Journal of Agricultural Research Advances
ISSN: 2582-7227

Research Article
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Dissection of genetic variability, correlations and character contribution in Opium poppy (*Papaver somniferum* L.)

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Received on: 05/06/2025 Accepted on: 07/09/2025 Published on: 10/09/2025

ABSTRACT

Aim: The aim of the study was to investigate genetic variability and nature and amount of genetic variability, correlation and path coefficient for thirteen characters among forty accessions of opium poppy (*Papaver somniferum* L.).

Materials and Methods: Forty genotypes of opium poppies, including various breeding lines and landraces, were cultivated in 2021–2022 using randomized block designs (RBD) with three replications. Plants were planted in rows 4m long and 50 cm apart, and normal cultural procedures, irrigation, and fertilizer treatments (120 kg nitrogen, 80 kg phosphorus, and 60 kg potassium per hectare). For each of the thirteen features listed below, morpho-matric data was collected from five randomly chosen plants in every line of plants as well as Days to 50% flowering, plant height (cm), number of capsule/plant, Peduncle length (cm), Capsule index, Seed yield/plant (gm), Straw yield/plant (gm), Days to maturity, Morphine (%), Codeine (%), Thebaine (%), Papaverine (%), Narcotine (%) obtain from each selected plants.

Results: Correlation coefficient, highly high-significantly positive associated capsule index correlated with seed yield (0.678, 0.688), days to maturity correlated with Papaverine (0.641, 0.639), Thebaine correlated with Papaverine (0.588, 0.587), Morphine correlated with Codeine (0.542, 0.541) at both genotypic and phenotypic levels. The Peduncle length correlated with Capsule index (0.423, 0.279) showing that the only at genotypic level. Days to Maturity was significantly associated with Morphine (0.347, 0.346), Straw yield associated and Days to Maturity associated with Thebaine (0.312, 0.308) (0.308, 0.307) at both level genotypic and phenotypic. On the other hand, the Maximum direct positive effect on capsule index, Thebaine content, Morphine content, plant height and Codeine content.

Conclusion: It was concluded that variation in significant economic variables might assist in the selection of opium poppy genotypes for additional genetic improvement.

Keywords: Correlations; genetic variability; morphine, path coefficient

How to cite this article: Kumar V, Singh VR, Namita Singh, Lal RK, Kishor R, Siddiqui S, Tiwari N and Srivastva D (2025). Dissection of genetic variability, correlations and character contribution in Opium poppy (*Papaver somniferum* L.). J. Agri. Res. Adv., 07(03): 15-24.

Introduction

Opium poppy is a valuable medicinal plant that is a self-pollinated crop. Poppy seed is a biological source of *Papaver somniferum*, belonging to the family of Papaveraceae. Depending on kinds of cultivars, wind speed, bee visits, insects, and weather, outcrossing can range from 2 to 70% (Khanna and Shukla, 1983; Bhandari, 1990). Poppy seeds are a fantastic source of energy since they contain fixed oil, which may also be utilized as edible oil. In pharmaceutical preparations, it used to create emulsions. Here, it sought to cultivate, harvest and extract poppy for medical and pharmacological purposes (Khanna and Shukla, 1983 and Lahiri *et al*., 2018). The opium poppy is distributed in the temperate and subtropical regions. The opium poppy was cultivated in India, the USSR, Turkey, and Australia. Now, India cultivates it largely in Rajasthan, Madhya Pradesh, and Uttar Pradesh; in other parts, minor cultivation is also practiced. It is also cultivated as an ornamental plant in many parts of the world, including Turkey, India, Burma, Thailand, and Australia (Lal *et al*., 1996; Lahiri *et al*., 2018). Among the fifty species in the genus Papaver, only six are found in India. According to CK. Kokate (2014), they are *P. somniferum* (Opium poppy), *P. nudicaule* (Ice land poppy), *P. rhoeas* (Corn poppy), *P. orientale*, *P. argemone*,

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and *P. dubium*. The genus Papaver, which is part of the Papaveraceae family, contains a large number of annual and perennial herb species. Indian land races of opium poppies have been described in a variety of sources and have been shown to exhibit significant heterogeneity in regard to alkaloid production as well as seed and seed oil quality (Lal *et al*., 1996; Lal and Sharma, 1991; Lahiri *et al*., 2018). Besides their pharmaceutical importance, opium poppy seeds are also a rich source of herb-based protein supplement for community consumption (Lahiri *et al*., 2018; Kumar *et al*., 2021). The opium poppy seeds, having no narcotic influence, are very useful owing to the presence of high protein content (up to 24%) and edible oil (50%), having linoleic acid (up to 68%), which helps in lowering blood cholesterol in the human system (Lal *et al*., 1996; Kumar *et al*., 2024). The opium is obtained by lancing semi-ripe capsules of opium poppy, and it has approximately 12% morphine and low quantities of other alkaloids like thabaine, codeine, papaverine, noscapine, etc. (Lal *et al*., 2011). Morphine, the major opium morphinane alkaloid, is present in the root, stem, leaf, and fruit wall of the *Papaver somniferum* L. plant (Lal *et al*., 1996). Opium poppy seeds are free from narcotic constituents and they used for foodstuffs and bakery productions. Seeds are quite nutritious and have a pleasant nutty flavor, and are often added to cakes or sprinkled on breads. The increasing demand for opium alkaloids can be met by the development of high opium yielding varieties able to produce the specific alkaloids. It is used in the treatment of diarrhea, dysentery, and scalds. For successful breeding in opium poppy, sufficient genetic diversity/genetic variability is required. Increasing the seed yield and alkaloid content in poppy straw is one of the main objectives of poppy breeding, and the productivity is affected by weather conditions, particularly temperature and rainfall at the time of germination, flowering, capsule lancing, and capsule drying (Lal *et al*., 2011; 2013; Lahiri *et al*., 2018). The successful development of high-yielding cultivars would be facilitated by knowledge of the relationship between yield and its contributing features (Lahiri *et al*., 2018). The selection of particular attributes to be utilized as indirect selection criteria for heritable yield improvement depends on the nature of the relationship between yield and its contributing traits (Guljar and Patil, 2016). By Ahmadzadeh *et al*. (2012), path analysis is used to assess the direct and indirect impacts of several variables on the dependent variable. The objective of the study was to investigate genetic variability and nature and amount of genetic variability, correlation and path coefficient for thirteen characters among forty accessions of opium poppy (*Papaver somniferum* L.).

Materials and Methods

In spite of its favorable production in cold climates, opium poppy was successfully grown in sub-tropical regions during the wintertime. At the CSIR--Central Institute of Medicinal and Aromatic Plants (CIMAP) research farm, which is situated at 26.5° N latitude and 80.50° E longitude and 120 meters above sea level, 40 genotypes of opium poppies, including various breeding lines and landraces, were cultivated in 2021–2022 using randomized block designs (RBD) with three replications. Plants were planted in rows 4m long and 50 cm apart, and normal cultural procedures, irrigation and fertilizer treatments (120 kg nitrogen, 80 kg phosphorus and 60 kg potassium per hectare). For each of the thirteen features listed below, morpho-matric data was collected from five randomly chosen plants in every line of plants as well as Days to 50% flowering, plant height (cm), number of capsule/plant, Peduncle length (cm), Capsule index, Seed yield/plant (gm), Straw yield/plant (gm), Days to maturity, Morphine (%), Codeine (%), Thebaine (%), Papaverine (%), Narcotine (%) obtain from each selected plants.

Chemical analysis: For preparation for chemical analysis, samples were taken for HPTLC analysis once 1g of dry ground capsule husk powder was first soaked in methanol, sonicated for 30 minutes in an ultrasonic bath, and then the solution was centrifuged at 10,000 rpm for 10 minutes. Every standard was weighed separately, and a stock solution was made. Created a working standard, an equal volume of each standard stock solution has been taken and pooled. TLC-densitometric procedure were using analyzed the five main opium alkaloids morphine, codeine, thebaine, papaverine and narcotine (Gupta and Verma, 1996). Toluene-acetone-methanol-ammonia (40:40:6:2) was used as a mobile phase. Silica gel plates 60 F254 were scanned after derivatization using Dragendorff

reagent no. llC, which is used to detect alkaloid content (Wagner and Bladt, 1996) at 540 nm.

Statistical analysis: Statistically analyzed the overall mean data of two consecutive years, CSIR-CIMAP, Lucknow, developed Statistical Software 4.0, which was usable in the institute's Genetics and Plant Breeding Division, Singh and Chaudhary (1979), and Panse (1957). The mean, standard error and ranges were determined subsequently (Singh and Chaudhary, 1979). A study of variance was carried out following the procedure given by Panse and Sukhatme (1967). The data arranged 13 morpho-metric characters were analyzed using ANOVA, mean value, range, standard error, variability parameters, relationships, character contributions through path analysis, and heredity are all included in the analysis of variances, permitting the use of the conventional technique (Dewey and Lu, 1959; Singh and Chaudhary, 1979).

Results and Discussion

At the 0.01% and 0.05% significant levels, the augmented design's analysis of variance ANOVA showed highly significant and exploitable variation among the analyzed genotypes for each of the thirteen characters (Table 1 and Fig. 1). Higher diversity in the initially developed breeding sources improves the probability that they will produce desirable recombinants for crop development. Genotypic and phenotypic correlation coefficient between all possible combinations was estimated. The successful outcome of selection in any breeding effort was influenced by genetic correlations. The direction and strength of the genetic association between and throughout the various attributes determine the breeding program's subsequent outcome after selection. The level of relationship between two variables, which translates into the genetic gain obtained from a correlated response to selection, determines the magnitude of the direct selection responses. The majority of the variables analyzed show that the genotypic correlations were greater than the phenotypic correlations (Table 2). The correlation coefficients between the thirteen characters shown that capsule index positive and highly significant correlated with seed yield (0.678**, 0.688**) followed by days to maturity correlated with Papaverine (0.641**, 0.639**), Thebaine correlated with Papavervine (0.588**, 0.587**), Morphine correlated with Codeine (0.542**, 0.541**) at both genotypic and phenotypic level. The Peduncle length correlated with Capsule index (0.423**, 0.279), showing that correlation was only at genotypic level. The Days to Maturity was positive significantly associated with Morphine (0.347*, 0.346*) followed by Straw yield associated with Thebaine (0.312*, 0.308*) and Days to Maturity associated with Thebaine (0.308*, 0.307*) at both genotypic and phenotypic levels. The number of capsules/plant showed that negative was significantly associated with Straw yield (-0.345*, -0.207) and Number of capsules/plant correlated with Thebaine (-0.335*, -0.234) at only the genotypic level. All thirteen characters correlated with all possible combinations at both the genotypic and phenotypic. In genetics, coupling phase of linkage leads to a positive correlation; however, genes' repulsion linkage results in a negative correlation. Additionally, it has been found that environmental factors have little impact on appearance of attributes, indicating that relationship between individual characteristics was frequently controlled by genetics. Later, these outcomes were a good benchmark for selection.

The path coefficient exploration has been exploited to observe the proportional strength of direct and indirect association between dependent and independent variables for selection in plant breeding programmes (Mary and Gopalan, 2006; Lal, 2017; Yadav *et al*., 2018) (Table 3). Seed yield (g/pl.) was taken as a dependent character, and other characters were independent. The Maximum direct positive effect on capsule index (0.4170) fallowed by Thebaine content (0.2598), Morphine content (0.2455), plant height (0.1589) and Codeine content (0.1532) and another traits were negative direct effect was Straw yield (-0.3746) followed by Papaverineconent (-0.1927), days to 50 % flowering (-0.1563), Peduncle length (-0.0968), Narcotine content (-0.0779), days to maturity (-0.0372) and number of Capsule/plant (-0.0114) but their indirect contribution was invariably maximum and positivecapsule index (0.1763) and Thebaine (0.1409). The maximum indirect contribution was negative via Straw yield (-0.2542) and Capsule Index (-0.1107) although residual effect was 0.8457 (Fig. 2 and Table 3). These results were also in agreement of several researchers (Lal, *et al*., 1996; Lal and Sharma, 1991; Lahiri *et al*., 2028).

Table1: Analysis of variance (ANOVA) of thirteen traits of Opium poppy

Source of variation	df	Characters mean sum of squares												
		Days to 50% flowering	Plant height (cm)	No. of capsules / plant	Pedicel length (cm)	Capsule index	Seed yield (g/plant)	Straw yield (g/plant)	Days to maturity	Morphine content (%)	Codeine content (%)	Thebaine content (%)	Papaverine content (%)	Narcotine content (%)
Replications	2	173.233	253.425	5.308	14.658	5.351	3.069	0.123	718.725	0.047	0.002	0.001	0.002	0.007
Treatments	39	15.015**	86.420**	2.533**	27.674**	4.068**	1.768**	1.435**	71.759**	2.178**	0.133**	0.049**	0.316**	1.200**
Error	78	0.815	0.211	0.693	5.146	1.105	0.738	0.009	0.588	0.0037	0.00009	0.00008	0.0001	0.00038

* =p < 0.05; ** = p < 0.01, respectively.

Table 2: Genotypic (r_g), Phenotypic (r_p) and environmental correlation (r_e) among thirteen traits of Opium poppy accessions

Traits		Days to 50% flowering	Plant height (cm)	No. of capsules /plant	Peduncle length (cm)	Capsule index	Seed yield (gm/pl.)	Straw yield (gm/pl.)	Days to maturity (days)	Morphine	Codeine	Thebaine	Papaverine	Narcotine
Days to 50% flowering	r_g	--	0.249	-0.105	-0.027	0.017	0.128	0.029	0.053	0.208	0.111	0.279	0.026	-0.137
	r_p		0.234	-0.030	0.026	0.007	0.041	0.020	0.049	0.193	0.105	0.257	0.027	-0.124
Plant height (cm)	r_e	0.144	--	0.033	0.030	-0.266	-0.169	-0.359	-0.029	-0.221	-0.279	-0.131	0.005	-0.006
				0.032	0.028	-0.200	-0.107	-0.354	0.029	-0.220	-0.278	-0.130	0.005	-0.006
No. of capsules/ plant	r_e	0.130	0.157	--	-0.136	0.143	0.009	-0.345*	0.139	0.222	0.200	-0.335*	-0.184	0.294
					0.029	0.075	-0.013	-0.207	0.092	0.153	0.138	-0.234	-0.125	0.209
Peduncle length	r_e	-0.028	0.101	0.093	--	0.423**	0.113	0.179	0.113	-0.087	0.244	0.094	0.294	0.077
						0.279	0.079	0.129	0.088	-0.067	0.184	0.077	0.228	0.065
Capsule index	r_e	-0.014	-0.300	0.014	0.119	--	0.678**	0.240	-0.101	-0.094	-0.066	0.213	0.104	-0.039
							0.688**	0.161	0.072	-0.069	-0.041	0.145	0.067	-0.021
Seed yield (gm/pl.)	r_e	-0.081	-0.172	-0.022	0.057	0.709	--	-0.002	-0.190	-0.069	-0.023	0.219	0.025	-0.257
								-0.000	0.107	-0.036	0.001	0.125	0.012	-0.134
Straw yield (gm/pl.)	r_e	-0.107	-0.065	0.235	-0.069	-0.018	0.005	--	0.046	0.194	0.075	0.312*	0.283	-0.034
									0.045	0.192	0.074	0.308*	0.280	-0.033
Days to maturity (days)	r_e	0.001	-0.052	-0.051	0.025	-0.051	-0.013	0.025	--	0.347*	0.191	0.308*	0.641**	0.240
										0.346*	0.190	0.307*	0.639**	0.238
Morphine	r_e	0.102	0.047	0.022	-0.006	-0.132	0.071	0.064	0.101	--	0.542 **	0.294	0.277	0.218
											0.541**	0.293	0.276	0.216
Codeine	r_e	0.123	-0.079	0.010	-0.072	0.085	0.241	0.076	0.055	0.227	--	0.048	0.085	0.264
												0.047	0.084	0.262
Thebaine	r_e	-0.008	-0.059	-0.220	0.217	-0.062	0.072	0.091	0.114	0.255	0.359		0.588**	-0.180
													0.587**	-0.178
Papaverine	r_e	0.325	0.141	0.021	0.072	-0.182	-0.075	0.114	0.164	0.118	0.192	0.304	--	0.025
														0.024
Narcotine	r_e	0.027	-0.021	0.100	0.076	0.053	0.082	-0.026	0.062	0.018	0.127	-0.069	0.008	--

Genotypic and Phenotypic correlation = Upper values above diagonal; Environmental correlation =Lower values above diagonal; *, **= p<0.05 and p<0.01, respectively.

Table 3: Direct (bold) and Indirect effects in detail for different yield traits on Seed yield of *Papaversomniferum* L. accessions.

S.No.	Pathways of associations	Direct effects (P)	Indirect effects (P×r)	Correlations (r_g) Seed yield
1.	Days to 50% flowering			
	Direct effect	**-0.1563**		
	Indirect effect via			
	Plant height (cm)		0.0396	
	No. of capsules/plant		0.0012	

	Peduncle length (cm)		0.0026	
	Capsule index		0.0070	
	Straw yield (gm/pl.)		-0.0478	
	Days to maturity (days)		-0.0011	
	Morphine %		0.0130	
	Codeine%		0.0319	
	Thebaine%		0.0288	
	Papaverine%		-0.0538	
	Narcotine %		-0.0020	
	Total effect			-0.1369
2.	Plant height (cm)			
	Direct effect	**0.1589**		
	Indirect effect via			
	Days to 50% flowering		-0.0390	
	No. of capsules/plant		-0.0004	
	Peduncle length		-0.0029	
	Capsule index		-0.1107	
	Straw yield (gm/pl.)		0.0634	
	Days to maturity (days)		0.0134	
	Morphine		-0.0073	
	Codeine		-0.0340	
	Thebaine		-0.0726	
	Papaverine		0.0253	
	Narcotine		-0.0004	
	Total effect			-0.0062
3.	Number of capsules/plant			
	Direct effect	**-0.0114**		
	Indirect effect via			
	Days to 50% flowering		0.0164	
	Plant height (cm)		0.0053	
	Peduncle length		0.0132	
	Capsule index		0.0594	
	Straw yield (gm/pl.)		-0.0003	
	Days to maturity (days)		0.0128	
	Morphine		0.0340	
	Codeine		0.0340	
	Thebaine		0.0521	
	Papaverine		0.0646	
	Narcotine		0.0143	
	Total effect			0.2944
4.	Pedicel length			
	Direct effect	**-0.0968**		
	Indirect effect via			
	Days to 50% flowering		0.0042	
	Plant height (cm)		0.0048	
	Number of capsules/plant		0.0016	
	Capsule index		0.1763	
	Straw yield (gm/pl.)		-0.0424	
	Days to maturity (days)		-0.0067	
	Morphine		0.0279	
	Codeine		-0.0135	
	Thebaine		0.0635	
	Papaverine		-0.0183	
	Narcotine		-0.0230	
	Total effect			0.0777
5.	Capsule index			
	(a) **Direct effect**	**0.417**		
	(b) Indirect effect via			
	Days to 50% flowering		-0.0026	

	Plant height (cm)		-0.0422	
	Number of capsules/plant		-0.0016	
	Pedicel length		-0.0409	
	Straw yield (gm/pl.)		-0.2542	
	Days to maturity (days)		-0.0089	
	Morphine		-0.0250	
	Codeine		-0.0144	
	Thebaine		-0.0174	
	Papaverine		-0.0412	
	Narcotine		-0.0082	
	Total effect			-0.0396
6.	Straw yield (gm/pl.)			
	(a) **Direct effect**	**-0.3746**		
	(b) Indirect effect via			
	Days to 50% flowering		-0.0199	
	Plant height (cm)		-0.0269	
	No. of capsules/plant		-0.0001	
	Peduncle length		-0.0109	
	Capsule index		0.2830	
	Days to maturity (days)		0.0001	
	Morphine		-0.0467	
	Codeine		-0.0106	
	Thebaine		-0.0062	
	Papaverine		-0.0422	
	Narcotine		-0.0020	
	Total effect			-0.2570
7.	Days to maturity (days)			
	(a) **Direct effect**	**-0.0372**		
	(b) Indirect effect via			
	Days to 50% flowering		-0.0046	
	Plant height (cm)		-0.0570	
	No. of capsules/plant		0.0039	
	Peduncle length		-0.0174	
	Capsule index		0.1002	
	Straw yield (gm/pl.)		0.0007	
	Morphine		0.0113	
	Codeine		0.0298	
	Thebaine		0.0193	
	Papaverine		-0.0602	
	Narcotine		-0.0220	
	Total effect			-0.0332
8.	Morphine			
	(a) **Direct effect**	**0.2455**		
	(b) Indirect effect via			
	Days to 50% flowering		-0.0083	
	Plant height (cm)		-0.0047	
	No. of capsules/plant		-0.0016	
	Peduncle length		-0.0110	
	Capsule index		-0.0425	
	Straw yield (gm/pl.)		0.0713	
	Days to maturity (days)		-0.0017	
	Codeine		0.0532	
	Thebaine		0.0498	
	Papaverine		-0.0593	
	Narcotine		-0.0499	
	Total effect			0.2408
9.	Codeine			
	(a) **Direct effect**	**0.1532**		
	(b) Indirect effect via			
	Days to 50% flowering		-0.0325	

	Plant height (cm)		-0.0352	
	No. of capsules/plant		-0.0025	
	Peduncle length		0.0085	
	Capsule index		-0.0393	
	Straw yield (gm/pl.)		0.0260	
	Days to maturity (days)		-0.0072	
	Morphene		0.0852	
	Thebaine		0.1409	
	Papaverine		-0.0565	
	Narcotine		-0.0215	
	Total effect			0.2188
10.	Thebaine			
	(a) **Direct effect**	**0.2598**		
	(b) Indirect effect via			
	Days to 50% flowering		-0.0173	
	Plant height (cm)		-0.0444	
	No. of capsules/plant		-0.0023	
	Peduncle length		-0.0237	
	Capsule index		-0.0279	
	Straw yield (gm/pl.)		0.0089	
	Days to maturity (days)		-0.0028	
	Morphene		0.0470	
	codeine		0.0830	
	Papaverine		-0.0091	
	Narcotine		-0.0066	
	Total effect			0.2647
11.	Papaverine			
	(a) **Direct effect**	**-0.1927**		
	(b) Indirect effect via			
	Days to 50% flowering		-0.0436	
	Plant height (cm)		-0.0208	
	No. of capsules/plant		0.0038	
	Peduncle length		-0.0092	
	Capsule index		0.0891	
	Straw yield (gm/pl.)		-0.0820	
	Days to maturity (days)		-0.0116	
	Morphene		0.0755	
	Codeine		0.0449	
	Thebaine		0.0122	
	Narcotine		-0.0458	
	Total effect			-0.1802
12.	Narcotine			
	(a) **Direct effect**	**-0.0779**		
	(b) Indirect effect via			
	Days to 50% flowering		-0.0040	
	Plant height (cm)		0.0007	
	No. of capsules/plant		0.0021	
	Peduncle length		-0.0285	
	Capsule index		0.0437	
	Straw yield (gm/pl.)		-0.0094	
	Days to maturity (days)		-0.0105	
	Morphine		0.1574	
	Codeine		0.0424	
	Thebaine		0.0220	
	Papaverine		-0.1134	
	Total effect			0.0246
Residual effects = 0.8457				

Fig. 1. Field view and variation among flower colour of opium poppy accessions

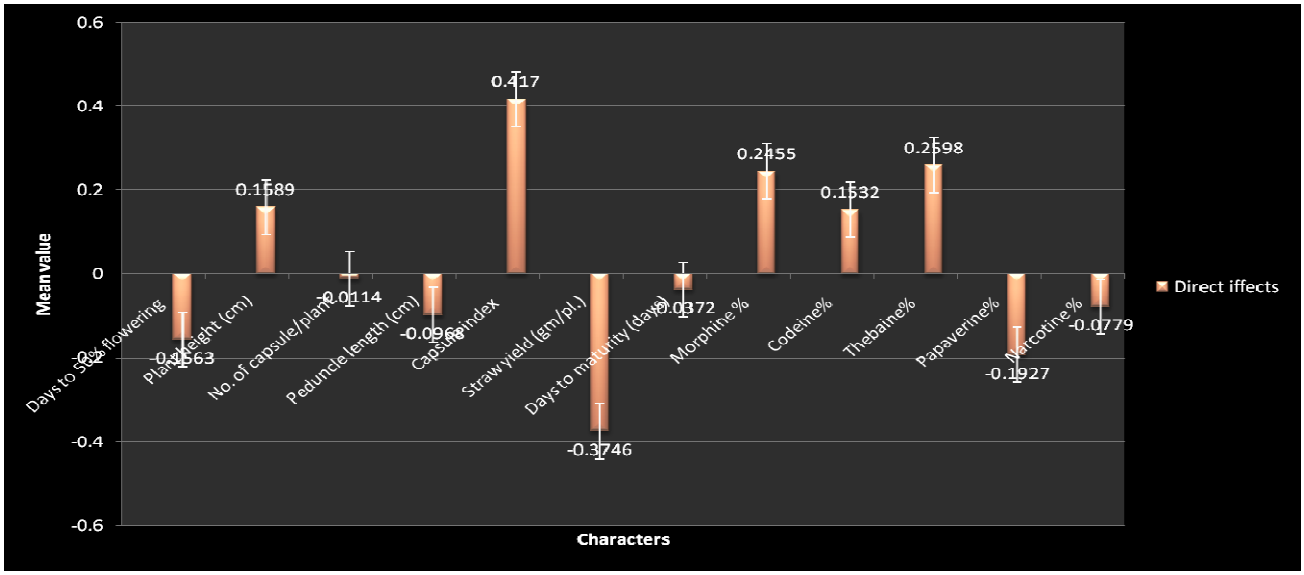

Fig. 2. Graphical estimation of direct effect (Positive & Negative) for seed yield

In a nutshell, Significantly positive correlation coefficients were found between the capsule index and seed yield, days to maturity, and papaverine, thebaine, and papaverine (0.588, 0.587) and morphine and codeine (0.542, 0.541) at both the genotypic and phenotypic levels. Only at the genotypic level does the peduncle length correspond with the capsule index (0.423, 0.279). At both the genotypic and phenotypic levels, Days to Maturity was positively and substantially correlated with Morphine (0.347, 0.346), Straw yield, and Thebaine (0.312, 0.308) (0.308, 0.307). Conversely, there was the greatest direct benefit to the capsule index, the content of thebaine, morphine, plant height, and codeine. The findings clearly demonstrated that variation in important economic factors could help choose genotypes of opium poppies for further genetic advancement.

Conclusions

The justification underlying the current study could be enhanced in order to develop strategies aimed at increasing seed production. The investigation of the variance of all the characters studied was significant and shown a wide range of variability among genotypes of Opium poppy. Breeders and agrarians may be able to improve the cultivar alkaloids yield and seed yield of this crop by taking into account the

mean, range, and all genetic standards for selection based on the necessity of initiative for numerous agro environments. Morpho-metric variation was also studying flower color was whitish to red and pink, fringed and non-fringed different flowering stage, leaf had fringed and non-fringed, narrow and broad leaf in different vegetative stage green and capsule green to brown color in maturity (harvesting) stage and different number of races. The coefficient correlation shows that the genotypic correlations were larger than the phenotypic correlations for almost all traits studied among the characters. Correlation coefficient is significantly positive and highly correlated with capsule index with seed yield, days to maturity correlated with Papaverine, Thebaine correlated with Papavervine, Morphine correlated with Codeine at both levels, Peduncle length correlated with Capsule index at only the genetic level. Days to Maturity was significantly associated with Morphine, Straw yield with Thebaine, and Days to Maturity with Thebaine at both levels. Maximum direct positive effect on capsule index, Thebaine content, Morphine content, plant height, and Codeine content. Characteristics that directly increase seed yield have been considered to be appropriate selection criteria for developing genotypes that have high yields.

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