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Research Note

Inter-association and path coefficient analysis for yield and yield attributing traits in ash gourd [*Benincasa hispida* (Thunb) Cogn.]

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Abstract
Twenty nine genotypes of ash gourd (land races and released varieties) were evaluated during summer season (March to July) of 2022 and 2023. The main objective of the study was to evaluate the inter-associations among 15 yield and yield attributing traits, and estimate the direct and indirect effects of these traits on yield. Yield per plot (YPP) was significantly and positively correlated with number of fruits per plot (FPP), average fruit weight (AFW), equatorial diameter of fruit (ED), length of seed (LoS), width of seed (WdoS), weight of 100 seed (WoS), thickness of flesh (ToF) and equatorial diameter of cavity (EDC). The present study also revealed high positive direct effect of equatorial diameter of fruit (ED), fruit shape index (FSI), percent proportion of cavity (PPC), AFW, FPP and LoS on yield per plant. The combined results of path analysis and correlation coefficients indicated that AFW, ED, LoS, Wdos, WoS, Tof , EDC FSI and FPP are important yield attributing traits and more emphasis should be given to these traits, while going for selection of high yielding genotypes.

Keywords: Ash gourd, Genotypic, Phenotypic correlation, Path coefficient analysis

Grown primarily in tropical and subtropical regions of the world, cucurbits, or members of the Cucurbitaceae family, are a vast collection of economically significant vegetables that include cucumbers, melons, gourds, pumpkins, and squashes. Despite sharing a common parent, there is a significant amount of variety across cucurbit species in terms of possible sex forms, vine morphology, inflorescence, and fruit. The diversity of sex forms found in this group of plants includes monoecious, dioecious, gynoecious, andromonoecious, among others. The sole member of the genus, *Benincasa hispida***,** goes by several names, including white pumpkin, wax gourd, ash gourd, winter melon and white gourd (Chopra and Nayar 1956; Chen *et al.,* 2021). The wax gourd's thick skin and wax covering allow it to be preserved for extended periods of time, making it an essential vegetable for managing off-season vegetable sales and guaranteeing its availability all year long (Liu *et al.,* 2018; Yan *et al.,* 2021).

The pulp, leaves, seeds, and flowers of the plant have anti-inflammatory, antibacterial, anticancerous, anti-obesity, neuroprotective, antipyretic, and diuretic qualities, among other medicinal qualities. As a result, ash gourds are highly valued for their potential medical benefits (Islam *et al.,* 2021). Not only does the fruit include essential nutrients like vitamins and flavonoids, but it also contains metabolites that can be used to treat a wide range of illnesses (Grover *et al.*, 2001; Gu *et al.,* 2013 and Han, 2013). A valued vegetable that can be eaten raw or cooked, ash gourd may also have medicinal purposes. Ash gourd is utilised in India to manufacture petha, a regional sweet that is also a global delicacy. It also carries religious importance since it is presented to Devi as a sacrifice during Ayudh Puja in Andhra Pradesh, Telangana, and West Bengal, as well as during Durga Puja in West Bengal, Bihar, Jharkhand, and Uttar Pradesh (Rodrigues, 2018).

The varietal improvement of the current strains of ash gourd that are available in various parts of India has received comparatively little attention, despite the fact that ash gourd is becoming a crop of industrial importance. In order to meet the increasing demand, it is necessary to select an optimum plant variety with the highest number of favourable traits.

The yield is a complex trait which is influenced by both genetic factors as well as environmental conditions. The study of these inter-associations among yield and constitutive traits play an important role in planning effective breeding programmes and selection of need based plant types. Correlation coefficients also provide the in-depth knowledge about the extent and nature of relationship among the characters under study. Correlations among yield and constitutive traits provide knowledge about the extent and nature of relationship among the characters under study (Savaliya *et al.,* 2024). Positive correlations between traits suggest that improvement in one trait could mean corresponding improvements in yield, and negative correlations may indicate trade-offs in which improving one trait comes at the expense of another.

The path coefficient analysis is an important tool to estimate the effect of its yield attributing traits on the final yield. Path coefficient analysis partitions the direct and indirect effects of these traits on yield and, therefore, indicates which of the character has maximum effect on the yield. Apart from helping to prioritize breeding efforts on the identification of to be targeted for improvement, it also offers insights into the complex ways of interaction among various characters. Path coefficient analysis increases understanding of the underlying factors which influence yield, thus offering useful guidance for a planning of the breeding programmes.

Table 1. List of genotypes used in the study

S. No.	Genotype code	Place of collection
1	AG-1	Punjab, India
2	AG -2	Himachal Pradesh, India
3	AG-4	Himachal Pradesh, India
4	AG-5	Himachal Pradesh, India
5	AG-6	Himachal Pradesh, India
6	AG-7	Himachal Pradesh, India
7	AG-8	Himachal Pradesh, India
8	AG-9	Himachal Pradesh, India
9	AG-10	Himachal Pradesh, India
10	AG-11	Himachal Pradesh, India
11	AG-12	Himachal Pradesh, India
12	AG-13	Himachal Pradesh, India
13	AG-14	Himachal Pradesh, India
14	AG-15	Orissa, India
15	AG-16	Meghalaya, India
16	AG-17	Meghalaya, India
17	AG-18	Manipur, India
18	AG-19	Manipur, India
19	AG-20	Manipur, India
20	AG-21	Himachal Pradesh, India
21	AG-22	Rajasthan, India
22	AG-23	Himachal Pradesh, India
23	AG-24	Rajasthan, India
24	AG-25	Rajasthan, India
25	AG-26	Himachal Pradesh, India
26	PAG-3 (Check)	Punjab, India
27	Kashi Surbhi	Uttar Pradesh, India
28	Kashi Ujawal	Uttar Pradesh, India
29	Kashi Dhawal	Uttar Pradesh, India

AG: Ash gourd,

Keeping in view the above, the present investigation was undertaken to understand the inter-associations among the yield and yield attributing traits of ash gourd; and direct/indirect effects of the various characters on yield.

Twenty nine genotypes of ash gourd comprising local landraces collected from Punjab and Himachal Pradesh, and released varieties were used in the investigation (**Table 1**). These 29 genotypes were evaluated in randomized block design during summer season (March–July) with three replications for two consecutive years i.e. 2022 and 2023. The nursery was raised in the month of January in protrays containing cocopeat, perlite and vermiculite in a 3:1:1 ratio. Transplanting was done in the first fortnight of March on 3 meter raised beds. The seedlings were planted 80 cm apart from each other at both the edges of the bed. The crop was raised as per the package of practices of Punjab Agricultural University, Ludhiana. Each genotype had four plants per replication, and data was recorded from all four plants. The data was recorded for number of days to first female flower after transplanting (DFFAT), vine length (VL), number of fruits per plot (FPP), yield per plot (YPP), average fruit weight (AFW)), polar diameter of fruit (PDF), equatorial diameter of fruit (ED), fruit shape index (FSI), length of seed (LoS), width of seed (WdoS), weight of 100 seed (WoS), thickness of flesh (ToF), polar diameter of cavity (PDC), equatorial diameter of cavity (EDC), and percent proportion of cavity (PPC). The correlation coefficients (genotypic and phenotypic) among 15 yield and yield attributing traits were estimated according to Al-jibouri *et al*. (1958) from the corresponding variance and covariance components with Variability package (Popat *et al.,* 2020) of R software. Path coefficient analyses were worked as per Dewey and Lu (1959) to know the direct and indirect effects of component traits on yield using genotypic correlation values.

At phenotypic level, YPP showed significantly positive correlation with FPP (0.619), AFW (0.498), ED (0.564), LoS (0.174), WdoS (0.379), WoS (0.243), ToF (0.450) and EDC (0.411), while significantly negative correlation with DFFAT (-0.307), FSI (-0.377) and PPC (-0.319) (**Table 2**). The results are in line with Nagaraju *et al.* (2016), Manikandan *et al.* (2017), Pradhan *et al.* (2020) and Ananda *et al.* (2023) who also reported strong positive correlations of YPP with FPP, AFW, ED, WdoS, WoS and negative correlation DFFAT. DFFAT exhibited significantly positive correlation with PPC (0.149) and significantly negative correlation with AFW (-0.402), ED (-0.391), LoS (-0.181), WdoS (0.232), WoS (-0.323), ToF (-0.326) and EDC (-0.327). This indicated that increase in the days to appearance of first female flower negatively impacted fruit size as well as most of the seed characters. VL showed significantly positive correlation with FPP (0.215) only, whereas significantly negative correlation was observed with AFW (-0.208), PDF (-0.261), FSI (-0.407), LoS (-0.341), WdoS (-0.341), WoS (-0.351), ToF (-0.168) and PDC (-0.258). Similarly, the FPP had significantly negative correlation with most of the yield attributing traits. This showed that with the increased vine length (VL) increased FPP which lead to reduction in other important yield traits like AFW, PDF, FSI, PDC and traits related to seed. Manikandan *et al*. (2017) also reported

Table 2. Genotypic correlations among yield and yield attributing traits of ash gourd

Trait	DEEAT	VL	FPP	AFW	PDF	ED	FSI	LoS	WdoS	WoS	ToF	PDC	EDC	PPC
VL	0.093^{NS}													
FPP	-0.045^{NS}	0.204**												
AFW	-0.553**	-0.334**	-0.227**											
PDF	-0.080^{NS}	-0.403**	-0.423**	0.425**										
ED	-0.642**	-0.093^{NS}	0.184*	0.694**	-0.127^{NS}									
FSI	0.274**	-0.156*	-0.359**	-0.203**	0.757**	-0.704**								
LoS	-0.219**	-0.539**	-0.327**	0.587**	0.258**	0.557**	-0.268**							
WdoS	-0.298**	-0.487**	-0.076^{NS}	0.674**	0.136^{NS}	0.747**	-0.449**	0.895**						
Wos	-0.439**	-0.472**	-0.190*	0.593**	0.034^{NS}	0.643**	-0.442**	0.858**	0.845**					
ToF	-0.517**	-0.240**	-0.197**	0.900**	0.204**	0.752**	-0.380**	0.523**	0.717**	0.610**				
PDC	0.052^{NS}	-0.342**	-0.395**	0.241**	0.978**	-0.321**	0.864**	0.123^{NS}	-0.040^{NS}	-0.128^{NS}	-0.008^{NS}			
EDC	-0.554**	-0.024^{NS}	0.155*	0.600**	-0.192*	0.958**	-0.732**	0.609**	0.705**	0.662**	0.608**	-0.363**		
PPC	0.462**	0.003^{NS}	-0.314**	-0.323**	0.433**	-0.583**	0.615**	0.033^{NS}	-0.350**	-0.253**	-0.602**	0.564**	-0.386**	
YPP	-0.414**	-0.104^{NS}	0.647**	0.541**	-0.045^{NS}	0.682**	-0.464**	0.178*	0.441**	0.288**	0.546**	-0.178*	0.568**	-0.580**

**Significant at 1 per cent level; *Significant at 5 per cent level; NS – Non significant

DFFAT: Days to first female flower after transplanting, VL: Vine length, FPP: Fruits per plot (FPP), YPP: Yield per plot, AFW: Average fruit weight, PDF: Polar diameter of fruit, ED: Equatorial diameter of fruit, FSI: Fruit shape index, LoS: Length of seed, WdoS: Width of seed, WoS: Weight of 100 seeds, TOF: Thickness of flesh, PDC: Polar diameter of cavity, EDC: Equatorial diameter of cavity, PPC: Percent proportion of cavity

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similar type of correlation in ash gourd. AFW showed significantly positive correlation with PDF (0.410), ED (0.670), LoS (0.553), WdoS (0.632), WoS (0.562), ToF (0.836), PDC (0.219) and EDC (0.517), while negative correlation FSI (-0.213) and PPC (-0.265). This indicated that AFW increased with increase in characters related to seed and fruit size, while decreased with increase in PPC. The results are in line with the results reported by earlier workers (Kumar *et al.,* 2012 and Pradhan *et al.,* 2020). PDF exhibited significantly positive correlation with FSI (0.710), LoS (0.214), ToF (0.200) and PDC (0.923), whereas negative association with EDC (-0.171). Significantly positive association of ED was observed with LoS (0.482), WdoS (0.641), WoS (0.564), ToF (0.662) and EDC (0.836), while associative was negative with FSI (-0.694), PDC (-0.308) and PPC (-0.463); which revealed that the increase in equatorial diameter of the fruit has resulted in increase in seed size, thickness of flesh and equatorial cavity diameter, while there was reduction in polar cavity parameters. FSI showed positive association with PDC (0.827) and PPC (0.409); negative association of FSI was observed with LoS (-0.268), WdoS (-0.449), WoS (-0.442), ToF (-0.380) and EDC (-0.732). LoS had positive correlation with WdoS (0.895), WoS (0.858), ToF (0.523) and EDC (0.609). WdoS showed positive association with WoS (0.845), ToF (0.717) and EDC (0.705); and negative association with PPC (-0.305). Positive correlation of WoS with ToF (0.610) and EDC (0.662) was observed; ToF showed positive association with EDC (0.608) and negative association with PPC (-0.602). PDC exhibited positive correlation with PPC (0.564), while negative correlation with EDC (-0.363). Similar associations among different characters of ash gourd were reported by Latif *et al*. (2008), Resmi and Sreelathakumary (2012), Bhardwaj *et al.* (2013), Nagaraju *et al.* (2016), Manikandan *et al*. (2017), Pradhan *et al.* (2020), Ananda *et al.* (2023) and Praneetha *et al.* (2024). The genotypic correlations were having higher values than phenotypic correlation thereby indicating that there is a strong inherent association among the traits studied (**Table 2 & 3**). The lower phenotypic values can be attributed to the interaction of the genotypes with the environment *i.e.* to the environmental factors (Pradhan *et al.,* 2020 and Ananda *et al.,* 2023).

Yield being a complex trait exhibits low heritability. Moreover, yield is influenced by interaction among different yield attributing traits and also by various environmental factors; therefore the selection for yield is more effective based on those yield attributing traits (Kumar and Kumar, 2021). The path coefficient analysis is biometrical tools which provide us with a realistic view of the interrelationship among characters and partition the correlation coefficients into direct as well as indirect effects of different characters. The present study revealed high positive direct effect of ED (14.491), FSI (4.835), PPC (4.304), AFW (1.826), FPP (1.178) and LoS (1.671) on YPP, whereas high negative direct effect of EDC (-11.528), PDC (-3.508) and PDF (-3.057) on YPP was also observed (**Table 4**). This indicated that the traits like ED, AFW, FSI, PPC and FPP are the characters which are positively and directly influencing the yield per plant

Table 3. Phenotypic correlations among yield and yield attributing traits of ash gourd

	DEEAT	VL	FPP	AFW	PDF	ED	FSI	LoS	WdoS	WoS	ToF	PDC	EDC	PPC
VL	0.044^{NS}													
FPP	-0.069^{NS}	0.215**												
AFW	-0.402**	-0.208**	-0.185*											
PDF	-0.049^{NS}	-0.261**	-0.374**	0.410**										
ED	-0.391**	0.015^{NS}	0.187*	0.670**	-0.085^{NS}									
FSI	0.138^{NS}	-0.132^{NS}	-0.308**	-0.213**	0.710**	-0.694**								
LoS	-0.181*	-0.407**	-0.286**	0.553**	0.214**	0.482**	-0.245**							
WdoS	-0.232**	-0.341**	-0.070^{NS}	0.632**	0.126^{NS}	0.641**	-0.394**	0.830**						
WoS	-0.323**	-0.351**	-0.182*	0.562**	0.032^{NS}	0.564**	-0.406**	0.824**	0.792**					
ToF	-0.326**	-0.168*	-0.185*	0.836**	0.200**	0.662**	-0.355**	0.482**	0.634**	0.560**				
PDC	0.028^{NS}	-0.258**	-0.376**	0.219**	0.923**	-0.308**	0.827**	0.106^{NS}	-0.025^{NS}	-0.121^{NS}	-0.013^{NS}			
EDC	-0.327**	-0.014^{NS}	0.089^{NS}	0.517**	-0.171*	0.836**	-0.656**	0.511**	0.572**	0.566**	0.488**	-0.292**		
PPC	0.149*	-0.116^{NS}	-0.261**	-0.265**	0.134^{NS}	-0.463**	0.409**	0.037^{NS}	-0.193*	-0.128^{NS}	-0.395**	0.407**	0.020^{NS}	
YPP	-0.307**	-0.002^{NS}	0.619**	0.498**	-0.043^{NS}	0.564**	-0.377**	0.174*	0.379**	0.243**	0.450**	-0.141^{NS}	0.411**	-0.319**

**Significant at 1 per cent level; *Significant at 5 per cent level; NS – Non significant
DFFAT: Days to first female flower after transplanting, VL: Vine length, FPP: Fruits per plot (FPP), YPP: Yield per plot, AFW: Average fruit weight, PDF: Polar diameter of fruit, ED: Equatorial diameter of fruit, FSI: Fruit shape index, LoS: Length of seed, WdoS: Width of seed, WoS: Weight of 100 seeds, TOF: Thickness of flesh, PDC: Polar diameter of cavity, EDC: Equatorial diameter of cavity, PPC: Percent proportion of cavity

Table 4. Estimates of direct and indirect effects of component characters on yield of ash gourd using genotypic correlations

Trait	DFFAT	VL	FPP	AFW	PDF	ED	FSI	LoS	WdoS	WoS	ToF	PDC	EDC	PPC
DFFAT	**0.508**	0.010	-0.053	-1.009	0.246	-9.302	1.325	-0.365	0.378	-0.113	-0.225	-0.182	6.381	1.989
VL	0.047	**0.108**	0.240	-0.609	1.233	-1.343	-0.755	-0.901	0.618	-0.122	-0.104	1.199	0.272	0.012
FPP	-0.023	0.022	**1.178**	-0.414	1.294	2.664	-1.737	-0.546	0.096	-0.049	-0.086	1.387	-1.789	-1.350
AFW	-0.281	-0.036	-0.268	**1.826**	-1.299	10.060	-0.981	0.980	-0.856	0.153	0.392	-0.844	-6.915	-1.391
PDF	-0.041	-0.044	-0.498	0.776	**-3.057**	-1.836	3.658	0.431	-0.172	0.008	0.089	-3.431	2.207	1.862
ED	-0.326	-0.010	0.217	1.267	0.387	**14.491**	-3.405	0.931	-0.948	0.166	0.327	1.125	-11.032	-2.509
FSI	0.139	-0.017	-0.423	-0.370	-2.313	-10.207	**4.835**	-0.448	0.569	-0.113	-0.165	-3.032	8.435	2.649
LoS	-0.111	-0.058	-0.385	1.071	-0.789	8.076	-1.296	**1.671**	-1.135	0.221	0.227	-0.433	-7.022	0.142
WdoS	-0.151	-0.053	-0.089	1.231	-0.415	10.821	-2.168	1.495	**-1.269**	0.217	0.312	0.139	-8.124	-1.504
WoS	-0.223	-0.051	-0.223	1.083	-0.103	9.324	-2.135	1.434	-1.072	**0.257**	0.265	0.449	-7.629	-1.089
ToF	-0.262	-0.025	-0.232	1.644	-0.624	10.899	-1.838	0.874	-0.910	0.157	**0.435**	0.029	-7.010	-2.589
PDC	0.0263	-0.037	-0.466	0.439	-2.989	-4.648	4.178	0.206	0.050	-0.033	-0.003	**-3.508**	4.181	2.425
EDC	-0.281	-0.003	0.183	1.096	0.586	13.875	-3.539	1.018	-0.894	0.171	0.265	1.273	**-11.528**	-1.659
PPC	0.234	0.000	-0.369	-0.589	-1.322	-8.448	2.975	0.055	0.444	-0.065	-0.262	-1.977	4.442	**4.304**

Residual are 0.07301

DFFAT: Days to first female flower after transplanting, VL: Vine length, FPP: Fruits per plot (FPP), AFW: Average fruit weight, PDF: Polar diameter of fruit, ED: Equatorial diameter of fruit, FSI: Fruit shape index, LoS: Length of seed, WdoS: Width of seed, WoS: Weight of 100 seeds, TOF: Thickness of flesh, PDC: Polar diameter of cavity, EDC: Equatorial diameter of cavity, PPC: Percent proportion of cavity

and improvement in these traits can further enhance the yield, whereas fruits with higher value of fruit cavity characters and polar diameter should not be selected they had negative direct effects on yield per plant. The effect of residual factors was 0.073 which is negligible suggesting that no major yield attributing character was left over. Ananda *et al.* (2023) reported that more emphasis should be given to selecting genotypes having maximum average fruit weight and number of fruits per plant and vine length. The AFW, LoS, Wdos, WoS, ToF and EDC exerted high positive indirect effects, while DFFAT, PDC and PPC had negative indirect effect through ED on YPP. DFFAT, FSI, PDC, PPC exerted a high positive effect, however AFW, ED, LoS, WdoS, Wos, ToF exerted high negative in direct effect through EDC on YPP.

The combined results of path analysis and correlation coefficients in the present study indicated that that more emphasis should be given to AFW, ED, LoS, Wdos, WoS, Tof , EDC FSI, PPC and FPP, while going for selection of high yielding genotypes in the ash gourd breeding programmes. Earlier workers like Resmi and Sreelathakumary (2012), Bhardwaj *et al.* (2013), Nagaraju *et al.* (2016), Manikandan *et al.* (2017), Pradhan *et al.* (2020) and Ananda *et al.* (2023) also reported similar type of results in their studies.

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