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Original Research Article

## Inheritance pattern and association study of agronomical traits in 47 elite accessions/genotypes of Opium poppy (*Papaver somniferum* L.)

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### ABSTRACT

Opium poppy (*Papaver somniferum* L.), a member of family Papaveraceae is an important source of several benzylisoquinoline derived alkaloids known to the human race since the ancient civilizations for their therapeutic and narcotic values. In the present study a total number of 47 accessions/genotypes of Opium poppy were procured from various resources and screened for economic yield, variability, heritability, correlation and path coefficient. Among them G-18 was identified as highest seed yielding 10.45 g/plant, G-3 & G-6 (0.092%, 0.086%) as high morphine containing accessions. Maximum Genotypic Coefficient of Variance (GCV) recorded for papaverine content. The estimate of heritability in the broad sense was recorded higher side for morphine content (99.96%) and papaverine (99.85 %) while lower for days to 50% flowering (4.22%). The genotypic and phenotypic correlation coefficient amongst codeine and thebaine content were found highly significant and positively associated with morphine content followed by narcotine content. The path coefficient analysis revealed that the highest direct contribution to seed yield was made by capsule straw yield (0.8730) followed by days to maturity (0.3758).

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## 1. Introduction

The genus *Papaver* L. member of family Papaveraceae includes about 100 species well-known for their pharmaceutically important alkaloid. *Papaver somniferum* L. is a famous cultivated plant known to mankind since ages. It is utilized as a drug since the beginning of civilization (Frick et al., 2007). The plant is a rich source of physiologically active alkaloids which contains about eighty different tetrahydro-benzylisoquinoline derived alkaloids, including several other of medicinal importance. The main alkaloids of latex are morphine, codeine, thebaine among phenanthrene alkaloids and papaverine, narcotine and narceine among benzylisoquinoline alkaloids occur in measurable quantity (Lal and Sharma, 1991). Analgesics of narcotic morphine drug origin are used mainly to control severe pain such as migraine. For anti-diarrhea

and sedative effects, narcotic codeine and to a lesser extent pholcodeine and ethyl morphine and narcotine are utilized to promote anti-tussive and analgesic activities. Noscapine is reported as an antitussive and apoptosis inducer (Ye et al., 1998; Demir and Başayığit, 2019). In recent past scope of this species widened and also utilized for nanoparticles (NPs) synthesis (Muhammad et al., 2019a, 2019b).

As an exploration of genetic variability and depiction of the interrelationship between the yield character and its associated characters are prerequisite feature of any crop improvement program, it is also necessary to explore genetic diversity along with aforesaid interrelationship. The correlation coefficient is used to find out the degree and direction of the relationship between two or more variables. It assists in measuring the mutual relationship between two or more variables, but not able to determine the cause and effect

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relationship of traits contributing directly or indirectly to economic yield (Singh et al., 2004). Path coefficient analysis is a standardized regression coefficient, which helps to splits the coefficient into the measures of direct and indirect effects. It measures the direct and indirect contribution of independent variables on dependent variable and helps in determining yield components (Mishra et al., 2013). Considering the above mentioned facts, an attempt was made to explore the genetic diversity and to gain sufficient knowledge of the heritability, interrelationship, path coefficient between seed yield and its components.

## 2. Experimental

In present investigation, 47 accessions of Opium poppy belonging to different genetic stocks, improved varieties and land races (Table 1) were procured from various resources. These accessions were grown, in a randomized block design (RBD) with three replications at the experimental field of Genetics & Plant Breeding Unit of CSIR, CIMAP, Lucknow, located at 26.5° N latitude and 80.50° E longitude and 120 m above sea level. In each replication intra and inter row spacing were maintained about 10 cm and 40 cm, respectively. All the standard cultural practices were followed throughout the crop season, which include pre-sowing, the addition of farmyard manure at the rate of 10 t/ha and 80, 40, 40 kg/ha of nitrogen, phosphorus and potassium, respectively as basal covering of land. An additional dose of nitrogen of 40 kg/ha was top dressed in two equal splits at 40 days and 60 days after sowing. Besides these plants were sprayed with the fungicide Dithane M-45 0.2% at 45 and 60 days after sowing and irrigated as and when required (Lahiri et al., 2018). The detailed observations were recorded on days to 50% flowering (DOF), plant height (PH), peduncle length (PL), capsules/plant (CP), capsule size (CS), capsule weight/plant (CWP), seed yield/plant (SYP), capsule straw yield/plant (CHY), alkaloid content i.e. morphine, codeine, thebaine, papaverine and narcotine (Mishra et al., 2016). Alkaloid % was assayed in form of percentage yield. For which the dry powder of capsule straw (1 g) was extracted with (3×10 mL) methanol by boiling over water bath for 30 min. The extract was pooled, concentrated and re-dissolved in 1.0 mL methanol. The samples were centrifuged at 10,000 rpm before HPTLC analysis. The referred chemical, i.e. morphine, codeine, thebaine, papaverine and narcotine were provided by Government Opium & Alkaloid Works, Neemuch, India. The purity of each opiate was ~98% by HPLC peak and normalization method. The stock solution of each estimated compound was prepared separately. The quantification was performed using linear regression curve. For validation TLC-densitometric procedure was applied to quantify the aforesaid opium alkaloids (Gupta and Verma, 1996). Toluene-acetone-methanol-ammonia (40:40:6:2) v/v was used as a mobile phase. Silica gel plates 60 F254 (Merck, Darmstadt, Germany) were scanned at 540 nm after derivatization using Dragendorff reagent (Lahiri et al., 2018).

The pooled data of the two consecutive generations (2013-14 and 2014-15) was statically analyzed for mean value, genotypic coefficient of variability (GCV), phenotypic coefficient of variability (PCV), heritability, genetic advance, genotypic coefficient of correlation, phenotypic coefficient of correlation, and path coefficient analysis of seed yield using Statistical Software 4.0 version using standard methodologies recommended by earlier workers (Dewey and Lu, 1956; Panse and Sukhatme, 1967; Singh and Chaudhary, 1979; Yadav et al., 2007).

## 3. Results and Discussion

Nowadays, the studies on poppy are going in two directions either to increase seed yield and less amount of morphine or to increase morphine content which is of immense importance in the pharmaceutical industry. In the present study, 47 accessions were studied for morphological and biochemical traits.

### 3.1. Variability and analysis of variance

Among the accessions, notable variation was recorded for different parameters. G-18 (10.44 ± 0.40 g/plant) and G-8 (10.23 ± 0.60 g/plant) were identified as highest seed yielding accession whereas G-3 (0.092%) and G-6 (0.086%) as high morphine % containing accessions. On other hand, G-6 (morphine 0.086% and seed yield 8.11 g/plant), G-19 (morphine 0.0700 % and seed yield 8.97 g/plant), and G-4 (0.075% and seed yield 7.54 g/plant) were found superior for morphine content with a compromising seed yield (Table 2 and Table 3).

The analysis of variance showed significant differences for all the thirteen characters demonstrating a considerable amount of variation among genotype and thus there is the further scope of genetic improvement. The magnitude of phenotypic variance was higher than genotypic variance for most of the characters that reveal the influence of the environment. In the context of papaverine, narcotine, thebaine and morphine content the negligible differences between genetic & phenotypic variance were recorded that indicates imperativeness of environmental factors. The recorded mild difference between both variances was only due to the genotypic effect.

The maximum GCV, 164.077 was observed for papaverine content. This was followed by the codeine (103.996), thebaine (101.185), morphine (88.87) and narcotine content (77.64). A lowest estimate of GCV, 0.952 was recorded for days to 50% flowering (Table 4). The values for PCV were found to be higher than their corresponding genotypic GCV, suggesting that the noticeable variation was not only due to genotype but also due to the cumulative effect of genotype and environment (Verma et al., 2014). The difference between PCV and GCV was negligible for morphine content (%) followed by papaverine content, suggesting that these traits were least affected by environment (Bhandari et al., 1997).

**Table 1**  
Genetic stocks/ accessions and place of collection of Opium poppy.

S.No.	Accession code	Details	Origin
1	G-1	Lucknow local	Uttar Pradesh, India
2	G-2	Jewely pink	Rajasthan, India
3	G-3	Talia	Rajasthan, India
4	G-4	Dhawala Chhota Gotia	Rajasthan, India
5	G-5	Talia Kantiya	Rajasthan, India
6	G-6	LL3	New Delhi, India
7	G-7	GS-24	CIMAP, Lucknow, U.P. India
8	G-8	Mandsourgulab	Madhya Pradesh, India
9	G-9	Red Mandsour	Madhya Pradesh, India
10	G-10	N-3 type (CIMAP)	Lucknow, Uttar Pradesh, India
11	G-11	DhoriaButiaMandsour	Madhya Pradesh, India
12	G-12	IS-34	CIMAP, Lucknow, U.P. India
13	G-13	Dhowla Dhoria Zhalawar	Rajasthan, India
14	G-14	Safed Kangari Zhalawar	Rajasthan, India
15	G-15	Ranijhar Kangriwala	Rajasthan, India
16	G-16	Chittorgarh (Talia)	Rajasthan, India
17	G-17	Dhawala Chhota Chittorgarh	Rajasthan, India
18	G-18	Dhawala Chhota Chittorgarh	Rajasthan, India
19	G-19	Dhawala Chhota Gotia	IARI, New Delhi, India
20	G-20	Mass 2B	CIMAP, Lucknow, U.P. India
21	G-21	Ran jhatak (C-516) Talia	IARI, New Delhi, India
22	G-22	108/bulk PKII Talia	IARI, New Delhi, India
23	G-23	Material 110 yellow ped.	IARI, New Delhi, India
24	G-24	Material 110 Talia yellow ped.	IARI, New Delhi, India
25	G-25	109/bulk Disease sucept.	IARI, New Delhi, India
26	G-26	Material 113	IARI, New Delhi, India
27	G-27	Material 114 diseased	IARI, New Delhi, India
28	G-28	Material 116	IARI, New Delhi, India
29	G-29	Material 121	IARI, New Delhi, India
30	G-30	LL-34	CIMAP, Lucknow, India
31	G-31	Material 131	IARI, New Delhi, India
32	G-32	Material 127	IARI, New Delhi, India
33	G-33	Material 122	IARI, New Delhi, India
34	G-34	Material 130	IARI, New Delhi, India
35	G-35	Material 131	IARI, New Delhi, India
36	G-36	Material 133	IARI, New Delhi, India
37	G-37	Material 134	IARI, New Delhi, India
38	G-38	Material 135	IARI, New Delhi, India
39	G-39	Material 136 (Cap oblong)	IARI, New Delhi, India
40	G-40	Material 137	IARI, New Delhi, India
41	G-41	Material 116	IARI, New Delhi, India
42	G-42	SPS-24	CIMAP, Lucknow, India
43	G-43	Material 122	IARI, New Delhi, India
44	G-44	109/bulk (prickles,tall,white)	IARI, New Delhi, India
45	G-45	109/bulk (scarlet medium fr.)	IARI, New Delhi, India
46	G-46	Jewli pink	IARI, New Delhi, India
47	G-47	Talia kantia	IARI, New Delhi, India

**Table 2**

Values for different morphological parameters in different accessions of Opium poppy.

Accessions	Days to 50% flowering	Plant height (cm)	Peduncle length (cm)	Days to maturity	No. of capsule/plant	Capsule Index (width/length in cm)	Seed yield/plant (gm)	Capsule straw yield/plant (gm)
G1	91.33 ± 0.67	83.40 ± 2.27	23.65 ± 0.80	154.00 ± 0.57	2.11 ± 0.40	0.90 ± 0.023	8.20 ± 0.17	7.37 ± 0.49
G2	106.00 ± 0.01	92.91 ± 0.36	24.99 ± 0.61	155.66 ± 0.88	1.88 ± 0.11	0.93 ± 0.012	7.55 ± 0.77	7.55 ± 0.29
G3	102.00 ± 0.58	92.93 ± 0.58	23.89 ± 0.38	167.33 ± 0.33	1.88 ± 0.22	0.90 ± 0.082	7.54 ± 0.23	8.03 ± 0.61
G4	101.00 ± 1.00	96.38 ± 1.16	23.14 ± 0.58	165.66 ± 0.66	1.77 ± 0.22	1.00 ± 0.021	6.10 ± 0.07	7.13 ± 0.07
G5	103.33 ± 0.88	97.41 ± 0.45	22.16 ± 0.48	149.66 ± 0.33	1.66 ± 0.33	0.99 ± 0.006	7.18 ± 0.34	6.82 ± 0.17
G6	100.00 ± 1.53	95.75 ± 0.50	21.52 ± 0.65	148.00 ± 0.01	2.00 ± 0.01	0.95 ± 0.0038	8.11 ± 0.07	7.07 ± 0.44
G7	102.00 ± 0.58	99.65 ± 0.01	22.79 ± 0.90	148.66 ± 0.33	2.11 ± 0.29	0.93 ± 0.0067	7.32 ± 0.28	6.33 ± 0.42
G8	10.00 ± 0.01	88.61 ± 0.89	24.17 ± 1.32	141.66 ± 0.33	1.88 ± 0.29	0.93 ± 0.021	10.23 ± 0.60	11.54 ± 0.48
G9	103.60 ± 0.67	90.57 ± 3.23	21.64 ± 1.09	147.66 ± 0.33	1.44 ± 0.11	0.79 ± 0.069	9.03 ± 0.16	8.35 ± 0.32
G10	102.60 ± 0.33	89.79 ± 0.53	23.24 ± 0.47	147.66 ± 0.33	2.11 ± 0.11	0.91 ± 0.016	6.903 ± 0.21	7.83 ± 0.39
G11	111.00 ± 0.58	61.52 ± 0.55	23.24 ± 0.49	142.66 ± 0.33	1.66 ± 0.19	0.88 ± 0.028	8.13 ± 0.09	9.79 ± 0.27
G12	109.00 ± 0.01	89.51 ± 0.53	22.40 ± 1.37	147.66 ± 0.33	2.44 ± 0.22	0.78 ± 0.082	5.96 ± 0.21	8.0 ± 0.28
G13	104.60 ± 1.33	81.01 ± 0.58	24.56 ± 0.55	141.33 ± 0.33	2.00 ± 0.38	0.93 ± 0.017	8.41 ± 0.24	9.11 ± 0.59
G14	92.33 ± 0.33	77.92 ± 0.56	23.47 ± 0.56	145.33 ± 0.33	2.00 ± 0.19	0.83 ± 0.0072	8.07 ± 0.09	9.78 ± 0.55
G15	112.66 ± 0.33	91.56 ± 1.51	24.56 ± 1.28	142.66 ± 0.33	2.00 ± 0.19	0.92 ± 0.0131	5.59 ± 0.38	9.56 ± 0.32
G16	102.33 ± 0.33	94.65 ± 4.11	22.47 ± 1.06	142.66 ± 0.66	2.66 ± 0.33	1.01 ± 0.010	6.80 ± 0.25	9.40 ± 0.26
G17	104.33 ± 0.33	96.90 ± 0.75	24.43 ± 0.75	136.33 ± 0.66	2.55 ± 0.44	0.92 ± 0.004	8.92 ± 0.31	9.49 ± 0.44
G18	107.00 ± 0.01	95.41 ± 3.09	23.41 ± 1.32	136.66 ± 0.33	2.11 ± 0.40	0.93 ± 0.015	10.44 ± 0.40	12.06 ± 1.38
G19	102.33 ± 0.33	93.77 ± 3.18	20.81 ± 0.87	137.33 ± 1.20	2.11 ± 0.29	0.93 ± 0.0022	8.97 ± 0.09	11.41 ± 0.41
G20	103.00 ± 0.01	93.06 ± 2.47	22.51 ± 1.41	140.66 ± 0.33	2.11 ± 0.29	0.93 ± 0.0061	7.69 ± 0.48	9.81 ± 0.52
G21	109.00 ± 0.01	94.41 ± 1.92	24.53 ± 1.36	141.33 ± 0.66	2.00 ± 0.66	0.88 ± 0.024	6.91 ± 0.56	8.32 ± 0.51
G22	109.00 ± 0.058	96.37 ± 1.16	22.34 ± 0.69	143.66 ± 0.88	2.33 ± 0.01	0.90 ± 0.020	8.59 ± 0.29	9.38 ± 1.41
G23	104.00 ± 0.58	95.96 ± 3.19	22.35 ± 0.71	145.66 ± 0.66	2.44 ± 0.11	0.95 ± 0.006	7.88 ± 0.34	10.29 ± 0.54
G24	106.33 ± 0.33	96.68 ± 1.06	23.59 ± 0.56	141.33 ± 0.66	2.33 ± 0.51	0.93 ± 0.010	9.00 ± 0.15	9.6 ± 0.61
G25	112.00 ± 1.0	88.58 ± 3.15	24.50 ± 0.64	136.66 ± 0.33	1.88 ± 0.22	0.86 ± 0.033	6.00 ± 0.40	6.54 ± 0.64
G26	102.00 ± 0.58	98.03 ± 1.24	23.59 ± 0.55	136.66 ± 0.33	2.11 ± 0.29	0.90 ± 0.005	5.48 ± 0.32	6.89 ± 0.31
G27	103.33 ± 0.88	92.38 ± 1.87	22.66 ± 1.27	140.66 ± 0.33	2.77 ± 0.22	0.87 ± 0.011	8.93 ± 0.15	9.47 ± 0.58
G28	107.00 ± 0.58	73.62 ± 1.32	20.18 ± 0.46	153.33 ± 0.33	2.33 ± 0.19	0.80 ± 0.088	7.02 ± 0.89	8.6 ± 0.99
G29	103.33 ± 0.67	57.85 ± 0.15	19.42 ± 0.14	142.33 ± 0.66	2.00 ± 0.33	0.83 ± 0.106	8.02 ± 0.09	10.18 ± 0.51
G30	100.00 ± 0.01	82.42 ± 3.59	19.34 ± 0.16	141.66 ± 0.33	2.11 ± 0.48	0.87 ± 0.014	5.81 ± 0.84	7.47 ± 0.54
G31	109.00 ± 0.58	86.38 ± 3.58	19.45 ± 0.13	142.33 ± 0.66	2.55 ± 0.22	0.94 ± 0.009	7.95 ± 0.27	9.10 ± 0.28
G32	102.00 ± 0.01	81.18 ± 3.08	19.67 ± 0.23	143.33 ± 1.45	2.66 ± 0.51	0.89 ± 0.032	8.5 ± 0.42	8.98 ± 0.77
G33	111.33 ± 0.33	97.46 ± 1.75	19.38 ± 0.49	142.66 ± 0.88	2.55 ± 0.22	0.87 ± 0.029	8.22 ± 0.58	9.74 ± 0.59
G34	101.00 ± 0.01	90.90 ± 4.11	20.30 ± 0.27	145.00 ± 0.01	2.22 ± 0.29	0.88 ± 0.031	7.66 ± 0.24	8.56 ± 0.51
G35	112.33 ± 0.33	95.63 ± 1.0	20.84 ± 0.75	145.66 ± 1.20	1.66 ± 0.19	0.89 ± 0.020	7.43 ± 0.19	9.06 ± 0.63
G36	109.00 ± 0.01	89.70 ± 0.69	20.70 ± 0.75	141.66 ± 0.66	1.66 ± 0.19	0.92 ± 0.010	8.35 ± 0.19	9.98 ± 0.22
G37	93.00 ± 0.58	73.67 ± 1.18	22.13 ± 0.61	150.66 ± 1.60	2.33 ± 0.33	0.88 ± 0.009	8.85 ± 0.20	9.12 ± 0.25
G38	97.00 ± 0.58	63.45 ± 2.81	21.15 ± 0.94	142.33 ± 0.33	1.33 ± 0.19	0.87 ± 0.032	7.336 ± 0.17	9.58 ± 0.55
G39	102.00 ± 0.01	89.61 ± 0.26	19.53 ± 2.05	148.66 ± 0.33	1.22 ± 0.11	0.90 ± 0.006	6.97 ± 0.25	8.63 ± 0.30
G40	116.00 ± 0.58	89.61 ± 1.20	23.54 ± 0.28	144.00 ± 0.01	3.00 ± 0.38	0.91 ± 0.010	6.97 ± 0.32	6.44 ± 0.60
G41	106.00 ± 0.01	88.15 ± 0.51	23.72 ± 0.48	146.33 ± 0.33	2.00 ± 0.38	0.91 ± 0.011	8.45 ± 0.28	9.94 ± 0.20
G42	102.00 ± 0.58	90.21 ± 1.14	23.53 ± 0.34	143.33 ± 0.33	2.00 ± 0.01	0.91 ± 0.034	5.90 ± 0.25	8.83 ± 0.86
G43	104.00 ± 0.01	98.88 ± 0.07	24.14 ± 0.54	150.33 ± 0.33	1.77 ± 0.11	0.93 ± 0.015	6.77 ± 0.34	7.23 ± 0.46
G44	104.00 ± 0.58	99.35 ± 0.85	25.04 ± 1.10	143.66 ± 0.33	2.66 ± 0.01	0.89 ± 0.041	7.12 ± 0.45	8.71 ± 0.48
G45	103.33 ± 0.67	96.65 ± 1.14	23.08 ± 0.58	150.33 ± 0.33	2.77 ± 0.29	0.89 ± 0.015	7.93 ± 0.39	6.91 ± 0.94
G46	102.00 ± 0.01	101.36 ± 0.59	24.11 ± 0.70	137.00 ± 1.00	2.33 ± 0.19	0.87 ± 0.013	7.26 ± 0.36	7.96 ± 0.45
G47	102.00 ± 1.00	84.21 ± 0.73	22.84 ± 0.74	143.66 ± 0.33	2.55 ± 0.11	0.87 ± 0.036	6.81 ± 0.37	7.88 ± 0.41

**Table 3**

Alkaloid content (%) in different accessions of Opium poppy.

Accession	Morphine %	Codeine %	Thebaine%	Papaverine%	Narcotine%
G1	0.026	0.000	0.005	0.020	0.010
G2	0.062	0.015	0.008	0.020	0.016
G3	0.092	0.016	0.022	0.001	0.023
G4	0.075	0.020	0.019	0.003	0.028
G5	0.068	0.023	0.008	0.004	0.020
G6	0.086	0.034	0.010	0.001	0.020
G7	0.015	0.000	0.004	0.005	0.004
G8	0.041	0.006	0.013	0.001	0.310
G9	0.062	0.037	0.022	0.030	0.420
G10	0.057	0.021	0.024	0.003	0.023
G11	0.026	0.006	0.024	0.001	0.016
G12	0.031	0.021	0.011	0.026	0.032
G13	0.000	0.000	0.002	0.000	0.004
G14	0.006	0.026	0.004	0.002	0.007
G15	0.022	0.020	0.003	0.003	0.018
G16	0.030	0.034	0.006	0.003	0.019
G17	0.030	0.013	0.005	0.001	0.020
G18	0.038	0.024	0.005	0.027	0.012
G19	0.038	0.026	0.005	0.030	0.011
G20	0.065	0.022	0.017	0.002	0.016
G21	0.065	0.014	0.005	0.031	0.014
G22	0.058	0.025	0.010	0.008	0.013
G23	0.072	0.007	0.011	0.002	0.008
G24	0.005	0.000	0.005	0.002	0.002
G25	0.004	0.030	0.005	0.000	0.005
G26	0.012	0.000	0.007	0.000	0.004
G27	0.014	0.001	0.000	0.012	0.000
G28	0.012	0.000	0.000	0.000	0.004
G29	0.034	0.006	0.000	0.000	0.020
G30	0.013	0.002	0.000	0.000	0.027
G31	0.013	0.000	0.000	0.000	0.024
G32	0.008	0.002	0.000	0.029	0.015
G33	0.004	0.002	0.002	0.000	0.010
G34	0.002	0.004	0.000	0.000	0.027
G35	0.007	0.001	0.000	0.044	0.019
G36	0.009	0.002	0.000	0.000	0.021
G37	0.004	0.003	0.004	0.000	0.006
G38	0.012	0.000	0.006	0.002	0.004
G39	0.008	0.012	0.008	0.000	0.005
G40	0.008	0.010	0.014	0.000	0.002
G41	0.020	0.007	0.002	0.000	0.005
G42	0.019	0.013	0.003	0.013	0.000
G43	0.013	0.003	0.002	0.000	0.002
G44	0.012	0.000	0.000	0.000	0.003
G45	0.009	0.000	0.000	0.000	0.007
G46	0.013	0.000	0.004	0.000	0.008
G47	0.008	0.000	0.008	0.000	0.000

### 3.2. Heritability and genetic advance

However, variability alone is not enough in determining the heritable portion of variation. Hence the expected amount of variation from selection can be obtained by the estimates of the coefficient of variability along with heritability. Estimates of heritability and their significance in predicting gains in crop species have been reported by Kang et al. (1983), Kole and Saha (2013) and Ezeaku et al. (2015). The heritability in broad sense for worked out parameters ranged between 4.20-99.9%. The high heritability was recorded for morphine content (99.9%), papaverine (99.85%), thebaine (99.13%), codeine content (97.81%), days to maturity (81.20%) and seed yield (73.70%). The high heritability estimates for above traits indicates that the characters are under genetic control and easy to select. However, low heritability for days to flowering revealed the role of the environment and not easy and reliable to select. Estimates of heritability (broad sense) are considered important, in the selection based as phenotypic performance if it is considered in combination of genetic advance (Kumar et al., 2014). Heritability in combination with the intensity of the selection and amount of variability present in population influences the gain to be obtained from selection. The direct genetic gain/ advance also ranged from 0.014-15.596 (Table 4). For more efficient selection heritability in conjunction with genetic advance are more reliable than heritability alone (Johnson et al., 1955). Heritability along with genetic advance would be helpful in assessing the nature of gene action. The high genotypic coefficient of variation coupled with high heritability and genetic advance indicates that expression of respective traits is governed by additive gene action and as a result there is scope of improving these traits through selection procedure (Vir and Gupta, 2001). Low genetic advance with moderate heritability shows that these traits are most probably governed by non-additive gene action. It is a guiding factor in selection of desirable genotype.

### 3.3. Correlation among studied parameters

The studies on relationship among yield and various morphological and quality characters of the plant population which influences yield and quality is of great value indeed, as it furnishes the plant breeder with an easy and fairly reliable means of isolating high yielding and better quality genotypes from the breeding material (Mumtaz, et al., 2017). Grafius (1959) pointed out that there is no way in which yield could be changed without changing one or more of the components and that all changes in yield must be accompanied by changes in one or more of the components. According to Mather and Harission (1949), most probably polygenes affecting the same characters are intermingled along the chromosome in balanced conditions which are held together as units, in the absence of recombination, are responsible for such correlations. In present investigation, the genotypic and phenotypic correlation coefficients were worked out in all possible combination

for thirteen characters.

Days to flowering exhibits significant genotypic correlation with plant height (-0.465), peduncle length (-0.443), number of capsule/plant (-0.525), capsule index (+0.571), capsule straw yield (+ 0.527), morphine (+ 0.741), codeine (+ 0.998), thebaine (+0.413), papaverine (+0.314) and narcotine content (+0.901). Plant height represents significant genotypic correlation with peduncle length (+0.388) and number of capsules/plant (+0.324), suggesting that increased peduncle size would contribute to plant height and increases number of capsules. The genotypic correlation of days to maturity is significantly correlated with number of capsule (+0.296), capsule index (+0.433), morphine content (+0.388), thebaine content (+0.369) and capsule straw yield (-0.482) while, phenotypic correlation were noted significant for morphine content (+0.350), thebaine content (+0.331) and capsule straw yield (-0.313). Number of capsules represents significant genotypic correlation with morphine (-0.332), codeine (-0.319), thebaine (-0.412) and narcotine content (-0.348) that clearly indicate that increased number of capsules results in reduction of the alkaloid content. Capsule index denotes significant genotypic and phenotypic correlation with morphine content (+0.608, +0.465), thebaine content (+0.396, +0.293) whereas only significant genotypic correlation with codeine (+0.352) and narcotine content (+0.330). Capsule size is related to the amount of opium yield and morphine content (Bhandari et al., 1997; Saini and Kaicker, 1982; Yadav et al., 2014; Lahiri et al., 2018).

Straw yield shows significant genotypic and phenotypic correlation with seed yield (+0.683; +0.558). Morphine also possessed significant genotypic and phenotypic correlation with codeine (+0.612; +0.605), thebaine (+0.628; +0.625) and narcotine content (+0.378; +0.377). The positive correlation among morphine and codeine is shown previously by Bajpai et al. (2000, 2001). The codeine shows positive and significant genotypic and phenotypic correlation with thebaine (+0.480; +0.473) and narcotine content (+0.331; +0.327). Significant genotypic and phenotypic correlation estimated between thebaine and narcotine content (+0.380; +0.377) as shown in Table 5.

### 3.4. Path coefficient analysis

In light of the fact, that correlation coefficient does not consider extremely complex interrelationship between various characters, the path analysis was applied to partition correlation into direct and indirect effect. The phenotypic, as well as genotypic correlation coefficients between seed yield and different characters were subjected to path coefficient analysis separately for partitioning these values into direct and indirect effects. In the context of aforesaid species path coefficient analysis was applied by several workers (Brezinova et al., 2009; Yadav et al., 2006, 2007). The results obtained for direct and indirect effects of different characters and seed yield are summarized in Table 6 and Fig. 1. The direct effects of days to 50% flowering, plant

**Table 4**  
Genetic components and other allied genetic parameter in Opium poppy.

Parameter	Genetic variance	Phenotypic variance	GCV	PCV	Heritability	Genetic Advance
Days to 50% flowering	0.98097	23.20109	0.95254	4.63243	4.22	0.0862
Plant Height(cm)	90.19384	113.1341	10.6498	11.9175	79.72	15.5969
Peduncle length	2.17609	4.28589	6.5471	9.1883	50.77	1.5429
Days to maturity (days)	38.79620	47.72826	4.2898	4.7580	81.28	10.4297
No. of Capsule/plant	0.06978	0.317228	12.407	26.4541	21.99	0.1197
Capsule index( width/length in cm)	0.00145	0.00248	4.2122	5.5056	58.54	0.0460
Capsule straw yield (g/plant)	1.51583	2.51011	14.1150	18.1636	60.38	1.5310
Morphine content (%)	0.00067	0.00068	88.8759	88.8931	99.96	0.0535
Codeine content(%)	0.00012	0.00012	103.9961	105.1519	97.81	0.0226
Thebaine content(%)	0.000046	0.00004	101.8553	102.2961	99.13	0.0139
Papaverine content(%)	0.00012	0.00012	164.0771	164.1974	99.85	0.0234
Narcotine content (%)	0.00010	0.00010	77.6447	77.7842	99.64	0.0206
Seed yield (g/plant)	1.1367	1.54153	13.9420	16.2354	73.74	1.6190

height, days to maturity, number of capsules/plant, capsule index, straw yield, thebaine content and papaverine content on seed yield was noted positive while for peduncle length, morphine, codeine and narcotine content recorded negative. In general, all the components show either low or negligible indirect effect. The highest direct effect was exhibited by capsule straw yield and followed by days to maturity. The direct effect of days to 50% flowering on seed yield is positive (0.1246). Indirect effect via peduncle length, capsule index, capsule straw yield, thebaine content, papaverine content were positive while plant height, number of capsule/plant, morphine content, codeine content, narcotine content and seed yield

were negative. Direct effect of plant height on seed yield was recorded positive (0.1529) and indirect effect via days to maturity, number of capsule/plant, capsule index, thebaine content, papaverine content, narcotine content was positive while negatively affected by all other characters. Peduncle length shows low and negative direct effect on seed yield. Days to maturity, no of capsule per plant, capsule index, thebaine content and narcotine content exhibit positive indirect effect while capsule straw yield, morphine, codeine and papaverine content exhibit negative indirect effect. Days to maturity has a moderate positive direct effect (+0.3758) on seed yield. Capsule straw yield exhibits high and negative indirect effect along with number

**Table 5**  
Correlation coefficient among different traits in Opium poppy.

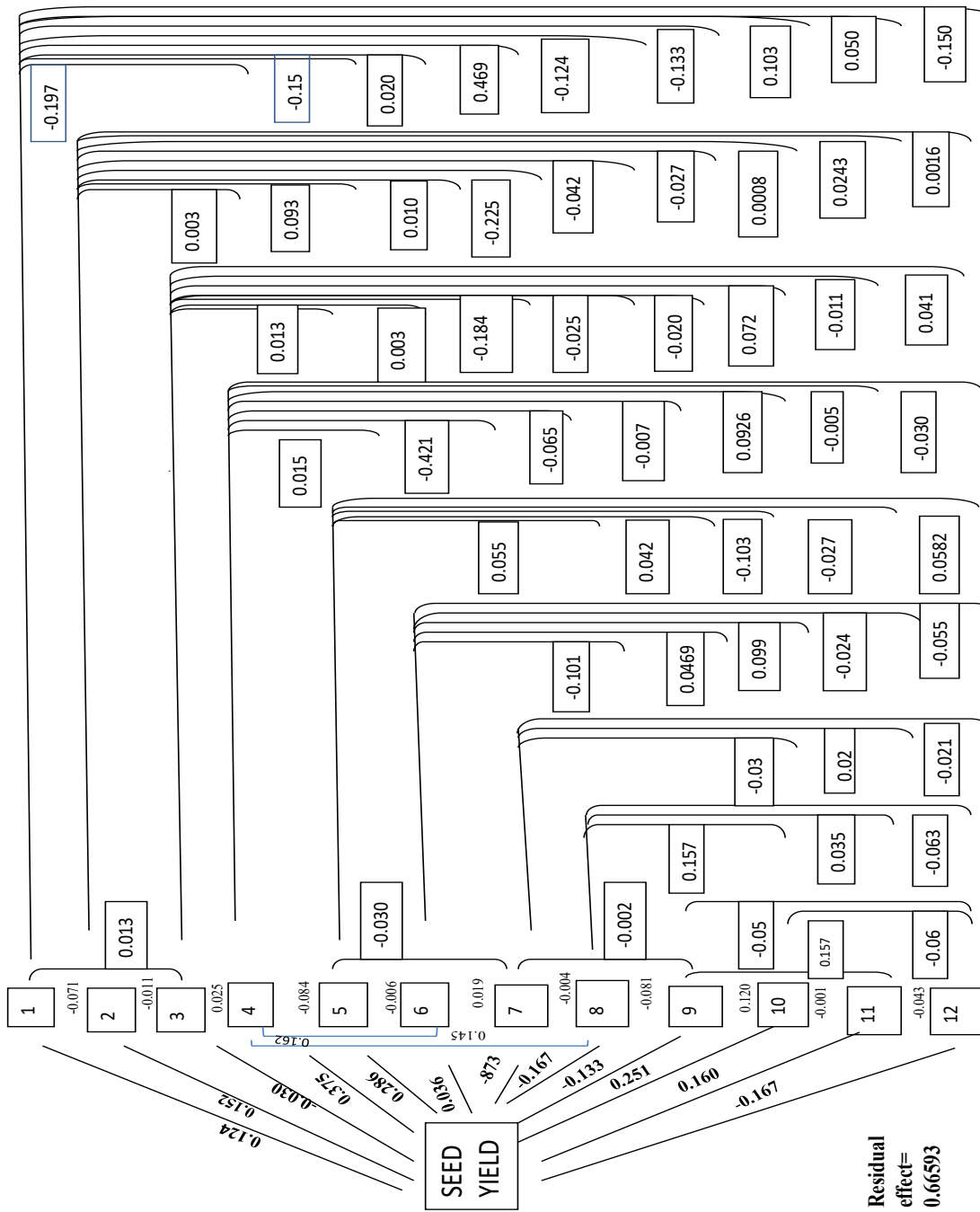
Traits	Days to flowering (50%)	Plant height (cm)	Peduncle length	Days to maturity (days)	No. of capsule/plant	Capsule index (width/length in cm)	Capsule straw yield (g/plant)	Morphine content (%)	Codeine content (%)	Thebaine content (%)	Papaverine content (%)	Narcotine content (%)	Seed yield
Days to flowering (50%)	-	-0.465** -0.074	-0.443** -0.046	-0.052 -0.120	-0.525** -0.120	0.571** 0.052	0.527** 0.231	0.741** 0.151	0.998** 0.205	0.413** 0.082	0.314* 0.059	0.901** 0.059	0.046 0.054
Plant height (cm)	0.025 1.153	-	0.388** 0.230	0.007 0.015	0.324* 0.147	0.277 0.181	-0.257 -0.195	0.251 0.223	0.204 0.194	0.003 0.000	0.151 0.137	0.0098 0.0105	0.078 0.069
Peduncle length	0.027 1.403	-0.524 1.071	-	0.067 -0.001	0.047 0.064	0.082 0.037	-0.211 -0.108	0.149 0.106	0.150 0.109	0.287 0.194	-0.070 -0.052	-0.249 -0.185	-0.111 -0.019
Days to maturity (days)	-0.054 0.807	0.047 0.411	-0.150 -22.41	-	0.296* -0.0161	0.433** 0.287	-0.482** -0.313*	0.388** 0.350*	0.0533** 0.038	0.369* 0.331*	-0.036 -0.030	0.181 0.161	-0.196 -0.150
No. of capsule/plant	-0.022 0.721	0.027 0.925	0.077 0.248	-0.095 0.774	-	-0.183 -0.016	-0.035 -0.035	-0.332* -0.158	-0.319* -0.150	-0.412** -0.189	-0.169 -0.086	-0.348* -0.154	0.145 0.009
Capsule index (width/length in cm)	-0.058 1.699	-0.027 1.043	-0.016 1.198	-0.042 1.041	0.086 3.973	-	0.022 -0.001	0.608** 0.465**	0.352* 0.279	0.396** 0.293**	-0.149 -0.115	0.330* 0.256	0.148 0.026
Capsule straw yield (g/plant)	0.236 0.370	-0.057 0.916	0.019 1.077	0.088 1.077	-0.041 0.357	-0.035 -11.69	-	0.026 0.020	0.021 0.003	-0.120 -0.101	0.163 0.128	0.127 0.096	0.683** 0.558**
Morphine content (%)	-0.38 1.004	-0.553 1.002	-0.0003 1.000	0.035 0.999	-0.114 0.987	0.0124 0.999	-0.009 1.005	-	0.612** 0.605**	0.628** 0.625**	0.222 0.221	0.378** 0.377**	0.102 0.088
Codeine content (%)	0.014 0.989	0.206 0.929	0.027 0.974	-0.137 1.227	-0.018 0.983	0.133 0.954	0.173 0.511	-0.083 1.000	-	0.480** 0.473**	0.231 0.228	0.331* 0.327*	-0.022 -0.010
Thebaine content (%)	-0.019 1.021	0.0003 -0.062	-0.139 1.04	-0.0034 1.000	0.0363 1.015	-0.144 1.029	-0.143 0.917	0.086 0.999	0.028 0.999	-	-0.0066 -0.0067	0.380** 0.377**	-0.009 -0.011
Papaverine content (%)	-0.136 1.085	-0.100 0.987	-0.078 0.959	0.114 1.061	-0.15 0.916	-0.033 0.992	0.070 0.986	-0.237 1.000	-0.029 1.000	-0.010 0.106	-	0.260 0.260	-0.009 -0.011
Narcotine content (%)	0.037 0.988	-0.010 -0.066	-0.185 -0.178	-0.072 1.011	0.162 1.055	0.107 0.983	-0.068 1.026	-0.298 1.000	0.041 0.998	-0.059 1.000	0.230 0.997	-	0.072 0.055

\*P <0.05; \*\*P <0.01, respectively; Upper GCV and lower PCV



**Table 6**  
Direct and indirect effects of different polygenic character in Opium poppy.

Traits	Days to flowering (50%)	Plant height (cm)	Peduncle length	Days to maturity (days)	No. of capsule/plant	Capsule index (width/length in cm)	Poppy straw yield (g/plant)	Morphine content (%)	Codeine content (%)	Thebaine content (%)	Papaverine content (%)	Narcotine content (%)	Seed yield
Days to flowering (50%)	0.1246	-0.0711	0.0136	-0.1970	-0.1522	0.0208	0.4690	-0.1241	-0.1332	0.1038	0.0504	-0.1509	-0.0469
Plant height (cm)	-0.0580	0.1529	-0.0119	0.0031	0.0930	0.0101	-0.2251	-0.0420	-0.0272	0.00082	0.0243	0.0016	-0.0785
Peduncle length	-0.0552	0.0594	-0.0307	0.0255	0.0136	0.00302	-0.1848	-0.0250	-0.0201	0.0721	-0.01134	0.0418	-0.1117
Days to maturity (days)	-0.0654	0.0012	-0.0020	0.3758	-0.0848	0.0157	-0.4212	-0.0650	-0.0071	0.0926	-0.0058	-0.0304	-0.1964
No. of capsule/ plant	-0.0663	0.0496	-0.0014	-0.1114	0.2861	-0.0066	-0.0306	0.0557	0.0426	-0.1034	-0.0272	0.0582	0.1451
Capsule index	0.0712	0.0424	-0.0025	0.1629	-0.0525	0.0364	0.0192	-0.1018	-0.0469	0.0995	-0.0240	-0.0552	0.1486
Poppy straw yield	0.0669	-0.0394	0.0065	-0.1813	-0.0100	0.0008	0.8730	-0.0043	-0.0029	-0.0302	0.0261	-0.0213	0.6836
Morphine content (%)	0.0924	0.0384	-0.0046	0.1459	-0.0952	0.0221	0.0227	-0.1674	-0.0817	0.1577	0.0356	-0.0634	0.1026
Codeine content (%)	0.1244	0.0312	-0.0046	0.0200	-0.0914	0.0128	0.0191	-0.1025	-0.1334	0.1205	0.0371	-0.0554	-0.0220
Thebaine content (%)	0.0515	0.0005	-0.00884	0.1386	-0.1179	0.0144	-0.1053	-0.1051	-0.06406	0.2510	-0.0010	-0.0636	-0.0098
Papaverine content (%)	0.0391	0.0231	0.00217	-0.0136	-0.0485	-0.00545	0.1423	-0.0371	-0.0309	-0.00167	0.1604	-0.0436	0.1862
Narcotine content (%)	0.1122	-0.0015	0.0076	0.0683	-0.0995	0.0120	0.1112	-0.0634	-0.0442	0.0954	0.0418	-0.1675	0.0726



**Fig. 1.** Path diagram representing direct and indirect effect of seed yield on other 12 quantitative characters of *Opium poppy*. (1: Days to flowering; 2: Plant height; 3: Peduncle length; 4: Days to maturity 5: Number of capsule; 6: Capsule index; 7: Capsule straw yield; 8: Morphine content; 9: Coedine content; 10: Thebaine content; 11: Papaverine content; 12: Narcotine content).

of capsules per plant, morphine, codeine, papaverine and narcotine content. Positive indirect effect acted by capsule index and thebaine content. The direct effect of number of capsule on seed yield is positive (0.2861). The indirect effect acted by morphine content, codeine content, narcotine content and seed yield is positive, while capsule index, capsule straw yield; thebaine and papaverine content are negative. The highest direct effect on seed yield was acted through capsule straw yield (+0.8730). The other character shows the negative indirect effect on seed yield except papaverine content whose indirect effect is low. Morphine content exhibits negative direct effect on seed yield (-0.1674). The negative indirect effect is acted by codeine and narcotine content. Codeine also exhibits negative direct effect (-0.1334). While thebaine and papaverine content shows positive indirect effect and narcotine shows negative indirect effect on seed yield. The direct effect exhibited via thebaine is positive (0.2510) while indirect effect of papaverine and narcotine is negative. Papaverine also exhibits positive direct effect on seed yield (+0.1604) while negative indirect effect is exhibited by narcotine content. Narcotine content exhibits negative direct effect (-0.1675) on seed yield.

#### 4. Concluding remarks

To conclude, the present findings illuminate various morphological, agronomical and biochemical aspects of almost unexplored 47 accessions of *P. somniferum*. The outcomes of variability, heritability and path coefficient analysis would enrich the available information on worked out plant species in public domain which possesses potential for utilization by researchers in better understanding of various factors influencing their qualitative and quantitative yield. While our findings similar to the earlier workers authenticate their work on one hand, the contrary finding also open new vistas for future research on the other hand and the identified high alkaloid and seed yielding accessions may be utilized for genetic improvement of *P. somniferum*.

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#### Conflict of interest

The authors declare that there is no conflict of interest.

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