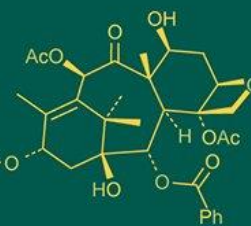
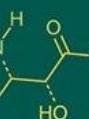
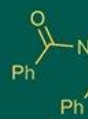


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Studies on Correlation and Path-Coefficient Analysis for Fruit Yield and Its Contributing Characters in Sponge Gourd (*Luffa cylindrica* L. Roem.) Cross HR-1 × SG-3

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Abstract

The present investigation was carried out to assess the nature and magnitude of association among fruit yield and its component characters in the F_2 population of sponge gourd (*Luffa cylindrica* L. Roem.) derived from the cross HR-1 × SG-3, raised during the late kharif season at Kittur Rani Channamma College of Horticulture (KRCH), Arabhavi and to partition the phenotypic correlation coefficients into direct and indirect effects through path-coefficient analysis. Sixteen quantitative traits were studied for their relationship with fruit yield per vine in a crop breeding trial. Fruit yield showed highly significant positive phenotypic correlations with vine length (45 and 90 DAS), primary branches (45 & 90 DAS), total leaf area, per cent fruit set, days to last harvest, fruit length, number of fruits per vine and average fruit weight. It correlated negatively with days to first flowering, days to 50% flowering, and node of first female flower appearance. Path-coefficient analysis identified number of fruits per vine (0.3808) as having the highest direct positive effect on yield, followed by average fruit weight (0.3621), fruit set percent (0.3131), fruit diameter (0.1699), days to first harvest (0.1446) and fruit length (0.1052). Vine length (45 and 90 DAS), flowering-related traits and node of first female flower showed negative direct effects. A low residual effect (0.2283) confirmed that the fifteen traits explained most of the variation in yield.

Keywords: Sponge gourd, *Luffa cylindrical*, correlation, path-coefficient analysis, fruit yield, HR-1 × SG-3, direct effect

Introduction

Sponge gourd [*Luffa cylindrica* (L.) Roem.; $2n = 2x = 26$] is a warm-season vegetable crop of the family Cucurbitaceae, grown extensively in the tropical and sub-tropical regions of the Indian sub-continent and South-East Asia during the summer and rainy seasons (Obboh and Aluyor, 2002) [1]. The tender, fibre-free young fruits are consumed as a cooked vegetable and are valued as a low-calorie source of moisture, minerals, dietary fibre and vitamin C (Obboh and Aluyor, 2002 and Wehner *et al.*, 2020) [1, 2], while the mature, fully lignified fruit yields a fibrous vascular skeleton (loofah) that is used as a natural scrubber and in cottage-level fibre industries, giving the crop importance well beyond the kitchen garden (Obboh and Aluyor, 2002) [1].

Sponge gourd is predominantly cross-pollinated, its insect-pollinated flowers being visited chiefly by bees and other pollinator groups (Halder *et al.*, 2022) [3] and this floral biology offers considerable scope for the exploitation of hybrid vigour. Identification of promising cross combinations and within them of the component characters that translate most directly into fruit yield, is therefore a pre-requisite for a successful heterosis-breeding programme in this crop.

Fruit yield is a complex, polygenically controlled character that is the resultant of several interrelated component traits and direct selection for yield alone is consequently often unreliable. Correlation studies help in understanding the degree and direction of association between yield and its component characters, but because the component traits themselves are inter-correlated, the simple correlation coefficient does not by itself indicate the real, causal

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contribution of each character towards yield. Path-coefficient analysis, as suggested by Dewey and Lu, 1959^[4] using the genetic and environmental variability framework of Johnson *et al.*, 1955^[5], as modified by Al-Jibouri *et al.*, 1958^[13], partitions the correlation coefficient into direct and indirect effects and thus provides a clearer picture of the cause-and-effect relationship between the component traits and yield, enabling breeders to identify the most dependable selection criteria.

Correlation and path-coefficient analyses have been reported in varietal collections and germplasm lines of sponge gourd by several workers, who have consistently identified number of fruits per plant/vine and average fruit weight as the traits exerting the greatest direct positive effect on yield, along with variable contributions from vine length, branching, fruit length, fruit diameter and days to flowering/harvest (Chithra *et al.*, 2023, Kumar *et al.*, 2013, Sarma *et al.*, 2022, Yadav *et al.*, 2017, Khule *et al.*, 2011 and Parveen *et al.*, 2019)^[6, 7, 8, 9, 10, 14]. Similar work in the closely related species ridge gourd (Karuppaiah *et al.*, 2005 and Choudhary *et al.*, 2014)^[16, 17] and bottle gourd (Varalakshmi *et al.*, 2018)^[18] has likewise identified fruit number and fruit weight as principal direct contributors to yield, and comparable correlation and path studies in the related cucurbit cucumber have similarly shown that number of fruits per plant, fruit weight, number of primary branches, fruit length and vine length are the principal direct contributors to yield, indicating that the underlying architecture of yield determination is broadly conserved across the Cucurbitaceae even though the magnitude of individual effects differs with the crop and the genetic material used (Kumar *et al.*, 2018)^[11]. However, information on such association for specific inter-varietal or inter-line cross combinations of sponge gourd, as distinct from open-pollinated varietal collections, remains limited, particularly for crosses involving diverse parents such as HR-1 and SG-3.

A companion analysis of genetic variability, heritability and genetic advance carried out on this very F₂ population of the cross HR-1 × SG-3 showed that, although the phenotypic and genotypic coefficients of variation were low (<10%) for all twenty growth, flowering, yield and quality traits recorded, heritability in the broad sense was high (>60%) for fourteen of these traits, being highest for total leaf area (94.83%), number of fruits per vine (91.94%) and average fruit weight (91.49%), while genetic advance over mean did not exceed 20% for any character. Because high heritability by itself does not guarantee that a trait will respond predictably to direct selection, particularly in a segregating F₂ generation where dominance variance can inflate heritability estimates Johnson *et al.*, 1955^[5], it becomes necessary to examine how these heritable traits are correlated with and causally related to fruit yield before they can be recommended as selection criteria.

The present investigation was therefore undertaken to work out the correlation and path-coefficient analysis for fruit yield and its contributing characters in the cross HR-1 × SG-3 of sponge gourd, with a view to identifying reliable and effective selection indices for yield improvement in this specific cross.

Materials and Methods

Experimental site and planting materials

The present study was carried out on the segregating F₂ population derived from selfing the F₁ of the cross HR-1 ×

SG-3 of sponge gourd (*Luffa cylindrica* L. Roem.), raised at the Department of Vegetable Science, Kittur Rani Channamma College of Horticulture (KRCCH), Arabhavi, [University name], during the late *kharif* season [year]. The crop was raised following the recommended agronomic package of practices for the region, with plants spaced at [row × plant spacing].

Observations were recorded on individual F₂ plants for sixteen quantitative characters, namely vine length at 45 DAS [VL(45), m] and 90 DAS [VL(90), m], number of primary branches at 45 DAS [NBP(45)] and 90 DAS [NBP(90)], total leaf area [TLA, cm²], days to first flowering (DFF), days to 50% flowering (D50%F), node at which first female flower appears (NFF), per cent fruit set (PFS), days to first harvest (DFH), days to last harvest (DLH), fruit length [FL, cm], fruit diameter [FD, cm], number of fruits per vine (NFPV), average fruit weight [AFW, g] and fruit yield per vine [FYPV, kg].

Statistical analysis

Phenotypic correlation coefficients among the sixteen characters were computed following the method suggested by Johnson *et al.*, 1955^[5] and Al-Jibouri *et al.*, 1958^[13] using the phenotypic variance-covariance components estimated from the analysis of variance. The phenotypic correlation coefficients of the component characters with fruit yield per vine, as well as among themselves, were further partitioned into direct and indirect effects by path-coefficient analysis following the method of Dewey and Lu 1959^[4], taking fruit yield per vine as the resultant (dependent) variable and the remaining fifteen characters as the causal (independent) variables.

Results and Discussion

Correlation studies

The phenotypic correlation coefficients among the sixteen characters studied in the cross HR-1 × SG-3 are presented in Table 1. Fruit yield per vine registered highly significant and positive phenotypic correlation with vine length at 45 DAS (0.224*) and 90 DAS (0.420), number of primary branches at 45 DAS (0.193) and 90 DAS (0.365), total leaf area (0.392), per cent fruit set (0.509), days to last harvest (0.390), fruit length (0.417), number of fruits per vine (0.598) and average fruit weight (0.663). This indicated that vines that were longer and more profusely branched, bore a larger leaf area, exhibited a higher percentage of fruit set and produced longer fruits and a greater number of heavier fruits per vine tended to yield more, a trend generally consistent with the reports of Kumar *et al.*, 2013^[7] and Yadav *et al.*, 2017^[9] in sponge gourd and with the positive association of branching, fruit number and fruit weight with marketable yield reported in Assam sponge gourd germplasm by Sarma *et al.*, 2022^[8] and by Chithra *et al.*, 2023^[6].

Fruit yield per vine, on the other hand, exhibited highly significant negative correlation with days to first flowering (-0.391**), days to 50% flowering (-0.245) and node at which first female flower appears (-0.311**), indicating that early-flowering plants bearing female flowers at lower nodes were associated with higher yield, in agreement with the negative association of earliness traits with yield reported by Sarma *et al.*, 2022^[8]. Days to first harvest (-0.115) and fruit diameter (0.100) did not show a significant association with fruit yield in this cross.

Among the component traits, number of fruits per vine showed strong positive correlation with average fruit weight (0.387**) and per cent fruit set (0.166*), while it was negatively associated with days to first flowering (-0.157*) and node at which first female flower appears (-0.163*). Average fruit weight was positively correlated with fruit diameter (0.275**), fruit length (0.333) and days to last harvest (0.326) and negatively correlated with days to first flowering (-0.342) and days to 50% flowering (-0.290**).

Days to first flowering and days to 50% flowering were strongly and positively inter-correlated with each other and with node at which first female flower appears and negatively correlated with most of the yield-contributing traits, confirming that early flowering behaviour favours better expression of yield components in this cross, a pattern also noted for flowering-node traits by Khule *et al.*, 2011^[10] and Kamble, 2024^[12].

Table 1: Phenotypic Correlation Matrix of Sponge Gourd Cross (HR-1 × SG-3)

Traits	VL(45)	VL(90)	NBP(45)	NBP(90)	TLA	DFH	D50%F	NFF	PFS	DFH	DLH	FL	FD	NFPV	AFW	FYPV
VL(45)	1.000**	0.305**	0.519**	0.422**	0.307**	-0.237**	-0.336**	-0.203**	0.170*	-0.298**	0.036	0.146*	0.373**	0.445**	0.235**	0.224*
VL(90)		1.000**	0.197**	0.271**	0.364**	-0.241**	-0.258**	-0.293**	0.261**	-0.294**	0.205**	0.264**	0.245**	0.382**	0.490**	0.420
NBP(45)			1.000**	0.157*	0.137	-0.186**	-0.114	-0.131	0.126	-0.102	-0.010	0.198**	0.143*	0.197**	0.252**	0.193**
NBP(90)				1.000**	0.297**	-0.220**	-0.199**	-0.226**	0.242**	-0.194**	0.139*	0.199**	0.241**	0.303**	0.307**	0.365**
TLA					1.000**	-0.224**	-0.316**	-0.196**	0.183**	-0.110	0.195**	0.278**	0.291**	0.322**	0.391**	0.392**
DFH						1.000**	0.154*	0.167*	-0.120	0.143*	-0.139*	-0.241**	-0.177*	-0.231**	-0.342**	-0.391**
D50%F							1.000**	0.221**	-0.183**	0.185**	-0.112	0.221**	-0.279**	-0.289**	-0.290**	-0.245**
NFF								1.000**	-0.159*	0.275**	-0.224**	-0.157*	-0.163*	-0.260**	-0.284**	-0.311**
PFS									1.000**	-0.157*	0.145*	0.216**	0.112	0.166*	0.274**	0.509**
DFH										1.000**	-0.115	-0.149*	-0.175*	-0.250**	-0.250**	-0.115
DLH											1.000**	0.232**	0.141*	0.276**	0.326**	0.390**
FL												1.000**	0.190**	0.287**	0.333**	0.417**
FD													1.000**	0.240**	0.275**	0.100
NFPV														1.000**	0.387**	0.598**
AFW															1.000**	0.663**
FYPV																1.000**

* and ** indicate significance at $P \leq 0.05$ and $P \leq 0.01$, respectively.

Path-coefficient analysis

The direct and indirect effects of the fifteen component characters on fruit yield per vine, worked out through path-coefficient analysis, are presented in Table 2. The residual effect was 0.2283, indicating that the fifteen characters considered in the present study accounted for the major share of variability in fruit yield, with the remaining variation attributable to other yield-contributing traits not included in the present analysis and to environmental factors.

Number of fruits per vine exerted the highest positive direct effect on fruit yield (0.3808), followed by average fruit weight (0.3621), per cent fruit set (0.3131), fruit diameter (0.1699), days to first harvest (0.1446), fruit length (0.1052) and days to last harvest (0.0887). Total leaf area (0.0494), number of primary branches at 90 DAS (0.0782) and number of primary branches at 45 DAS (0.0037) also recorded positive, though comparatively smaller, direct effects. Since these traits recorded high correlation coefficients with yield that were closely in agreement with their direct effects, the correlation between them and yield truly reflects a direct cause-and-effect relationship and direct selection based on these traits would be effective and reliable for improving fruit yield in this cross. These findings are in general agreement with Kumar *et al.*, 2013^[7] and Khule *et al.*, 2011^[10] who also reported high positive direct effects of number of fruits per plant and fruit weight on yield in sponge gourd and with the large direct effects of fruit number and fruit weight on marketable yield reported

for indigenous Assam germplasm by Sarma *et al.*, 2022^[8] for a 40-genotype panel by Kamble, 2024^[12], in a multivariate assessment of a wider sponge gourd germplasm set by Chithra *et al.*, 2024^[15], and for cucumber, a related cucurbit by Kumar *et al.*, 2018^[11].

In contrast, vine length at 45 DAS (-0.0958), vine length at 90 DAS (-0.0148), days to first flowering (-0.1374), days to 50% flowering (-0.0305) and node at which first female flower appears (-0.0570) exhibited negative direct effects on fruit yield despite vine length showing a significant positive correlation with yield. This apparent contradiction can be explained by the strong positive indirect effects that vine length exerted on yield through number of fruits per vine (0.1695 and 0.1456 via VL45 and VL90, respectively) and average fruit weight (0.0850 and 0.1774, respectively), which more than compensated for its negative direct effect, resulting in an overall positive and significant correlation with yield. Similarly, days to first harvest recorded a small negative correlation with yield (-0.115) despite a comparatively high positive direct effect (0.1446), a discrepancy attributable to its negative indirect effects through days to first flowering (-0.0197), node at which first female flower appears (-0.0157), average fruit weight (-0.0906) and number of fruits per vine (-0.0952). Such situations, where direct and indirect effects act in opposing directions, necessitate restricted simultaneous selection or the use of a selection index rather than reliance on the correlation coefficient alone (Dewey and Lu, 1959)^[4].

Table 2: Path Coefficient Analysis of Fruit Yield per Vine (FYPV) of Sponge Gourd Cross (HR-1 × SG-3)

Traits	VL(45)	VL(90)	NBP(45)	NBP(90)	TLA	DFH	D50%F	NFF	PFS	DFH	DLH	FL	FD	NFPV	AFW	FYPV
VL(45)	-0.0958	-0.0045	0.0019	0.0330	0.0152	0.0326	0.0102	0.0116	0.0532	-0.0432	0.0032	0.0153	-0.0633	0.1695	0.0850	0.224
VL(90)	-0.0292	-0.0148	0.0007	0.0211	0.0180	0.0330	0.0079	0.0167	0.0816	-0.0425	0.0182	0.0277	-0.0417	0.1456	0.1774	0.420
NBP(45)	-0.0497	-0.0029	0.0037	0.0123	0.0068	0.0256	0.0035	0.0075	0.0394	-0.0147	-0.0009	0.0209	-0.0242	0.0750	0.0912	0.193
NBP(90)	-0.0405	-0.0040	0.0006	0.0782	0.0146	0.0303	0.0061	0.0129	0.0759	-0.0281	0.0124	0.0210	-0.0409	0.1153	0.1111	0.365
TLA	-0.0294	-0.0054	0.0005	0.0232	0.0494	0.0308	0.0096	0.0112	0.0574	-0.0159	0.0173	0.0292	-0.0494	0.1226	0.1416	0.392
DFH	0.0227	0.0036	-0.0007	-0.0172	-0.0111	-0.1374	-0.0047	-0.0095	-0.0375	0.0207	-0.0124	-0.0253	0.0300	-0.0880	-0.1240	-0.391
D50%F	0.0322	0.0038	-0.0004	-0.0156	-0.0156	-0.0211	-0.0305	-0.0126	-0.0574	0.0267	-0.0100	0.0233	0.0474	-0.1100	-0.1052	-0.245
NFF	0.0195	0.0043	-0.0005	-0.0177	-0.0097	-0.0230	-0.0067	-0.0570	-0.0497	0.0398	-0.0199	-0.0165	0.0278	-0.0991	-0.1028	-0.311
PFS	-0.0163	-0.0039	0.0005	0.0190	0.0090	0.0164	0.0056	0.0090	0.3131	-0.0227	0.0129	0.0227	-0.0191	0.0634	0.0992	0.509
DFH	0.0286	0.0044	-0.0004	-0.0152	-0.0054	-0.0197	-0.0056	-0.0157	-0.0490	0.1446	-0.0102	-0.0157	0.0298	-0.0952	-0.0906	-0.115
DLH	-0.0034	-0.0030	-0.0000	0.0109	0.0096	0.0192	0.0034	0.0128	0.0453	-0.0167	0.0887	0.0244	-0.0239	0.1050	0.1180	0.390
FL	-0.0140	-0.0039	0.0007	0.0156	0.0137	0.0331	-0.0067	0.0089	0.0676	-0.0216	0.0206	0.1052	-0.0323	0.1094	0.1207	0.417
FD	-0.0357	-0.0036	0.0005	0.0188	0.0144	0.0243	0.0085	0.0093	0.0351	-0.0254	0.0125	0.0200	0.1699	0.0916	0.0996	0.100
NFPV	-0.0426	-0.0057	0.0007	0.0237	0.0159	0.0317	0.0088	0.0148	0.0521	-0.0362	0.0245	0.0302	-0.0409	0.3808	0.1401	0.598
AFW	-0.0225	-0.0073	0.0009	0.0240	0.0193	0.0470	0.0089	0.0162	0.0857	-0.0362	0.0289	0.0350	-0.0468	0.1474	0.3621	0.663

Residual effect = 0.2283

It is noteworthy that number of fruits per vine and average fruit weight, the two traits with the highest direct effects on yield in the present path analysis, were also the traits reported to have the highest heritability (91.94% and 91.49%, respectively) in the companion heritability and genetic-advance study of this same F_2 population. Because heritability computed on a segregating F_2 population can be inflated by non-additive (dominance) variance and only the additive fraction of the variability is expected to respond predictably to phenotypic selection (Johnson *et al.*, 1955) [5] the close correspondence between high heritability and high, consistent direct effect on yield observed here for these two traits provides converging evidence, from two independent analyses of the same population, that they are governed predominantly by additive gene action and hence constitute dependable, repeatable selection criteria for yield improvement in the HR-1 × SG-3 cross.

Conclusion

In the sponge gourd cross HR-1 × SG-3, fruit yield per vine was found to be significantly and positively associated with vine length, number of primary branches, total leaf area, per cent fruit set, days to last harvest, fruit length, number of fruits per vine and average fruit weight, while early flowering behaviour and a lower node of first female flower appearance also favoured higher yield. Path-coefficient analysis revealed that number of fruits per vine, average fruit weight, per cent fruit set, fruit diameter, days to first harvest, fruit length and days to last harvest exerted the greatest direct positive influence on fruit yield. Since these traits showed a close correspondence between their correlation coefficients and direct effects and since number of fruits per vine and average fruit weight in particular also recorded the highest heritability in a parallel analysis of the same population, they may be considered reliable and effective selection criteria for improving fruit yield in the HR-1 × SG-3 cross of sponge gourd.

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