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Full Length Research Paper

Genetic parameters and path analysis of yield and its components in okra at different sowing dates in the Gangetic plains of eastern India

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There is continuing need to identify traits that can facilitate selection of productive progenies. For this, 18 genotypes of okra [*Abelmoschus esculentus* (L.) Moench] were evaluated for the extent of genetic variability, heritability, correlation and path analysis among various morphological, reproductive and nutritional characters related to fruit yield over two growing seasons in the Gangetic plains of eastern India. Phenotypic co-efficient of variation (PCV) agreed closely with the genotypic co-efficient of variation (GCV) but the magnitude of PCV was higher than GCV for almost all the characters studied during both seasons which reflect the influence of environment on the expression of traits. High PCV and GCV values were shown by fruit yield per plant, numbers of fruit per plant and plant height at flowering during both seasons. The remaining traits recorded moderate to low PCV and GCV estimates, indicating that selection for these characters will be less effective. All characters studied exhibited moderate to high heritability. However, pooled genetic advance (GA) expressed as percentage of mean was high for fruit yield per plant, numbers of fruit per plant, plant height at flowering and fruit weight. Characters showing moderate to high genetic gain also showed high heritability, indicating that most genetic variations in these characters were due to additive gene effects. From the correlation and path coefficient analyses, it revealed that the top priority should be given to selection based on numbers of fruit per plant and fruit weight for yield improvement and could be considered while formulating selection indices in the improvement of okra.

Key words: Okra, genetic variability, heritability, correlation, path analysis.

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is an important vegetable of tropical and sub-tropical part of the world, mainly grown for its tender fruits, which are cooked and consumed as vegetable (Chattopadhyay et al., 2011). The cultivated okra is popular due to its nutritive and medicinal values and is said to be useful against fever, catarrhal attacks, genito-urinary disorders, spermatorrhoea, gonorrhea, leucorrhoea and chronic dysentery (Nadkarni, 1927). India ranks first in okra production which contributes 67% of the total world production (Anonymous, 2010). However, the productivity (10.6 ton/ha) is much less than the potential productivity. Several reasons for low productivity include use of local unimproved cultivars, less adoption of existing commercial varieties/hybrids, and heavy incidence of biotic stresses particularly yellow vein mosaic disease. Therefore, much concentrated efforts are necessary to improve its yield and yield components. Hence, evaluation

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of the potentialities of the existing cultivars is essential because it depicts the genetic diversity of the base materials on which depends the promise for further improvement. The success of a breeding programme for the improvement of quantitative attributes depends to a great extent on the magnitude of genetic variability existing in the germplasm. Burton (1952) suggested that genetic variability along with heritability should be considered for assessing the maximum and accurate effect of selection. Studies on the variability using genetic parameters like genotypic coefficient of variation (GCV), heritability and genetic advance is essential for initiating an efficient breeding programme. High yield can be achieved by selection of those characters that have high heritability values coupled with high genetic advance. Selection is an indispensable component of the variety development process. Breeders search for dependable parameters that are less affected by the environment. Again, selection of the trait invariably affects a number of associated traits, which evokes the necessity in finding out the interrelationship of various yield components both among themselves and with yield. Therefore, knowledge of correlation and causation among yield and yield components is of paramount importance in okra breeding programme. Okra is primarily cultivated in spring-summer and rainy seasons in India. Information on the extent of genetic variability, heritability and character associationship over two growing seasons in okra is lacking under the Gangetic plains of eastern India. Under this context, the objective of the present work was to determine genetic variability components for important growth, fruit and nutritional characters influencing yield as well as interrelationship among the characters and their direct and indirect effects on fruit yield of okra in order to find out important selection indices of okra.

MATERIALS AND METHODS

Field growing and data recording

The present investigation was undertaken during spring-summer and rainy seasons during year 2009 for studying the characters evaluation of 18 okra genotypes following Randomized Block Design with three replications at research plot of AICRP on Vegetable Crops, District Seed Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal which is situated at 23.5°N latitude and 89°E longitude with a mean sea level of 9.75 m. Seed of genotypes, after treatment with Thiram (3 g kg^{-1} of seed), were sown during the 1st week of February during spring-summer and 1st of July during rainy season at 2.5 cm deep furrows with 45 cm spacing between rows and 30 cm between plants in plots that were 2.25 × 2.4 m in well prepared land having sandy loam soil (pH 6.5). Fertilizer at the rate of 60 kg N from urea, 60 kg P from single super phosphate and 60 kg K from muriate of potash ha^{-1} was applied as basal to the soil. Top dressing of nitrogen at 60 kg ha^{-1} was applied in two equal split doses at 30 and 55 days after transplanting. Management practices for cultivation were followed as per Chattopadhyay et al. (2007).

Ten randomly selected plants from each replication were taken to record 15 quantitative traits namely: plant height at flowering (cm), numbers of lateral branch per plant, numbers of node on the main stem, numbers of leaf per plant, days to first flowering, node at first flowering, numbers of ridge per fruit, fruit length (cm), fruit diameter (cm), fruit weight (g), numbers of fruit per plant, numbers of seed per fruit, ascorbic acid content of fruit (mg/100 g), crude protein content of fruit 9%) and fruit yield per plant (g). Fruit characters of each genotype were taken after six days of anthesis by tagging the flowers. Ascorbic acid (Ranganna, 1986) and crude protein contents (Nitrogen content by Micro-Kjeldahl Method × 6.25) of tender fruits were estimated as per standard methods.

Statistical analysis

Data were subjected to analysis of variance (Panse and Sukhatme, 1984). The genotype co-efficient of variation (GCV) and phenotype co-efficient of variation (PCV) were calculated by following the formula given by Burton (1952). For the estimates of heritability and genetic advance, the method of Hanson et al. (1956) was followed. Later, correlation coefficients at genotypic and phenotypic levels were calculated (Johnson et al., 1955). Path coefficient was done as per Dewey and Lu (1959).

RESULTS AND DISCUSSION

Analysis of genetic variability and heritability

The present study was initiated to examine the nature of variability in different characters of okra genotypes. Analysis of variance of 15 traits revealed that mean squares due to genotypes were highly significant except numbers of lateral branch per plant, node at first flowering, and numbers of ridge per fruit, fruit diameter and crude protein content of fruit (Table 1). The co-efficient of variation (CV) were below 10% for all the characters studied confirming the reliability of the experiment and also suggesting less G × E interactions.

Phenotypic co-efficient of variation (PCV) agreed closely with the genotypic co-efficient of variation (GCV) but the magnitude of PCV was higher than GCV for almost all the characters during both seasons (Table 2) which was well supported by Yadav et al. (2002). High PCV and GCV values were shown by fruit yield per plant followed by numbers of fruit per plant and plant height at flowering during both seasons. These observations find support from the previous workers (Mehta et al., 2006; Magar and Madrap, 2009; Akotkar et al., 2010; Guddadamath et al., 2011). On the other hand, low PCV and GCV values were shown by days to first flowering, node at first flowering and numbers of ridge per fruit. The result corroborates the earlier findings of Jaiprakashnarayan et al. (2006). Pooled broad sense heritability values were higher (more than 90 %) for all the characters except node at first flowering (80%), number of nodes on main stem (83%), numbers of leaf per plant and fruit diameter (84%) which corroborates the findings of earlier workers (Reddy et al., 1985; Sarkar et al., 2005; Mehta et al., 2006; Magar and Madrap, 2009; Pal et al., 2010). These broad sense heritability values

Table 1. Analysis of variance for fifteen different characters in 18 genotypes of okra in spring-summer and rainy seasons.

Source of variation (d.f.)	Mean Sum of Square (MS)														
	Plant height	No. of lateral branches per plant	No. of nodes on main stem	No. of leaves per plant	Days to first flowering	Node at first flowering	No. of ridges per fruit	Fruit length	Fruit diameter	Fruit weight	No. of fruits per plant	No. of seeds per fruit	Ascorbic acid content	Crude protein content	Fruit yield per plant
Replication (2)															
S	12.99	0.01	1.20	1.05	0.45	0.11	0.02	1.94	0.04	0.70	1.18	6.72	0.64	0.004	665.04
R	6.44	0.06	0.02	10.28	1.44	0.007	0.002	0.38	0.002	0.58	0.41	1.18	0.34	0.04	612.86
Genotypes (17)															
S	533.08**	0.83	15.81**	35.59**	56.81**	0.78	0.46	6.88**	0.10	27.88 **	38.36**	287.36**	8.38**	0.15	28035.47**
R	584.16**	1.09	12.17**	20.83**	60.71**	0.53	0.44	8.01**	0.13	32.11**	51.14**	284.83**	8.67**	0.19	39619.28**
Error (34)															
S	4.21	0.05	1.35	1.76	0.45	0.08	0.02	0.12	0.007	0.58	1.05	10.43	0.25	0.01	621.43
R	5.23	0.03	0.51	1.51	0.43	0.03	0.003	0.25	0.01	0.23	0.73	9.55	0.23	0.01	453.37
CV (%)															
S	3.24	8.49	5.81	6.06	1.40	5.69	2.39	2.92	5.58	4.82	6.31	6.08	4.11	5.14	9.73
R	3.20	5.74	3.12	4.59	1.32	2.81	1.11	3.84	4.85	2.95	4.82	5.40	3.78	5.52	7.28

No.= number; S = spring-summer season; R = rainy season; * significant at 5 % level; ** significant at 1 % level; Figures.

were likely to be over estimated as in this calculation it was not possible to exclude variation due to different genetic components and their interactions. The heritability estimates were, therefore, to be considered with these limitations in view. However, pooled genetic advance (GA) expressed as percentage of mean was high for the characters like fruit yield per plant, numbers of fruit per plant, plant height at flowering and fruit weight. According to Johnson et al. (1955) and Ghandi et al. (1964), high heritability estimates along with high genotypic coefficient of variation and genetic advance is usually more useful in predicting the response of an individual to selection than heritability values alone. Percy and Turcotte (1991) argued that when heritability is mainly due to non-additive genetic effects (dominance and epistasis), genetic advance will be low, while in cases where heritability is chiefly due to additive gene effects, a high genetic advance may be expected. In the present study, high heritability coupled with high genetic advance was observed for green fruit yield per plant, numbers of fruit per plant, plant height at flowering and fruit weight indicating good response to selection for these characters. High heritability and high genetic advance for the above mentioned characters revealed that such characters are controlled additive gene action (Panse, 1957) and selection based on these characters will be effective. These results find support with the observations of earlier workers (Jayapandi and Balakrishnan, 1992; Sarkar et al., 2005; Mehta et al., 2006; Magar and Madrap, 2009; Pal et al., 2010; Guddadamath et al., 2011).

The low heritability is being exhibited due to high environmental effects. High heritability accompanied with low genetic advance for the characters like numbers of ridge per fruit, node at first flowering, numbers of node on main stem, days to first flowering, fruit diameter and numbers of leaf per plant suggesting that these characters were influenced due to favourable influence of environment rather than genotypes.

Correlation co-efficient

In any improvement program, selection is effective

Table 2. Genetic variability parameters in different characters in spring-summer and rainy seasons of 18 okra genotypes.

Character	Season	Plant height	No. of lateral branches per plant	No of nodes main stem	No of leaves per plant	Days to first flowering	Node at first flowering	Fruit length	Fruit diameter	No of ridges per fruit	Fruit weight	No of fruits per plant	No of seeds per fruit	Ascorbic acid content	Crude protein content	Fruit yield per plant
Mean	S	65.55	2.55	20.00	21.90	47.48	5.08	12.03	1.53	5.14	15.73	16.22	53.12	12.25	1.74	256.26
	R	71.35	2.93	22.83	26.74	49.58	5.66	13.07	1.67	5.13	16.43	17.76	57.24	12.61	1.77	292.56
	P	68.45	2.74	21.415	24.32	48.53	5.37	12.55	1.6	5.135	16.08	16.99	55.18	12.43	1.755	274.41
Range	S	42.68-90.02	1.60-3.38	16.95-24.23	15.08-27.63	41.02-57.12	4.23-5.78	9.68-15.34	1.20-1.85	5-6.27	9.82-19.53	10.13-22.69	34.10-69.83	9.26-14.50	1.33-2.04	95.79-422.21
	R	50.35-97.19	1.61-4.06	19.45-26.51	22.19-31.55	44.83-59.57	4.97-6.05	10.16-16.98	1.20-1.94	5-6.26	10.14-21.22	11.75-25.91	38.21-73.91	9.61-15.78	1.31-2.12	115.54-518.41
	P	46.52-93.61	1.61-3.72	18.2-25.37	18.63-29.59	42.93-58.35	4.60-5.92	9.92-16.16	1.20-1.89	5-6.26	9.98-20.37	10.94-24.30	36.15-71.87	9.45-15.14	1.32-2.08	105.66-470.21
PCV (%)	S	23.55	21.85	12.42	16.49	9.24	11.11	12.81	12.81	7.90	19.77	22.64	19.08	14.06	13.83	38.55
	R	19.73	21.18	9.18	10.54	9.14	7.83	12.89	13.43	7.54	20.07	23.58	17.59	13.83	14.96	39.73
	P	21.64	21.51	10.80	13.51	9.19	9.47	12.85	13.12	7.72	19.92	23.11	18.33	13.94	14.40	39.14
GCV (%)	S	23.34	20.13	10.98	15.33	9.13	9.54	12.47	11.53	7.53	19.18	21.74	18.09	13.44	12.84	37.30
	R	19.47	20.39	8.64	9.49	9.04	7.30	12.31	12.53	7.46	19.85	23.09	16.74	13.30	13.91	39.06
	P	21.40	20.26	9.81	12.41	9.08	8.42	12.39	12.03	7.50	19.51	22.42	17.41	13.37	13.38	38.18
Heritability (%) in b.s.	S	98.0	85.0	78.0	86.0	98.0	74.0	95.0	81.0	91.0	94.0	92.0	90.0	91.0	86.0	94.0
	R	97.0	93.0	88.0	81.0	98.0	87.0	91.0	87.0	98.0	98.0	96.0	91.0	93.0	86.0	97.0
	P	98.0	89.0	83.0	84.0	98.0	80.0	93.0	84.0	94.0	96.0	94.0	90.0	92.0	86.0	95.0
GA (%) of mean	S	47.65	38.22	19.99	29.37	18.59	16.87	25.02	21.39	14.80	38.31	43.02	35.32	26.49	24.56	74.36
	R	39.58	40.43	16.74	17.61	18.43	14.04	24.21	24.06	15.20	40.44	46.55	32.81	26.36	26.63	79.09
	P	43.61	39.32	18.36	23.49	18.51	15.46	24.61	22.73	15.00	39.38	44.79	34.07	26.43	25.60	76.72

S = Spring-summer season; R = rainy season; P = pooled; PCV= phenotypic coefficient of variation; GCV= genotypic coefficient of variation; GA= genetic advance; b.s = broad sense.

only if adequate genetic variability is present. However, simultaneous selection for several characters needs to be correlated to explain the interrelationships between characters and helps in effective identification of potential genotypes. It is beneficial to know the interrelationships between various economically important characters. Association analysis of different morphological, reproductive and nutritional characters with fruit yield of okra genotypes and their inter-relationships were investigated through the study of both phenotypic and genotypic correlation co-efficients during spring-summer and rainy seasons. In the present study, 15 characters were recorded and their genotypic and phenotypic correlation co-efficient were analysed during both the seasons (Tables 3 and 4). Phenotypic and genotypic correlation co-efficients, in general, agreed very closely. However, the genotypic correlations were higher than phenotypic correlations in most of the cases.

These could occur when the genes governing Two traits were similar and environmental factors played a small part in the expression of these traits.

Out of 15 characters studied during spring season, 10 characters namely: plant height at flowering, numbers of node on main stem, numbers of leaf per plant, fruit length, fruit diameter, fruit weight, numbers of fruit per plant,

Table 3. Phenotypic and genotypic correlation coefficients of fifteen characters of okra in spring-summer season.

Character	Plant height	No. of lateral branches per plant	No of nodes on main stem	No of leaves per plant	Days to first flowering	Node at first flowering	Fruit length	Fruit diameter	No of ridges per fruit	Fruit weight	No of fruits per plant	No of seeds per fruit	Ascorbic acid content	Crude protein content	Fruit yield per plant
Plant height	P	0.184	0.534*	0.749**	-0.428*	-0.233	0.471*	0.349	-0.117	0.524*	0.581**	0.600**	0.520*	0.299	0.538*
	G	0.202	0.600	0.821	-0.440	-0.251	0.479	0.392	-0.130	0.547	0.611	0.655	0.546	0.328	0.564
No. of lateral branches per plant		P	0.119	0.067	-0.104	-0.169	0.138	0.025	-0.014	0.060	0.263	-0.134	-0.011	-0.031	0.161
		G	0.080	0.103	-0.115	-0.182	0.149	0.062	-0.014	0.086	0.298	-0.096	-0.042	-0.054	0.196
No of nodes on main stem			P	0.479*	-0.690**	-0.645**	0.484*	0.508*	-0.338	0.643**	0.693**	0.693**	0.700**	0.539*	0.690**
			G	0.577	-0.800	-0.836	0.610	0.699	-0.322	0.756	0.794	0.834	0.800	0.662	0.799
No of leaves per plant				P	-0.299	-0.072	0.550**	0.423	-0.044	0.539*	0.478*	0.613**	0.450*	0.200	0.453*
				G	-0.341	-0.087	0.605	0.459	-0.050	0.553	0.525	0.692	0.498	0.234	0.474
Days to First Flowering					P	0.689**	-0.575**	-0.628**	0.227	-0.793**	-0.720**	-0.747**	-0.799**	-0.723**	-0.788**
					G	0.805	-0.603	-0.697	0.234	-0.826	-0.759	-0.784	-0.853	-0.760	-0.822
Node at first flowering						P	-0.376	-0.445*	0.303	-0.598**	-0.648**	-0.479*	-0.632**	-0.664**	-0.684**
						G	-0.435	-0.642	0.380	-0.709	-0.789	-0.629	-0.810	-0.840	-0.818
Fruit length							P	0.600**	-0.263	0.548**	0.529*	0.676**	0.606**	0.558**	0.508*
							G	0.657	-0.294	0.594	0.569	0.754	0.644	0.613	0.552
Fruit diameter								P	-0.063	0.656**	0.543**	0.704**	0.725**	0.514*	0.599**
								G	-0.081	0.719	0.666	0.832	0.808	0.581	0.696
No of ridges per fruit									P	-0.003	-0.282	-0.092	-0.245	-0.313	-0.182
									G	-0.003	-0.315	-0.094	-0.258	-0.363	-0.205
Fruit weight										P	0.810**	0.848**	0.832**	0.698**	0.924**
										G	0.857	0.913	0.884	0.756	0.938
No of fruits per plant											P	0.739**	0.804**	0.707**	0.962**
											G	0.782	0.905	0.769	0.975
No of seeds per fruit												P	0.777**	0.643**	0.800**
												G	0.884	0.719	0.843
Ascorbic acid content													P	0.803**	0.854**
													G	0.889	0.934
Crude Protein														P	0.749**
														G	0.806

P = Phenotypic correlation coefficients; G = genotypic correlation coefficients; *significant at 5 % level; **significant at 1 % level.

Table 4. Phenotypic and genotypic correlation coefficients of fifteen characters of okra in rainy season.

Character	Plant height	No. of lateral branches per plant	No of nodes on main stem	No of leaves per plant	Days to first flowering	Node at first flowering	Fruit length	Fruit diameter	No of ridges per fruit	Fruit weight	No of fruits per plant	No of seeds per fruit	Ascorbic acid content	Crude protein content	Fruit yield per plant
Plant height	P	-0.137	0.513*	0.873**	-0.306	-0.136	0.584**	0.494*	-0.039	0.438*	0.320	0.615**	0.464*	0.241	0.314
	G	-0.153	0.549	0.966	-0.316	-0.160	0.610	0.527	-0.045	0.448	0.326	0.651	0.484	0.271	0.320
No. of lateral branches per plant		P	-0.098	-0.156	-0.105	-0.064	-0.166	-0.099	0.086	0.045	0.203	-0.279	0.081	-0.027	0.132
		G	-0.123	-0.168	-0.113	-0.076	-0.186	-0.104	0.086	0.054	0.232	-0.318	0.088	-0.059	0.153
No of nodes main stem			P	0.434*	-0.648**	-0.726**	0.569**	0.632**	-0.336	0.576**	0.661**	0.693**	0.649**	0.523*	0.649**
			G	0.449	-0.682	-0.832	0.613	0.719	-0.358	0.622	0.719	0.761	0.738	0.650	0.705
No of leaves per plant				P	-0.330	-0.091	0.461*	0.413*	-0.051	0.402*	0.260	0.513*	0.424*	0.242	0.265
				G	-0.348	-0.120	0.475	0.477	-0.047	0.440	0.298	0.604	0.453	0.334	0.300
Days to First Flowering					P	0.783**	-0.540*	-0.804**	0.215	-0.757**	-0.788**	-0.681**	-0.769**	-0.744**	-0.811**
					G	0.839	-0.569	-0.870	0.215	-0.776	-0.812	-0.732	-0.809	-0.821	-0.833
Node at first flowering						P	-0.407*	-0.640**	0.280	-0.645**	-0.823**	-0.572**	-0.718**	-0.728**	-0.811**
						G	-0.461	-0.737	0.299	-0.704	-0.893	-0.657	-0.850	-0.803	-0.883
Fruit length							P	0.605**	-0.236	0.464*	0.440*	0.748**	0.539*	0.472*	0.436*
							G	0.664	-0.246	0.483	0.466	0.759	0.553	0.552	0.460
Fruit diameter								P	-0.015	0.803**	0.679**	0.829**	0.783**	0.730**	0.759**
								G	-0.029	0.873	0.729	0.914	0.887	0.803	0.813
No of ridges per fruit									P	0.022	-0.292	-0.085	-0.222	-0.332	-0.187
									G	0.026	-0.298	-0.087	-0.225	-0.374	-0.189
Fruit weight										P	0.770**	0.810**	0.822**	0.712**	0.900**
										G	0.788	0.860	0.854	0.789	0.908
No of fruits per plant											P	0.665**	0.866**	0.748**	0.963**
											G	0.707	0.937	0.829	0.967
No of seeds per fruit												P	0.779**	0.693**	0.742**
												G	0.820	0.771	0.792
Ascorbic acid Content													P	0.820**	0.883**
													G	0.935	0.941
Crude Protein														P	0.778**
														G	0.863

P = Phenotypic correlation coefficients; G = genotypic correlation coefficients; * significant at 5% level; ** significant at 1% level.

numbers of seed per fruit, ascorbic acid content and crude protein content exhibited significantly positive correlation co-efficient with green fruit yield per plant. Besides, the character like numbers of lateral branch per plant showed positive but non significant correlation with fruit yield per plant. However, days to first flowering and node at first flowering exhibited significantly negative correlation with fruit yield per plant. This indicates that early in first flowering, and lower number of flowering node helped in improving fruit yield of okra. The inter-relationships among the characters showed that 42 correlation co-efficient were significantly positive. They also showed high genotypic correlations as well.

The correlation analysis during spring season indicate that the characters namely: plant height at flowering, numbers of node on main stem, numbers of leaf per plant, fruit length, fruit diameter, fruit weight, numbers of fruit per plant, numbers of seed per fruit, ascorbic acid content and crude protein content not only exhibited highly positive correlation co-efficient with green fruit yield per plant but they were also positively and significantly inter-related to each other. Hence, the selection on the basis of any of the significantly positive inter-related characters was expected to give a desired correlated response in other characters.

However, during rainy season, eight characters namely: numbers of node on main stem, fruit length, fruit diameter, fruit weight, numbers of fruit per plant, numbers of seed per fruit, ascorbic acid content and crude protein content exhibited significantly positive correlation co-efficient with green fruit yield per plant. Besides, the characters like plant height at flowering, numbers of lateral branch per plant and numbers of leaf per plant showed positive but non significant correlation with green fruit yield per plant. However, days to first flowering and node at first flowering exhibited significantly negative correlation with green fruit yield per plant during rainy season. This was a desirable situation as early flowering would help to minimize the crop duration and ultimately okra could be adjusted profitably in different crop rotations. The inter-relationships among the characters showed that 42 correlation co-efficients were significantly positive. They also showed high genotypic correlations as well.

The correlation analysis during rainy season indicates that numbers of node on main stem, fruit length, fruit diameter, fruit weight, numbers of fruit per plant, numbers of seed per fruit, ascorbic acid content and crude protein content not only exhibited highly positive correlation co-efficient with green fruit yield per plant but they were also positively and significantly inter-related to each other. Hence, the selection on the basis of any of the significantly positive inter-related characters was expected to give a desired correlated response in other characters.

While considering correlation analyses during both seasons, it was observed that the characters with significantly positive correlation with green fruit yield per plant were numbers of node on main stem, fruit length, fruit diameter, fruit weight, numbers of fruit per plant, numbers of seed per fruit, ascorbic acid content and crude protein content exhibited significantly positive correlation co-efficients with green fruit yield per plant. Such positive and significant associationships with green fruit yield per plant had already been observed by previous workers (Gondane et al., 1995; Chandra Deo et al., 1996, Sood et al., 1995; Dhankar and Dhankar, 2002; Sarkar et al., 2005; Mehta et al., 2006; Mohapatra et al., 2007; Magar and Madrap., 2009; Rashwan, 2011). Negatively significant associationships between days to first flowering and node at first flowering with green fruit yield per plant was also observed by Padda et al. (1970), Sarkar et al. (2005), Jaiprakashnarayan et al.(2006) and Rashwan (2011).

Path co-efficient analysis

The complexity of character relationships among themselves and with fruit yield became evident from the discussion alone but did not provide a comprehensive picture of relative importance of direct and indirect influences of each of the characters to the fruit yield, as these traits were the resultant product of combined effects of various factors complementing or counter-acting. The path co-efficient analyses developed by Wright (1921) provides an effective means of untangling direct and indirect causes of association and permits a critical examination of the specific forces acting to produce a given co-relation. In the present study, the phenoltypic correlations were partitioned into direct and indirect effects to identify relative importance of yield component towards fruit yield of okra during both the seasons.

Green fruit in okra is important as this is utilized as vegetable throughout the world. Hence, the direct effect and positive association with fruit yield per plant was considered essential. Among the 14 yield component traits, numbers of fruit per plant and fruit weight showed highly positive direct effects on fruit yield per plant during spring season (Table 5). This was the main cause of their positive association with fruit yield per plant. The direct selection for these characters could be beneficial for yield improvement of okra since these characters also showed positive correlation with fruit yield per plant. The direct effects of other characters were negligible. One character namely, fruit diameter had significant positive correlation with fruit yield per plant but their direct effect was negligible because of high positive indirect effect via numbers of fruit per plant and fruit weight. Thus, selection based on this character will not be beneficial. Residual effect was very low (0.027) suggesting inclusion of maximum fruit yield influencing characters of okra in the present analysis.

Table 5. Path-coefficient analysis of the components of fruit yield per plant at phenotypic level for spring-summer season.

Character	Plant height	No. of lateral branches per plant	No of nodes on main stem	No of leaves per plant	Days to first flowering	Node at first flowering	Fruit length	Fruit diameter	No of ridges per fruit	Fruit weight	No of fruits per plant	No of seeds per fruit	Ascorbic acid content	Crude protein content	Phenotypic correlation with yield / plant
Plant height	**-0.01042**	0.00200	0.01049	-0.09379	0.01926	-0.00086	-0.00463	0.01875	-0.00321	0.14360	0.35829	-0.00945	-0.07695	0.00389	0.538*
No. of lateral branches per plant	0.00022	**-0.09500**	0.00146	-0.00996	0.00798	-0.00404	-0.00113	0.00221	-0.00052	0.02945	0.25767	0.00132	0.00762	-0.00132	0.161
No of nodes main stem	-0.00594	-0.00757	**0.01839**	-0.05596	0.05568	-0.01859	-0.00465	0.02478	-0.01176	0.25743	0.68696	-0.01145	-0.14487	0.01633	0.690
No of leaves per plant	-0.01007	-0.00975	0.01061	**-0.09700**	0.02371	-0.00193	-0.00461	0.01626	-0.00181	0.18828	0.45413	-0.00950	-0.09018	0.00577	0.453
Days to First Flowering	0.00288	0.01090	-0.01472	0.03305	**-0.06959**	0.01791	0.00460	-0.02471	0.00853	-0.28120	-0.65643	0.01076	0.15445	-0.01875	-0.788**
Node at first flowering	0.00040	0.01726	-0.01537	0.00842	-0.05602	**0.02225**	0.00332	-0.02277	0.01387	-0.24145	-0.68217	0.00864	0.14677	-0.02072	-0.684**
Fruit length	-0.00632	-0.01414	0.01122	-0.05864	0.04199	-0.00968	**-0.00763**	0.02330	-0.01073	0.20250	0.49228	-0.01035	-0.11669	0.01513	0.508*
Fruit diameter	-0.00551	-0.00593	0.01285	-0.04449	0.04848	-0.01429	-0.00501	**0.03546**	-0.00298	0.24496	0.57611	-0.01142	-0.14631	0.01433	0.599**
No of ridges per fruit	0.00092	0.00134	-0.00592	0.00480	-0.01626	0.00845	0.00224	-0.00289	**0.03653**	-0.00085	-0.27271	0.00128	0.04682	-0.00896	-0.182
Fruit weight	-0.00439	-0.00821	0.01390	-0.05361	0.05744	-0.01577	-0.00453	0.02550	-0.00009	**0.34064**	0.74156	-0.01254	-0.16015	0.01864	0.924**
No of fruits per plant	-0.00431	-0.02830	0.01461	-0.05093	0.05281	-0.01755	-0.00434	0.02362	-0.01152	0.29206	**0.86491**	-0.01074	-0.16392	0.01896	0.962**
No of seeds per fruit	-0.00717	0.00915	0.01534	-0.06709	0.05455	-0.01400	-0.00575	0.02949	-0.00342	0.31115	0.67667	**-0.01373**	-0.16016	0.01774	0.800**
Ascorbic acid content	-0.00442	0.00399	0.01471	-0.04828	0.05933	-0.01802	-0.00491	0.02864	-0.00944	0.30113	0.78258	-0.01214	**-0.18117**	0.02193	0.854**
Crude Protein	-0.00164	0.00510	0.01217	-0.02267	0.05288	-0.01869	-0.00468	0.02060	-0.01327	0.25742	0.66473	-0.00987	-0.16106	**0.02467**	0.749**

Residual effect = 0.027; direct effects = bold diagonal; *significant at 5 % level; **significant at 1% level.

Table 6. Path-coefficient analysis of the components of fruit yield per plant at phenotypic level for rainy season.

Character	Plant height	No. of lateral branches per plant	No of nodes on main stem	No of leaves per plant	Days to first flowering	Node at first flowering	Fruit length	Fruit diameter	No of ridges per fruit	Fruit weight	No of fruits per plant	No of seeds per fruit	Ascorbic acid content	Crude protein content	Phenotypic correlation with yield / plant
Plant height	**0.00272**	0.01835	0.08213	-0.13531	0.02869	-0.03804	0.00305	-0.02154	-0.00205	0.21918	0.25671	-0.12332	0.01801	0.01132	0.314
No. of lateral branches per plant	-0.00042	**-0.11997**	-0.01846	0.02352	0.01027	-0.01822	-0.00093	0.00424	0.00391	0.02617	0.18234	0.06023	0.00329	-0.00248	0.132
No of nodes main stem	0.00149	0.01482	**0.14947**	-0.06295	0.06197	-0.19834	0.00307	-0.02939	-0.01624	0.30429	0.56638	-0.14405	0.02749	0.02713	0.649**
No of leaves per plant	0.00262	0.02013	0.06715	**-0.14014**	0.03162	-0.02852	0.00237	-0.01951	-0.00213	0.21533	0.23496	-0.11443	0.01687	0.01396	0.265
Days to First Flowering	-0.00086	0.01357	-0.10201	0.04880	**-0.09081**	0.19998	-0.00285	0.03557	0.00977	-0.37928	-0.63935	0.13857	-0.03013	-0.03430	-0.811**
Node at first flowering	-0.00043	0.00917	-0.12432	0.01676	-0.07615	**0.23846**	-0.00231	0.03011	0.01359	-0.34398	-0.70351	0.12435	-0.03166	-0.03354	-0.811**
Fruit length	0.00166	0.02235	0.09166	-0.06654	0.05168	-0.11000	**0.00500**	-0.02713	-0.01117	0.23592	0.36680	-0.14369	0.02061	0.02305	0.436*
Fruit diameter	0.00143	0.01246	0.10750	-0.06688	0.07903	-0.17570	0.00332	**-0.04087**	-0.00131	0.42653	0.57393	-0.17317	0.03303	0.03355	0.759**

Table 6. Continued

No of ridges per fruit	-0.00012	-0.01033	-0.05349	0.00657	-0.01955	0.07137	-0.00123	0.00118	0.04539	0.01287	-0.23445	0.01650	-0.00838	-0.01563	-0.187
Fruit weight	0.00122	-0.00642	0.09304	-0.06173	0.07046	-0.16780	0.00241	-0.03566	0.00119	**0.48884**	0.62053	-0.16296	0.03182	0.03294	0.900**
No of fruits per plant	0.00089	-0.02777	0.10749	-0.04181	0.07372	-0.21300	0.00233	-0.02978	-0.01351	0.38515	**0.78760**	-0.13391	0.03489	0.03462	0.908
No of seeds per fruit	0.00177	0.03815	0.11369	-0.08467	0.06644	-0.15657	0.00379	-0.03737	-0.00395	0.42063	0.55688	**-0.18939**	0.03054	0.03218	0.963**
Ascorbic acid content	0.00131	-0.01060	0.11031	-0.06345	0.07344	-0.20268	0.00277	-0.03624	-0.01021	0.41757	0.73760	-0.15526	**0.03725**	0.03903	0.742**
Crude Protein	0.00074	0.00713	0.09711	-0.04684	0.07457	-0.19150	0.00276	-0.03283	-0.01699	0.38550	0.65280	-0.14594	0.03482	**0.04177**	0.883**

Residual effect =0.048; direct effects = bold diagonal; * significant at 5 % level; ** significant at 1% level.

During rainy season, same two characters namely, numbers of fruit per plant and fruit weight also showed highly positive direct effects on fruit yield per plant (Table 6). Negligible direct effects of other characters were found. Three character namely, numbers of node on main stem, ascorbic acid and crude protein content had significant positive correlation with fruit yield but their direct effects were negligible because of high positive indirect effects via numbers of fruit per plant and fruit weight. The maximum fruit yield influencing characters of okra were taken into consideration in the present analysis as the residual effect was very low (0.030) . The results are in conformity with the observations of early workers (Vijoy and Monohar, 1990; Mishra et al., 1996; Mandal and Dana, 1994; Gondane et al., 1995; Dash and Mishra, 1995; Chandra Deo et al., 1996; Singh et al., 2007; Magar and Madrap., 2009) who observed positive and significant correlation and direct effects for numbers of fruit per plant and fruit weight with fruit yield per plant.

Thus, okra fruit yield is a cumulative consequence of fruit number and fruit weight. These two traits deserve considerable attention by okra breeders and need to be collectively enhanced to develop an ideotype.

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