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DISCRIMINANT FUNCTION ANALYSIS FOR OPIUM AND SEED YIELD IN OPIUM POPPY (*Papaver somniferum* L.)

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Opium poppy (*Papaver somniferum* L.) is an important medicinal plant of pharmacopoel uses. Opium latex and its derivatives are used in different medicines as analgesic, narcotic, sedative, sudorific, hyponitic, antispasmodic, ant diarrhea and cough etc. Genetic improvement in opium and seed yield, component breeding is important and selection based on multiple characters is more beneficial in developing desired plant types. Therefore the present study was made on group of 22 strains of opium poppy to find out variability and suitable selection indices for opium and seed yield. Heritability in broad sense was high for capsule weight/plant, plant height, capsule length, stem diameter and opium yield. The discriminant functions based on single character were less efficient while on the basis of combination it was in general more efficient. The comparison of different functions revealed

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that capsule weight/plant, capsule length, plant height are major yield component and thus practicing selection for attainment of high opium and seed yield lines, maximum weight age could be given to these characters. The positive association of opium yield and seed yield suggested that by adopting suitable component breeding and selection, a dual-purpose variety (opium and seed yield) may be developed.

Key words: Discriminant, Opium, Relative efficiency index, Selection index, Variability,

INTRODUCTION

The opium poppy (*Papaver somnifeurm* L.) is an important crop of pharmacopoel uses. Opium is one of the oldest known pain killer and is source of several alkaloids used for analgesic, hypnotic, sedative, antispasmodic, antitussive & sudorific purpose in modern medicine. Morphine is the major alkaloid present in opium ranges from 7-17% mainly used to relieve from almost all type of severe pains. Other important alkaloids are codeine (2.1-4.4%) used as mild analgesic, respiratory sedative; thebaine (1.0- 3.0%) is used as analgesic & sedative; papaverine (0.5- 3.0%) is used as antispasmodic and also have strong effect on blood vessel & abdominal viscera and narcotine (3.0-10.0%) is beneficial in allaying cough & headache. Beside this, the seeds and seeds oil with no narcotic effect, are also very useful due to high nutritional value (protein up to 24%) and high amount of linoleic acid (SINGH *et. al*. 1995a, 1998a), which helps in lowering blood cholesterol in human system.

Considering the importance of the crop for medicinal aspects, sufficient genetically studies have been done on its basic and applied aspects on selected genotypes (SINGH *et. al.* 1995b, 1997, 1998b; SHUKLA and SINGH 1999, 2000, 2001) as a result some improved varieties have been developed for high latex and morphine percentage. India is one of the largest producer and supplier of opium and its alkaloids to meet the world demand in medicinal use. Opium poppy varieties developed so far are primarily rich in morphine with low thebaine (SINGH *et. al.* 1999). The global consumption of morphine has steadily increased from 2 MTs in 1981-83 to a level of more than 20 MTs in 1998-2000. Similarly the consumption of codeine has increased from 160 MTs in 1981-82 to 169 MTs in 2002, while the demand of the thebaine is increasing as this alkaloid is used as important material for the manufacturing a number of opiates, namely oxycodone, oxymorphine, buprenorphine etc. Its global utilization has increased from level of 5-8 MTs during the period of 1981-1994 to 45.6 MTs in 2000. The demand for all the three alkaloids codeine, morphine and thebaine is on the rise in the international market and the sharpest increase is in respect of thebaine (ANONYMOUS 2002). For improvement in opium and seed yield, component breeding is important and selection based on multiple characters is more beneficial in developing desired plant types. The theory of selection indices is based on the concept of manipulating several attributes simultaneously (SMITH 1936; HAZEL

1943; BRIM *et. al.* 1959; SINGH and BELLMAN 1974) and has definitely proved advantageous over the selection for individual characters (HAZEL and LUSH 1942; ROBINSON *et. al.* 1951; YOUNG and WEILER 1961; SINGH and SINGH 1980). This would probably be much more effective than any other system of selection involving either level of culling or arbitrary choice in the genetic improvement of complex characters or group of characters in crop plant. Therefore in present set of material the utilization of appropriate selection procedure based on selection indices was used for economic traits contributing to opium and seed yield in opium poppy (*Papaver somniferum* L.).

MATERIAL AND METHOD

The present studies were confined to 22 genotypes developed through different breeding programs (SINGH *et. al*. 1999). These 22 selections were evaluated in randomized block design with 4 replications during 2000-2001 under Initial Evaluation Trial. Each block consisted of 22 plots with six rows per plot. The rows were 3 meter long. The spacing was 30 cm between rows and 10 cm within rows. Non-experimental rows were planted to check the border effects. Ten plants of each treatments per replication were selected at random before flowering to record observations on plant height (cm), leaves/plant, capsules/plant, stem diameter (cm), capsule diameter (cm), capsule length (cm), capsule weight/plant (g), seed yield/plant (g), husk yield/plant (g), opium yield/plant (g) and morphine percentage.

Plot means per replication were used for statistical analysis. The coefficient of variability, and heritability were estimated according to JOHNSON *et. al*. (1955). The selection indices were estimated according to BRIM *et. al.* 1959, using phenotypic and genotypic variances and co-variances. Expected genetic advance of each index was calculated at 5% intensity level. Relative efficiency indices were calculated as -

RI = {GA (D)/GA (S)} x 100
Where as
RI = Relative efficiency indices.
GA (D) = Genetic advance through discriminant function
GA (S) = Genetic advance through straight selection.

RESULTS AND DISCUSSION

Analysis of variance of 22 treatments was significantly different for all the 10 characters indicating that genotypes possess much variability and thus further genetic study is warranted.

Variability

As analysis of variance showed no difference among the blocks, the data from all the four replications were pooled. The plant height and leaves/plant varied from 89.10 (BR241) to 123.98 (BR 234) and 14.55 (BR 241) to 18.90 (BR227) with arithmetic mean of 109.75 $\pm$ 2.12 and 16.71 $\pm$ 0.59, respectively. Capsule weight/plant was variable between 6.98g (BR 241) to 14.23g (BR234) with average capsule weight of 9.73 $\pm$ 0.43. Capsule diameter and capsule length ranged from 3.65 to 4.36 cm and 3.03 to 4.00 cm respectively. Seed yield/plant was variable between 3.50g (BR 241) to 7.45g (BR 234). Only 8 genotypes out of 22 were higher yielder than arithmetic mean (5.23 $\pm$0.39). Opium yield/plant varied from 0.17g to 0.33g and considering the arithmetic mean, 11 genotypes were high yielder than arithmetic mean (0.22 $\pm$ 0.02). The morphine, which is main component of opium, was variable between 12.82 to 17.80% with arithmetic mean of 15.13 $\pm$ 0.66. Variability among population would help a great deal in detecting the range of genetic diversity for various traits in population. A wide range of variability was noticed for opium yield, seed yield and other component characters. The variability was maximum for capsules/plant (20.7 %) followed by opium yield (20.5%), seed yield/plant (17.5%) and capsule weight/plant (17.5%). Lowest variability was noticed for leaves/plant (6.5%) followed by plant height (7.1%) (Table 1). However, variability alone is not much helpful in determining the heritable portion of variation. BURTON (1952) suggested that the amount of advance to be expected from selection could be obtained by studying coefficient of variability along with heritability. Heritability estimate in broad sense ranged from 61.8 to 88.5 percent. The maximum heritability was noticed for capsule weight/plant (88.5%) followed by plant height (87.0%), capsule length (85.60%), stem diameter (79.3%) and opium yield (78.9%) indicates that these characters are under genotypic control. Low heritability for husk yield/plant (61.8%) and leaves/plant (63.2%) suggested the major role of environmental effect.

Discriminant Function

Selection indices were considered for opium and seed yield/plant separately based on 11 characters under study. In formulating selection index opium yield and seed yield were taken dependent as well as independent variables while others 9 characters were considered as independent variables. Different functions, their relative efficiencies over straight selection are presented in table 2a, b.

The magnitude of straight selection and discriminant function was equal when only opium yield and seed yield was included in selection index. Considering individual independent traits, the estimates of relative efficiencies were low as compared to selection of opium and seed yield. This ranged from 0.25 to 5.61 percent for seed yield and 0.005 to 0.47 percent for opium yield. The result indicated that there was no substantial gain through discriminant function for opium yield when either yield/plant or its individual contributing characters were taken separately. Thus it is emphasized that selection for yield or its components individually does not to be efficacious.

Table 1: Variability and mean values of different morphological traits in opium poppy.

Sl. No.	Genotypes	Plant height (cm)	Leaves/ plant	Capsule/ plant	Capsule diameter (cm)	Capsule Length (cm)	Capsule wt/plant (g)
1	BR226	111.50	17.05	2.38	3.94	3.03	9.12
2	BR227	114.32	18.90	1.90	3.86	3.26	9.38
3	BR228	115.95	17.02	1.35	3.91	3.36	7.82
4	BR229	107.97	17.30	1.55	3.66	3.45	8.55
5	BR230	109.57	17.80	2.40	3.76	3.51	11.20
6	BR231	115.90	17.38	1.97	3.96	3.42	10.05
7	BR232	109.32	16.33	1.65	3.65	3.46	8.85
8	BR233	117.15	16.48	2.12	4.36	3.50	11.30
9	BR234	123.98	18.12	2.88	3.98	3.83	14.23
10	BR235	112.57	15.72	2.00	4.04	3.65	10.15
11	BR236	115.15	16.48	1.65	3.70	4.00	8.85
12	BR237	110.15	15.30	2.40	3.93	3.88	10.65
13	BR238	111.57	15.40	2.22	3.98	3.74	11.62
14	BR239	100.75	16.28	1.65	3.65	3.79	8.15
15	BR240	96.40	15.50	2.38	3.66	3.55	8.35
16	BR241	89.10	14.55	2.57	3.87	3.40	6.98
17	BR242	103.98	17.00	3.02	4.36	3.33	12.93
18	BR243	99.67	14.83	2.10	4.08	3.53	8.73
19	BR244	111.48	18.62	1.90	3.96	3.25	9.50
20	BR245	119.15	17.65	1.47	3.93	3.94	9.02
21	BR246	107.07	16.48	1.67	4.18	3.31	8.12
22	BROP-1	111.85	17.38	2.22	3.78	3.42	10.62
X (Mean)		109.75	16.71	2.067	3.91	3.53	9.73
SE		2.12	0.59	0.17	0.15	0.13	0.43
GCV (%)		7.1	6.5	20.7	4.43	6.54	17.5
Heritability%		87	63.2	76.1	71.34	85.60	88.5

Table 1 continued: Variability and mean values of different morphological traits in opium poppy.

Sl. No.	Genotypes	Stem diameter (cm)	Seed yield/ Plant (g)	Husk yield /plant (g)	Opium yield /plant (g)	Morphine (%)
1	BR226	1.04	4.61	4.50	0.21	14.95
2	BR227	1.10	5.02	4.35	0.17	17.15
3	BR228	1.23	4.59	3.23	0.17	15.35
4	BR229	1.10	5.02	3.54	0.24	15.60
5	BR230	1.12	6.70	4.50	0.25	12.85
6	BR231	1.14	4.96	5.09	0.18	13.60
7	BR232	0.99	4.66	4.18	0.14	15.15
8	BR233	1.18	5.64	5.67	0.27	16.48
9	BR234	1.24	7.45	6.78	0.23	15.67
10	BR235	1.05	5.05	5.10	0.19	16.17
11	BR236	1.06	4.62	4.25	0.21	17.25
12	BR237	1.08	6.20	4.46	0.23	14.30
13	BR238	1.15	5.90	5.73	0.26	12.82
14	BR239	1.09	4.61	3.53	0.24	14.00
15	BR240	1.04	4.26	4.10	0.33	13.08
16	BR241	0.94	3.50	3.99	0.19	16.17
17	BR242	1.19	6.90	5.68	0.21	16.35
18	BR243	1.01	4.92	3.81	0.16	15.30
19	BR244	0.99	5.36	4.14	0.24	14.95
20	BR245	1.07	5.11	3.92	0.19	17.80
21	BR246	1.00	4.11	4.05	0.25	13.50
22	BROP-1	1.10	5.91	4.73	0.31	14.48
X (Mean)		1.08	5.23	4.52	0.22	15.13
SE		0.03	0.39	0.44	0.02	0.66
GCV (%)		7.2	17.5	17.4	20.5	9.0
Heritability%		79.3	72.8	61.8	78.9	68.3

Table 2a: Selection index, genetic advance and relative efficiency indices for seed yield in opium poppy.

Sl. No.	Selection index (b Value)	GA (S)	GA (D)	RSE
1	0.000 x8	30.78	0.00	0.00
2	0.052 x1		0.899	2.92
3	0.224 x2		0.636	2.06
4	0.960 x3		0.972	3.15
5	6.597 x4		1.192	3.87
6	1.179 x5		0.499	1.62
7	1.643 x6		0.844	2.74
8	0.462 x7		1.726	5.61
9	0.598 x9		1.244	4.04
10	3.461 x10		0.363	1.18
11	–0.023 x11		0.079	0.25
12	1.220 x8 + 0.859 x1		4.201	13.64
13	0.864 x8 + 0.675 x2		2.070	6.72
14	0.722 x8 + 0.99 x3		1.883	6.12
15	0.637 x8 + 3.108 x4		1.715	5.57
16	1.191 x8 –0.516 x5		1.776	5.77
17	0.7014 x8 + 1.391 x6		1.762	5.72
18	0.321 x8 +1.187 x7		2.966	9.64
19	0.934 x8 + 0.767 x9		2.305	7.49
20	0.725 x8 + 1.448 x10		1.625	5.28
21	0.862 x8 + 0.746 x11		1.817	5.90
22	1.51 x8 + 0.83 x1 -0.073 x3		4.271	13.87
23	1.054 x8 + 0.840 x1 + 6.09 x4		4.252	13.81
24	0.283 x8 + 0.859 x1 + 1.55 x7		4.876	15.84
25	1.28 x8 + 0.852 x 1 + 1.163 x9		4.557	14.80
26	0.696 x8 + 0.925 x3 + 1.88 x4		1.948	6.33
27	0.337 x8 + 0.836 x3 + 1.195 x7		3.119	10.13
28	0.943 x8 + 0.944 x3 + 0.750 x9		2.496	8.11
29	0.246 x8 + 4.232 x 4 + 1.138 x7		3.021	9.82
30	0.874 x8 + 2.693 x4 + 0.729 x9		2.362	7.67
31	1.471 x8 + 0.971 x6 –0.720 x9		3.105	10.08
32	0.926 x8 + 0.852 x1 + 0.149 x3 + 8.589 x4		4.30	13.97
33	0.4017 x8 + 1.21 x7 – 0.611 x5 +0.525 x6		3.058	9.93

x1= Plant height, x2= No. of leaves/plant, x3= Capsules/plant, x4= Stem diameter, x5= Capsule diameter, x6= Capsule length, x7= Capsule weight/plant, x8 =seed yield/plant, x9= Husk yield/plant, x10=opium yield, x11=Morphine content.

Table 2b. Selection index, genetic advance and relative efficiency indices for opium yield in opium poppy.

Sl No.	Selection index	GA (S)	GA (D)	RSE
1	0.000 x10	36.36	0.000	0.000
2	0.00061 x1		0.0106	0.029
3	–0.00074 x2		0.0021	0.005
4	0.0237 x3		0.0239	0.065
5	0.0649 x4		0.0117	0.032
6	–0.033 x5		0.014	0.038
7	0.0578 x6		0.0297	0.082
8	0.0055 x7		0.0204	0.056
9	0.0078 x8		0.0172	0.470
10	0.00725 x8		0.0151	0.041
11	–0.0112 x11		0.0384	0.106
12	0.538 x10 + 0.871 x1		0.405	1.110
13	–1.81 x10 + 0.633 x2		0.232	0.637
14	1.261 x10 + 0.0754 x3		0.171	0.470
15	0.857 x10+ 0.805 x4		0.0966	0.270
16	–0.191 x10 – 0.678 x5		0.0483	0.133
17	0.939 x10 + 0.856 x6		0.1316	0.362
18	1.26 x10 + 0.885 x7		0.280	0.772
19	1.480 x10 + 0.725 x8		0.202	0.556
20	1.847 x10 + 0.610 x9		0.188	0.519
21	4.165 x10 +0.641 x11		0.348	0.995
22	1.23 x10 + 0.759 x3 + 1.144 x4		0.178	0.490
23	4.588 x10 + 3.331 x3 + 0.307 x7		0.313	0.860
24	1.335 x10 + 2.656 x4 + 0.836 x7		0.285	0.780
25	1.473 x10 + 3.241 x4 + 0.625 x8		0.209	0.570
26	1.742 x10+ 2.593 x4 + 0.553 x9		0.196	0.538
27	1.10 x10 + 1.308 x7 + 0.139 x8		0.339	0.932
28	1.569 x10 + 1.160 x3 + 0.540 x9		0.242	0.668
29	1.419 x10 + 0.99 x3 + 0.717 x8		0.253	0.690
30	1.234 x10 + 1.291 x7 – 0.030 x9		0.332	0.920
31	0.903 x10 + 0.933 x8 + 0.7689 x9		0.260	0.716
32	–1.98 x10 + 1.21 x7 + 4.52 x5+ 0.377 x6		0.237	0.650
33	-8.68 x10 + 2.83 x7 + 3.94x5 + 0.64 x8		0.378	1.040
34	5.56 x10 + 1.37 x7 – 2.38 x6 + 0.097 x8		0.349	0.950

x1= Plant height, x2= No. of leaves/plant, x3= Capsules/plant, x4= Stem diameter, x5= Capsule diameter, x6= Capsule length, x7= Capsule weight/plant, x8 =seed yield/plant, x9= Husk yield/plant, x10=opium yield, x11= Morphine content

. Selection criterion based on multiple characters would be more effective and could be worthwhile in obtaining the rapid progress of opium and seed yield. It is also clear that selection based on more than one character, which did not include yield, also showed decline in relative efficiency (SINGH and SINGH 1980). Considering the criterion the selection indices were computed for 22 and 23 different combinations among two or more than two characters each for seed yield and opium yield respectively. ROBINSON (1951) indicated that relative efficiencies of discriminant function were increased in maize when yield was included in selection index. In present investigation too when yield (opium or seed) was taken into consideration along with their component traits, the relative efficiency of discriminant function was higher over straight selection and ranged from 5.28 percent to 15.84 percent for seed yield and 0.27 percent to 1.11 percent for opium yield. When two characters included in selection, the combination including seed yield and plant height (13.64%) was most efficient followed by seed yield and capsule weight/plant (9.63) and seed yield and husk yield (7.49%). When function was constructed for 3 characters, the function including seed yield + plant height + capsule weight/plant had maximum efficiency (15.84%) followed by seed yield + plant height + husk yield (14.80%) and seed yield + plant height + capsules/plant (13.87) (Table 2a). This indicates that for increased seed yield, the characters i.e. medium plant height, more capsule weight/plant, husk yield/plant and medium capsule width and capsule length should be considered to develop a novel plant type, since, these characters are positively correlated with yield and among themselves (SHUKLA and KHANNA 1987; SINGH and KHANNA 1993).

For opium yield, index including opium yield and plant height gave maximum relative efficiency (1.11%) in two character combinations followed by opium yield and morphine content (0.995%) and opium yield and capsule weight (0.772%). When three characters were taken in selection index the combination opium yield + capsule weight + seed yield had maximum relative efficiency (0.932%) followed by opium yield + capsule weight + husk yield (0.92%) and opium yield + seed yield + husk yield (0.716%) (Table 2b).

From above study this may be concluded that maximum gain for opium yield can be achieved for making selection of relatively big capsules with more weight, high seed yield and husk yield. A positive correlation of opium yield with seed yield, capsule diameter and length and husk yield reported earlier (SHUKLA and KHANNA 1987; SINGH and KHANNA 1993), is in conformity of present findings. Since, seed yield and opium yield is positively correlated with each, the emphasis should be given to develop dual-purpose varieties. It may therefore be suggested that characters, capsule weight, husk yield and capsule number/plant should be given due weight age in component breeding program to develop an ideal plant type for high opium and seed yield in opium poppy.

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ANALIZA DISKRIMINANTNE FUNKCIJE ZA OPIJUM I PRINOS SEMENA OPIJUMSKOG MAKA (*Papaver somniferum* L.)

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I z v o d

Opijumski mak (*Papaver somniferum* L.) je značajna biljka u farmakološkom korišćenju u medicini. Opijumska tečnost i njeni derivati se koriste kao komponente različitih lekova kao što su analgetici, narkotici, sedativi, hiponitici, antispazmici, lekovi za diareu, kašalj itd. U cilju genetičkog poboljšanja kvaliteta opijuma i povećanja prinosa značajno je oplemenjivanje na pojedine komponente i selekcija koja se zasniva na multiplim osobinama daje bolje rezultate u razvoju željenog tipa biljke. Rezultati istraživanja prikazani u ovom radu su dobijeni ispitivanjem 22 sorte opijumskog maka sa ciljem utvrđivanja varijabilnosti i pogodnih selekcionih pokazatelja za prinos opijuma i semena. Heritabilnost u širem smislu je bila visoka za težinu kapsula po biljci, visinu biljke, dužinu kapsule, prečnik drške i prinos opijuma. Diskriminantne funkcije bazirane na pojedinačnim osobinama su manje efikasne u odnosu na diskriminantne funkcije zasnovane na kombinaciji više osobina. Poređenje različitih funkcija potvrđuje da su težina kapsule po biljci, dužina kapsule i visina biljke glavne komponente prinosa. Zbog toga se proces selekcije linija na visok sadržaj opijuma i prinos biljaka mora zasnivati na navedenim komponentama prinosa. Pozitivna korelacija svojstva prinosa opijuma i prinosa semena sugeriše da se selekcijom na ove komponente prinosa mogu razviti sorte sa visokim prinosom opijuma uz visok prinos semena.

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