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Postharvest Longevity of Cut-flower *Gerbera*. II. Heritability of Vase Life

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***Abstract*. Intensive selection to improve vase life was performed on a sample population of *Gerbera* ×*hybrida* Hort. from a broad source of germplasm. Progeny of a 5 × 5 diallel cross yielded estimates of narrow sense heritability (h^2 = 0.28) and broad sense heritability (H^2 = 0.28) for vase life based on a mean of 1.96 measurements per plant. Additive gene action is postulated to control this character since the difference between total genotypic variance and additive genetic variance components was small. Repeatability (*r* = 0.57) based on a single measurement per plant was moderately high. Heritability estimates were also determined based on 1, 2, 3, 5, and ∞ measurements per plant. Heritability ranged from 22% to 39%.**

Gerbera ×*hybrida* is a popular cut flower, but its postharvest performance is often less than desirable. Postharvest treatments (i.e., floral preservatives) are used to enhance the vase life of gerbera (Accati, 1989) but developing cultivars with genetically superior postharvest longevity may provide the consumer with a reliable expectation for postharvest quality. Therefore, research to evaluate the potential of plant breeding as a method to improve vase life in gerbera is important.

Estimates for heritability of vase life have been previously reported. However, estimates can vary based on the population of plants evaluated, selection intensity, mating design, and environment (Simmonds, 1979). Serini and De Leo (1978) concluded that selection should be based more on families than individual plants, since their estimate of narrow sense heritability was higher among full-sib families (h_2 = 0.67) than among plants (h^2 = 0.17). Tesi (1978), using clones from a population of *Gerbera jamesonii* with semi-double flowers, concluded that vase life is strongly influenced by environmental factors. He observed only 15% of the phenotypic variation in vase life was due to genotype (h_2 = 0.15). Harding et al. (1981) based their results on a nonrandom sample population of gerbera genotypes from their Davis population, which consisted of half-sib families and clonal parents. They concluded that since narrow sense heritability (h^2 = 0.24 and 0.38) and broad sense heritability (H^2 = 0.36 and 0.46) were moderately low for two successive generations, either intense selection or selection over a large number of generations would be required to increase mean vase life. Harding et al. (1987) compared their earlier average estimate of narrow sense heritability (21%) to a new average of narrow sense heritability (18.5%). Both averages were calculated using data from three generations of half-sib family mating. Realized heritability estimated from the ratio of the selection response to the selection differential was about 30%.

The objectives of this study were to determine narrow sense heritability and broad sense heritability of vase life by diallel analysis using a broad based source of germplasm.

Materials and Methods

A breeding experiment was designed to evaluate the potential for genetically improving vase life in gerbera. We made a 5 × 5 diallel cross using parents selected for high vase life. A detailed description of this experiment and procedures for collecting vase life data were presented previously (Wernett et

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al., 1996). A general summary is provided.

A random population of 953 plants varying phenotypically in stem and inflorescence traits were grown. From these, a parental generation of 325 plants was selected based on plants that produced single, daisy-type inflorescences, stem length over 45 cm, and at least three flowers during a 6 week vase life evaluation period. A vase life mean for each plant, based on three flowers per plant was determined. About 10% of this generation, plants with the highest mean vase life and lowest coefficient of variation, were selected and used in a top-cross with ‘Appleblossom’ as the male donor. A vase life progeny mean for each cross was determined based on three flowers per plant. Five plants with the highest progeny mean vase life (about 1.5% of the original parental generation) were selected and used as parents in a 5 × 5 diallel.

Plants were irrigated 2–3 h before harvest each evening to reduce possible preharvest water stress. Flowers with one to two rows of open disc florets were harvested and cut to a uniform length of 30 cm. Single flowers were placed into sterilized glass bottles containing 100 ml of deionized water, buffered with a citrate-phosphate buffer. Vase solutions were replaced every other day until senescence occurred. Vase life was measured by the number of days to senescence.

Vase life data were initially analyzed according to the random model for Griffing Method 3 (Griffing, 1956). This method describes a diallel mating design that includes reciprocal crosses but excludes self crosses. No reciprocal differences were observed. Subsequently, analysis of variance for combining ability, using a general least squares diallel analysis program (Schaffer and Usanis, 1969), was performed on pooled data of plant means.

Narrow sense heritability (h^2) and broad sense heritability (H^2) for vase life were estimated from ratios of the following variances (Falconer, 1960)

V_A = additive genetic variance
V_G = total genotypic variance (additive + nonadditive)
V_P = total phenotypic variance (genotypic + environmental)
$h^2 = V_A/V_P \qquad H^2 = V_G/V_P$

Genotypic and phenotypic variances were determined from the following equations using the variance components for general combining ability (σ^2_{gca}), specific combining ability (σ^2_{sca}), and error (σ^2_e) (Hallauer and Miranta, 1981) which were calculated by the diallel analysis program developed by Schaffer and Usanis (1969)

$$V_A = 4\sigma^2_{gca}$$
$$V_G = 4\sigma^2_{gca} + 4\sigma^2_{sca}$$
$$V_P = 4\sigma^2_{gca} + 4\sigma^2_{sca} + \sigma^2_e$$

Thus, heritability (h^2 and H^2) were estimated from the formulae

$$h^2 = 4\sigma^2_{gca}/4\sigma^2_{gca} + 4\sigma^2_{sca} + \sigma^2_e \qquad H^2 = 4\sigma^2_{sca}/4\sigma^2_{gca} + 4\sigma^2_{sca} + \sigma^2_e$$

Predicted estimates of narrow sense heritability and broad sense heritability for n measurements per plant were also made. This required partitioning the environmental variance (V_E), a component of phenotypic variance (V_P), into general environmental variance (V_{Eg}) and special environmental variance (V_{Es}) to determine the phenotypic variance ($V_{P(n)}$) for each case (Falconer, 1960).

$$V_P = V_G + V_E$$
$$V_E = V_{Eg} + V_{Es}$$
$$V_{P(n)} = V_G + V_{Eg} + 1/n\ V_{Es}$$

Special environmental variance (V_{Es}) or within-individual variance for a single measurement per plant may be derived by the error variance component ($4\sigma^2_{sca}\,^2_e$) from a one-way analysis of variance (Falconer, 1960). Henderson’s Method 3 (Henderson, 1953) for obtaining variance components was performed on vase life using individual flowers as observations rather than plant means. The SAS procedure VARCOMP (SAS Inst., Cary, N.C.) was used to obtain the σ^2_e or error MS. General environmental variance (V_{Eg}) or between-individual variance (Falconer, 1960) was calculated by subtracting the quotient of this error MS/n, whereby n = no. of flowers per no. of plants evaluated in the diallel cross, from the error MS or $4\sigma^2_{sca}\,^2_e$ obtained by the combining ability analysis of variance.

Repeatability for vase life was determined from the following ratio of variances whereby n = 1 (Falconer, 1960).

$$r = \frac{V_G + V_{Eg}}{V_{P(n)}}$$

Results

Sixteen progeny means for vase life were obtained from a 5 × 5 diallel cross (Table 1). The range of vase life means for these progenies was 8.5 to 15.5 days. Reciprocal differences were nonsignificant (unpublished data). The cross between 83-7-4 and 83-7-10 resulted in the highest progeny mean (14.3 days) for vase life after reciprocals were pooled. Data previously presented (Wernett et al., 1996) show these two parent lines had the highest progeny means for

Table 1. A 5 × 5 diallel. Vase line means (days) based on progeny means of gerbera crosses (n = no. of progeny).

Male	Female				
parents	83-1-77	83-4-69	83-5-109	83-7-4	83-7-10
83-1-77	***	x = 9.2	x = 9.3	x = 12.5	x = 9.8
	***	n = 13	n = 18	n = 19	n = 13
83-4-69	x = 11.0	***	x = 8.5	x = 12.2	x = 11.7
	n = 19	***	n = 16	n = 18	n = 21
83-5-109	x = 8.6	***	***	***	***
	n = 12	***	***	***	***
83-7-4	x = 11.8	x = 11.1	x = 11.4	***	x = 14.3
	n = 21	n = 9	n = 22	***	n = 25
83-7-10	x = 15.5	x = 14.0	x = 12.5	***	***
	n = 3	n = 1	n = 18	***	***

Table 2. A 5 × 5 diallel. Combining ability analysis of variance for gerbera vase life.

Source of variation	df	MS	F ratio
General combining ability	4	106.12	8.03*
Specific combining ability	5	13.21	1.01NS
Error	238	13.08	

*Significant or nonsignificant at at $P \leq 0.05$.

Table 3. A 5 × 5 diallel. Variances and heritability[z] estimates for gerbera vase life (N = 1.96).

V_A	V_G	V_P	h^2	H^2
5.08	5.12	18.20	0.28	0.28

[z]V_A = additive genetic variance. V_G = total genotypic variance. V_P = total phenotypic variance. h^2 = narrow-sense heritability. H^2 = broad-sense heritability.

Table 4. A 5 × 5 diallel. Predicted estimates of heritability for gerbera vase life.

	No. of measurements				
Heritability[z]	1	2	3	5	∞
h^2	0.22	0.28	0.31	0.34	0.39
H^2	0.22	0.28	0.31	0.34	0.39

h^2 = narrow-sense heritability. H^2 = broad-sense heritability.

vase life resulting from the top-cross compared to the other three parent lines. Combining ability analysis of variance was performed on plant means from a 5 × 5 diallel (Table 2). General combining ability effects were significant. Specific combining ability effects were nonsignificant. Heritability was determined from a set of variances (Table 3). Narrow sense heritability (h^2 = 0.28) and broad sense heritability (H^2 = 0.28) estimates were equal. This indicates nonadditive genetic variance ($V_G - V_A$) is negligible.

Estimates of heritability were based on an average of 1.96 measurements per plant. This value (n) resulted by evaluating 487 flowers from 248 plants. The error variance component (σ^2_e = 9.88) for a single measurement per plant was obtained by an analysis of variance using vase life data from individual flowers of the diallel generation. Results of this analysis were presented in Wernett et al. (1996). Also, this analysis indicated differences in vase life of flowers among crosses and among plants within crosses were highly significant. Environmental variances for this population were determined to be: V_E = 13.08, V_{Eg} = 8.04, and V_{Es} = 9.88. Predicted estimates of narrow sense heritability and broad sense heritability for vase life were then calculated for 1, 2, 3, 5, and measurements per plant from the ratios of genetic variance (V_A or V_G) to phenotypic variance ($V_{P(n)}$) (Falconer, 1960). Estimates ranged from 22% to 39% (Table 4). Repeatability *(r* = 0.57) based on a single measurement per plant for vase life was moderately high.

Discussion

Estimates of heritability for vase life determined from this experiment (h^2 = 0.28 and H^2 = 0.28), based on 1.96 measurements per plant, are moderately low. These estimates are within proximity of those reported by other researchers: 15% (Tesi, 1978); 17% (Serini and De Leo, 1978); 0%, 24%, and 38% (Harding et al., 1981), and 23%, 17%, and 16% (Harding et al., 1987). This reflects some consistency in the proportion of genetic variance to phenotypic variance for vase life in gerbera, regardless of genetic diversity in populations sampled, breeding procedures, and environment.

It appears that genetic variation may be largely controlled by additive gene action since broad sense and narrow sense heritability were about equal. Therefore, in a fixed model experiment, progeny means obtained from a top-cross mating would effectively determine parents with good combining ability for increased vase life.

Falconer (1960) demonstrated a method to predict estimates of heritability for a specified number of measurements per experimental unit. This involved partitioning environmental variance (V_E) into general environmental variance (V_{Eg}) and special environmental variance (V_{Es}). Special environmental variance (V_{Es}), or within-plant variation, is the environmental variation for a single observation per experimental unit. The magnitude for special environmental variance (V_{Es}) is then divided by a specified number of measurements per experimental unit (n) as part of the calculation to obtain the phenotypic variance for each special case. Ideally, if n = ∞, then V_{Es} will be reduced to zero, thereby deleting a significant source of environmental variation. In that case, the highest possible estimate of heritability could be obtained for a given population.

Using this method, predicted estimates of heritability for vase life in gerbera ranged from 22% to 39% with n specified as 1, 2, 3, 5 and flowers per plant. Since these calculations assumed no change in genotypic effects, broad sense and narrow sense heritability estimates for each case were about equal. In spite of varying the magnitude of environmental variance, this range of predicted estimates remained within proximity to those determined by other researchers (Harding et al., 1981; Serini and De Leo, 1978; Tesi, 1978). Harding et al. (1978) commented that their calculation for realized heritability (about 30%) may indicate an estimated response higher than should be expected. According to our range of predicted estimates for heritability, their estimate may be more reasonable than initially thought.

The repeatability estimate for vase life (*r* = 0.57) is moderately high, indicating that two to three flowers per plant may be adequate for determining the average vase life per plant. Falconer (1960) recommends that further gain in accuracy by more than two measurements does not justify additional expense or time required to collect more data when repeatability is high. This was demonstrated by comparing the relative increase in heritability from predicted estimates based on 1, 2, 3, 5, and ∞ measurements per plant. Between one and three measurements, heritability increased by 9%, while beyond three measurements through infinity, the gain in heritability was only 8%.

Results from this study have provided further evidence that improvement of postharvest longevity in gerbera can be obtained by intense selection and mating of plants with good combing ability for high vase life, despite the conclusion that heritability of vase life was moderately low. The low heritability can be attributed to the fact that vase life in gerbera is a composite character of at least three components (DeJong and Garretsen, 1985; Wernett et al., 1996).

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