THE USE OF A SELECTION INDEX TO IMPROVE GERBERA CUT-FLOWERS

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Abstract

A selection index was derived for cut-flower yield, consumer-rating, and vase-longevity as a function of phenotypic and genetic covariances of the characters. It was used to select parents for generations 8, 9, and 10 in the Davis Population of gerbera. Parent-offspring heritability of the index was 0.301. Cut-flower yield and vase-longevity responded to the index selection, but consumer-rating did not. The use of selection indices in flower crop breeding was discussed.

1. Introduction

Cut-flower crops have been selected by plant breeders for many characteristics. However, selection practiced in most experiments has focused on single characters, or on a primary character with only varying degrees of culling for secondary characters. This method was used in the selection for increased cut-flower yield in the Davis Population of *Gerbera hybrida* (Harding, Byrne and Nelson; 1981). Culling included the removal of those high yielding parents that were in the lowest 20% for vase-longevity and in the lowest 20% for flower quality, determined subjectively. The population responded to selection for cut flower-yield in generations 1-3, but flower quality was not maintained by culling. Therefore, it appeared that quality and yield of cut-flowers must both be treated as primary characters in the selection process.

Hence, cut-flower yield and flower quality, as measured by consumer-preference, were selected jointly from generations 5-8 (for a discussion of consumer evaluation see Drennan, Hodgson and Harding; 1980). The consumer-preference score was determined by a panel of about 100 judges who ranked their favorite flowers from random samples of the population. Parents were chosen by the method of independent-selection. The population responded to selection for consumer-preference (Drennan, Harding and Byrne; 1983), and continued to respond to selection for cut-flower yield (Harding, Drennan and Byrne; 1985). Hence, it was possible to improve two characters simultaneously.

However, there are many other important characters in flower crops that need to be included in the selection process. Accordingly, vase-longevity was added as the third character in the selection process, beginning in generation 8. It was also determined that the selection index method would be genetically more efficient than the independent selection method. The purpose of this study was to determine if the three characters, cut-flower yield, flower quality, and vase-longevity, could be improved by the selection index method.

2. Materials and methods

2.1. The Davis Population

A variable gene-pool was established in 1970 by crossing plants from a large number of mixed seed lots. One generation has been grown in most years; the population is now in generation 11. In each generation, plants with highest cut-flower yield were chosen to be parents of the next generation. Culling for vase-longevity and flower quality was practiced in generations 1-3, and selection for consumer-preference was practiced in generations 4-8 (for details see Harding, Byrne, and Nelson; 1981; and Drennan, Harding, and Byrne; 1983).

2.2. Characters

Each plant was evaluated in generations 8, 9, and 10 for cut-flower yield (Y), consumer-rating (R), and vase-longevity (V). Yield was the number of cut-flowers produced in a 24 week period, beginning the first Monday of September in each year. The consumer-rating score was determined by a panel of ca. 100 judges who were asked to rate each flower on a scale from 9 (exceptional) to 1 (poor). Two flowers from each plant were evaluated at different times by the panel; the mean of the two replications was used in the analysis. Similarly, two flowers were selected from each plant to analyze vase-longevity. Each flower was placed in a separate sterile container with deionized water. Vase-longevity was the number of days before a flower wilted; the mean of the two replications was used in the analysis.

2.3. Mating Scheme

Forty plants were selected by the selection index method as parents for a population of ca. 400 in each generation. Hence, the intensity of selection was 10%. Within each cohort of selected parents, each was crossed at random to several others. This procedure created a population composed of half-sib families that were randomly structured from the selected parents.

2.4. Covariance matrices

Since the population was structured into half-sib families, the between- and within-family variances for each of the characters, and the between- and within-family covariances for the three character-pairs were estimated. This analysis provided phenotypic, genetic (additive), and environmental covariance and correlation matrices for each generation (for technical explanation see Falconer, 1960).

2.5. Selection index

The Fairfield Smith Index (1936) is a function of the covariance matrices and the heritabilities that are derived from them.

The index for the Davis Population was

$$I_i = b_1 Y_i + b_2 R_i + b_3 V_i$$

where I_i is the index score, Y_i is the cut-flower yield, R_i is the consumer-rating, and V_i is the vase-longevity of plant i; the b values are weights for the three characters. The matrix solution for the weights is

$$\mathbf{b} = \mathbf{P}^{-1} \mathbf{A}$$

where b is the vector of weights, **P** is the phenotypic covariance matrix, and **A** is the additive genetic covariance vector (for a detailed explanation see Brim, Johnson, and Cockerham; 1959). In this analysis we have assumed equal economic values for the three characters.

An index, I(8), was computed from the data of generation 8 and used to select parents for generation 9. Another index, I(9), was computed from the data of generation 9. The weights from the generation 8 and 9 indices were averaged for each character in order to obtain the best current (cummulative) set of weights; this index, I(8,9), was used to select parents for generation 10. Similarly, an index, I(10), was computed from the data of generation 10, and the weights were averaged with those from generations 8 and 9 to obtain the final index, I(8,9,10). The index was developed in this cummulative manner in order to increase the statistical efficiency of the estimates of b.

Data for the three characters was standardized to correct for errors that result when different scales are combined into the same mathematical function. Therefore, means for each character and the mean index in each generation equal zero.

2.6. Heritability

The heritability of each character in each generation can be computed from the components of variance in the covariance matrices; these are half-sib family estimates of narrow-sense heritability. Realized heritabilities were estimated from the ratio of the selection response to the selection differential. The narrow-sense heritability of the index was estimated from parent-offspring regression methods.

3. Results

3.1. Correlation of characters

3.1.1. Cut-flower yield and consumer-rating

	Generation			
	8	9	10	Mean ± S.E.
Phenotypic	0.137	0.094	0.050	0.094 ± 0.025
Genetic	0.309	-0.455	0.506	0.120 ± 0.318
Environmental	0.030	0.190	-0.057	0.054 ± 0.072

The positive, mean phenotypic correlation of 0.094 between cut-flower yield and consumer-rating is statistically significant at P = 0.05 (S.E. denotes standard error of the mean).

3.1.2. Cut-flower yield and vase-longevity

	Generation			
	8	9	10	Mean ± S.E.
Phenotypic	0.071	0.122	-0.032	0.054 ± 0.045
Genetic	0.362	-0.097	0.106	0.124 ± 0.133
Environmental	-0.071	0.169	-0.067	0.010 ± 0.079

There appears to be no correlation; phenotypic, genetic, or environmental, between cut-flower yield and vase-longevity.

3.1.3. Consumer-rating and vase-longevity

	Generation			
	8	9	10	Mean ± S.E.
Phenotypic	0.006	0.068	-0.067	0.002 ± 0.039
Genetic	-0.108	-0.021	0.153	0.008 ± 0.077
Environmental	0.049	0.083	-0.105	0.009 ± 0.058

There appears to be no correlation; phenotypic, genetic, or environmental, between consumer-rating and vase-longevity.

3.2. Selection indices

The phenotypic and genetic covariance matrices from each generation were used to estimate the coefficients in a selection index for each generation. In the index equation, Y denotes cut-flower yield, R denotes consumer-rating, and V denotes vase-longevity.

3.2.1. Generation 8

$$I(8) = 1.175\ Y + 0.607\ R + 0.504\ V$$

This index places approximately equal weight on consumer-preference and vase-longevity and twice the weight on cut-flower yield. It was calculated for each plant in generation 8; plants with the highest values were used as parents for generation 9.

3.2.2. Generation 9

$$I(9) = 0.400\ Y + 0.139\ R + 0.656\ V$$

This index was derived from the data of generation 9 to be combined with the index from generation 8.

3.2.3. Generation 8,9

$$I(8,9) = 0.787\ Y + 0.373\ R + 0.580\ V$$

The weights in this index are arithmetic means of the weights in the generation 8 and 9 indices. It was calculated for each plant of generation 9; those with the highest values were used as parents for generation 10.

3.2.4. Generation 10

$$I(10) = 0.092\ Y + 0.064\ R + 0.058\ V$$

This index was derived from the data of generation 10 to be combined with the indices from generations 8 and 9.

3.2.5. Generation 8,9,10

$$I(8,9,10) = 0.556\ Y + 0.270\ R + 0.406\ V$$

This is the final index that includes the data from all three generations.

3.3. Heritability

3.3.1. Index

The narrow-sense heritability of the index was estimated from the regression of offspring in generation 9 on their parents of generation 8, and of offspring in generation 10 on their parents of generation 9.

Generation of Parent	Heritability ± S.E.
8	0.344 ± 0.202
9	0.142 ± 0.266
combined	0.301 ± 0.161

In each generation there is a positive regression of offspring on parents, but neither is significant at P = 0.05 (S.E. denotes standard error of the estimate). When the data from the two generations are combined into one analysis, the heritability estimate of 0.301 borders on significance (P = 0.06).

3.3.2. Characters

3.3.2.1. Cut-flower yield

Half-sib family estimates of narrow-sense heritability for each generation were:

Generation	Heritability
8	0.457
9	0.186
10	0.255
Mean ± S.E.	0.299 ± 0.081

The realized heritability from generation 8 to 9 was 0.322, and from generation 9 to 10 was 0.336; the mean was 0.329.

3.3.2.2. Consumer-rating

Half-sib family estimates of narrow-sense heritability for each generation were:

Generation	Heritability
8	0.323
9	0.116
10	0.140
Mean ± S.E.	0.193 ± 0.065

The realized heritability from generation 8 to generation 9 was -0.039, and from generation 9 to 10 was -0.418; the mean was -0.229.

3.3.2.3. Vase-longevity

Half-sib family estimates of narrow-sense heritability for each generation were:

Generation	Heritability
8	0.229
9	0.169
10	0.157
Mean $\pm$ S.E.	0.185 $\pm$ 0.023

The realized heritability from generation 8 to 9 was 0.318, and from generation 9 to 10 was 0.306; their mean was 0.312.

4. Discussion

There are a number of ways to construct a selection index. In the one developed by Smith (1936) and elaborated by Hazel (1943), the aggregate genetic value (G) of a plant is defined as the sum of the additive (breeding) values of the individual characters,

$$G_i = a_1 g_{i1} + a_2 g_{i2} + \dots a_j g_{ij},$$

where a_j are economic weights assigned to breeding values, g_{ij}, of the j characters. In the derivation of this index, a solution for b_i is obtained that maximizes the increase in G. With this criterium, greater weights are placed on characters with higher heritabilities and on those with positive genetic correlations.

The results of this study indicate that the selection index was successful. There was a near-significant (P = 0.06) heritability for the index, estimated from parent-offspring regression. Two of the three characters in the index appear to have increased over the three generations.

An increase of approximately 30% per generation, i.e. realized heritability, was observed for cut-flower yield. This was somewhat larger than the 20% reported for the first 3 generations of the Davis Population (Harding, Drennan, and Byrne; 1985). The increase in cut-flower yield was expected, because cut-flower yield had the highest half-sib heritability of the characters in this study. Moderate to high heritabilities for cut-flower yield were also reported by Maurer and Horn, 1967; Wricke and Horn, 1971; and DeLeo and Ottaviano, 1978.

A realized heritability of ca. 30% was also observed for vase-longevity, although the half-sib heritability was only 18.5%. Three early generation estimates of half-sib heritability averaged 21% (Harding, Byrne, and Nelson, 1981). Hence, the estimated response of 30% may be higher than should be expected.

Consumer-rating did not respond to selection; in fact, it may have been reduced. This was confirmed by our visual observation of generation 10 flowers. In our previous study (Drennan, Harding, and Byrne; 1983), consumer-preference was found to have a narrow-sense heritability of ca. 70% and a response to selection of ca. 70%. Yet, in the present study the narrow-sense heritability of consumer-rating was only 19% and the response to selection was negative. Clearly, consumer-rating and consumer-preference are not equivalent. Apparently, judges can rank their preference of flowers more consistantly than they can rate flowers on a hedonic scale. We cannot say which correlates better with parameters of flower quality, but we do conclude that the more heritable consumer-preference is preferred from the breeders point of view.

Accurate estimates of the weights in a selection index require extraordinarily large samples of families. This prompted our use of cummulative weights. However, it is only after a number of generations that the estimates become reliable. After one generation it appeared that cut-flower yield and consumer-rating were strongly genetically correlated, but after three generations they appear to be genetically independant. Consequently, precise results should not be expected from a selection index until it has been used for a number of generations.

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