant (-0.5376)**.** The intercorrelation of fruit length with the traits fruit girth (0.8232), fruit weight (0.6768) and number of fruits per plant (0.8913) was positive and significant whereas, negative and significant intercorrelation was expressed by percent disease incidence (-0.282). The association of fruit girth was significant and positive with the traits fruit weight (0.4826) and number of fruits per plant (0.8025). Fruit weight expressed positive and significant intercorrelation with number of fruits per plant (0.6974)**.** Total phenols expressed positive and significant intercorrelation with plant disease incidence (0.2783). Peroxidase activity expressed positively significant association with percent disease incidence (0.3569). Significant and positive intercorrelation was observed with percent disease incidence (0.2704) by polyphenol oxidase activity. The correlation studies have shown that there is significance high and positive correlations of yield per plant with plant height, fruit length, fruit girth, fruit weight and number of fruits per plant which indicates that selection of okra genotypes based on these traits will enhance the overall yield of okra. The findings are in accordance with the results of Das *et al.* (2012) [4], Kumar *et al.* (2012) [9] and Sogalad *et al*. (2012) [17].

Days to first flowering and days to 50 per cent flowering showed high negative and significant association with yield per plant, which indicates that the lesser duration of days to flowering or earliness will ultimately lead to an increase in the yield of okra. These findings are in line with the findings of Sharma *et al*. (2007) [15], Balakrishnan and Sreenivasan (2010) [10], Kumar *et al*. (2011) [8] and Adiger *et al*. (2011) [1].

Percent disease incidence i.e, Yellow Vein Mosaic Virus (YVMV) disease exhibited negative correlation with yield per plant indicating that the disease play a vital role in the overall yield of okra. Plant height showed negative and significant intercorrelation with per cent disease incidence suggesting that plant height is retarded by YVMV infestation. Fruit length expressed negative and significant intercorrelation with percent disease incidence which suggest that YVMV disease has an adverse effect on the growth of the plant which ultimately reduces the overall yield in okra. These results were in line with the findings of Jamir *et al*. (2020) [6] and Mahalik (2018) [11]. Positive and significant intercorrelation was recorded by total phenols, peroxidase activity and polyphenol oxidase activity with plant disease incidence. This signify that with increase in the incidence of YVMV disease the activities of secondary metabolites also increases which serve as the biochemical basis of resistance against the disease. Similar reports were found by Prabhu and Warade (2009) and Mahalik (2018) [11].

Table 2: Genotypic correlation coefficients among yield and yield related traits in okra

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1	0.762**	-0.8115**	0.1601	0.4128**	-0.7566**	-0.6512**	-0.4973**	-0.7661**	-0.1913	-0.1293	-0.1516	-0.1255	-0.6868**
2		1	-0.7015**	-0.0557	0.4605**	-0.5704**	-0.4179**	-0.5754**	-0.668**	-0.0922	-0.0714	-0.1167	-0.2355	-0.5087**
3			1	0.1482	-0.5121**	0.8334**	0.7105**	0.6999**	0.9504**	0.140	0.159	0.0128	-0.2856*	0.6725**
4				1	-0.271	0.0649**	-0.0042	0.4166**	0.1934	0.1312	0.182	-0.0855	0.1574	0.1617
5					1	-0.4429**	-0.6068**	-0.4439**	-0.5376**	-0.1244	-0.1981	-0.2092	-0.1435	-0.6746**
6						1	0.8232**	0.6768**	0.8913**	0.1066	0.1361	0.1091	-0.282*	0.7414**
7							1	0.4826**	0.8025**	0.181	0.1616	0.046	0.1077	0.7803**
8								1	0.6974**	0.1359	0.134	0.1937	-0.0017	0.6311**
9									1	0.1581	0.1066	0.1684	0.1569	0.6884**
10										1	0.206	0.1412	0.2783*	0.1671
11											1	0.1066	0.3569*	0.103
12												1	0.2704*	0.1715
13													1	-0.2844*
														1

**Significant at 1 per cent level of probability, *Significant at 5 per cent level of probability

1. Days to first flowering
2. Days to 50 % flowering
3. Plant height
4. Number of branches per plant
5.Internodal length
6.Fruit length
7.Fruit girth
8. Fruit weight
9. Number of fruits/plant
10. Total Phenol
11. Peroxidase activity
12. Polyphenol oxidase activity
13. Per cent disease incidence
14. Yield per plant

Path coefficient analysis

Path coefficient analysis is a standardized partial regression coefficient which divides the correlation coefficients in direct and indirect effects of a set of independent variables on the dependent variable. This analysis helps us to understand whether the relationship of these traits with yield is due to the direct effect of the trait, reflects a true relationship between them and selection can be practiced for such a variable to improve yield. For estimating the
direct and indirect effect of constituent characters on yield, the genotypic correlation of all characters under study was included (Table. 3)

The high positive direct effect on yield plant was contributed by fruit girth (0.6153) followed by plant height (0.5625), fruit weight (0.409), fruit length (0.3865) and number of branches per plant (0.3437). This suggest that direct selection of these traits would enhance the overall yield in okra. These results were showing similarity with Gangashetty *et al.* (2010) [5], Adiger *et al.* (2011) [1], Sogalad *et al.* (2012) [17] and Das *et al.* (2012) [4].

Days to first flowering (-0.4034) and days to 50 per cent flowering (-0.0381) exerted negative direct effect on yield. Lesser duration of days to flowering or earliness play a vital towards enhancing yield as suggested by Balakrishnan and Sreenivasan (2010) [3], Sogalad *et al.* (2012) [17] and Das *et al.* (2012) [4]. In case of per cent disease incidence (-0.353), which also recorded a negative direct effect suggest that with higher incidence of YVMV disease there will be reduction in total yield. Similar results was reported by Seth *et al.* (2017) [14] and Mahalik (2018) [11]. Negative direct effects were low for internodal length and number of fruits per plant, indicating that the association of these traits with yield were low, hence selection based on these traits would not be effective. The results are similar to those reported by Verma *et al.* (2007) [18] and Naidu *et al.* (2007) [12].

Days to first flowering and days to 50 per cent flowering exerted the highest positive indirect effect on yield per plant through number of fruits per plant (0.9264) and (0.8078) respectively. This is supported by Yadav *et al.* (2010) [20] and Balakrishnan and Sreenivasan (2010) [3]. Plant height possessed high and positive indirect effect through fruit girth (0.4371), followed by days to first flowering (0.3273) and fruit length (0.3221). These were in line with the findings of Balakrishnan and Sreenivasan (2010) [3] and Kumar *et al.* (2012) [9]. Internodal length recorded positive indirect association through number of fruits per plant (0.65) which is supported by Balakrishnan and Sreenivasan (2010) [3] and Adiger *et al.* (2011) [1]. Indirect association of fruit length was high and positive towards yield per plant through fruit girth (0.5065) followed by plant height (0.4688) and days to first flowering (0.3052). Fruit girth showed high and positive indirect association through plant height (0.3996), fruit length (0.3182) and days to first flowering (0.2627). Similar reports were found by Adiger *et al.* (2011) [1] and Kumar *et al.* (2012). Positive indirect effect was recorded through plant height (0.3936), fruit girth (0.2969), fruit length (0.2616) and days to first flowering (0.2006) for fruit weight which were in line with the findings of Balakrishnan and Sreenivasan (2010) [3] and Kumar *et al.* (2012). Similarly, positive indirect effect was observed for number of fruits per plant through plant height (0.5346), fruit girth (0.4937), fruit length (0.3445) and days to first flowering (0.309) which were in accordance to the findings of Balakrishnan and Sreenivasan (2010) [3] and Kumar *et al.* (2012) [4].

The characters *viz.*, days to first flowering, days to 50 per cent flowering, plant height, internodal length, fruit length, fruit girth, fruit weight and number of fruits per plant which exhibited high positive indirect effects towards yield signify that selection of these traits would indirectly improve the yield. An overall observation of path analysis of yield per plant and its relationship with other yield contributing traits or components i.e., plant height, number of branches per plant, fruit length, fruit girth and fruit weight which expressed high and positive direct effects on yield per plant play an important role in determining the overall yield of the plant. Hence, selection pressure on these traits must be given due importance.

Apart from the characters and traits which are understudy, we have other component traits which are not included in the study but still contribute towards yield of the plant. These characters are termed as residual characters and their contribution toward yield is called residual effect. As the residual effect of the current investigation was found to be low i.e, 0.2999 which indicated and reflected the involvement of maximum yield contributing characters or traits of okra in the study.

Table 3: Genotypic path coefficient analysis of yield contributing traits with yield per plant in okra

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	-0.4034	-0.0291	-0.4564	0.055	-0.1113	-0.2925	-0.4007	-0.0204	0.9264	0.0726	0.0052	-0.0766	0.0443	-0.6868**
2	-0.3073	-0.0381	-0.3946	-0.0192	-0.1242	-0.2205	-0.2571	-0.0236	0.8078	0.0517	0.0057	-0.0725	0.0831	-0.5087**
3	0.3273	0.0268	0.5625	0.0509	0.1381	0.3221	0.4371	0.0287	-1.1492	-0.0672	-0.0044	0.0709	-0.0711	0.6725**
4	-0.0646	0.0021	0.0833	0.3437	0.0731	0.0251	-0.0026	0.0171	-0.2339	-0.0138	-0.0022	-0.0101	-0.0556	0.1617
5	-0.1665	-0.0176	-0.288	-0.0932	-0.2696	-0.1712	-0.3733	-0.0182	0.65	0.0656	0.0048	-0.0481	0.0507	-0.6746**
6	0.3052	0.0218	0.4688	0.0223	0.1194	0.3865	0.5065	0.0277	-1.0778	-0.0847	-0.0065	0.0834	-0.0311	0.7414**
7	0.2627	0.0159	0.3996	-0.0014	0.1636	0.3182	0.6153	0.0198	-0.9704	-0.0715	-0.0044	0.0711	-0.038	0.7803**
8	0.2006	0.0219	0.3936	0.1432	0.1197	0.2616	0.2969	0.409	-0.8433	-0.0668	-0.0077	0.0698	0.0006	0.6311**
9	0.309	0.0255	0.5346	0.0665	0.1449	0.3445	0.4937	0.0286	-0.2092	-0.0691	-0.0037	0.0786	-0.0554	0.6884**
10	0.0278	0.0188	0.036	0.0451	0.1683	0.03117	0.0419	0.026	-0.1958	-0.105	-0.0086	0.0754	-0.0276	0.1671
11	0.1732	0.018	0.2019	0.0625	0.1073	0.2072	0.2225	0.026	-0.1707	-0.0741	-0.0122	0.0713	0.0201	0.103
12	0.2628	0.0235	0.1339	-0.0294	0.1103	0.2741	0.1372	0.0243	-0.1808	-0.0673	-0.0074	0.1176	0.0601	0.1715
13	0.0506	0.009	0.1132	0.0541	0.0387	0.0341	0.0662	-0.0001	-0.1897	-0.0082	0.0007	-0.02	-0.353	-0.2844*

**Significant at 1 per cent level of probability, *Significant at 5 per cent level of probability

1. Days to first flowering
2. Days to 50 % flowering
3. Plant height
4. Number of branches per plant
5. Internodal length
6. Fruit length
7. Fruit girth
8. Fruit weight
9. Number of fruits/plant
10. Total Phenol
11. Peroxidase activity
12. Polyphenol oxidase activity
13. Per cent disease incidence
14. Yield per plant

Residual effect = 0.299

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