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Short Communication

Relationship of downy mildew resistance with yield related traits helpful for achieving reliable selection criteria in opium poppy (*Papaver somniferum* L.)

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Abstract

Present study aims to understand the nature and degree of relationships between different morphometric and yield influencing traits using correlation and path coefficient analysis in medicinally important plant opium poppy. Genotypic and phenotypic correlation coefficients analysis showed significant negative correlation between downy mildew disease severity Index (DSI) and seed and straw yield. Furthermore, path analysis showed direct and positive effect of capsule diameter and number of capsule/plant to straw yield. In contrast, DSI had highest direct and negative contribution to straw yield. These results support effectiveness of selections for high seed and straw yield together with downey mildew-resistance in development of effective selection criteria for crop improvement.

Key words: Downy mildew, disease resistance, opium poppy, *Peronospora arborescens*, straw alkaloid

Opium poppy (*Papaver somniferum* L.) produces more than 80 alkaloids including pharmaceutically important morphine, codeine, papaverine, narcotine, narcine and noscapine (Winzer et al. 2012). In addition, the opium poppy is cultivated as a source of poppy seeds and seed oil, which is rich in unsaturated fatty acids (Mishra et al. 2013). Opium poppy plant is vulnerable to several fungal, bacterial and viral pathogens. Downy mildew (DM) is the most alarming and widespread fungal disease caused by an ascomycetous fungus *Peronospora arborescens*. Development of DM resistant cultivars with high seed and straw yielding traits is required for sustainable opium poppy breeding (Mishra et al. 2013). In order to develop selection criteria for developing DM-resistant and high yielding variety, the relationships among DM-resistance and yield contributing traits need to be studied. In the present study, the nature and degree of relationships between different markers and yield influencing traits including the DM-resistance are analyzed with an aim to facilitate selection strategies for development of disease resistant and high yielding varieties in opium poppy.

Thirty five different accessions of opium poppy, maintained at National Gene Bank of Medicinal and Aromatic Plants at CSIR-Central Institute of Medicinal and Aromatic Plants (CSIR-CIMAP), Lucknow, India, were used in this study. The field experiments were conducted in randomized block design during three consecutive years (2004-05 to 2006-07) at the experimental field station of CSIR-CIMAP and also under glasshouse conditions. Field experiments were performed in three replicates (plot size 4m×4m per replication with rows 40 cm apart, plant to plant spacing 10 cm) and for glasshouse experiments, the seeds were sown in 25cm diameter earthen pots in four replications (three replications for treatment and one replication as control). Ten plants per pot were maintained after thinning the 15 days old plants. The

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data of various morphometric traits and DM disease reaction was recorded on ten plants of each replication in field trials; however, pot experiment under glasshouse conditions was used only for DM screening.

DM disease reaction was scored in field trial and under glasshouse conditions on ten opium poppy plants (total 30 plants in three replicates) at flowering stage by scoring the severity of necrotic spots on the leaves. Preparation of *Peronospora arborescens* inoculums, scoring of disease severity and calculation of disease severity index (DSI) was done as described before (Dubey et al. 2009a; Dubey et al. 2009b; Dubey et al. 2010; Alam et al. 2014). Correlation coefficients among yield contributing traits such as plant height, leaf area (third leaf from top; cm^2), number of capsules per plant, number of stigmatic rays per capsule (central capsule), capsule diameter (central; cm), capsule length (central; cm), straw yield per plant (g), seed yield per plant (g) and DSI for DM- resistance in field and glasshouse for each accession were calculated according to the method of Miller et al. (1958), whereas co-heritability of a pair of characters was calculated by using the method of Hazel (1943). Path coefficient was calculated according to Dewey and Lu (1959) selecting straw yield as dependent variable and the nine plant characteristics (mentioned above) as independent variables.

Mean values of the data recorded during 2004-05, 2005-06 and 2006-07 field trials for 10 different marker and yield contributing traits for each accession were used for analysis. On the basis of the mean DSI values obtained from the trial in glasshouse and field conditions, 35 genotypes of opium poppy are classified into highly resistant (0.00-12.21), resistant (12.22-33.33), tolerant (33.34-55.55), susceptible (55.56-77.77), and highly susceptible (77.78-99.99) groups (Table 1).

Coefficients of genotypic correlations (rg) and phenotypic correlations (rp) were computed using mean data of field trials to estimate the degree of linear associations among various selected morphometric traits (Table 2; above diagonal). Most of the correlations were found to be significant. With regard to correlations expressed in terms of character associations, both positive and negative associations were observed among all the traits at genotypic and phenotypic level. The phenotypic and genotypic correlations were of same sign, though, genotypic correlation values were somewhat higher than the phenotypic values in most cases. This suggested that there was strong inherent correlation among the selected traits and influence of the environment on these correlations was minimal.

Table 1. Categorization of germplasm lines on the basis of disease severity index for downy mildew resistance under glasshouse and field conditions

Category	Glasshouse conditions	Field conditions
Highly Resistant (HR)	I-14, Pps-1	I-14, Pps-1
Resistant (R)	N-3, Rakshit, T-210, T-850, T-849, T-1018	N-3, Rakshit, T-210, T-850, T-849, T-1018
Tolerant (T)	Ib-38, IS-18, IS-22, I-267, I-295, I-299, I-302, I-303, I-311, I-318, I-332, I-344	Ib-38, IS-18, IS-22, I-267
Susceptible (S)	H-9, SPS-23, Shweta Broad, Sanchita, Shubhra, Shyama, Thailand, I-48, I-264, I-266, I-293, I-294, I-309, Y-ims	H-9, SPS-23, Shweta Broad, Sanchita, Shyama, I-48,I-264, I-266, I-293,I-294, I-295, I-299, I-302, I-303, I-309, I-311, I-318, I-332, I-344,Y-ims
Highly Susceptible (HS)	Jawahar-16	Jawahar-16, Shubhra, Thailand

Genotypes were classified on the basis of disease severity index (DSI) which was calculated as per the disease score taken on 0-9 scale on 10 individual plants in each replication. DSI 0-12 = highlyt resistant (HR), DSI 12-33 = resistant (R), DSI 34-55 = tolerant (T), DSI 56-77 = susceptible (S) and DSI 78-100 = highly susceptible (HS)

The DSI for DM-resistance showed negative correlation with all the traits considered in this study with the exception of seed and straw yield per central capsule (Table 2; above diagonal). This illustrates that while making selections for high seed and straw yield, emphasis should be given not only to these morphometric traits but also to the DM resistance or susceptibility. The significant positive correlation between seed and straw yield with remaining traits indicated that these are genetically dependent on each other and therefore could be improved by selecting unanimously or individually. In order to investigate the co-inheritance pattern, co-heritability of different pairs of characters was studied. Higher co-heritability values were found between all the characters studied (Table 2; below diagonal), which suggested that increase in one of the characters would couple with an increase in its co-heritable characters.

Table 2. Genotypic (rg) and phenotypic (rp) correlations (above diagonal), and co-heritability (below diagonal and bold) of 10 economic traits of opium poppy[a]

Morphomatric traits[a]		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)	(rg)		0.813**	0.759**	0.766**	0.673**	0.410*	-0.032	-0.235	0.787**	0.706**
	(rp)		0.804**	0.749**	0.468**	0.625**	0.407*	-0.033	-0.213	0.781**	0.699**
(2)		**0.998**		0.829**	0.841**	0.700**	0.411*	0.028	-0.144	0.790**	0.754**
				0.820**	0.525**	0.650**	0.408*	0.027	-0.136	0.783**	0.746**
(3)		**1.000**	**0.999**		0.881**	0.762**	0.497**	-0.046	-0.209	0.865**	0.724**
					0.562**	0.711**	0.495**	-0.045	-0.196	0.860**	0.719**
(4)		**1.000**	**0.994**	**0.973**		0.703**	0.627**	-0.179	-0.415*	0.818**	0.779**
						0.382*	0.393*	-0.110	-0.237	0.507**	0.480**
(5)		**1.000**	**0.994**	**0.998**	**1.000**		0.178	-0.150	-0.310	0.875**	0.651**
							0.167	-0.140	-0.289	0.818**	0.610**
(6)		**0.999**	**1.000**	**0.997**	**0.996**	**1.000**		-0.252	-0.213	0.436**	0.648**
								-0.251	-0.199	0.435**	0.643**
(7)		**0.970**	**1.010**	**1.000**	**1.000**	**0.998**	**0.997**		0.907**	-0.224	-0.347*
									0.847**	-0.224	-0.345*
(8)		**1.000**	**0.987**	**0.992**	**1.000**	**0.946**	**1.000**	**1.000**		-0.329*	-0.358*
										-0.307	-0.331*
(9)		**1.000**	**1.000**	**0.999**	**1.000**	**0.999**	**1.000**	**0.998**	**1.000**		0.847**
											0.843**
(10)		**1.000**	**0.999**	**0.997**	**1.000**	**0.996**	**1.000**	**0.999**	**1.000**	**1.000**	

* and ** significant value at 5% and 1% level of significance, respectively. [a]1 = Number of stigmatic rays on central capsule; 2 = Leaf area (cm^2) of third leaf from top; 3 = Capsule length (cm) of central capsule; 4 = Capsule diameter (cm) of central capsule; 5 = Number of capsules/plant; 6 = Plant height (m); 7 = DSI (%) in glasshouse; 8 = DSI (%) in field; 9 = Seed yield (g)/capsule (central) and 10 = Straw yield/capsule (central)

Table 3. Direct (in bold) and indirect effects of yield contributing traits on straw yield per central capsule

Morphomatric traits[a]	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	r(g)
(1)	**0.7966**	-0.4956	-0.5591	2.3759	0.0960	-0.3660	0.1108	-0.8611	-0.3914	0.7063
(2)	0.6479	**-0.6093**	-0.6106	2.6087	0.0998	-0.3670	-0.0960	-0.5271	-0.3925	0.7538
(3)	0.6046	-0.5050	**-0.7366**	2.7329	0.1087	-0.4432	0.1577	-0.7649	-0.4300	0.7240
(4)	0.6103	-0.5125	-0.6491	**3.1013**	0.1002	-0.5594	0.6122	-1.5173	-0.4068	0.7789
(5)	0.5364	-0.4265	-0.5614	2.1792	**0.1426**	-0.1591	0.5128	-1.1372	-0.4349	0.6519
(6)	0.3268	-0.2506	-0.3660	1.9445	0.0254	**-0.8922**	0.8592	-0.7822	-0.2170	0.6479
(7)	-0.0259	-0.0171	0.0340	-0.5560	-0.0214	0.2245	**-3.4148**	3.3185	0.1114	-0.3467
(8)	-0.1874	0.0878	0.1539	-1.2858	-0.0443	0.1906	3.6598	**-3.0963**	0.1634	-0.3582
(9)	0.6272	-0.4810	-0.6372	2.5376	0.1247	-0.3894	0.7657	-1.2033	**-0.4972**	0.8471

Residual effect = 0.218 [a]1 = Number of stigmatic rays on central capsule; 2 = Leaf area (cm^2) of third leaf from top; 3 = Capsule length (cm) of central capsule; 4 = Capsule diameter (cm) of central capsule; 5 = Number of capsules/plant; 6 = Plant height (m); 7 = DSI (%) in glasshouse; 8 DSI (%) in field) and 9 = Seed yield (g)/capsule (central)

The genetic correlations were further explored using path coefficient analysis. Path analysis showed that capsule diameter contributed directly and positively to the straw yield to the highest extent followed by number of stigmatic rays and number of capsules/plant (Table 3). Despite that, all other traits except DSI were found to contribute indirectly to straw yield through capsule diameter and number of capsules

/plant. DSI showed highest direct and negative contribution to the straw yield and also indirect and negative contribution to capsule diameter, number of stigmatic rays on central capsule and number of capsules/plant. Furthermore, characters like seed yield, straw yield, DSI for DM-resistance, stigmatic rays on central capsule and capsule diameter interacted very well together as it was evident by strong genotypic and phenotypic associations, and also have appreciable influence directly and indirectly towards straw yield due to positive and negative associations among them. Taking together results showed that the traits mentioned above, either in co-operation or simultaneously are reliable components for opium poppy breeding for selection of high seed- and straw-yielding genotypes with downy mildew resistance.

In conclusion, this study suggests for the utilization of effectiveness of correlations and path analysis in developing reliable selection criteria in opium poppy. Utilization of distinct marker traits such as stigmatic rays and capsule diameter as selection criteria can greatly help in the development of high yielding and DM-resistant varieties in opium poppy.

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