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TRAIT ASSOCIATION WITH RESPECT TO FLORAL MORPHOLOGY AND AGRO-MORPHOLOGY IN SELECTED CULTIVARS AND WILD GENOTYPES OF BRASSICACEAE

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ABSTRACT

Basic information on any crop like, available variability, divergence and character association help in efficient selection of desirable genotypes leading to crop improvement. The present experiment was undertaken to study character association in a set of 15 diverse genotypes of brassicaceae which included cultivars as well as wild allies. The genotypes belonged to two genera *Brassica* spp. and *Diplotaxis* spp., which are considered major oilseeds and vegetables. The present study revealed higher magnitude of genotypic correlations than phenotypic correlations in most of the cases indicating strong and inherent association between character pairs and a little environmental influence only. It may be inferred that larger plant parts lead to delayed flowering, maturity and less seed yield but better leaf yield. It was also found that lesser seeds per siliqua had offered better 1000 seed weight and higher oil content. Hence, if cultivating *Brassica* spp. and *Diplotaxis* spp. as oilseeds, smaller leaves and early flowering are to be selected at early crop stages for better economic return, on the other hand, if cultivated as leafy vehetables, taller plants with larger leaves and short main shoot are ideal traits for selection for these species during *Rabi*, in middle Gujarat condition.

Key words : Wild relatives, *Brassica*, *Diplotaxis*, Correlation.

Introduction

Mustard is one of the oldest recorded domesticated spices. It belongs to the family Brassicaceae (erstwhile Cruciferae). In the trade, it is commonly referred as rape seed-mustard, which includes a number of cultivated species, *viz*., *Brassica juncea* (2n=36), *Brassica rapa* (2n = 20), *Brassica napus* (2n=38), *Brassica carinata* (2n=34) and *Brassica nigra* (2n=16). Rapeseed-mustard is cultivated widely in tropical and sub-tropical countries, as well as in temperate ones.

Brassicaceae also include *Diplotaxis* species. Both the genera *Brassica* and *Diplotaxis* have their centre of origin in Mediterranean basin; *Brassica* spp. is cultivated across tropics, sub-tropics and temperate region of the world, whereas *Diplotaxis* spp. is majorly confined in Central Europe and Mediterranean region.

Both the species offer multiple advantages. Leaves of all available mustard cultivars are rich in nutrients like Calcium, Copper and vitamins, *viz*., C, A and K, while seeds are particularly rich in Selenium, Magnesium and Manganese (https://www.usda.gov/) and are a good source of fiber. Mustard seed is crushed majorly for edible oil and is a rich source of energy. The oil has ayurvedic applications for digestion and in neutralizing muscle pain, whereas *Diplotaxis* spp. are majorly consumed as leafy vegetables and also are utilized to extract oil rich in erucic acid, which has industrial application like paints, lubricants, textile and pharmaceuticals and also in ayurveda. Oil cake of both the species are popular animal feed. High amount of sulphur containing glucosinolates (180 to 200 µ moles) in mustard oil is responsible for the characteristic aroma and pungency. It is also suspected that the volatile isothiocyanates from residue of *Brassica* crops result in inhibitory effects on some subsequent crops due to allelopathy. In *Diplotaxis* spp., two components *viz*., 4 (Methylsulfinyl) butyl and 4-(Methylthio) butyl3 play a role in plant protection (Prieto *et al*., 2019), as well. In damaged tissue these components are converted into isothiocynates and nitriles, to repel pest and microbes. Moreover cytoplasmic male sterility genes found in *Diplotaxis* spp. mark their importance in plant breeding.

India is a major producer of mustard in the world, where Rajasthan, a state in Western India contributes most to the total mustard production of the country (http://agricoop.nic.in/). In Gujarat, it is mostly grown in the Northern and middle part of the state.

Cultivar development in any crop aims at satisfying requirements of producers, millers and consumers. Yield improvement along with modification in fatty acid composition, fiber content, elimination of glucosinolates and resistance to biotic and abiotic stressesin mustard oil drew attention of mustard breeders across the world.In *Diplotaxis* spp. focus is mainly on improving antioxidant activity and reducing glucosinolate content, along with enhancing female fertility, anther morphology, nectary development, and also increasing health-promoting components like glucoerucin and glucoraphanin for cancer, cardiovascular disease, and other chronic conditions (D'Antuono *et al*., 2009; Pignone *et al*., 2010; Malorni *et al*., 2023).

Prior to any crop improvement programme, it is essential to obtain information regarding inter-relationship of different characters, since it facilitates precise selection of desirable genotypes and also plays significant role in intergeneric or interspecific transfer of traits. Association between characters can be directly observed through phenotypic correlation, whereas true association could be known through genotypic correlation, which eliminates environmental influence. Genotypic correlation helps in predicting correlated response and evaluation of relative influence of one character on the other.

Keeping the above facts in focus, present investigation aims to elucidate the genotypic and phenotypic correlation among agro economic traits and some others related to floral morphology in some selected species of Brassicaceae.

Materials and Methods

A collection of 15 different genotypes from brassicaceae (Table 1), which included cultivars as well as wild relatives were considered for the present investigation and were planted with a spacing of 45 × 10cm in randomized complete block design with three replications at the Experimental Farm, Department of Genetics and Plant Breeding, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat (22^{o} 35' N, 72^{o} 55' E, 45.01 meters above mean sea level) during *Rabi*, 2020-21. All the recommended package of practices was followed for raising the crop.

A total of 17 different quantitative characters and one biochemical character *i.e.* oil content (%) were

Table 1 : List of genotypes used in the present study.

S. no.	Species/Genotypes	Source
1.	*Brassica fruticulosa* (Spain)	Indian Agricultural Research Institute (IARI), New Delhi, India
2.	*Brassica fruticulosa* (Japan)	
3.	*Brassica fruticulosa* (India)	
4.	*Brassica tournifortii*	
5.	*Diplotaxis assurgens*	
6.	*Diplotaxis cretacia*	
7.	*Diplotaxis viminea*	
8.	Sangam (*Brassica nigra*)	Sardar Krushinagar Dantiwada Agricultural University, Sardar Krushinagar, Gujarat, India
9.	Pusa swarnim (*Brassica carinata*)	
10.	Kiran (*Brassica carinata*)	
11.	NPC 9 (*Brassica carinata*)	
12.	GM1 (*Brassica juncea*)	
13.	GM2 (*Brassica juncea*)	
14.	GM3 (*Brassica juncea*)	
15.	GDM4 (*Brassica juncea*)	

recorded as listed and described in DUS guidelines (https://www.plantauthority.gov.in/). Floral characters other than those mentioned in DUS guidelines are included in the present study arelength of sepal and pollen diameter (polar axes-P, equatorial axes-E and P/ E ratio). Genotypic correlation coefficients and phenotypic correlation coefficients were estimated as suggested by Hazel *et al.* (1943).

Results and Discussion

It is evident from analysis of variance (Table 2), that the genotypes under study performed variably for all the 18 quantitative characters observed.

Estimates of genotypic correlation coefficients (r_g)for most of the traits were found higher than the estimates of phenotypic correlation coefficients (r_p) except for a few traits (Tables 3 and 4), where r_p estimates were higher than r_g *i.e.*; between number of leaf lobes and pollen polar axes, days to 50% flowering and pollen equatorial axes, number of leaf lobes and P/E ratio, leaf length and P/E ratio, length of petal and main shoot length, number of leaf lobes and days to maturity, number of silique on main shoot and silique density on main shoot and between plant height and number of seeds per silique. Higher r_p estimates than that of r_g indicated influence of environment.

It was observed that plant height and main shoot length had positive (significant or non-significant) association with all traits, but both the characters were negatively (significant or non-significant) associated with, hence affected number of seeds per siliqua inversely, at both levels indicating that better vegetative growth may negatively affect some economic traits at maturity.

Number of leaf lobes, leaf length and leaf width, the three leaf characters were associated positively with all the other characters at both levels with some exceptions. Number of leaf lobes was positively correlated with leaf width which was obvious, whereas leaf length had a positive association with *viz*., plant height, siliqua length, main shoot length and length of siliqua beak. Hence, longer leaves were indicators of taller plants and longer petals, longer siliquae with longer beaks (Jamali *et al*., 2016; Aktar *et al*., 2019). Some negative associations were observed for the leaf traits. Number of leaf lobes were negatively correlated with plant main shoot length (cm), number of silique on main shoot and siliqua density on main shoot, whereas leaf length was negatively associated with number of seeds per siliqua, respectively, at the both levels (either significantly or non-significantly). So it may be inferred that larger leaf morphology had some negative impact on economic traits related to reproductive structures.

Taking into consideration the traits related to vegetative parts *i.e.* stem and leaves, it is concluded that taller plants and longer leaves though lead to longer productive shoot and larger silique it reduces silique density and number of seeds per silique. This altogether not always affect the ultimate seed yield negatively, as length of pod/ silique with less seeds but high seed weight has been reported earlier not only in *Brassica* (Depar *et al*., 2017; Singh *et al*., 2019), but in other crops also like field pea (Meena *et al*., 2022),

Table 2 : Analysis of variance.

S. no.	Characters \ df	Mean Sum of Square		
		Replication	Genotypes	Error
		2	14	28
1.	Number of leaf lobes	0.867	3.762**	0.629
2.	Leaf length	0.282	450.544**	0.813
3.	Leaf width	0.307	72.842**	0.520
4.	Days to 50% flowering	1.689	143.365**	4.213
5.	Length of petal	0.003	0.321**	0.012
6.	Width of petal	0.001	0.085**	0.005
7.	Length of sepal	0.0001	0.910**	0.095
8.	Pollen diameter			
	i. Polar axes	1.000	29.229**	1.301
	ii. Equatorial axes	3.127	18.469**	1.939
	iii. P/ E Ratio	0.001	0.005**	0.001
9.	Plant height	38.467	24523.900**	33.800
10.	Main shoot length	19.072	1184.606**	11.489
11.	Siliqua length	0.038	3.066**	0.114
12.	Length of siliqua beak	0.008	0.345**	0.006
13.	Number of siliqua on main shoot	1.489	523.118**	4.156
14.	Siliqua density on main shoot	0.006	0.217**	0.016
15.	Number of seeds per silique	0.622	153.403**	3.051
16.	Days to maturity	2.867	417.286**	3.509
17.	1000 seed weight	0.001	2.330**	0.003
18.	Oil content	0.813	327.199**	0.639

*,**Significant at 5% and 1% level, respectively.

Table 3 : Genotypic correlation coefficients among different characters in *Brassica* spp. and its wild relatives.

		1	2	3	4	5	6	7	8			9	10	11	12	13	14	15	16	17	18
									i	ii	iii										
1		1.00																			
2		0.11	1.00																		
3		1.00**	1.00**	1.00																	
4		1.00	0.22	0.18	1.00																
5		0.33	0.65**	0.82**	0.70**	1.00															
6		0.34	0.23	0.61*	0.65**	0.88**	1.00														
7		0.28	0.65**	0.66**	0.46	0.90**	0.79**	1.00													
8	i	0.01	0.48	0.34	-0.10	-0.10	-0.37	0.18	1.00												
	ii	-0.02	0.52*	0.41	0.05	-0.04	-0.34	0.18	0.95**	1.00											
	iii	0.06	0.17	0.03	-0.42	-0.20	-0.21	0.13	0.67**	0.43	1.00										
9		0.07	0.95**	1.00**	0.42	0.80**	0.45	0.75**	0.36	0.40	0.10	1.00									
10		-0.31	0.43	0.53*	-0.09	0.09	-0.002	0.43	0.76**	0.69**	0.67**	0.43	1.00								
11		0.59*	0.63*	0.66**	0.16	0.41	0.23	0.60*	0.67**	0.68**	0.40	0.56*	0.51	1.00							
12		0.14	0.57*	0.45	-0.27	-0.08	0.37	0.16	0.93**	0.90**	0.60*	0.40	0.64*	0.77**	1.00						
13		-0.29	0.59*	0.54*	0.15	0.31	0.15	0.57*	0.65**	0.63*	0.47	0.65**	0.90**	0.51	0.54*	1.00					
14		-0.23	0.43	0.19	0.33	0.36	0.11	0.08	-0.29	-0.18	-0.45	0.49	-0.30	-0.26	-0.24	0.09	1.00				
15		0.46	-0.59*	0.38	-0.14	-0.19	0.16	-0.17	-0.23	-0.29	0.04	-0.54*	-0.15	-0.16	-0.26	-0.39	-0.66**	1.00			
16		0.29	0.70**	0.68**	0.73**	0.95**	0.76**	0.80**	0.03	0.08	-0.10	0.81**	0.04	0.49	0.05	0.29	0.43	-0.30	1.00		
17		0.43	0.82**	0.85**	0.49	0.81**	0.60*	0.88**	0.44	0.43	0.29	0.89**	0.56*	0.74**	0.44	0.70**	0.15	-0.32	0.83**	1.00	
18		0.19	0.85**	1.00**	0.36	0.81**	0.61*	0.88**	0.36	0.39	0.15	0.91**	0.54*	0.68**	0.42	0.70**	0.22	-0.33	0.77**	0.95**	1.00

*,**Significant at 0.05 and 0.01 levels, respectively.

S. no.	Character name	S. no.	Character name	S. no.	Character name	S. no.	Character name	S. no.	Character name
1	Number of leaf lobes	5	Length of petal (cm)	8(ii)	Pollen equatorial axes (µm)	11	Siliqua length(cm)	15	Number of seeds per silique
2	Leaf length (cm)	6	Width of petal (cm)	8(iii)	P/E ratio	12	Length of siliqua beak (cm)	16	Days to maturity
3	Leaf width(cm)	7	Length of sepal (cm)	9	Plant height (cm)	13	Number of siliqua on main shoot	17	1000 seed weight
4	Days to 50% flowering	8(i)	Pollen polar axes (µm)	10	Main shoot length (cm)	14	Siliqua density on main shoot	18	Oil content (%)

Table 4 : Phenotypic correlation coefficients among different characters in *Brassica* spp. and its wild relatives.

		1	2	3	4	5	6	7	8			9	10	11	12	13	14	15	16	17	18
									i	ii	iii										
1		1.00																			
2		0.10	1.00																		
3		-0.02	0.21	1.00																	
4		0.17	0.21	0.01	1.00																
5		0.30*	0.61**	0.24	0.64**	1.00															
6		0.31*	0.22	0.13	0.57**	0.80**	1.00														
7		0.18	0.60**	0.27	0.40**	0.82**	0.67**	1.00													
8	i	0.04	0.45**	0.08	-0.05	-0.08	-0.31*	0.15	1.00												
	ii	0.01	0.45**	0.06	0.11	-0.02	-0.26	0.13	0.93**	1.00											
	iii	0.07	0.14	0.10	-0.41	-0.18	-0.18	0.12	0.46**	0.13	1.00										
9		0.06	0.95**	0.32*	0.40**	0.75**	0.42**	0.69**	0.32*	0.33*	0.09	1.00									
10		-0.22	0.42**	0.13	-0.08	0.10	-0.01	0.38**	0.70**	0.58**	0.56**	0.43**	1.00								
11		0.42**	0.60**	0.17	0.13	0.38**	0.19	0.54**	0.58**	0.34*	0.34*	0.53**	0.47**	1.00							
12		0.11	0.56**	0.09	-0.25	-0.08	-0.31*	0.16	0.87**	0.51**	0.50**	0.37**	0.62**	0.67**	1.00						
13		-0.20	0.59**	0.14	0.12	0.30*	0.12	0.53**	0.60**	0.53**	0.41**	0.64**	0.87**	0.48**	0.52**	1.00					
14		-0.17	0.40**	0.03	0.23	0.29	0.06	0.07	-0.23	-0.14	-0.33*	0.44**	-0.30*	-0.21	-0.20	0.12	1.00				
15		0.38*	-0.58**	0.14	-0.12	-0.18	0.15	-0.17	-0.20	-0.24	0.06	-0.52**	-0.14	-0.16	-0.25	-0.37*	-0.57	1.00			
16		0.33*	0.70**	0.25	0.69**	0.90**	0.71**	0.74**	0.02	-0.07	-0.07	0.80**	0.03	0.44**	0.05	0.28	0.40**	-0.28	1.00		
17		0.23	0.81**	0.26	0.46**	0.77**	0.56**	0.81**	0.41	0.25	0.25	0.89**	0.55**	0.70**	0.43**	0.69**	0.13	-0.31*	0.81**	1.00	
18		0.16	0.85**	0.30*	0.34*	0.77**	0.57**	0.82**	0.33*	0.13	0.13	0.91**	0.54**	0.65**	0.40**	0.69**	0.20	-0.32*	0.76**	0.94**	1.00

*, **Significant at 0.05 and 0.01 levels, respectively

S. no.	Character name	S. no.	Character name	S. no.	Character name	S. no.	Character name	S. no.	Character name
1	Number of leaf lobes	5	Length of petal (cm)	8(ii)	Pollen equatorial axes (µm)	11	Siliqua length(cm)	15	Number of seeds per silique
2	Leaf length (cm)	6	Width of petal (cm)	8(iii)	P/E ratio	12	Length of siliqua beak (cm)	16	Days to maturity
3	Leaf width(cm)	7	Length of sepal (cm)	9	Plant height (cm)	13	Number of siliqua on main shoot	17	1000 seed weight
4	Days to 50% flowering	8(i)	Pollen polar axes (µm)	10	Main shoot length (cm)	14	Siliqua density on main shoot	18	Oil content (%)

sesame (Sasipriya *et al*., 2022) and chickpea (Jain *et al*., 2023).

Days to 50% flowering exhibited positive and highly significant correlation with length of petal, width of petal and days to maturity at both levels, whereas with pollen viability it showed negative and significant association. Positive but non-significant correlation was observed with number of leaf lobes, leaf length, leaf width, pollen equatorial axes, siliqua length, number of siliqua on main shoot and siliqua density on main shoot at both levels, while negative and non-significant correlation was observed with pollen polar axes, main shoot length, length of siliqua beak and number of seeds per siliqua. Such type of positive and non-significant association of days to 50% flowering with siliqua length was observed by Azam *et al.* (2013) and Nasim *et al*. (2013). Positive correlation of days to 50% flowering with siliqua number on plants was observed by Pal *et al.* (2019). The results of association of 50% flowering indicated that delayed flowering leads to less productive length of plants with larger leaves and flowers but with smaller and less viable pollens and less number of seeds.

In case of floral morphology traits, length of petal, width of petal and length of sepal were positively correlated with each other. But length of petal and width of petal had negative correlation with all pollen traits. In case of length of sepal, though positive association was found with most of the traits, negative correlation was noted for the trait with number of seed per silique. Pollen traits uniformly had negative association with siliqua density on main shoot and number of seeds per silique; this indicated that large floral parts do not always lead to better performance for silique traits in *Brassica* spp. and *Diplotaxis* spp.

Taking into consideration the observation of days to 50% flowering and floral traits, it can be inferred that though delayed flowering leads to larger flowers its negative impact on pollen traits affects final seed yield negatively.

Siliqua length and length of siliqua beak had positive or negative association with other characters, significantly or non-significantly; both the characters were positively related with number of silique on main shoot, though these two traits were related negatively with density of siliqua on main shoot and seeds per siliqua. The result indicated that length of silique had negative impact on density of silique and seeds. Number of silique on main shoot and density of silique on main shoot had negative relation with number of seeds per silique indicating that number of seeds per silique and number of silique were inversely related. Also longer silique were indicators of lesser silique density. Number of seeds per siliqua though had significant or non-significant positive association with some traits, were negatively (significantly or non-significantly) correlated at both levels with 1000 seed weight and also with oil content leading to the conclusion that less number of seeds per siliqua had offered better1000 seed weight and higher oil content.

From the present study on association of traits in *Brassica* spp. and *Diplotaxis* spp., it may be inferred that vigorous vegetative growth delays flowering and along with larger floral parts it delays maturity too. Moreover, larger leaves and late onset of flowering lead tolesser seed yield hence lesser economic return when seed is the economic part; inversely it leads to better yield for longer period where leaves or other vegetative parts contribute to yield. Siliqua morphology also had negative association on density of silique and seeds, whereas number of siliqua and its density led to lesser number of seed density. But it was found that lesser seeds per siliqua had offered better 1000 seed weight and higher oil content, which are the major traits of concern for an oilseed. It inversely suggests that less seeds per silique is an indicator of better vegetative yield.

Conclusion

Traits associated positively with better test weight (1000 seed weight) and oil content *i.e.*; smaller and narrower leaves with less number of lobes, longer main shoot, early flowering are to be selected at early crop stages for better economic return while cultivating *Brassica* spp. and *Diplotaxis* spp. as oilseeds. On the other hand, if cultivated as leafy vegetables, taller plants with larger and wider leaves and short main shoot are ideal traits for selection.

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