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Character association and path analysis for yield and yield related traits in market and seed crop of okra (*Abelmoschus esculentus* (L.) Moench)

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Abstract
Thirty genotypes of okra (*Abelmoschus esculentus* (L.) Moench) were used for the evaluation of character association and direct and indirect effects of pod/seed yield and yield-related traits in okra. The experiment was laid out at Vegetable Research Farm, CSK HPKV Palampur (H.P.) during summer-rainy season 2018. The character association analysis revealed that pod yield per plant showed positive correlation with pods per plant (0.631 and 0.765), nodes per plant (0.553 and 0.706), duration of availability of edible pods (0.425 and 0.561), plant height (0.420 and 0.466) and average pod weight (0.364 and 0.429) at phenotypic and genotypic level, respectively. In seed crop, traits *viz.*, seeds per pod (0.443 and 0.485), plant height (0.384 and 0.456), nodes per plant (0.372 and 0.532) and 100-seed weight (0.345 and 0.363) at phenotypic and genotypic level, respectively and seed vigour (0.291) at genotypic level showed positive correlation with seed yield per plant. The maximum direct positive correlation on pod yield per plant showed by pods per plant (1.119 and 0.915) and average pod weight (0.864 and 0.723) at both phenotypic and genotypic levels, nodes per plant (0.762) and internodal length (0.632) at genotypic and plant height (0.418) at phenotypic were also substantial whereas, in seed crop nodes per plant (0.316 and 1.302), seeds per pod (0.572 and 0.627) and 100-seed weight (0.325 and 0.246) had maximum positive direct effects on seed yield at both phenotypic and genotypic level, internodal length (0.603) at genotypic and plant height (0.166) and days to 50 per cent flowering (0.123) at phenotypic level was also important. The characters like pods per plant, nodes per plant, average pod weight, plant height and internodal length in market crop and seeds per pod, 100-seed weight and nodes per plant in seed crop showed that they are the most important pod yield and seed yield determinants, because of their high direct and indirect effects via many other yield improving characters. Hence, selection should be practice for these characters in order to isolate superior plant types for improvement of pod yield and seed yield of okra.

Keywords: Okra, pod yield, seed yield, character association and path analysis

Introduction
Okra (*Abelmoschus esculentus* (L.) Moench) is popularly known as lady's finger or okra belongs to the class dicotyledonae, order Malvales, family Malvaceae and genus *Abelmoschus* (syn. *Hibiscus*) (Schippers, 2000) [37]. It is native to West Africa (Murdock, 1959) [27]. It is grown extensively in tropical, subtropical and Mediterranean climatic zones of the world (Hammon and Van Sloten, 1989) [18]. It is a multipurpose crop valued for its tender and delicious pods (Chinatu and Okocha, 2006) [10]. It is grown extensively in tropical, subtropical and Mediterranean climatic zones of the world (Hammon and Van Sloten, 1989) [18]. It is a multipurpose crop valued for its tender and delicious pods (Chinatu and Okocha, 2006) [10]. It is a powerhouse of valuable nutrients, low in calories, fat-free and provides a valuable supplementary nutrition in human diet in developing countries where there is often a great alimentary imbalance (Kumar and Sreeparvathy, 2010) [25]. It has good medicinal value with its antispasmodic, demulcent, diaphoretic, diuretic, emollient, stimulant and vulnery properties (Mehta, 1959; Nadkarni, 1972) [26]. Its potential as an industrial crop also has been tested in the developed world (Camciuc *et al*. 1998) [8]. Okra has got potential to boost food, nutritional and health security, foster rural development and support sustainable land utilization (Reddy, 2010) [33]. Okra ripe seeds can be dried, roasted and ground to be used as a coffee substitute (Gemede *et al*. 2015) [17] besides being rich in protein (Karakoltisdis and Constandinides, 1975) [22]. The oil from its seeds is utilized in perfume industry (Clopton *et al*. 1948) [11]. The dried pod shell and stem containing crude fibre are used in paper industry.

Okra is an important vegetable crop in India, West Africa, South-East, Asia, USA, Brazil, Australia and Turkey. It is the most important fruit vegetable crop in India. As it is a tropical, hot weather, low land crop and susceptible to low night temperatures, it is extensively cultivated in *kharif* and summer seasons in India. Being an upright, quick growing and medium duration annual herb, it fits well into multiple cropping systems either as a sole crop or intercrop (Reddy, 2010) [33]. Optimizing pod/seed yield is one of the most important goals for most okra growers and, consequently, most okra breeding programmes. For improving this crop through conventional breeding and selection, adequate knowledge of association that exists between yield and yield related characters is essential for the identification of selection procedure.

In okra, all growth, earliness and yield associated traits are quantitative in nature. Such characters are controlled by polygenes and are much influenced by environmental fluctuations. Pod/Seed yield of okra is a complex quantitative trait, which is conditioned by the interaction of various growth and physiological processes throughout the life cycle (Adeniji and Peter, 2005) [1]. Improvement of complex characters such as pod/seed yield may be accomplished through the component approach of breeding. The development of plant breeding strategy hinges mainly on the support provided by genetic information on inheritance and behavior of major quantitative characters associated with yield and yield components (Arunachalam, 1976) [4]. A better understanding of the contribution of each trait in building up the genetic makeup of the crop may be obtained through yield component analysis. Determination of the yield components through correlation and path coefficient analyses will improve the efficiency of a breeding programme.

Correlation and path coefficient analyses are prerequisites for improvement of any crop including okra for selection of superior genotypes and improvement of any trait. In plant breeding, correlation analysis provides information about yield components and thus helps in selection of superior genotypes from diverse genetic populations. The correlation studies simply measure the associations between yield and other traits. Usefulness of the information obtained from the correlations coefficients can be enhanced by partitioning into direct and indirect effects for a set of a pair-wise cause-effect inter relationships (Kang *et al*. 1983) [21]. Path coefficient analysis permits the separation of correlation coefficient into direct and indirect effects. It is basically a standardized partial regression analysis and deals with a closed system of variables that are linearly related. Such information provides realistic basis for allocation of appropriate weightage to various yield components. In okra, correlation and path coefficient analyses have been used by several researchers to measure the associations between yield and other traits and to clarify interrelation between pod yield and other traits, respectively.

Materials and Methods

The present investigation was carried out at the Experimental Farm of Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during summer rainy season of 2018. The experimental farm situated at 32˚ 6' N latitude, 76˚ 3' E longitude and 1291 m altitude. The place is characterized by severe winters and mild summers with high rainfall during monsoon. Agro-climatically, the location represents mid-hill zone of Himachal Pradesh and is characterized by humid-sub temperate climate. The experimental material consisted of 30 genotypes of okra Table 1. The experiment was laid out in a Randomized Complete Block Design with three replications. Seeds of okra were sown on 5th June, 2018 and each entry was accommodated in two rows spaced 45 cm apart with an intra-row spacing of 15 cm. Farm Yard Manure [@ 10 tonnes/ha] and chemical fertilizers (100 kg N, 50 kg P_2O_5, 50 kg K_2O /ha) were applied as per the recommended package of practices. Half dose of N and full doses of P_2O_5 and K_2O were applied at the time of field preparation. The remaining half dose of N was top dressed in two equal amounts, first at earthing up and second after one month. The intercultural operations including thinning, irrigations and pest-control were carried out in accordance with the recommended package of practices. The observations were recorded from 5 randomly selected plants from each treatment and their average values were used for statistical analysis.

The data on various characters *viz.,* days to 50 per cent flowering, node at which the first pod set, plant height (cm), nodes per plant, internodal length (cm), days to marketable maturity, pod length (cm), pod diameter (cm), ridges per pod, average pod weight (g), pod yield per plant (g), pods per plant, duration of availability of edible pods, dry matter (%), mucilage (%), immature pod colour and pod pubescence in market crop whereas, in seed crop it was recorded on days to 50 per cent flowering, node at which the first pod set, plant height (cm), nodes per plant, internodal length (cm), days to seed maturity, seeds per pod, seed yield (q/ha), 100-seed weight (g), seed germination (%) and seed vigour.

Table 1: List of okra genotypes and their sources

Genotype	Source
Punjab Suhawani, Punjab-8	Punjab Agricultural University, Ludhiana (Punjab)
Kashi Vibhuti, Kashi Pragati, Shitla Uphar, Shitla Jyoti, Kashi Satdhari	Indian Institute of Vegetable Research, Varanasi (UP)
DPO-1, DPO-2, DPO-3, DPO-4, DPO-5, DPO-6, DPO-7, DPO-8, DPO-9, DPO-10, DPO-11, DPO-12, DPO-13, DPO-14, DPO-15, DPO-16, DPO-17, DPO-18, DPO-19, DPO-20, 9801, Palam Komal	CSK Himachal Pradesh Krishi Vishvavidyala, Palampur (HP)
Arka Anamika	Indian Institute of Horticultural Research, Bangalore (Karnataka)

Character Association by Correlation Study and Path Analysis

Correlation and path-coefficient analysis were estimated by the association of characteristics and cause effect relationship studied for yield and component characteristics.

Estimation of Correlation

Association of different characteristics under the study was analyzed by the working out genotypic and phenotypic degree of correlation and simple correlation coefficient for all the possible parts of characteristics combination by the method of Hayes *et al.* 1955 and Al-Jabouri *et al.* 1958 [19, 3].

Estimation of Direct and Indirect Effect of Different Characters on Yield

In order to find a clear picture of the inter-relationship between fruit yield and other components, path analysis splits the correlation coefficient into the measure of the direct and indirect effect of each contributing characteristics towards yield was done as per method by Dewey, D.R. and K.H. Lu 1959 [14].

Calculation of Residual Effect

After calculating the direct and indirect effect of different characteristics, the residual effect was calculated using the formula suggested by Singh and Choudhury, 1985 [41].

Results and Discussion

Character association by correlation and path coefficient analysis

For a sound-breeding programme information on the genetic association between yield and its components is a pre-requisite. From this point of view the relationship between pod/seed yield of okra and 15 another important characteristics in market crop and 11 in seed crop were endeavoured to find out through correlation and path coefficient analysis.

Correlation for market and seed crop

Knowledge of the relationship among plant characteristics is useful while selecting traits for yield improvement. The phenotypic and genotypic correlation coefficients between different characters are presented in Table 2 & 3. Genotypic coefficient of correlation, in general, were greater in magnitude than the corresponding phenotypic ones, indicating that there is a strong inherent association between various characters and phenotypic expression of correlation was less under the influence of environment. Pod yield per plant showed positive association with pods per plant (0.631 and 0.765), nodes per plant (0.553 and 0.706), duration of availability of edible pods (0.425 and 0.561), plant height (0.420 and 0.466) and average pod weight (0.364 and 0.429) at phenotypic and genotypic level, respectively in market crop whereas, in seed crop seeds per pod (0.443 and 0.485), plant height (0.384 and 0.456), nodes per plant (0.372 and 0.532) and 100-seed weight (0.345 and 0.363) at phenotypic and genotypic level, respectively and seed vigour (0.291) at genotypic level showed positive correlation with seed yield per plant indicating mutual association of these traits in both market and seed crop. Looking at these association appeared that higher pod yield can be obtained by increasing pods per plant, nodes per plant, duration of availability of edible pods, plant height and average pod weight for market crop and seeds per pod, plant height, nodes per plant and 100-seed weight for higher seed yield. Positive association of pod yield per plant was reported with pods per plant (Bediger *et al*. 2017; Kerure *et al*. 2017; Pithiya *et al*. 2017; Singh *et al*. 2017; Yadav *et al*. 2017, Samim *et al*. 2018 and Kumar *et al*. 2019) [23, 30, 40, 45, 34, 24], nodes per plant (Yadav *et al*. 2010; Pachiyappan and Saravannan 2016; Patil *et al*. 2016; Kerure *et al*. 2017, Singh *et al*. 2017, Samim *et al*. 2018a and Kumar *et al*. 2019) [23, 40, 44, 28, 29, 34, 24], average pod weight (Ramya and Senthilkumar 2009; Yadav *et al*. 2010; Balai *et al*. 2014; Archana *et al*. 2015; Kerure *et al*. 2017, Singh *et al*. 2017, Samim *et al*. 2018 and Singla *et al*. 2018) [23, 40, 44, 34], duration of availability of edible pods (Chandramouli *et al*. 2016 and Samim *et al*. 2018) [34] and plant height (Sawant *et al*. 2014; Chandramouli *et al*. 2016; Patil *et al*. 2016 and Rajeev *et al*. 2017, Samim *et al*. 2018 and Kumar *et al*. 2019) [36, 9, 29, 32, 34, 24]. Positive association of seed yield with 100-seed weight and nodes per plant was reported by (Arya *et al*. 1994, Sood 2006 and Akinyele and Osekita 2006) [5, 43, 2].

The negative association of pod yield was observed with mucilage, days to 50 per cent and days to marketable maturity in market crop. In case of seed crop, it was negatively correlated with days to 50 per cent flowering and days to seed maturity. Similar results had been reported for days to 50 per cent flowering (Sawant *et al*. 2014; Sharma and Prasad 2015; Prasath *et al*. 2017; Kerure *et al*. 2017 and Samim *et al*. 2018) [36, 38, 31, 23, 34], days to marketable maturity (Sharma and Prasad 2015; Prasath *et al*. 2017 and Samim *et al*. 2018) [38, 31, 34]. Negative association of seed yield with days to 50 per cent flowering (Arya *et al*. 1994 and Akinyele and Osekita 2006) [5, 2].

Positive association was observed for plant height with nodes per plant, pods per plant, internodal length, pod length and days to marketable maturity; nodes per plant with pods per plant; days to marketable maturity with pod length; pod length with pod diameter; pod diameter with ridges per pod; ridges per pod with average pod weight and dry matter; average pod weight with duration of availability of edible pods; pods per plant with duration of availability of edible pods at phenotypic and genotypic level, respectively. Similarly, positive correlation at genotypic level was recorded for days to 50 per cent flowering with days to marketable maturity, pod length, node at which the first pod set, pod diameter, internodal length and plant height; node at which the first pod set with days to marketable maturity and pod length; nodes per plant with duration of availability of edible pods and pod length; internodal length with days to marketable maturity and pod length; days to marketable maturity with pod diameter; pod diameter with average pod weight; ridges per pod with duration of availability of edible pods; pods per plant with duration of availability of edible pods in market crop. In case of seed crop, the positive association of days to 50 per cent flowering with days to seed maturity; plant height with nodes per plant, internodal length and 100-seed weight; nodes per plant with 100-seed weight; seeds per pod with seed vigour and seed germination and seed germination with seed vigour. Similarly, positive and significant correlation at genotypic level was observed for internodal length with seed vigour. Selection based on either of these characters for both market and seed crop could improve the pod/seed yield. Correlation analysis revealed that direct selection for the traits like pods per plant, nodes per plant, duration of availability of edible pods, plant height and average pod weight for market crop and seeds per pod, plant height, nodes per plant and 100-seed weight for seed crop could be effectively used as selection indices for improvement of okra.

Table 2: Estimates of correlation at the phenotypic (P) and genotypic (G) levels in market crop of okra

Traits		Node at which the first pod set	Plant height (cm)	Nodes per plant	Internodal length (cm)	Days to marketable maturity	Pod length (cm)	Pod diameter (cm)	Ridges per pod	Average pod weight (g)	Pods per plant	Duration of availability of edible pods	Dry matter (%)	Mucilage (%)	Pod yield per plant (g)
Days to 50% flowering	P	0.191	0.143	0.116	-0.002	0.960*	0.161	0.024	-0.123	-0.137	-0.021	-0.502*	-0.034	0.106	-0.133
	G	0.330*	0.235*	0.035	0.255*	0.974*	0.360*	0.311*	-0.231*	-0.276*	-0.076	-0.694*	-0.084	0.116	-0.234*
Node at which the first pod set	P		0.187	0.071	0.102	0.238*	0.185	-0.028	-0.129	-0.023	0.010	-0.264*	0.012	0.092	0.011
	G		0.197	0.062	0.172	0.413*	0.236*	-0.060	-0.148	-0.027	0.010	-0.338*	-0.020	0.102	0.011
Plant height (cm)	P			0.612*	0.416*	0.207*	0.262*	0.069	-0.157	-0.239*	0.575*	0.064	-0.187	-0.189	0.420*
	G			0.697*	0.529*	0.367*	0.344*	0.062	-0.173	-0.229*	0.636*	0.141	-0.253*	-0.213*	0.466*
Nodes per plant	P				-0.453*	0.168	0.141	-0.005	-0.223*	-0.502*	0.944*	0.096	-0.191	-0.290*	0.553*
	G				-0.236*	0.105	0.219*	0.003	-0.273*	-0.329*	0.994*	0.352*	-0.257*	-0.381*	0.706*
Internodal length (cm)	P					0.009	0.144	0.088	0.079	0.311*	-0.411*	0.001	-0.020	0.086	-0.141
	G					0.353*	0.215*	0.086	0.100	0.073	-0.312*	-0.205	-0.060	0.144	-0.205
Days to marketable maturity	P						0.241*	0.039	-0.126	-0.180	0.020	-0.512*	-0.093	0.121	-0.132
	G						0.546*	0.373*	-0.248*	-0.345*	-0.028	-0.653*	-0.196	0.142	-0.240*
Pod length (cm)	P							0.246*	-0.035	-0.284*	0.104	-0.156	-0.036	-0.060	-0.154
	G							0.224*	-0.043	-0.480*	0.150	-0.311*	-0.149	-0.093	-0.172
Pod diameter (cm)	P								0.297*	0.186	-0.042	-0.016	-0.014	0.049	0.101
	G								0.422*	0.272*	-0.055	0.018	-0.153	0.071	0.108
Ridges per pod	P									0.222*	-0.185	0.149	0.215*	-0.048	-0.021
	G									0.310*	-0.228*	0.238*	0.336*	-0.051	-0.027
Average pod weight (g)	P										-0.483*	0.265*	0.023	-0.051	0.364*
	G										-0.253*	0.277*	-0.091	-0.067	0.429*
Pods per plant	P											0.197	-0.165	-0.355*	0.631*
	G											0.431*	-0.142	-0.429*	0.765*
Duration of availability of edible pods	P												-0.027	-0.158	0.425*
	G												-0.026	-0.184	0.561*
Dry matter (%)	P													0.066	-0.131
	G													0.076	-0.170
Mucilage (%)	P														-0.432*
	G														-0.453*

*Significant at 5% level.

Table 3: Estimates of correlation coefficients at the phenotypic (P) and genotypic (G) levels in seed crop of okra

Traits		Node at which the first pod set	Plant height (cm)	Nodes per plant	Intenodal length (cm)	Days to seed maturity	Seeds per pod	100-seed weight	Seed Germination (%)	Seed vigour	Seed yield (q/ha)
Days to 50% flowering	P	0.054	0.106	0.059	0.037	0.834*	-0.140	-0.063	-0.026	-0.050	-0.082
	G	0.001	0.199	0.133	0.074	0.726*	-0.268*	-0.056	-0.016	-0.042	-0.259*
Node at which the first pod set	P		0.140	0.151	-0.025	0.119	-0.009	-0.117	-0.212*	-0.171	0.011
	G		0.121	0.194	-0.074	0.159	-0.024	-0.117	-0.235*	-0.196	0.024
Plant height (cm)	P			0.606*	0.444*	0.020	-0.138	0.344*	-0.009	0.041	0.384*
	G			0.663*	0.555*	0.066	-0.178	0.420*	-0.030	0.033	0.456*
Nodes per plant	P				-0.436*	0.005	-0.240*	0.214*	-0.028	-0.097	0.372*

	G				-0.254*	0.038	-0.310*	0.309*	-0.069	-0.204	0.532*
Internodal length (cm)	P					0.015	0.115	0.143	0.045	0.177	0.014
	G					0.022	0.109	0.187	0.062	0.304*	-0.002
Days to seed maturity	P						-0.161	-0.096	-0.113	-0.173	-0.188
	G						-0.391*	-0.148	-0.147	-0.246*	-0.529*
Seeds per pod	P							-0.161	0.277*	0.398*	0.443*
	G							-0.212*	0.376*	0.525*	0.485*
100-seed weight	P								-0.239*	-0.166	0.345*
	G								-0.237*	-0.163	0.363*
Seed germination (%)	P									0.653*	0.142
	G									0.674*	0.185
Seed vigour	P										0.206
	G										0.291*

*Significant at 5% level.

Path Analysis for market and seed cop

The path coefficient analysis allows partitioning of correlation coefficients into direct and indirect effects of various traits towards dependent variable and thus, helps in assessing the cause-effect relationship as well as effective selection. It plays an important role in determining the degree of relationship between yield and its component effects and also permits critical examination of specific factors that provide a given correlation. The study of path analysis revealed that the direct phenotypic contribution of pods per plant (1.119), average pod weight (0.864), plant height (0.418), days to 50 per cent flowering (0.045), dry matter (0.016) and node at which the first pod set (0.013) towards pod yield per plant was positive and substantial in market crop (Table 4). At genotypic level, pods per plant (0.915) had the highest direct contribution followed by nodes per plant (0.762), average pod weight (0.723), internodal length (0.632), dry matter (0.065), days to 50 per cent flowering (0.025), pod length (0.013), mucilage (0.005) and node at which the first pod set (0.001). Of all the traits studied in the market crop pods per plant was the most important character for its direct contribution towards pod yield. Besides its highest direct effect, the indirect contribution of nodes per plant towards pod yield was also substantial. Average pod weight was the next important trait, not only for the direct contribution at phenotypic and genotypic level, but also for indirect contribution through nodes per plant and plant height at phenotypic and genotypic level, respectively. The other less important characters were plant height, nodes per plant and intermodal length. As observed in the present study, the large contribution of pods per plant has been reported (Dhankar and Dhankhar 2002, Gandhi 2002, Jaiprakashnarayan and Mulge 2004, Singh *et al*. 2006, Dakane *et al*. 2007, Das *et al*. 2012, Yonas *et al*. 2014 and Saryam *et al*. 2015) [15, 16, 13, 20, 39, 46, 35]; average pod weight (Jaiprakashnarayan and Mulge 2004, Singh *et al*. 2006, Das *et al*. 2012, Balai *et al*. 2014, Yonas *et al*. 2014) [20, 39, 13, 46] and nodes per plant (Jaiprakashnarayan and Mulge 2004) [20]. The low magnitude of unexplained variation at phenotypic level (0.012) and genotypic level (-0.005) for marketable pod yield per plant indicated that the traits included in the present investigation accounted for the greater part of the variation present in the dependent variable.

In seed crop, nodes per plant was the most important character for its direct contribution (Table 5). As observed in the present study, the large contribution of nodes per plant has been reported (Arya *et al*. 1994 and Sood 2006) [5, 43]. It also contributed indirectly via plant height. Seeds per pod was the next important character for its direct contribution. Besides its substantial direct contribution, it also contributed indirectly through plant height and days to seed maturity at genotypic level. 100-seed weight and internodal length were the next important characters having substantial direct contribution. The other less important characters were days to 50 per cent flowering and plant height. The present results are in agreement with the findings for nodes per plant (Arya *et al*. 1994 and Sood 2006) [5, 43]; seeds per pod (Arya *et al*.) and 100-seed weight (Arya *et al*. 1994 and Sood 2006) [5, 43]. The phenotypic and genotypic residual effects were 0.423 and 0.096 respectively. There might be some characters other than those included in the present study, which may also playing a role in determining seed yield. Such characters could be branches per plant, height at flowering, root length and other physiological parameters. Inclusion of these attributes in path analysis might lead to a somewhat different, but perhaps a more realistic picture.

Table 4: Estimates of direct and indirect effects at the phenotypic (P) and genotypic (G) levels in market crop of okra

Traits		Days to 50% flowering	Node at which the first pod set	Plant height (cm)	Nodes per plant	Internodal length (cm)	Days to marketable maturity	Pod length (cm)	Pod diameter (cm)	Ridges per pod	Average pod weight (g)	Pods per plant	Duration of availability of edible pods	Dry matter (%)	Mucilage (%)	Correlation coefficient with pod yield
Days to 50% flowering	P	0.045	0.002	0.060	-0.056	0.001	-0.041	-0.003	0.000	0.003	-0.118	-0.023	0.002	-0.001	-0.003	-0.133
	G	0.025	0.000	-0.189	0.027	0.161	-0.012	0.005	-0.008	0.008	-0.200	-0.069	0.023	-0.005	0.001	-0.234*
Node at which the first pod set	P	0.009	0.013	0.078	-0.034	-0.034	-0.010	-0.004	0.000	0.003	-0.020	0.011	0.001	0.000	-0.003	0.011
	G	0.008	0.001	-0.158	0.047	0.108	-0.005	0.003	0.002	0.005	-0.019	0.009	0.011	-0.001	0.001	0.011
Plant height (cm)	P	0.006	0.002	0.418	-0.296	-0.140	-0.009	-0.005	0.000	0.004	-0.206	0.644	0.000	-0.003	0.005	0.420*
	G	0.006	0.000	-0.805	0.531	0.335	-0.005	0.004	-0.002	0.006	-0.165	0.582	-0.005	-0.016	-0.001	0.466*
Nodes per plant	P	0.005	0.001	0.256	-0.483	0.152	-0.007	-0.003	0.000	0.006	-0.434	1.056	0.000	-0.003	0.008	0.553*
	G	0.001	0.000	-0.561	0.762	-0.149	-0.001	0.003	0.000	0.010	-0.238	0.910	-0.012	-0.017	-0.002	0.706*
Internodal length (cm)	P	0.000	0.001	0.174	0.219	-0.336	0.000	-0.003	0.000	-0.002	0.269	-0.460	0.000	0.000	-0.002	-0.141
	G	0.006	0.000	-0.426	-0.180	0.632	-0.005	0.003	-0.002	-0.004	0.053	-0.286	0.007	-0.004	0.001	-0.205
Days to marketable	P	0.043	0.003	0.087	-0.081	-0.003	-0.043	-0.005	0.000	0.003	-0.156	0.022	0.002	-0.002	-0.003	-0.132

maturity	G	0.025	0.000	-0.295	0.080	0.223	-0.013	0.007	-0.010	0.009	-0.249	-0.026	0.021	-0.013	0.001	-0.240*
Pod length (cm)	P	0.007	0.002	0.109	-0.068	-0.048	-0.010	-0.020	0.000	0.001	-0.246	0.117	0.001	-0.001	0.002	-0.154
	G	0.009	0.000	-0.277	0.167	0.136	-0.007	0.013	-0.006	0.002	-0.347	0.137	0.010	-0.010	0.000	-0.172
Pod diameter (cm)	P	0.001	0.000	0.029	0.002	-0.030	-0.002	-0.005	0.000	-0.007	0.161	-0.047	0.000	0.000	-0.001	0.101
	G	0.008	0.000	-0.050	0.002	0.054	-0.005	0.003	-0.026	-0.015	0.197	-0.050	-0.001	-0.010	0.000	0.108
Ridges per pod	P	-0.006	-0.002	-0.065	0.108	-0.026	0.005	0.001	0.000	-0.025	0.192	-0.207	-0.001	0.004	0.001	-0.021
	G	-0.006	0.000	0.139	-0.208	0.063	0.003	-0.001	-0.011	-0.036	0.224	-0.209	-0.008	0.022	0.000	-0.027
Average pod weight (g)	P	-0.006	0.000	-0.100	0.242	-0.104	0.008	0.006	0.000	-0.006	0.864	-0.541	-0.001	0.000	0.001	0.364*
	G	-0.007	0.000	0.184	-0.251	0.046	0.004	-0.006	-0.007	-0.011	0.723	-0.231	-0.009	-0.006	0.000	0.429*
Pods per plant	P	-0.001	0.000	0.240	-0.456	0.138	-0.001	-0.002	0.000	0.005	-0.418	1.119	-0.001	-0.003	0.010	0.631*
	G	-0.002	0.000	-0.512	0.758	-0.197	0.000	0.002	0.001	0.008	-0.183	0.915	-0.014	-0.009	-0.002	0.765*
Duration of availability of edible pods	P	-0.023	-0.003	0.027	-0.046	0.000	0.022	0.003	0.000	-0.004	0.229	0.221	-0.004	0.000	0.004	0.425*
	G	-0.018	0.000	-0.114	0.268	-0.130	0.008	-0.004	0.000	-0.009	0.201	0.394	-0.033	-0.002	-0.001	0.561*
Dry matter (%)	P	-0.002	0.000	-0.078	0.092	0.007	0.004	0.001	0.000	-0.005	0.020	-0.184	0.000	0.016	-0.002	-0.131
	G	-0.002	0.000	0.204	-0.196	-0.038	0.003	-0.002	0.004	-0.012	-0.065	-0.130	0.001	0.065	0.000	-0.170
Mucilage (%)	P	0.005	0.001	-0.079	0.140	-0.029	-0.005	0.001	0.000	0.001	-0.044	-0.398	0.001	0.001	-0.027	-0.432*
	G	0.003	0.000	0.171	-0.291	0.091	-0.002	-0.001	-0.002	0.002	-0.048	-0.393	0.006	0.005	0.005	-0.453*

Residual effects: P=0.012
G= -0.005
Underlined values denote direct effects and the remaining indirect effects.
*Significant at 5% level.

Table 5: Estimates of direct and indirect effects at the phenotypic (P) and genotypic (G) levels in seed crop of okra

Traits		Days to 50% flowering	Node at which the first pod set	Plant height (cm)	Nodes per plant	Internodal length (cm)	Days to seed maturity	Seeds per pod	100-seed weight (g)	Seed germination (%)	Seed vigour	Correlation coefficients with seed yield
Days to 50% flowering	P	0.123	0.000	0.018	0.019	-0.001	-0.138	-0.080	-0.021	-0.002	0.000	-0.082
	G	0.076	0.000	-0.146	0.173	0.045	-0.223	-0.168	-0.014	0.001	-0.003	-0.259*
Node at which the first pod set	P	0.007	0.008	0.023	0.048	0.001	-0.020	-0.005	-0.038	-0.012	-0.001	0.011
	G	0.000	-0.001	-0.088	0.252	-0.045	-0.049	-0.015	-0.029	0.013	-0.014	0.024
Plant height (cm)	P	0.013	0.001	0.166	0.192	-0.017	-0.003	-0.079	0.112	-0.001	0.000	0.384*
	G	0.015	0.000	-0.733	0.864	0.335	-0.020	-0.112	0.104	0.002	0.002	0.456*
Nodes per plant	P	0.007	0.001	0.101	0.316	0.017	-0.001	-0.137	0.070	-0.002	0.000	0.372*
	G	0.010	0.000	-0.486	1.302	-0.153	-0.012	-0.194	0.076	0.004	-0.015	0.532*
Intenodal length (cm)	P	0.005	0.000	0.074	-0.138	-0.039	-0.002	0.066	0.046	0.003	0.001	0.014
	G	0.006	0.000	-0.407	-0.330	0.603	-0.007	0.068	0.046	-0.003	0.022	-0.002
Days to seed maturity	P	0.103	0.001	0.003	0.002	-0.001	-0.166	-0.092	-0.031	-0.006	-0.001	-0.188
	G	0.055	0.000	-0.048	0.049	0.013	-0.307	-0.245	-0.036	0.008	-0.018	-0.529*
Seeds per pod	P	-0.017	0.000	-0.023	-0.076	-0.004	0.027	0.572	-0.052	0.016	0.002	0.443*
	G	-0.020	0.000	0.130	-0.403	0.066	0.120	0.627	-0.052	-0.020	0.038	0.485*
100-seed weight (g)	P	-0.008	-0.001	0.057	0.068	-0.006	0.016	-0.092	0.325	-0.014	-0.001	0.345*
	G	-0.004	0.000	-0.308	0.402	0.113	0.045	-0.133	0.246	0.013	-0.012	0.363*
Seed germination (%)	P	-0.003	-0.002	-0.001	-0.009	-0.002	0.019	0.159	-0.078	0.057	0.003	0.142
	G	-0.001	0.000	0.022	-0.090	0.037	0.045	0.236	-0.058	-0.054	0.048	0.185
Seed vigour	P	-0.006	-0.001	0.007	-0.031	-0.007	0.029	0.228	-0.054	0.037	0.004	0.206
	G	-0.003	0.000	-0.025	-0.265	0.184	0.076	0.330	-0.040	-0.037	0.071	0.291*

Residual effects: P = 0.423
G = 0.096
Underlined values denote direct effects and the remaining indirect effects
*Significant at 5% level.

Conclusion

Based upon correlation and path-coefficient analysis, pods per plant, average pod weight and plant height could be considered as the reliable selection parameters for evolving high yielding genotypes. Similarly, pods per plant, average pod weight, nodes per plant, intermodal length and plant height showed indirect effect on pod yield. Hence, due attention should also be given on these traits for yield improvement in market crop of okra. In seed crop, correlation and path analysis study revealed that direct selection for the traits like seeds per pod, 100-seed weight, nodes per plant and plant height could be effectively used as selection indices for the improvement of seed yield in okra. Similarly, indirect selection for seeds per pod, 100-seed weight, nodes per plant, intermodal length, days to seed maturity and plant height will be effective for yield improvement in seed crop of okra.

The application of the vortex-assisted MSPD method to the analysis of real samples showed TCS in some fish liver and fish gill samples at trace levels.

Sun *et al.* [14] developed a sensitive and efficient analytical method for TCS determination in water, which involved enrichment with bamboo-activated charcoal and detection with HPLC-ESI-MS. They investigated and optimized the influence of several operational parameters, including the eluant and its volume, the flow rate, the volume and acidity of the sample, and the amount of bamboo activated charcoal.

Under the optimum conditions, linearity of the method was observed in the range of 0.02–20μg/L and the limit of detection was 0.002μg/L. The spiked recoveries of TCS in real water samples were achieved in the range of 97.6–112.5%. The proposed method was applied to analyze TCS in real aqueous samples.

References

1. Adeniji OT, Peter JM. Stepwise regression analysis of pod and seed yield characters in segregating F2 population of West African okra (*Abelmoschus caillei*). Proceedings of 30th Conference, Genetics Society of Nigeria, 2005, 250-258.
2. Akinyele BO, Osekita OS. Correlation and path coefficient analysis of seed yield attributes in okra (*Abelmoschus esculentus* (L.) Moench). African Journal of Biotechnology. 2006; 5:1330-1336.
3. Al-Jabouri RA, Miller PA, Robinson HF. Genotypic and environmental variance in upland cotton cross of interspecific origin. Agronomy Journal. 1958; 50:633-637.
4. Arunachalam V. Evaluation of diallel crossesgraphical and combining ability method. Indian Journal of Genetics. 1976; 36:358-366.
5. Arya PS, Sood S, Singh Y. Correlation and path coefficient analyses in seed crop of okra (*Abelmoschus esculentus* (L.) Moench). Haryana Journal of Horticultural Sciences. 1994; 23:176-179.
6. Badiger M, Pitchaimuthu M, Pujer P. Genetic variability, heritability, genetic advance and correlation studies among quantitative traits in okra (*Abelmoschus esculentus* (L.) Moench). Global Journal of Bio-science and Biotechnology. 2017; 6:314-319.
7. Balai TC, Maurya IB, Verma S, Kumar N. Correlation and path analysis in genotypes of okra (*Abelmoschus esculentus* (L.) Moench). Supplement on Genetics and Plant Breeding. 2014; 9:799-802.
8. Camciuc M, Deplagne M, Vilarem G, Gaset A. Okra (*Abelmoschus esculentus* (L.) Moench), a crop with economic potential for set aside acreage in France. Industrial Crops Products. 1998; 7:257-264.
9. Chandramouli B, Rao MP, Shrihari PD, Rao AVDD. Correlation and path coefficient analysis in okra *Abelmoschus esculentus* (L.) genotypes. Advances in Life Sciences. 2016; 5:4055-4063.
10. Chinatu LN, Okocha PI. The prospect of increased production of okra (*Abelmoschus esculentus* (L.) Moench through heterosis. Journal of Sustainable Tropical Agricultural Research. 2006; 17:66-71.
11. Clopton JR, Roberts A, Jeskey HD. Chemical studies on oil bearing seeds in okra. Journal of the American Oil Chemists' Society. 1948; 25:401-404.
12. Dakahe K, Patil HE, Patil SD. Genetic variability and correlation studies in okra (*Abelmoschus esculentus* (L.) Moench). The Asian Journal of Horticulture. 2007; 2:188-191.
13. Das S, Chattopadhyay A, Chattopadhyay SB, Dutta S, Hazra P. Genetic parameters and path analysis of yield and its components in okra at different sowing dates in the Gangetic plains of Eastern India. African Journal of Biotechnology. 2012; 11:132-161.
14. Dewey DR, Lu KH. A correlation and path co-efficient analysis of components of crested wheat grass seed production. Agronomy Journal. 1959; 51:515-518.
15. Dhankhar BS, Dhankhar SK. Genetic variability, correlation and path analysis in okra (*Abelmoschus esculentus* (L.) Moench). Vegetable Science. 2002; 29:63-65.
16. Gandhi HT, Yadav MD, Navale PA. Character association and path analysis in okra. Journal of Maharashtra Agriculture University. 2002; 27:110-112.
17. Gemede HF, Ratta N, Haki GD, Ashagrie Z, Woldegiorgis, Beyene F. Nutritional quality and health benefits of okra (*Abelmoschus esculentus*): A review. International Journal of Nutrition and Food Sciences. 2015; 4:208-215.
18. Hammon S, Van Sloten DH. Characterization and evaluation of okra. In The use of plant genetic resources. 1989; p 173-174.
19. Hayes HK, Immer FR, Smith DC. Methods of Plant Breeding. (2 Ed.). McGraw Hill Nd Book Co. Inc. New York, 1955, 55I.
20. Jaiprakashnarayan RP, Mulge R. Correlation and path analysis in okra. Indian Journal of Horticulture. 2004; 63:232-235.
21. Kang MS, Miller JD, Tai PP. Genetic and phenotypic path analyses and heritability in sugarcane. Crop Science. 1983; 23:643-647.
22. Karakoltisidis PA, Constandinides. Okra Seeds. A new protein source. Journal of Agricultural and Food Chemistry. 1975; 23:1204-1207.
23. Kerure P, Pitchaimuthu M, Hosamani A. Studies on variability, correlation and path analysis of traits contributing to fruit yield and its components in okra (*Abelmoschus esculentus* (L.) Moench). Electronic Journal of Plant Breeding. 2017; 8:134-141.
24. Kumar A, Kumar M, Sharma VR, Singh MK, Singh B, Chand P. Character association and path coefficient analysis of yield and yield related traits in okra (*Abelmoschus esculentus* (L.) Moench). Progressive Agriculture. 2019; 19:140-145.
25. Kumar PS, Sreeparvathy S. Studies on heterosis in okra (*Abelmoschus esculentus* (L.) Moench). Electronic Journal of Plant Breeding. 2010; 1(6):1431-1433.
26. Mehta YR. 1959. Vegetable growing in Uttar Pradesh, Bureau of Agricultural Information, U.P., Lucknow.
27. Murdock GP. 1959. Africa, its people and their culture history. 456 p. McGraw-Hill, New York, USA.
28. Pachiyappan R, Saravannan K. Studies on genetic variability and correlation for fruit yield and fruit quantity characters of okra. The Asian Journal of Horticulture. 2016; 11:101-104.
29. Patil BT, Rode VR, Bhalekar MN, Shinde KG. Correlation and path analysis studies in okra (*Abelmoschus esculentus* (L.) Moench). Vegetable Science. 2016; 43:226-229.
30. Pithiya PH, Kulkarni GU, Jalu RK, Thumar DP. Correlation and path coefficient analysis of quantitative characters in okra (*Abelmoschus esculentus* (L.) Moench). Journal of Pharmacognosy and Phytochemistry. 2017; 6:1487-1493.
31. Prasath G, Reddy KR, Saidaiah P. Correlation and path coefficient analysis of fruit yield and yield attributes in okra (*Abelmoschus esculentus* (L.) Moench). International Journal of Current Microbiology and Applied Sciences. 2017; 6:463-472.
32. Rajeev YK, Syamal MM, Kumar M, Pandiyaraj P, Kattula N, Ashish K. Correlation and path analyses for fruit yield and its component traits in okra (*Abelmoschus

esculentus (L.) Moench) genotypes. International Journal of Agriculture Sciences. 2017; 9:4063-4067.

33. Reddy MT. Genetic diversity, heterosis, combining ability and stability in okra (*Abelmoschus esculentus* (L.) Moench). Ph. D. Thesis, Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad, 2010, 313.
34. Samim S, Sood S, Singh A. Genetic assessment for fruit yield and horticultural traits in okra (*Abelmoschus esculentus* (L.) Moench). International Journal of Current Microbiology and Applied Sciences. 2018; 7:947-957.
35. Saryam DK, Mittra SK, Mehta AK, Prajapati S, Kadwey S. Correlation and path coefficient analysis of quantitative traits in okra (*Abelmoschus esculentus* (L.) Moench). Journal of Environmental Science. 2015; 10:735-739.
36. Sawant SN, Nagre PK, Gudadhe PS, Narkhede GW. Correlation and path coefficient analysis studies in okra (*Abelmoschus esculentus* (L.) Moench). National Academy of Agricultural Sciences. 2014; 32:3-4.
37. Schippers RR. African Indigenous Vegetables-An overview of the cultivated species. 2000, 103-118.
38. Sharma RK, Prasad K. Genetic divergence, correlation and path coefficient analysis in okra. Indian Journal of Agricultural Research. 2015; 49:77-82.
39. Singh B, Pal AK, Singh S. Genetic variability and correlation studies in okra (*Abelmoschus esculentus* (L.) Moench). Indian Journal of Horticulture. 2006. 63:281-285.
40. Singh N, Singh DK, Pandey P, Panchbhaiya A, Rawat M. Correlation and path coefficient studies in okra (*Abelmoschus esculentus* (L.) Moench). International Journal of Current Microbiology and Applied Sciences. 2017; 6:1096-1101.
41. Singh RK, Choudhury BD. Biometrical methods in quantitative genetic analysis. Kalyani Publishers, New Delhi, 1985, 102-138.
42. Singla R, Kumari P, Sharma R, Thaneshwari, Sahare HA. Correlation studies in okra (*Abelmoschus esculentus* L. Moench) genotypes. Plant Archives. 2018; 18:1871-1874.
43. Sood S. Variation and heritability of different characters in okra (*Abelmoschus esculentus* (L.) Moench). Scientific Horticulture. 2006; 10:193-199.
44. Yadav M, Chaurasia PC, Singh DB, Singh GK. Genetic variability, correlation coefficient and path analysis in okra. Indian Journal of Horticulture. 2010; 67:456-460.
45. Yadav RK, Syamal MM, Kumar M, Pandiyaraj P, Nagaraju K, Kaushal A. Correlation and path analyses for fruit yield and its component traits in okra (*Abelmoschus esculentus* (L.) Moench) genotypes. International Journal of Agriculture Sciences. 2017; 9:4063-4067.
46. Yonas M, Garedew W, Debela A. Varibility and association of quantitative characters among okra collection in South Western Ethiopia. Journal of Biological Science. 2014; 14:336-342.