The Pharma Innovation Journal 2022; 11(2): 2050-2053

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(2): 2050-2053
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www.thepharmajournal.com
Received: 07-12-2021
Accepted: 21-01-2022

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Path coefficient analysis studies in okra [*Abelmoschus esculentus* (L.) Moench.]

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Abstract
Path analysis were studied using parents (VRO-3, VRO-6, 440-10-1, TCR-1674, JPM-20-16-39 and HRB-9-2), their F_1. Observations were recorded on eighteen yield and its contributing characters. Path coefficient analysis showed that traits like plant height, number of fruits per plant, fruit length, fruit girth, fruit weight, number of seeds per fruit and test weight exhibited high and positive direct effect on fruit yield per plant indicating that direct selection based on these traits would result in improved fruit yield per plant in okra.

Keywords: Okra, correlation, breeding programmes, yield

Introduction
Okra [*Abelomoschus esculentus* (L.) Moench] commonly known as lady's finger belongs to the family Malvaceae. Tender okra fruits are used as vegetable in countries like India, Brazil, West Africa and is also available in dehydrated and canned forms. The sun-dried (Africa, India), frozen and sterilized (USA) fruits are other important market products. Okra fruit contains 90% water, 3% dietary fibre, 7% carbohydrates, 2% protein, good quantities of minerals, vitamin C and A and moderate contents of thiamin, folate and magnesium (Chopra *et al*., 1956) [1].
The cause and effect relationship is well defined in path coefficient analysis. It is simply a standardized partial regression coefficient which splits the correlation coefficient into the measures of direct and indirect effects, *i.e.* it measures the direct and indirect contribution of various independent characters on a dependent character.

Materials and Methods
The experimental material consisted of 22 genotypes and were evaluated in randomized block design with three replications with spacing of 60 cm x 30 cm during *Kharif*, 2018. Observations were recorded on five randomly selected plants from each plot for traits *viz*., plant height (cm), days to first flowering, internodal length (cm), first flowering node, days to 50% flowering, days to first picking, days to last picking (days), number of fruits per plant, fruit length (cm), fruit diameter (cm), fruit weight (g), ridges per fruit, number of seeds per fruit, test weight (g/100), fruit yield per plant (g), fruit yield per hectare (t), fibre content (g/100g), ascorbic acid content (mg/100g) and shelf life (d).

Results and Discussion
Yield being a complex character, is composed of several components of which some would affect yield directly while others contribute towards it indirectly. Correlation studies provide an opportunity only to study the magnitude and direction of association of yield with its components and also among various components. But it is essential to know the direct and indirect effects of different traits on the dependent variable *i.e.*, yield per plant. Path analysis was used to work out the direct and indirect effects of contributing characters on yield per plant and were estimated and presented at table 1 and 2.
Plant height showed negative direct effect on yield per plant at both genotypic and phenotypic levels. At genotypic level, positive indirect with internodal length, days to first flowering, first flowering node, days to first picking, days to last picking, number of fruits per plant, fruit length and test weight. Negative indirect effect with days to 50% flowering, fruit girth, fruit weight, ridges per fruit and seeds per fruit. At phenotypic level, positive indirect effects with internodal length, days to first flowering, days to last picking, fruits per plant, fruit length,

fruit girth, ridges per fruit, seeds per fruit and test weight. Negative indirect effect with days to 50% flowering, first flowering node days to first picking and fruit weight.

Days to first flowering showed negative direct effect with yield per plant at genotypic level and phenotypic levels. At genotypic level, positive indirect effects with days to 50% flowering, internodal length, plant height, number of seeds per fruit, fruit girth, first flowering node, number of ridges per fruit and fruit weight while it had negative indirect effects via number of fruits per plant, test weight of seeds, fruit length, days to first picking and days to last picking. At phenotypic level, positive indirect effects with days to first picking, days to 50% flowering, plant height, internodal length and fruit weight. It had negative indirect effects through no. of fruits per plant, fruit length, no. of seeds per fruit, no. of ridges per fruit, first flowering node, days to last picking, fruit girth and test weight.

Intermodal length showed positive direct effect with yield per plant at genotypic level and phenotypic levels. At genotypic level, negative indirect effects via number of fruits per plant, days to first flowering, plant height, test weight of seeds, fruit length, no. of ridges per fruit, days to last picking, fruit weight and days to first picking while it had positive indirect effects via days to 50% flowering, fruit girth, number of seeds per fruit and first flowering node. At phenotypic level, negative indirect effects through all the component traits except days to first picking, number of ridges per fruit and days to 50% flowering. First flowering node showed positive direct effect and negative direct effect with yield per plant at genotypic level and phenotypic levels respectively. At genotypic level, negative indirect effects through all the component traits except days to 50% flowering, internodal length, fruit weight and number of ridges per fruit. At phenotypic level, positive indirect effect with days to first picking, fruit weight, internodal length, days to 50% flowering, number of seeds per fruit and fruit girth on yield per plant and also recorded negative indirect effects through days to first flowering, number of fruits per plant, fruit length, number of ridges per fruit, days to last picking, plant height and test weight.

Days to 50% flowering showed positive direct effect with yield per plant at genotypic level and phenotypic level. At genotypic level. negative indirect effects at genotypic level via days to first flowering, number of fruits per plant, test weight of seeds, fruit length, days to first picking and days to last picking. It had positive indirect effects via internodal length, plant height, fruit girth, number of seeds per fruit, first flowering node, number of ridges pr fruit and fruit weight. At phenotypic level, positive indirect effects via days to first picking, plant height, internodal length and fruit weight on yield per plant. It had negative indirect effects with days to first flowering, number of fruits per plant, fruit length, seeds per fruit, ridges per fruit, first flowering node, days to last picking, fruit girth and test weight.

Days to first picking showed negative direct effect and positive direct effect with yield per plant at genotypic level and phenotypic level. At genotypic level. indirect negative effects via days to first flowering, number of fruits per plant, test weight of seeds, fruit length and days to last picking and indirect positive effects via days to 50% flowering, plant height, internodal length, number of seeds per fruit, fruit girth, first flowering node, number of ridges per fruit and fruit weight. At phenotypic level, negative indirect effects via days to first flowering, number of fruits per plant, fruit length, number of seeds per fruit, ridges per fruit, first flowering node, days to last picking, fruit girth and test weight while it had positive indirect effects via days to 50% flowering, plant height, internodal length and fruit weight.

Days to last picking showed negative direct effect with yield per plant at genotypic level and phenotypic levels. This trait also recorded negative indirect effects through all the component traits except days to 50% flowering, internodal length, fruit weight, plant height, fruit girth, first flowering node at genotypic level and days to first picking, internodal length, fruit weight, plant height, seeds per fruit, number of ridges per fruit and days to 50% flowering at phenotypic level.

Number of fruits per plant showed positive direct effect with yield per plant at genotypic level and phenotypic levels. At genotypic level. positive indirect effect via days to first flowering, test weight of seeds, fruit length, days to first picking and days to last picking. At phenotypic level, positive indirect effect with days to first flowering, number of seeds per fruit, fruit length, number of ridges per fruit, days to last picking, first flowering node, fruit girth and test weight.

Fruit length showed positive direct effect with yield per plant at genotypic level and phenotypic levels. At genotypic level. positive indirect effects with days to first flowering, number of fruits per plant, test weight of seeds, fruit weight, days to first picking, days to last picking and number of ridges per fruit. At phenotypic level, positive indirect effects with number of fruits per plant, days to first flowering, fruit weight, number of seeds per fruit, fruit girth, first flowering node, days to last picking and test weight.

Fruit girth showed negative direct effect and positive direct effect with yield per plant at genotypic level and phenotypic levels. At genotypic level. positive indirect effects with days to first flowering, number of fruits per plant, test weight of seeds, fruit length, days to last picking, days to first picking, number of ridges per fruit and first flowering node. At phenotypic level, positive indirect effects with number of fruits per plant, days to first flowering, fruit length, fruit weight, number of seeds per fruit, days to last picking and test weight.

Fruit weight showed positive direct effect with yield per plant at phenotypic level and genotypic level. Negative indirect effects through all the component traits except plant height, days to 50% flowering, fruit length, number of ridges per fruit, first flowering node and fruit girth at genotypic level and plant height, number of seeds per fruit, days to first picking, fruit length, fruit girth and days to 50% flowering at phenotypic level.

Ridges per fruit showed positive direct effect and negative direct effect with yield per plant at genotypic and phenotypic levels. At genotypic level. negative indirect effects through all the component traits except days to 50% flowering, plant height, fruit weight, fruit length, days to last picking and first flowering node. At phenotypic level, positive indirect effects through all the components except days to first flowering, number of fruits per plant, internodal length, first flowering node and test weight.

Number of seeds per fruit showed negative direct effect and positive direct effect with yield per plant at genotypic level and phenotypic level. At genotypic level. positive indirect effects through all the component traits except days to 50% flowering, internodal length, plant height, fruit girth and days to last picking. At phenotypic level, positive indirect effects

through number of fruits per plant, days to first flowering, fruit weight, fruit length, fruit girth and test weight.

Test weight of seeds showed positive direct effect with yield per plant at genotypic level and phenotypic level. At genotypic level. positive indirect effects with days to first flowering, number of fruits per plant, fruit length, days to first picking and days to last picking. At phenotypic level, positive indirect effects with number of fruits per plant, days to first flowering, fruit length, seeds per fruit, ridges per fruit, first flowering node, days to last picking and fruit girth.

These findings are in agreement with those reported by Gangashetti *et al*. (2013) [2]. Mehta *et al*. (2006) [3], Reddy *et al*. (2013) [5], Yonas *et al*. (2014) and Rambabu *et al*. (2019) [4].

Table 1: Phenotypic path correlations (Direct and indirect effects) among fruit yield and yield contributing characters in okra

Character	Plant height	Internodal length	Days to first flowering	Days to 50% flowering	First flowering node	Days to first picking	Days to last Picking	Number of fruits per plant	Fruit length	Fruit girth	Fruit weight	Ridges per fruit	Number of seeds per fruit	Test weight of seeds	Yield per plant
Plant height	-0.1923	0.0697	0.0599	-0.0045	-0.0007	-0.0692	0.0027	0.5476	0.0003	0.0013	-0.1205	0.0371	0.0058	0.0012	0.3381**
Internodal length	-0.0743	0.1802	-0.0596	0.0040	-0.0044	0.0503	-0.0061	-0.2529	-0.0179	-0.0022	-0.0397	0.0390	-0.0074	-0.0007	-0.1917*
Days to first flowering	0.0230	0.0215	-0.4998	0.0326	-0.0103	0.4625	-0.0030	-0.2824	-0.0315	-0.0024	0.0062	-0.0177	-0.0216	-0.0023	-0.3251**
Days to 50% flowering	0.0265	0.0221	-0.4946	0.0329	-0.0098	0.4618	-0.0030	-0.3120	-0.0329	-0.0027	0.0068	-0.0165	-0.0216	-0.0026	-0.3455**
First flowering node	-0.0048	0.0268	-0.1731	0.0108	-0.0298	0.1474	-0.0084	-0.1157	-0.0137	0.0007	0.0480	-0.0086	0.0080	-0.0013	-0.1136
Days to first picking	0.0283	0.0193	-0.4920	0.0323	-0.0093	0.4699	-0.0038	-0.2894	-0.0333	-0.0025	0.0079	-0.0212	-0.0214	-0.0023	-0.3174**
Days to last picking	0.0098	0.0211	-0.0290	0.0019	-0.0048	0.0340	-0.0523	-0.0836	-0.0046	-0.0014	0.0206	0.0065	0.0091	-0.0006	-0.0734
Number of Fruits per plant	-0.1122	-0.0486	0.1503	-0.0109	0.0037	-0.1449	0.0047	0.9387	0.0170	0.0032	-0.0619	0.0083	0.0196	0.0028	0.7700**
Fruit length	-0.0006	-0.0348	0.1700	-0.0117	0.0044	-0.1691	0.0026	0.1725	0.0924	0.0048	0.0371	-0.0039	0.0210	0.0013	0.2861**
Fruit girth	-0.0208	-0.0337	0.1023	-0.0075	-0.0018	-0.0983	0.0065	0.2554	0.0378	0.0117	0.0182	-0.0168	0.0093	0.0019	0.2642**
Fruit weight	0.0493	-0.0152	-0.0066	0.0005	-0.0030	0.0079	-0.0023	-0.1236	0.0073	0.0005	0.4697	-0.0139	0.0154	-0.0010	0.3848**
Ridges per fruit	0.0669	-0.0658	-0.0829	0.0051	-0.0024	0.0932	0.0032	-0.0733	0.0034	0.0018	0.0613	-0.1068	0.0031	-0.0005	-0.0936
No of seeds per fruit	-0.0175	-0.0209	0.1688	-0.0111	-0.0037	-0.1576	-0.0075	0.2888	0.0305	0.0017	0.1132	-0.0052	0.0638	0.0011	0.4444**
Test weight of seeds	-0.0198	-0.0106	0.0956	-0.0071	0.0033	-0.0916	0.0027	0.2235	0.0105	0.0019	-0.0409	0.0044	0.0062	0.0118	0.1898*

r=correlation-coefficient (0.3416) * significant at 5% level ** significant at 1% level

Table 2: Genotypic path correlations (Direct and indirect effects) among fruit yield and yield contributing characters in okra

Character	Plant height	Internodal length	Days to first flowering	Days to 50% flowering	First flowering node	Days to first picking	Days to last Picking	Number of fruits per plant	Fruit length	Fruit girth	Fruit weight	Ridges per fruit	Number of seeds per fruit	Test weight of seeds	'r' with Yield per plant
Plant height	-0.4223	0.1565	0.3013	-0.3459	0.0013	0.0046	0.0037	0.6910	0.0021	-0.0094	-0.1152	-0.0112	-0.0048	0.0811	0.3326**
Internodal length	-0.1456	0.4537	-0.3449	0.3993	0.0067	-0.0039	-0.0093	-0.5523	-0.0219	0.0126	-0.0045	-0.0130	0.0072	-0.0539	-0.2697**
Days to First flowering	0.0522	0.0642	-2.4374	2.5248	0.0101	-0.0298	-0.0034	-0.3815	-0.0402	0.0167	0.0014	0.0053	0.0178	-0.1384	-0.3384**
Days to 50% flowering	0.0576	0.0714	-2.4268	2.5359	0.0097	-0.0297	-0.0034	-0.4129	-0.0423	0.0184	0.0010	0.0049	0.0178	-0.1571	-0.3552**
First flowering node	-0.0169	0.0926	-0.7445	0.7470	0.0330	-0.0082	-0.0128	-0.1369	-0.0197	-0.0027	0.0437	0.0028	-0.0074	-0.0863	-0.1164
Days to first picking	0.0645	0.0584	-2.4174	2.5037	0.0089	-0.0301	-0.0044	-0.3922	-0.0432	0.0175	0.0028	0.0064	0.0177	-0.1228	-0.3304**
Days to last picking	0.0335	0.0912	-0.1773	0.1836	0.0091	-0.0029	-0.0463	-0.1960	-0.0056	0.0137	0.0437	-0.0027	-0.0110	-0.0382	-0.1052
No of fruits per plant	-0.2481	-0.2131	0.7907	-0.8903	-0.0038	0.0100	0.0077	1.1761	0.0282	-0.0251	-0.0291	-0.0027	-0.0178	0.2034	0.7862**
Fruit length	-0.0079	-0.0890	0.8803	-0.9620	-0.0058	0.0117	0.0023	0.2974	0.1114	-0.0297	0.0193	0.0012	-0.0169	0.0957	0.3079**
Fruit girth	-0.0546	-0.0789	0.5589	-0.6428	0.0012	0.0072	0.0087	0.4057	0.0455	-0.0727	-0.0016	0.0051	-0.0075	0.1047	0.2789**
Fruit weight	0.1007	-0.0042	-0.0072	0.0053	0.0030	-0.0002	-0.0042	-0.0708	0.0044	0.0002	0.4834	0.0043	-0.0125	-0.0836	0.4186**
Ridges per fruit	0.1509	-0.1888	-0.4153	0.4003	0.0029	-0.0061	0.0040	-0.0996	0.0042	-0.0118	0.0664	0.0313	-0.0025	-0.0317	-0.0959
Number of	-	-0.0644	0.8542	-0.8920	0.0048	0.0105	-0.0101	0.4136	0.0371	-	0.1196	0.0016	-0.0507	0.0907	0.4643**

seeds per fruit	0.0398									0.0108					
Test weight of seeds	-0.1358	-0.0970	1.3387	-1.5807	-0.0113	0.0147	0.0070	0.9492	0.0423	-0.0302	-0.1603	-0.0039	-0.0182	0.2521	0.5664**

r=correlation-coefficient (0.2659) * significant at 5% level ** significant at 1% level

Conclusion

The traits vine length, average leaf area, number of pods per plant, pod length, pod weight, number of seeds per pod and 100 seed weight exhibited high and positive direct effect on fruit yield per plant and direct selection based on these traits would result in improved fruit yield per plant in okra.

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