Variation in Crambe, *Crambe abyssinica* Hochst[1]

K.J. LESSMAN, Department of Agronomy, Purdue University, West Lafayette, Indiana 47906

ABSTRACT

One hundred sixty-two lines were used to detect genotypic diversity for 7 characters in *Crambe abyssinica* Hochst during 1970 and 1972. Lines used were from 2000 randomly selected out of PI247310 and PI279345, and reselected on the basis of their progeny performance in head row nurseries. The cultivars, 'Prophet,' 'Meyer,' and 'Indy,' were used as checks. Characters studied were seed yield, test wt, plant ht, % oil (measured gravimetrically and by nuclear magnetic resonance), days to bloom, and % glucosinolates. Statistical differences were detected among lines for all characters except % glucosinolates, based on individual year and combined analyses of variance. Broad sense heritability estimates ranged from .22-.88. Gains from selection, as a % of the mean for each character, were estimated at 1.13-14.11. Intercharacter relationships were analyzed by correlation. The ranges in variation for traits are considered limited for good progress from selection within the germplasm represented, but advances can be expected.

INTRODUCTION

Crambe (*Crambe abyssinica* Hochst) has shown potential as a source of raw materials for industry and high quality protein if glucosinolates of seed can be reduced (1,2). However, attempts to evaluate crambe germplasm indicated inadequate diversity to encourage breeding for needed agronomic improvement (3,4). The conclusion of inadequate diversity was based on studies of the average performance of a limited number of introductions when cultured in replicated trials with row spacings and locations as additional variables. At that time, information about appropriate plot size and shape, as well as cultural practices for testing crambe, was not available. Thus, arbitrary choice of plot size may have contributed to difficulty in detecting less obvious differences among entries (5). Nevertheless, some plant-to-plant variability for branching tendency was noted within certain introductions (3,4). This is a report on variation of possible breeding value among crambe lines selected on the basis of progeny performance of individual plants in head row nurseries with subsequent testing in large plot trials.

[1]Purdue University Agricultural Experiment Station, Lafayette, Ind. Journal Paper No. 5863 Purdue AES.

MATERIALS AND METHODS

The primary plant materials used were individual selections from crambe introduction PI247310. Of original introductions evaluated in the U.S., it showed the most plant-to-plant variation (4).

In 1967, some 2000 plants were chosen for progeny testing. During selection, part of the inflorescence of each plant was bagged to assure self pollination. In 1968 and 1969, seed from unbagged flowers of each selection were planted in paired rows, 152.4 cm long, spaced 96.6 cm apart, thus comprising a screening nursery (head row nursery) for progeny evaluation. Seeds from bagged flowers were planted for increase, and subsequent plants were bagged to help maintain genetic purity. Included in the head row nursery were selections from P.I. 279346 then designated as *Crambe hispanica*. Primarily on the basis of their progeny performance for yield, oil production, test wt, and days to bloom, 162 selections were chosen for performance testing in a solid seeded, large plot nursery in 1970 and 1972. Selections chosen represented a spectrum of types for traits of interest. Included in the test were P.I. 247310, and the cultivars, 'Prophet,' 'Indy.' and 'Meyer,' as check entries. A solid seeded plot was 1.8 m x 9.1 m. An area 1.2 m x 7.9 m in the center of each was harvested. Plots were arranged in a randomized complete block design with three replicates at the Purdue Agronomy Farm, Lafayette, Indiana. A seeding rate of 20 lbs/acre was used. Stands were good, kept weed free, and plots harvested as plants matured with an SP 50 plot combine.

Characters studied were: a) Plant ht. Length in cm from the ground to the top of the plant. b) Oil production. Wt of oil obtained from a 3 g sample of depodded seeds, expressed as a percentage, nuclear magnetic resonance (NMR) analysis of a 15 g sample of seed with pods intact. c) Test wt. Expressed as kg/hl. d) Yield. Wt of seed per plot area expressed as kg/ha. e) Days to bloom. Days required from seedling emergence until 90% or more of the plants in a plot were in flower. f) Glucosinolate production. Mg glucosinolate in a 500 mg sample of defatted meal, determined by assay, and expressed as a percentage.

Gravimetric determinations of oil content were run according to AOCS extraction method Ba 3-38 using depodded seed. Oil content was determined from seeds with pods intact by NMR analysis at the University of Illinois, Urbana, Illinois.

Glucosinolate content of defatted seed meal was assayed by enzymatic hydrolysis according to procedures described by VanEtten, et al., (6). Titrations of HSO_4^- released dur-

TABLE I

Tests of Significance in Analyses of Variance for Different Crambe Characters

Source of variation	Seed yield	Test wt	Plant ht	Oil (%)	Oil by NMR (%)	Days to bloom	Glucosinolate production
				1970			
Selections	**[a]	**	**	**	**	**	NS[b]
				1972			
Selections	**	**	**	**	**	**	NS
				1970-1972 (combined)			
Years	**	**	**	**	**	**	**
Selections	**	**	**	**	**	**	NS
Years x selections	**	*	NS	**	**	**	NS

[a]* = Significant at 5% level ($P < 0.05$); ** = Significant at 1% level ($P < 0.01$).
[b]NS = not significant.

TABLE II

Means for Check Entries and Ranges for Selections of Crambe at Lafayette, Indiana, 1970 and 1972

Item	Seed yield (kg/ha)	Test wt (kg/hl)	Plant ht (cm)	Oil (%)	Oil by NMR (%)	Days to bloom	Glucosinolate (%)
				1970			
Prophet	2295.81	23.13	105.84	41.13	29.84	63.00	10.79
Indy	2106.36	26.31	98.96	43.92	31.07	57.33	11.65
P.I. 247310	2288.70	25.19	106.68	41.93	31.71	63.33	10.52
Meyer	2398.94	26.48	97.36	44.72	34.40	61.33	8.92
Grand mean	2241.20	25.63	99.21	42.59	30.48	58.74	10.88
Range among selections	1486.08-2773.72	20.60-30.48	88.06-112.60	36.23-46.17	27.08-33.31	49.00-70.67	7.19-36.43
No. above Meyer[a]*	0	16	48	0	0	24	3
No. below Meyer*	31	60	12	83	160	81	0
No. above Prophet*	7	66	0	78	41	8	1
No. below Prophet*	18	2	86	3	3	81	0
C.V.[b]	12.91%	5.94%	5.63%	3.41%	3.69%	3.08%	35.65%
				1972			
Prophet	2957.20	27.81	102.59	42.31	33.27	59.00	15.64
Indy	2712.07	30.31	91.59	42.98	33.10	55.00	16.40
P.I. 247310	2843.22	30.82	106.83	43.58	34.67	59.00	16.65
Meyer	2824.54	32.76	99.21	44.28	36.23	57.00	15.66
Grand mean	2727.51	31.62	98.70	43.76	33.59	57.00	15.05
Range among selections	2166.66-3095.08	27.34-36.11	92.28-124.46	40.54-46.43	31.10-35.10	55.00-59.00	12.17-17.06
No. above Meyer*	0	2	7	4	0	80	0
No. below Meyer*	13	62	18	33	165	81	10
No. above Prophet*	0	106	1	82	17	85	0
No. below Prophet*	42	0	35	1	3	0	9
C.V.	9.26%	5.67%	7.37%	2.66%	2.35%	1.10%	11.84%
				Combined 1970-1972			
Prophet	2626.50	25.47	109.65	41.72	31.55	61.00	13.22
Indy	2409.02	28.31	96.95	43.45	32.09	56.17	14.02
P.I. 247310	2565.97	27.99	112.19	42.76	33.19	61.17	13.59
Meyer	2611.74	29.61	103.71	44.50	35.32	61.33	12.31
Grand Mean	2483.99	28.63	104.37	43.18	32.04	57.92	12.97
Range among selections	1711.76-2900.40	24.67-33.29	91.44-116.00	38.84-45.49	30.01-33.72	52.00-64.83	10.38-26.31
No. above Meyer*	0	1	10	0	0	0	1
No. below Meyer*	1	59	4	57	158	76	0
No. above Prophet*	0	88	0	67	87	0	1
No. below Prophet*	3	0	44	1	0	75	0
C.V.	13.17%	6.49%	7.26%	4.03%	4.85%	6.33%	23.78%

[a]* = ($P < 0.1$).

[b]C.V. = Coefficient of Variation.

TABLE III

Estimates of Parameters for Crambe Data for 1970-72 Combined

Character	Mean	$\hat{\sigma}$Ph	Heritability	Expected gain[a]	G.C.V.[b]
Seed yield (kg/ha)	2483.99	179.27	.45	6.69	4.81
Test wt (kg/hl)	28.63	2.23	.88	14.11	7.34
Plant ht (cm)	104.37	6.34	.76	9.51	5.30
Oil (%)	43.18	1.31	.70	4.37	2.53
Oil by NMR (%)	32.04	.73	.24	1.13	1.10
Days to bloom	57.92	3.21	.78	8.91	4.90
Glucosinolate (%)	12.97	1.43	.22	5.00	5.19

[a]From selection in mean % (GS)

[b]Genetic coefficient of variability

TABLE IV

Intercharacter Correlations in Crambe in Lafayette, Indiana, 1970-72

	Seed yield	Test wt	Plant ht	Oil (%)	Oil by NMR (%)	Days to bloom	Glucosinolate production
Seed yield (P)[a]		-.4938**	.5834**	- .3179**	- .1165	.4481**	.2348**
Seed yield (G)[a]		-.7826	.8719	- .5270	.0636	.6660	.7047
Test weight (P)			-.8246**	.7861**	.5692**	- .8902**	-.1800*
Test weight (G)			-.9987	.9794	1.1108	-1.0711	-.4044
Plant height (P)				- .7350**	- .4590**	.8414**	.1937*
Plant height (G)				-1.0260	-1.0557	1.0857	.4076
Percent oil (P)					.6259**	- .8367**	-.1075
Percent oil (G)					1.0114	- .9663	-.2809
Percent oil NMR (P)						- .5145**	-.0626
Percent oil NMR (G)						- .5793	-.2822
Thioglucosides (P)							.1685**
Thioglucosides (G)							.4447

[a]P = phenotypic correlation coefficients; G = genotypic correlation coefficients.

[b]* = ($P < 0.05$); ** = ($P < 0.01$).

ing the hydrolysis were made using a Fischer automatic titrimeter model 36, at pH 6.2.

Plot means for each character were used in all analyses of variance. Analyses were calculated on both a yearly and combined basis. Heritability of each character was computed from the combined analysis using the formula:

$$H = \frac{\hat{\sigma}_G^2}{\hat{\sigma}_P^2}$$

where: $\hat{\sigma}_G^2$ = genotypic variance component

$\hat{\sigma}_P^2$ = phenotypic variance component

and: $$\hat{\sigma}_P^2 = \hat{\sigma}_G^2 + \frac{\hat{\sigma}_{YS}^2}{y} + \frac{\hat{\sigma}^2}{yr}$$

Estimates of expected gain from selection in % of the mean were obtained with the method used by Hanson, et al., (7).

$$GS = [K\hat{\sigma}p(H)100]/\bar{X}$$

where: K = the selection differential expressed in phenotypic standard deviations, and equals 2.06 when 5% of entries are selected.

$\hat{\sigma}p$ = the phenotypic standard deviation

H = the heritability

and: $\bar{X}$ = the character mean.

All possible intercharacter relationships were evaluated by correlation.

RESULTS AND DISCUSSION

Entry mean squares for all characters, except glucosinolate production, were highly significant in both yearly and combined analyses of variance (Table I). Year effects were highly significant in the combined analysis for all characters, as might be expected, on the basis of the difference in average year to year performance of the population of selections, on a grand mean basis, (Table II). In general, plants yielded less seed with lower test wts, less oil, and less glucosinolate, while being somewhat taller and taking longer to bloom in 1970 than in 1972. The years by selections interaction component in the combined analysis was highly significant ($P < 0.01$) for yield, % oil, and days to bloom, significant ($P < 0.05$) for test wt, but not significant for plant ht or glucosinolate content of seeds. Therefore, selections tended to differ in their relative average performance for most traits from one year to the next, implying a genotypic x environmental interaction among entries due to differences in their genotypic structure. These results indicate that selection of individual plants, based on their progeny evaluation in the head row nursery, was effective for separating variation that exists in the original germplasm, except for glucosinolate content. The titration method used in the present research is known to give high results for glucosinolates, and our values are higher than previously reported ones. However, these are not presented as absolute glucosinolate contents; they are used only for comparison of our selections and as such are internally consistent and suitable for use in the statistical analysis. Evaluations for glucosinolate were not made in head row nurseries. However, correlations between actual performance of entries in the head row nursery with that in large plots (grown in different years) were low, as might be expected in view of the significant entry x year interaction mean squares for most traits.

From a plant improvement standpoint, performance of selections relative to the check Meyer was discouraging as to their direct use as superior cultivars. No selections performed better than Meyer for yield, or % oil, and only 4 were shorter on a combined years basis (10% level), even though a large number required fewer days to bloom, an indication of earlier maturity (Table II). On the other hand, many selections were better than Prophet for test wt and % oil.

It should be noted at this point that the cultivars, 'Prophet' and 'Indy,' were developed by mass selection for large and small seed size from P.I. 247310 and P.I. 279346, respectively. In contrast, Meyer was developed by selection among progenies from the cross of *Crambe abyssinica* x a *C. hispanica* type. The latter is now believed to be an ecotype of *C. abyssinica*, rather than a different species (5). Therefore, the superiority of Meyer suggests crossing among diverse germplasm, followed by selection, as a practical step toward improvement, in addition to straight selection within and among existing germplasms.

Results of the analysis of the nature of variation among selections is somewhat encouraging. Heritability estimates for characters ranged from .22 (% glucosinolates) to .88 (test wt), indicating an appreciable portion of variation due to genotypic differences. Should these estimates of heritability be proven reasonably accurate for crambe germplasms in general, good progress in selection for these traits in diverse populations can be expected, whether they exist in a natural state or are synthesized by hybridization or mutagenesis. However, with the limited materials at hand, the range in variation of the population mean performance does not offer outstanding gains by selection (GS) using these specific materials. For example, an average gain of 166.2 kg/ha could be expected with selection of the best 5% of lines for seed yield (pods intact). Such a gain in yield would result in an estimated 62.8 kg/ha (or 56 lbs. per acre) of oil based on the average expected increase in % oil (NMR), and seed yield. Use of data based on NMR analysis for oil should give the more accurate estimate from a practical standpoint, because crambe is harvested and crushed with pods intact. The data based on gravimetric analysis indicates a higher % gain is possible, but these data are based on analysis of depodded seed. (Table III).

Phenotypic and genotypic intercharacter correlation coefficients (Table IV), as a basis for selection toward improved crambe lines, are encouraging in some respects, and discouraging in others. Selection for heavy test wt as a means to increased seed oil, shorter stature, and earlier maturity seems feasible because of the strong associations among these characters. On the other hand, associations between yield and test wt, and yield and oil content, are negative, and associations between yield and plant ht are positive. Therefore, if effective selection for short stature and early maturity to reduce lodging and climatic exposure is beneficial to the producer, it also should benefit the processor through increased oil content and test wt. However, effective selection for these traits could reduce yield and be disadvantageous to the producer, thereby cutting the incentive to produce. Reduced production could lead to higher prices for the processor.

On this basis it is necessary to seek recombination of characters through intercrossing and incorporation of diverse germplasm if continued improvement in crambe is to be realized.

REFERENCES

1. Nieschlag, H.J., and I.A. Wolff, JAOCS 48:723 (1971).
2. Tallent, W.H., Ibid. 49:15 (1972).
3. Lessman, K.J., and V.D. Meier, Crop Sci. 12:224 (1972).
4. Papathanasiou, G.A., K.J. Lessman, and W.E. Nyquist, Agron. J. 58:587 (1966).
5. Meier, V.D., and K.J. Lessman, Crop Sci. 11:648 (1971).
6. VanEtten, C.H., M.E. Daxenbichler, and I.A. Wolff, J. Agr. Food Chem. 17:483 (1969).
7. Hanson, C.H., and H.F. Robinson, and R.E. Comstock, Agron. J. 48:268 (1956).
8. VanEtten, C.H., C.E. McGrew, and M.E. Daxenbichler, J. Agr. Food Chem. 22:483 (1974).

[Received April 25, 1975]