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Correlation and path coefficient analysis for morphological and biochemical parameters in sunflower (*Helianthus annuus* L) advanced interspecific derivatives

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Abstract
The aim of this study was to evaluate the advanced interspecific derivatives derived from five annual diploid *Helianthus* species based on phenotypic and genotypic correlation so that we can find out the which trait directly or indirectly effect the yield and quality of the sunflower because being a breeder our main aim is yield and quality and the lines which are performing best can be further used in the breeding programs. The study was conducted at the Rajendranagar research farm of ICAR-Indian Institute of Oilseeds Research, Hyderabad, India during *kharif*-2023 and *rabi*-2023-24, respectively, to study the correlation among yield related characters, oil and protein content and fatty acids in sunflower. A total of 50 interspecific derivatives along with 3 checks were sown in augmented block design with five blocks. Association analysis between seed yield per plant and other seventeen characters revealed that seed yield per plant showed highly significant and positive correlation with 100 seed weight, head diameter, oil content, number of leaves per plant, plant height, leaf length and seed length at both genotypic and phenotypic levels, encouraging rapid improvement of seed yield. Path coefficient analysis helped us understand the direct and indirect impacts of these traits on seed yield per plant. Path analysis indicated that 100 seed weight had highest positive direct effect on seed yield per plant followed by head diameter, number of leaves, plant height, leaf length and seed length. The character oil content exhibited high significant negative direct effects, while days to 50% flowering, days to maturity and oleic content showed negative but low direct effects. Therefore, simultaneous selection for these traits is suggested for improvement of seed yield in sunflower.

Keywords: Character association, path analysis, sunflower

Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important non-traditional oilseed crops in India mainly used for oil extraction. The crop has been well accepted by farming community because of its desirable attributes such as photo and thermo insensitivity, short duration, low seed rate, high seed multiplication ratio, high yield, drought tolerance, high quality edible oil and high degree of poly unsaturated fatty acid content (Sharnkumar and Basavegowda, 2014) [15]. Around 90% of sunflower production is used to extract sunflower oil, whereas the remaining 10% are used for non-oil purposes such as confectionery or table purpose. Although there is huge production potential for the crop in India the acreage has drastically reduced since 2005 due to several contributing factors, including the narrow genetic base of Indian sunflower hybrid parental lines, frequent use of few selected breeding materials as parents in varietal/hybrid development programmes, genetic vulnerability and susceptibility to various biotic and abiotic stresses (Meena *et al.*, 2023) [8]. Various sunflower hybrids from public and private sectors have been developed and released for commercial cultivation in different sunflower growing states of the country. The yielding ability of sunflower hybrids may be influenced by the several factors including seed vigour as well as seed quality. In most of the breeding program, yield is the ultimate objective which has highly variable expression. Seed yield is a complex trait to carry out direct selection among breeding materials due to contribution of various traits towards seed yield and their interaction with environment. Evaluation of trait relationships between the yield component traits as well as other traits of interest like seed yield, seed length, oil content, hull content and other agronomic traits assists in indirect selection (Nadkarni *et al.*, 2017) [9] for yield. Thus, a knowledge of association of various characters with yield and among themselves would provide criteria for indirect selection through components for improvement in yield. Therefore, genotypic and phenotypic associations among important quantitative characters were analysed. The path coefficient analysis of cause-and-effect relationship provides the knowledge of relative importance of each of component characters. The path coefficient analysis was also undertaken to understand the direct and indirect effect of various traits on seed yield. Further nature of relationship with seed quality parameters an yield is meagre. Hence, this study was initiated.

Materials and Methods

The experimental material for present investigation consisted of 50 advanced interspecific derivatives developed at ICAR-Indian Institute of Oilseeds Research, Hyderabad using diploid cross compatible five annual *Helianthus* species and three checks (ARM-243B, DRSF-108 and DRSF-113) which were maintained at ICAR-IIOR, Hyderabad. The details of the breeding materials used in this study are presented in Table 1. The materials were grown in a augmented block design with five blocks consecutively two seasons (*kharif*-2023 and *rabi*-2023-24), at Research Farm of ICAR-Indian Institute of Oilseeds Research, Rajendranagar, Hyderabad, India at the latitude of

170 22'31"N and a longitude of 780 28'27"E. All of the test materials as well as checks were divided into 5 blocks keeping two replications in each block. Each pre-bred line was grown in two rows of 4.0 m with 60 x 30 cm spacing between rows and plants, respectively. Thirteen plants were maintained each row. Recommended crop production and protection measures were followed to raise the healthy crop. Observations were recorded from five randomly selected plants in each interspecific derivatives for eight quantitative characters, namely, days to 50% flowering, leaf length (cm), days to physiological maturity, number of leaves per plant, plant height (cm), stem girth (mm), head diameter (cm), 100 seed weight (g), volume weight (g/100 ml), seed length (mm), seed width (mm), oil content (%), oleic acid (%), linoleic acid (%), palmitic acid (%), stearic acid (%), protein content (%) and seed yield per plant (g). In order to determine the association between two or more quantitative characters, the phenotypic and genotypic association coefficients were worked out as per the formulae given by Al-Jibouri *et al.*, (1958) [1]. The path coefficient analysis were calculated from the genotypic correlation coefficient by solving simultaneous equations as suggested by Wright (1921) [19] and illustrated by Dewey *et al.*, (1959) [4].

Table 1: Details of sunflower interspecific derivatives derived using diploid annual *Helianthus* species

S. No.	Derived using	Generation	Stable interspecific derivatives	Checks
1	*H.annuus* (wild)	BC_2F_6	PB-1628, PB-1629, PB-1630, PB-1635, PB-1636, PB-1638, PB-1639, PB-1640, PB-1641, PB-1665	ARM-243B, DRSF-108, DRSF-113
2	*H. argophyllus*	BC_2F_6	PB-1307, PB-1308, PB-1310, PB-1311, PB-1312, PB-1314, PB-1316, PB-1320, PB-1321, PB-1324,	
3	*H. petiolaris*	BC_2F_6	PB-1462, PB-1463, PB-1464, PB-1467, PB-1468, PB-1469, PB-1470, PB-1471, PB-1475, PB-1480	
4	*H. praecox*	BC_2F_6	PB-1530, PB-1537, PB-1539, PB-1548, PB-1560, PB-1561, PB-1566, PB-1591, PB-1593, PB-1595	
5	*H. debilis*	BC_2F_6	PB-1224, PB-1225, PB-1226, PB-1231, PB-1233, PB-1240, PB-1244, PB-1245, PB-1246, PB-1248	

Results and discussion

Yield is a complex character that is a function of several component traits and largely influenced by the environment. Hence, it is important to understand the relationships between various characteristics and seed yield to enhance the usefulness of selection criteria to be followed while developing new cultivars (Meena *et al.,* 2023) [8]. The correlation studies of eighteen morphological including biochemical traits were worked out at genotypic and phenotypic levels in order to know the absolute association among the characters. In the present investigation genotypic correlation coefficients were in general, slightly higher than their corresponding phenotypic correlation coefficients (Table 2; Figure 1) for most of the characteristics, indicated that there was a higher degree of association between two traits at genotypic level or negligible role of environment on the genotypic expression. Their phenotypic association was lessened due to the influence of environment. However, in few cases, the phenotypic correlations were slightly higher than their genotypic counterparts, which implied that the non-genetic cause inflated the value of genotypic correlation because of the influence of the environmental factors. In the present investigation, seed yield per plant exhibited highly significant and positive association with 100 seed weight (0.33***, 0.65***), head diameter (0.33***, 0.63***), oil content (0.33***, 0.56***), number of leaves per plant (0.30**, 0.34**), seed length (0.24**, 0.34***), plant height (0.21**, 0.39***) and leaf length (0.18*, 0.23**) both at genotypic and phenotypic levels indicating that these attributes were mainly influencing the seed yield in sunflower and strong association of these traits with seed yield per plant could be fruitfully exploited for enhancing the yield potential in sunflower. Thus, selection practiced for the improvement in one character will automatically result in the improvement in the other character even though direct selection for improvement has not been made for the yield character. Genetic correlation between different characters of the plant could be due to linkage, pleiotropy or developmentally induced functional relationships. Similar results exhibiting highly significant and positive correlation between seed yield and other traits as obtained in the present investigation were reported by Deengra *et al.,* (2013) [3], Venkanna *et al.,* (2014) [18] and Mariyam *et al.,* (2024) [10]. Recently, Riaz *et al.,* (2020) [14] reported that plant height and 100 seed weight exhibited a significant positive correlation with achene yield, while Radić *et al.,* (2013) [13] found a positive and significant association between seed yield and 100 seed weight. Sincik and Goksoy (2014) [16] reported a significant positive correlation between seed yield and plant height, head diameter and 100 seed weight. Yasin and Singh (2010) [21] reported a significant positive correlation between seed yield and head diameter. Seed yield per plant also showed a positive association with stem girth (0.13, 0.27*), volume weight (0.09, 0.32***), seed width (0.16, 0.27**), linoleic (0.05, 0.18*), stearic (0.01, 0.01) and protein content (0.16, 0.20*) both at genotypic and phenotypic levels. All these correlations were found to be non-significant. It was suggested that contribution of these characters towards high seed yield is negligible. This disagreement among results is presumably associated with differences in the genetic material and environmental conditions where these studies were conducted.

Days to 50% flowering had significant and positive correlation with days to maturity, leaf length and plant height at both the genotypic and phenotypic levels, indicating that late flowering will result in broad leaf length, late maturity, and high seed yield. Oil content had significant and negative association with days to 50% flowering and days to maturity. The possible reason for deviation may be due to very low direct and indirect effects. It is an established fact that, the association between two characters is not a simple relationship, but is rather the product of the interaction of direct and indirect causes. Therefore, to obtain a realistic picture of the components which would effectively contribute the seed yield, the path coefficient analysis was performed. The genotypic correlations were partitioned into direct and indirect effects. The characters which emerged as the major component of seed yield per plant in path coefficient analysis (Table 3) was the 100 seed weight followed by head diameter, number of leaves per plant, plant height, leaf length and seed length which had the positive direct effect of very high magnitude on seed yield per plant. Besides this, stem girth, volume weight, seed width, linoleic, stearic and protein content also contributed directly to seed yield per plant in positive direction. It indicated that the direct selection for these characters will be rewarding to obtain the high yielding genotypes as revealed by their close association with seed yield per plant. These results are in consonance with the earlier reports of Arshad *et al.,* (2007) [2] and Kholghi *et al.,* (2011) [6].

Path coefficient analysis was performed for seed yield per plant taking it as a dependent variable and remaining seventeen characters are independent variables. Both phenotypic and genotypic paths were worked out, since the phenotypic path will have a greater influence of environmental factors, the genotypic path was considered with a greater weightage (Table 3). Traits like 100 seed weight, head diameter, number of leaves, plant height, leaf length and seed length had direct positive effect on seed yield per plant. Similar results were obtained by Kaur and Kaila (2023) [5], Zia *et al.,* (2013) [20] and Maria *et al.,* (2018) [7] reported similar results for 100 seed weight which had greatest positive direct effect on seed yield. The direct effect of rest of the characters *viz.,* days to 50% flowering, days to maturity and oleic content are negative but non-significant in magnitude indicated that direct improvement of seed yield per plant through these traits are not possible during yield improvement programme (Figure 2). The oil content had negative direct effect, this is in contrasts with the correlation result in which oil content was noticed to be significantly and positively associated with seed yield per plant. Similar finding also reported by Tilak *et al.,* (2016) [17] and Pandya *et al.,* (2015) [12]. However, the present findings do not support the conclusion of Naik and Ghodke (2021) [11], who reported positive direct effect of days to 50% flowering with seed yield. In general, character association and path coefficient analysis carried out in this study suggest that 100 seed weight, followed by number of seeds per head and volume weight influence the seed yield more than any of the characters taken for study. Hence, more emphasis would be given to these characters during selection to improve the seed yield. Also, the narrow differences between a genotypic and phenotypic values indicates that the environment does not play a major role in the relationship between traits. Hence, selection based on phenotypic performance of different traits will be fairly effective.

Table 2: Phenotypic (r_p) and genotypic (r_g) correlations for morphological and biochemical parameters in 50 advanced sunflower interspecific derivatives

Traits	R	DFF	DM	LL	NOL	PH	SG	HD	SW	VW	SL	SW	OC	OL	LN	PL	ST	PT
DFF	r_p	1.00																
	r_g	1.00																
DM	r_p	0.98***	1.00															
	r_g	1.00**	1.00															
LL	r_p	0.31***	0.32***	1.00														
	r_g	0.36***	0.37***	1.00														
NOL	r_p	-0.09	-0.08	0.06	1.00													
	r_g	-0.09	-0.10	0.04	1.00													
PH	r_p	0.25**	0.26**	0.25**	0.19*	1.00												
	r_g	0.46***	0.51***	0.46***	0.16	1.00												
SG	r_p	0.09	0.11	0.37***	0.25**	0.55***	1.00											
	r_g	0.19*	0.21*	0.57***	0.30**	0.93***	1.00											
HD	r_p	0.14	0.15	0.32***	0.20*	0.47***	0.53***	1.00										
	r_g	0.22**	0.23**	0.59***	0.27**	1.00***	0.70***	1.00										
SW	r_p	-0.09	-0.07	0.26**	0.31***	0.07	0.21*	0.26**	1.00									
	r_g	0.09	-0.08	0.29**	0.56***	0.46***	0.43***	0.82***	1.00									
VW	r_p	-0.14	-0.13	-0.13	0.27**	-0.13	-0.18*	-0.03	0.26**	1.00								
	r_g	-0.32**	-0.28**	-0.24**	0.37***	-0.81***	-0.50***	-0.44***	0.39***	1.00								
SL	r_p	-0.08	-0.10	0.14	0.33***	0.04	0.27**	0.14	0.34***	0.023	1.00							
	r_g	-0.06	-0.09	0.15	0.39***	0.20*	0.47***	0.49***	0.49***	0.02	1.00							
SW	r_p	-0.07	-0.07	0.08	0.03	-0.10	-0.10	-0.01	0.25**	0.07	-0.02	1.00						

	r_g	-0.12	-0.15	0.04	0.06	-0.09	-0.11	-0.10	0.22*	-0.06	0.02	1.00						
OC	r_p	-0.19*	-0.15	0.02*	0.40***	0.004	0.13	0.23*	0.44***	0.31***	0.18*	0.16	1.00					
	r_g	-0.31**	-0.27**	0.01	0.56***	0.28***	0.29**	0.40***	0.65***	0.36***	0.27**	0.31**	1.00					
OL	r_p	-0.18*	-0.14	0.09	0.07	0.01	0.13	0.05	0.22*	0.02	0.08	0.05	0.06	1.00				
	r_g	0.61***	0.72***	-0.36***	-0.79**	-1.72***	-1.19***	-0.61***	0.24*	-0.55***	-0.11	0.43***	-1.14***	1.00				
LN	r_p	0.13	0.09	-0.05	-0.03	-0.05	-0.12	-0.03	-0.07	0.02	-0.05	0.07	-0.02	-0.87***	1.00			
	r_g	0.38***	0.44***	-0.14	-0.29**	-1.39***	-0.91***	-0.79***	0.33**	-0.49***	0.003	0.50***	-0.49***	0.32**	1.00			
PL	r_p	0.12	0.12	-0.02	0.01	-0.08	-0.08	0.06	-0.26**	0.12	-0.15	-0.08	0.02	-0.16	-0.06	1.00		
	r_g	0.54***	0.33**	-0.13	-0.26**	-1.56***	-2.07***	-1.98***	-0.21*	1.52***	-0.12	-1.00***	-0.05	-4.07***	-4.20***	1.00		
ST	r_p	-0.02	-0.01	-0.09	0.10	0.01	0.10	0.01	-0.08	-0.08	0.13	-0.02	0.03	0.05	-0.08	0.11	1.00	
	r_g	0.08	0.17	0.18*	1.38***	0.72***	2.39***	-0.26**	0.58***	0.27**	1.83***	-0.30**	0.45***	4.38***	1.98***	-5.92***	1.00	
PT	r_p	-0.10	-0.10	0.06	0.25**	-0.11	0.01	0.09	0.37***	0.19*	0.13	-0.04	0.23**	-0.01	0.02	0.05	0.04	1.00
	r_g	-0.11	-0.12	0.06	0.35***	-0.04	0.15	0.25**	0.50***	0.29**	0.19*	-0.10	0.35**	0.77***	0.47***	0.24**	0.77***	1.00
SYP	r_p	-0.07	-0.08	0.18*	0.30**	0.21**	0.13	0.33***	0.37***	0.09	0.24**	0.16	0.33***	-0.01	0.05	0.004	0.01	0.16
	r_g	-0.12	-0.15	0.23**	0.34***	0.39***	0.27**	0.63***	0.65***	0.32***	0.34***	0.27**	0.56***	-0.13	0.18*	-1.07***	0.01	0.20*

DF=Days to 50% flowering, DM=Days to maturity, LL=Leaf length (cm), NOL=Number of leaves per plant, PH=Plant height (cm), SG=Stem girth (mm), HD=Head diameter (cm), SW=100 seed weight (g), VW=Volume weight (g/100 ml), SL=Seed length (cm), SW=Seed width (cm), OC=Oil content (%), OL=Oleic acid (%), LN=Linoleic acid (%), PL=Palmitic acid (%), ST=Stearic acid (%), PT=Protein content (%), SYP=Seed yield per plant (g)

Table 3: Genotypic (G) and phenotypic (P) path coefficients among yield attributes in 50 sunflower interspecific derivatives

Traits	PC	DFF	DM	LL	NOL	PH	SG	HD	SW	VW	SL	SW	OC	OL	LN	PL	ST	PT	SYP
DFF	P	0.14	0.14	0.04	-0.01	0.03	0.01	0.02	-0.01	-0.02	-0.01	-0.01	-0.03	-0.03	0.02	0.02	-0.003	-0.01	-0.073
	G	-1.80	-1.80	-0.64	0.16	-0.83	-0.35	-0.39	0.16	0.57	0.11	0.22	0.56	-1.09	-0.69	-0.97	-0.15	0.20	-0.12
DM	P	-0.27	-0.27	-0.09	0.02	-0.07	-0.03	-0.04	0.02	0.04	0.03	0.02	0.04	0.04	-0.03	-0.03	0.004	0.03	-0.08
	G	1.50	1.49	0.55	-0.15	0.76	0.32	0.34	-0.13	-0.41	-0.13	-0.22	-0.40	1.08	0.66	0.50	0.25	-0.18	-0.15
LL	P	0.03	0.03	0.10	0.01	0.03	0.04	0.03	0.03	-0.01	0.01	0.01	0.002	0.01	-0.01	-0.002	-0.01	0.01	0.18*
	G	0.10	0.10	0.28	0.01	0.13	0.16	0.16	0.08	-0.07	0.04	0.01	0.003	-0.10	-0.04	-0.04	0.05	0.02	0.23*
NOL	P	-0.01	-0.01	0.01	0.11	0.02	0.03	0.02	0.03	0.03	0.04	0.003	0.04	0.01	-0.004	0.001	0.01	0.03	0.29**
	G	-0.02	-0.02	0.01	0.20	0.03	0.06	0.05	0.11	0.07	0.08	0.01	0.11	-0.16	-0.06	-0.05	0.27	0.07	0.34**
PH	P	0.05	0.06	0.05	0.04	0.22	0.12	0.10	0.02	-0.03	0.01	-0.02	0.001	0.003	-0.01	-0.02	0.002	-0.02	0.21**
	G	0.002	0.002	0.002	0.001	0.004	0.004	0.004	0.002	-0.004	0.001	-0.0004	0.001	-0.01	-0.01	-0.01	0.003	-0.0002	0.39**
SG	P	-0.02	-0.03	-0.09	-0.06	-0.13	-0.23	-0.12	-0.05	0.04	-0.06	0.02	-0.03	-0.03	0.03	0.02	-0.02	-0.001	0.13
	G	-0.06	-0.07	-0.18	-0.10	-0.30	-0.32	-0.23	-0.14	0.16	-0.15	0.03	-0.09	0.39	0.29	0.67	-0.77	-0.05	0.27**
HD	P	0.03	0.03	0.07	0.04	0.10	0.12	0.22	0.06	-0.01	0.03	-0.001	0.05	0.01	-0.01	0.01	0.003	0.02	0.33**
	G	-0.08	-0.08	-0.21	-0.10	-0.36	-0.25	-0.36	-0.29	0.16	-0.18	0.03	-0.14	0.22	0.28	0.71	0.09	-0.09	0.63**
SW	P	0. 02	-0.01	0.05	0.06	0.01	0.04	0.05	0.20	0.05	0.07	0. 05	0.09	0.04	-0.02	-0.05	-0.02	0.07	0.37**
	G	0. 10	-0.10	0.34	0.64	0.53	0.50	0.94	1.15	0.45	0.56	0. 25	0.74	0.27	0.38	-0.24	0.67	0.58	0.65**
VW	P	0.01	0.01	0.01	-0.02	0.01	0.01	0.002	-0.02	-0.07	-0.002	-0.005	-0.02	-0.001	-0.001	-0.01	0.01	-0.01	0.09
	G	0.25	0.22	0.19	-0.29	0.63	0.39	0.34	-0.30	-0.78	-0.02	0.05	-0.28	0.43	0.38	-1.19	-0.21	-0.23	0.32**
SL	P	-0.01	-0.01	0.02	0.04	0.004	0.03	0.02	0.04	0.003	0.11	-0.002	0.02	0.01	-0.01	-0.02	0.02	0.02	0.24**
	G	0.003	0.004	-0.01	-0.02	-0.01	-0.02	-0.02	-0.02	0.001	-0.05	-0.001	-0.01	0.01	-0.0002	0.01	-0.09	-0.01	0.34**
SW	P	-0.01	-0.01	0.01	0.002	-0.01	-0.01	-0.001	0.02	0.01	-0.001	0.08	0.01	0.004	0.01	-0.01	-0.001	-0.003	0.16
	G	0.03	0.03	-0.01	-0.01	0.02	0.02	0.02	-0.05	0.01	-0.004	-0.23	-0.07	-0.10	-0.11	0.23	0.07	0.02	0.27**
OC	P	-0.03	-0.02	0.003	0.06	0.001	0.02	0.03	0.07	0.05	0.03	0.03	0.15	0.01	-0.003	0.003	0.005	0.03	-0.33**
	G	-0.15	-0.13	0.01	0.26	0.13	0.14	0.19	0.31	0.17	0.13	0.15	0.47	-0.54	-0.23	-0.02	0.21	0.17	-0.56**
OL	P	0.004	0.003	-0.002	-0.002	-	-0.003	-0.001	-0.01	-	-0.002	-0.001	-0.001	-0.02	0.02	0.004	-0.001	0.0001	-0.01

						0.0003				0.0004									
	G	0.11	0.13	-0.07	-0.15	-0.32	-0.22	-0.11	0.04	-0.10	-0.02	0.08	-0.21	0.19	0.06	-0.76	0.81	0.14	-0.13
LN	P	0.01	0.01	-0.003	-0.002	-0.003	-0.01	-0.002	-0.005	0.001	-0.003	0.004	-0.001	-0.05	0.06	-0.003	-0.01	0.001	0.05
	G	-0.03	-0.03	0.01	0.02	0.11	0.07	0.06	-0.03	0.04	-0.0002	-0.04	0.04	-0.02	-0.08	0.33	-0.15	-0.04	0.19*
PL	P	0.01	0.01	-0.002	0.001	-0.01	-0.01	0.005	-0.02	0.01	-0.01	-0.01	0.002	-0.01	-0.004	0.08	0.01	0.004	0.004
	G	0.07	0.04	-0.02	-0.03	-0.19	-0.25	-0.24	-0.03	0.19	-0.01	-0.12	-0.01	-0.50	-0.51	0.12	-0.73	0.03	-1.07**
ST	P	-0.0004	-0.0002	-0.001	0.002	0.0002	0.002	0.0002	-0.001	-0.001	0.002	-0.0003	0.001	0.001	-0.001	0.002	0.02	0.001	0.01
	G	0.003	0.01	0.01	0.05	0.03	0.10	-0.01	0.02	0.01	0.07	-0.01	0.02	0.17	0.08	-0.24	0.04	0.03	0.01
PT	P	-0.0002	-0.0002	0.0001	0.0004	-0.0002	0.0000	0.0001	0.001	0.0003	0.0002	-0.0001	0.0004	0.0000	0.0000	0.0001	0.0001	0.002	0.16
	G	0.05	0.06	-0.03	-0.17	0.02	-0.07	-0.12	-0.24	-0.14	-0.09	0.05	-0.17	-0.36	-0.22	-0.11	-0.36	-0.47	0.20*
Partial R^2	P	-0.01	0.02	0.02	0.03	0.04	-0.03	0.07	0.07	-0.01	0.03	0.01	0.05	0.0002	0.003	0.0003	0.0002	0.0003	
	G	0.22	-0.22	0.06	0.07	0.002	-0.09	-0.23	0.75	-0.25	-0.02	-0.06	0.26	-0.02	-0.01	-0.13	0.0003	-0.09	

DF=Days to 50% flowering, DM=Days to maturity, LL=Leaf length (cm), NOL=Number of leaves per plant, PH=Plant height (cm), SG=Stem girth (mm), HD=Head diameter (cm), SW=100 seed weight (g), VW=Volume weight (g/100 ml), SL=Seed length (cm), SW=Seed width (cm), OC=Oil content (%), OL=Oleic acid (%), LN=Linoleic acid (%), PL=Palmitic acid (%), ST=Stearic acid (%), PT=Protein content (%), SYP=Seed yield per plant (g)

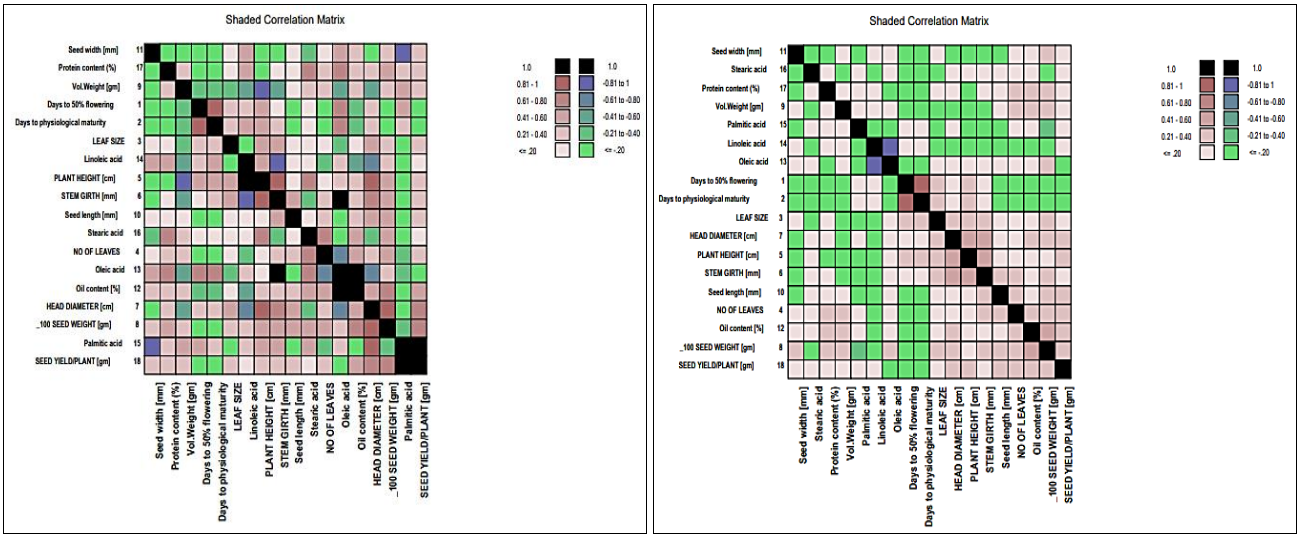

Fig 1: Genotypic and phenotypic correlation between yield and its components

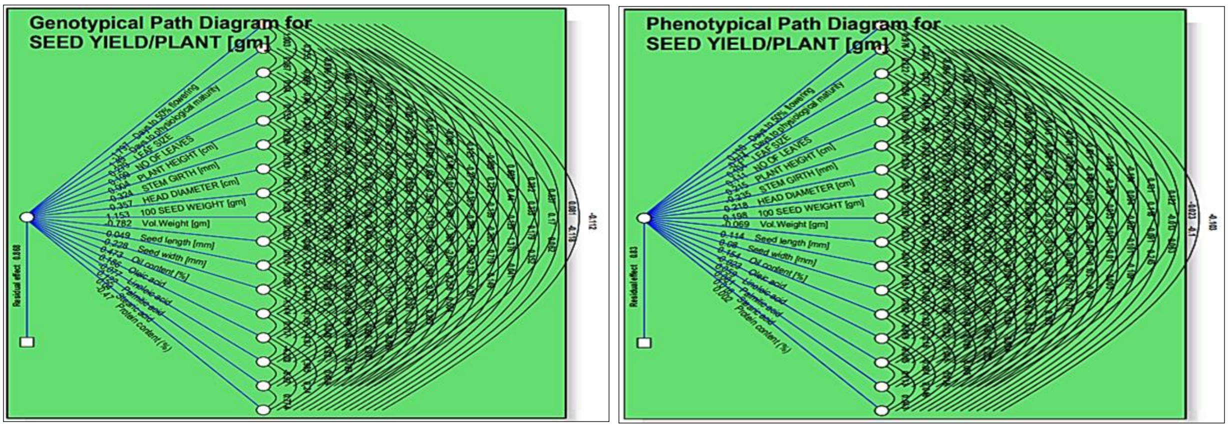

Fig 2: Genotypic and phenotypic path diagram showing direct and indirect effects of yield components on seed yield at phenotypic level

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