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Evaluation of *makoi* (*Solanum nigrum* L.) germplasm for growth, yield and quality

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Abstract

Evaluation of seventeen genotypes of *makoi* (*Solanum nigrum* L.) revealed maximum dry herbage yield in MG-1 (209.07 g) followed by MG-14 (161.73 g). While, for total alkaloid content the genotype MG-13 (0.23 % w/w) recorded highest followed by MG-16 (0.22 %w/w). The genotype MG-14 had maximum total alkaloid yield (12.26 kg ha^{-1}) followed by MG-13 (11.91 kg ha^{-1}). Result of genetic studies revealed that phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the traits studied, indicating environmental influence on expression of these characters. Both GCV and PCV were high for total alkaloid yield, moderate to high for remaining traits and low for days to maturity. High heritability coupled with high genetic advance was recorded for leaf area, total alkaloid content and total alkaloid yield indicating the presence of additive gene effects. Hence, selection can be employed for improvement of these characters in *makoi*. Dry herbage yield per plant was found to be positive and highly significant genotypic association with fresh herbage yield, leaf area, number of leaves, plant spread and plant height and significant with total alkaloid content. The total alkaloid yield had positive and highly significant genotypic correlation with total alkaloid content. The total alkaloid yield had the maximum direct positive effect on dry herbage yield followed by number of leaves and fresh herbage yield. The total alkaloid content and dry herbage yield had the maximum direct effect on total alkaloid yield.

Key words: Germplasm, growth, heritability, makoi, quality, yield.

Introduction

Black nightshade or *makoi* (*Solanum nigrum* Linn.) is an economically important medicinal crop belonging to the family Solanaceae. The leaves, immature green berries as well as whole herb are medicinally important and known to contain steroidal glyco–alkaloids solamargine and solasodine (Anonymous,1972). Besides, the herb also possesses two steroidal saponins nigrumnins- I & II (Tsuyoshi *et al.*, 2000). The juice of the leaf is effective in the treatment of cirrhosis of liver and haemoptesis and to alleviate pain in inflammation of the kidneys and bladder and also serves as an antidote in opium poisoning. Leaves are used as green or poultice over rheumatic and gouty joints and also a remedy for chronic skin ailments (psoriasis and ringworm). Berries are considered to posses tonic, diuretic and cathartic properties and are useful in anasarca and heart diseases. It is gaining importance among farming community and the phyto-pharmaceutical industry due to its high medicinal values and is used in many *Ayurvedic* formulations. Owing to its innumerable medicinal uses the demand for this herb seems to be increasing but commercial cultivation of crop to cope up the demand, genetically stable and high dry herbage and alkaloid yielding genotypes are not identified or developed as yet.

Genetic improvement of *makoi* largely depends on germplasm collection and assessment of magnitude of genetic variability existing in the material for quantitative as well as qualitative characters and their inter relationship which is an essential pre-requisite to formulate and accelerate the conventional breeding programme for achieving higher yield with better quality. Most of the economic traits including yield are polygenically controlled and are highly influenced by environmental factors. Therefore, improvement of such traits is determined by the magnitude and prevalence of genotypic and phenotypic variability. This necessitates the partitioning of observed phenotypic variability into heritable and non heritable components with suitable genetic parameters such as genotypic coefficient of variation, heritability and estimation of genetic advance which enables the selection of a genotype on a sound genetic basis. For successful selection, it is necessary to study the nature of association of the trait of interest with other relevant traits and also the genetic variability available for these. Path coefficient provides a better index for selection than mere correlation coefficient thereby separating the correlation coefficient of yield, quality and its components into direct and indirect effects. Information on genetic variability, character association and path co-efficient analysis which are indispensable in crop improvement programme is not available for *mokai*. Therefore, the present study was undertaken to understand the nature and magnitude of variability heritability and correlation coefficient for different quantitative and qualitative parameters in *makoi.*

Materials and methods

The experimental material comprised of seventeen genotypes obtained from different eco-geographical regions of the country (Table 1). The seeds of each genotype were sown in seed pans and thirty days old seedlings were transplanted in the field plots in Randomized Complete Block Design (RCBD) with three replications at 60 × 45 cm spacing during *Kharif* at Sanjeevini Vatika, Department of Horticulture, University of Agricultural

Table 1. Details of sources of *S. nigrum* L. genotypes

Sl.No.	Genotype	Sources
1	MG-1	Gandhi Krishi Vignana Kendra, Bangalore
2	MG-2	Tamil Nadu Agricultural University, Coimbotore
3	MG-3	College of Horticulture, Mudigere (Karnataka)
4	MG-4	Tropical Botonical Garden Research Institute –Trivendrum (Kerala)
5	MG-5	Haryana Agricultural University –Hissar
6	MG-6	Shilpa Agro Farm, Hyderabad
7	MG-7	Sanjeevini Muligai Farm, Hosur (Tamil Nadu)
8	MG-8	Hosur (Tamil Nadu)
9	MG-9	Regional Research Laboratory –Jorhat (Assam)
10	MG-10	All India Co-ordinated Research Project on Medicinal and Aromatic Plants, Gujarat Agricultural University-Anand (Gujarat)
11	MG-11	Y.S. Parmer University of Forestry &Horticulture, Nauni, Solan (Himachal Pradesh)
12	MG-12	Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharastra)
13	MG-13	Palakkad (Kerala)
14	MG-14	Udaipur (Rajasthan)
15	MG-15	Regional Research Laboratory -Bhuvaneshwar (Orissa)
16	MG-16	Regional Research Laboratory -Jammu, Tawi (Jammu & Kashmir)
17	MG-17	All India Co-ordinated Research Project on Medicinal and Aromatic Plants, Borivi, (Gujarat)

Sciences, GKVK, Bangalore. Recommended agronomical practices were followed to raise the crop. The observations such as plant height, number of branches, plant spread, number of leaves, leaf area, days to flower bud initiation, days to 50 % flowering, days to maturity, fresh and dry herbage yield per plant, total alkaloid content and total alkaloid yield were recorded in five randomly selected plants of each genotype. The total alkaloid content was estimated in the dried powdered samples by gravimetric method (Anonymous, 2003). The variability parameters such as range, mean GCV, PCV, heritability in broad sense and genetic advance as per cent of mean were calculated as per procedure outlined by Burton and Devane (1953). Correlation coefficient was worked out as per Webber and Moorthy (1952) and Path coefficient analysis was done as per Dewey and Lu (1959) procedure.

Results and discussion

Means of various characters of seventeen genotypes of *makoi* are presented in Table 2. Analysis of variance revealed significant difference among the genotypes for all the traits studied. These differences indicated presence of a wide variability and considerable scope for improvement in *makoi*. Maximum dry herbage yield per plant was recorded in MG-I (209.07g) followed by MG-14 (161.73g). While for total alkaloid yield the genotype MG-14 recorded highest (12.26 kg ha^{-1}) followed by MG-13 (11.91 kg ha^{-1}).

Estimates for various genetic parameters are presented in Table 3. Wide range of variation was observed in most of the traits like dry herbage yield (84.53 to 209.06 g) per plant, total alkaloid content (0.05 to 0.23 % w/w) and total alkaloid yield (1.55 kg to 12.26 kg ha^{-1}). Presence of this variability for the above parameters can form basis for effective selection of superior genotype in *S. nigrum*. The degree of variability shown by different parameters can be judged by the magnitude of GCV and PCV. GCV showed that extent of genetic variability in the population ranged from 6.28 (days to maturity) to 48.36 (total alkaloid yield per hectare). Perusal of data in Table 3 show a considerable difference between PCV and GCV values for all traits studied. This indicates presence of greater environmental influence on expression of all these traits and selection may not be effective in improvement of *makoi*. Further GCV values

Table 2. Mean performance of *S. nigrum* genotypes for different morphometric traits, yield and quality attributes

Genotype	Days to flower bud initiation	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Number of branches $plant^{-1}$	Plant spread (cm^2)	Number of leaves $plant^{-1}$	Leaf area (cm^2) $plant^{-1}$	Herbage yield (g $plant^{-1}$)		Total alkaloid content (% w/w)	Total alkaloid yield (kg ha^{-1})
									Fresh	Dry		
MG-1	13.00	17.00	55.00	155.10	97.30	27609.72	1190.50	18026.19	1586.33	209.07	0.08	6.05
MG-2	17.00	19.00	53.00	123.57	99.93	25785.82	830.53	7831.18	852.47	120.93	0.074	3.31
MG-3	21.00	24.00	53.00	110.50	78.80	21672.52	405.60	6123.88	847.87	129.87	0.06	2.85
MG-4	17.00	19.00	46.00	104.20	71.67	15900.63	668.80	8819.43	588.73	93.47	0.10	3.46
MG-5	19.00	22.00	52.00	114.07	90.00	19025.73	911.20	16412.75	843.93	130.40	0.14	6.69
MG-6	09.00	16.00	49.00	77.23	74.80	9463.52	236.87	3810.57	391.33	84.53	0.05	1.55
MG-7	19.00	24.00	53.00	108.03	95.73	15995.28	736.47	13030.79	830.33	119.60	0.057	2.51
MG-8	22.00	24.00	54.00	112.90	74.27	15864.90	570.07	10504.39	783.27	112.53	0.120	4.96
MG-9	19.00	22.00	54.00	111.87	91.07	16685.18	619.80	11160.86	919.73	149.13	0.152	8.37
MG-10	22.00	25.00	54.00	112.93	64.53	15091.53	414.87	7427.62	758.07	126.73	0.21	9.83
MG-11	20.00	23.00	52.00	112.93	77.67	18595.78	818.00	7958.90	888.00	154.00	0.192	10.97
MG-12	16.00	21.00	56.00	101.57	81.27	19463.12	478.00	7545.03	548.33	99.60	0.18	6.58
MG-13	20.00	23.00	52.00	124.00	87.67	20078.23	782.20	13922.67	934.33	140.80	0.23	11.91
MG-14	21.00	22.00	55.00	133.53	94.53	17332.12	940.33	14605.02	1094.67	161.73	0.21	12.26
MG-15	18.00	22.00	54.00	126.00	95.53	18537.15	895.93	6496.16	916.07	140.87	0.16	8.32
MG-16	19.00	24.00	49.00	114.43	86.53	14752.63	692.80	11833.98	735.60	137.73	0.22	11.11
MG-17	18.00	22.00	56.00	123.42	138.8	18637.60	930.00	7117.53	893.20	140.80	0.19	9.87
Mean	18.11	21.70	52.76	115.66	88.24	18264.20	713.23	10248.76	847.77	132.45	0.14	
SEm ±	1.27	1.32	1.49	7.80	10.50	2936.37	122.21	1631.27	126.80	15.33	0.01	
LSD (*P*=0.05)	3.50	3.66	4.13	21.61	29.10	8139.21	338.76	4521.66	351.48	42.51	0.03	

were low in magnitude compared to PCV values for all the characters studied. This also indicates that direct selection will not be effective in these characters and that heterosis breeding can be resorted to for further improvement. Similar variation was recorded by Singh *et al.* (2000) in opium poppy and Singh and Singh (1999) in lemongrass.

With help of GCV alone, it is not possible to determine the extent of heritable variation. Thus, the estimates for heritability indicate effectiveness with which selection may be expected to exploit existing genetic variability. Heritability in broad sense was high for alkaloid content (89.99 %), total alkaloid yield (81.40 %), leaf area per plant (65.40 %), days to flower bud initiation (64.13 %) and days to maturity (62.11 %). These results are in line with those of Krishnamoorthy and Madalagiri (2002) in ajowan and Srivastava *et al.* (2003) in Japanese mint.

The estimates of heritability value may not provide clear predictability of breeding value. Its estimate along with genetic advance is usually more useful than simple heritability values in predicting the resultant effect of selecting the best individual. The genetic advance as per cent of mean (GAM) was high for total alkaloid content (92.39), alkaloid yield (89.98), leaf area (59.56), number of leaves (41.94), fresh (37.30) and dry herbage (30.18) yield and days to flower bud initiation (26.96).

High values of GCV, heritability along with GAM was observed for leaf area, total alkaloid content and alkaloid yield indicating these traits were controlled by additive genes and selection procedure could be profitably employed for improvement of these characters. The characters such as dry and fresh herbage yield and number of leaves had high GAM but their heritability was moderate suggesting that these characters are governed by

Table 3. Estimates of genetic parameters for quantitative and qualitative characters in makoi

Character	Range		Mean	Coefficient of variability (%)		Heritability in broad sense (%)	Genetic advance (GA)	GA as per cent of mean (GAM)
	Minimum	Maximum		Genotypic	Phenotypic			
Days to flower bud initiation	13.00	22.00	18.11	16.32	20.35	64.31	4.88	26.96
Days to 50 per cent flowering	16.00	25.00	21.70	10.13	14.64	47.82	3.13	14.42
Days to maturity	46.00	56.00	52.76	6.28	7.94	62.11	5.38	10.19
Plant height (cm)	77.23	155.10	115.66	12.10	16.82	51.74	20.73	17.92
Number of branches plant^{-1}	64.53	138.80	88.24	14.54	25.23	33.20	15.22	17.25
Plant spread (cm^2)	9463.52	27609.72	18264.20	16.36	32.30	25.70	3119.03	17.07
Number of leaves plant^{-1}	236.87	1190.50	713.23	29.09	41.55	49.00	299.19	41.94
Leaf area (cm^2) plant^{-1}	3810.57	18026.19	10248.76	36.09	44.62	65.4	6104.84	59.56
Fresh herbage yield plant^{-1} (g)	391.33	1586.33	847.77	25.71	36.50	49.60	316.13	37.30
Dry herbage yield plant^{-1} (g)	84.53	209.06	132.45	20.50	28.67	51.09	39.97	30.18
Total alkaloid content (% w/w)	0.05	0.23	0.14	45.48	47.97	89.99	0.13	92.39
Total alkaloid yield (kg ha^{-1})	1.55	12.26	7.09	48.36	53.59	81.40	6.38	89.98

Table 4. Genotypic and phenotypic correlation coefficients among morphological and alkaloid yield related traits in makoi genotypes

Character		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
Days to flower bud initiation (X1)	rg	1.000	1.225**	-0.668**	0.216	-0.053	0.067	0.025	0.147	0.104	0.174	0.537*	0.494*
	rp		0.585*	-0.427	0.163	-0.157	0.029	0.022	0.083	0.062	0.023	0.406	0.303
Days to 50 per cent flowering (X2)	rg		1.000	-0.494*	0.116	-0.019	-0.038	-0.087	0.108	0.020	0.039	0.633**	0.527*
	rp			-0.298	-0.049	-0.146	-0.248	-0.140	-0.024	-0.100	0.008	0.421	0.338
Days to maturity (X3)	rg			1.000	-0.342	0.103	-0.315	-0.382	-0.389	-0.129	-0.117	-0.257	-0.229
	rp				-0.173	0.143	-0.159	-0.211	-0.216	-0.100	-0.046	-0.193	-0.164
Plant height (X4)	rg				1.000	0.451	0.986**	0.969**	0.619**	1.075**	1.093**	0.183	0.479
	rp					0.466	0.595*	0.732**	0.626**	0.792**	0.694**	0.091	0.374
Number of branches plant^{-1} (X5)	rg					1.000	0.232	0.662**	0.059	0.333	0.313	0.097	0.231
	rp						0.428	0.587*	0.260	0.448	0.428	0.036	0.180
Plant spread (X6)	rg						1.000	0.684**	0.387	0.853**	0.782**	-0.298	-0.012
	rp							0.587*	0.361	0.617**	0.497*	-0.114	0.020
Number of leaves plant^{-1} (X7)	rg							1.000	0.613**	0.821**	0.791**	0.127	0.392
	rp								0.712**	0.767**	0.720**	0.086	0.359
Leaf area plant^{-1} (X8)	rg								1.000	0.703**	0.640**	0.083	0.267
	rp									0.645**	0.586*	0.047	0.294
Fresh herbage yield plant^{-1} (X9)	rg									1.000	1.012**	-0.034	0.305
	rp										0.915**	-0.048	0.331
Dry herbage yield plant^{-1} (X10)	rg										1.000	0.186	0.494*
	rp											0.083	0.511*
Total alkaloid content (X11)	rg											1.000	0.959**
	rp												0.858**
Total alkaloid yield (X12)	rg												1.000
	rp												

*Significant at 5 per cent probability level, **Significant at 1 per cent probability level, rg: Genotypic correlation coefficient, rp: Phenotypic correlation coefficient additive gene effects. The moderate heritability being exhibited due to environmental effects and selections may be effective in these cases.

All possible correlation coefficients between dry herbage yield and total alkaloid yield and its component characters were estimated at phenotypic (P) and genotypic (G) levels and are presented in Table 4. From these associations, it is seen that higher dry herbage yield per plant was highly significant and positively associated both at genotypic and phenotypic levels with fresh herbage yield (1.012, 0.915) per plant, number of leaves (0.791, 0.720) and plant height (1.093, 0.694) respectively. Similar trends have been reported in *Solanum viarum* (Pal *et al.*, 1994), marjoram (Prasanna Kumar *et al.,* 1994), periwinkle (Dwivedi *et al.*, 1999), shankapushpi (Lal, 2003), senna (Singh *et al.*, 2003) and *Menth arvensis* (Srivastava *et al.*, 2003). Pal *et al.* (1987) observed a significant association of oil yield with dry herbage yield in ocimum and Dwivedi *et al.* (1999) in periwinkle. While, in marjoram Prasanna Kumar *et al.* (1994) observed positive correlation of alkaloid yield with fresh herbage yield.

Though correlation analyses can quantify the degree of association between two characters, it does not provide reasons for such association. Simple linear correlation is designed to detect presence of linear association between two variables. Path coefficient analysis resolves this mystery by breaking total correlation coefficients into components of direct and indirect effects. Therefore, path analysis was performed to asses direct and indirect effects of different characters on dry herbage yield per plant and total alkaloid yield per hectare as dependent variables (Table 5 and 6). Total Alkaloid yield had the maximum direct effect (0.976) on dry herbage yield per plant followed by number of leaves (0.934) and fresh herbage yield (0.932). Highest positive direct effect of fresh leaf yield on dry leaf yield was reported by Singh *et al.* (2003) in senna.

Table 5. Genotypic path coefficient analysis for dry herbage yield per plant in makoi genotypes

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	*rg* with dry herbage yield
Days to flower bud initiation (X1)	**0.169**	0.17	-0.160	-0.034	0.030	-0.027	0.024	-0.063	0.097	-0.513	0.482	0.175
Days to 50 per cent flowering (X2)	0.207	**0.139**	-0.115	-0.018	0.011	0.015	-0.082	-0.045	0.018	-0.605	0.514	0.039
Days to maturity (X3)	-0.116	-0.069	**0.233**	0.054	-0.059	0.127	-0.357	0.167	-0.120	0.246	-0.223	-0.117
Plant height (X4)	0.037	0.016	-0.08	**-0.157**	-0.259	-0.398	0.905	-0.266	1.002	-0.175	0.468	1.093**
Number of branches plant^{-1} (X5)	-0.009	-0.003	0.024	-0.071	**-0.573**	-0.094	0.618	-0.026	0.311	-0.093	0.225	0.313
Plant spread (X6)	0.011	-0.005	-0.074	-0.155	-0.133	**-0.404**	0.639	-0.166	0.795	0.285	-0.011	0.782**
Number of leaves plant^{-1} (X7)	0.004	-0.012	-0.089	-0.152	-0.379	-0.276	**0.934**	-0.264	0.766	-0.122	0.382	0.791**
Leaf area plant^{-1} (X8)	0.025	0.015	-0.091	-0.097	-0.034	-0.156	0.572	**-0.430**	0.655	-0.079	0.261	0.640**
Fresh herbage yield plant^{-1} (X9)	0.018	0.003	-0.030	-0.169	-0.191	-0.345	0.767	-0.302	**0.932**	0.033	0.297	1.012**
Total alkaloid content (X10)	0.091	0.088	-0.06	-0.029	-0.056	0.122	0.119	-0.036	-0.032	**-0.956**	0.935	0.186
Alkaloid yield (X11)	0.083	0.073	-0.053	-0.076	-0.132	0.005	0.366	-0.115	0.284	-0.917	**0.976**	0.494*

Residual effect = -0.0536, Direct effects on main diagonal; *significant at 5 per cent probability level

Table 6. Genotypic path analysis for total alkaloid yield in makoi genotypes

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	*rg* with alkaloid yield
Days to flower bud initiation (X1)	**-0.057**	0.000	-0.001	0.038	-0.003	-0.003	-0.002	0.004	-0.012	0.058	0.472	0.494*
Days to 50 per cent flowering (X2)	-0.070	**-0.002**	0.000	0.021	-0.001	0.002	0.007	0.003	-0.002	0.013	0.556	0.527*
Days to maturity (X3)	0.039	0.039	**0.002**	-0.061	0.006	0.016	0.030	-0.011	0.015	-0.039	-0.226	-0.229
Plant height (X4)	-0.012	-0.01	0.000	**0.177**	0.028	-0.050	-0.077	0.017	-0.126	0.363	0.160	0.479
Number of branches plant^{-1} (X5)	0.003	0.003	0.000	0.008	**0.061**	-0.012	-0.053	0.002	-0.039	0.103	0.086	0.231
Plant spread (X6)	-0.004	0.000	0.000	0.175	0.014	**-0.051**	-0.055	0.011	-0.100	0.260	-0.262	-0.012
Number of leaves plant^{-1} (X7)	-0.001	0.000	0.000	0.172	0.040	-0.035	**-0.080**	0.017	-0.096	0.263	0.112	0.392
Leaf area plant^{-1} (X8)	-0.008	0.000	-0.001	0.110	0.004	-0.020	-0.049	**0.028**	-0.082	0.212	0.073	0.267
Fresh herbage yield plant^{-1} (X9)	-0.006	0.001	0.000	0.191	0.020	-0.043	-0.066	0.019	**-0.117**	0.336	-0.030	0.305
Dry herbage yield per plant(X10)	-0.010	-0.010	-0.001	0.194	0.019	-0.040	-0.063	0.018	-0.118	**0.332**	0.163	0.49*
Total alkaloid content (X11)	-0.031	-0.031	0.000	0.032	0.006	0.015	-0.010	0.002	0.004	0.062	**0.878**	0.96**

Residual effect = -0.0182, *Significant at P=0.05, **Significant at P=0.01

Total alkaloid content exerted the highest positive direct effect (0.878) on alkaloid yield followed by dry herbage yield (0.332) and plant height (0.177). The results are in line with the results obtained by Dwivedi *et al.* (1999) in periwinkle.

In conclusion, it may be stated that for yield and quality improvement in *makoi,* emphasis may be laid on total alkaloid content, dry herbage yield and plant height.

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