Genotype $\times$ Season Interaction for Time to Flowering and Flower and Plant Diameter in *Exacum affine* Balf.

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Abstract. Genotype $\times$ season interaction was investigated for days to first flower and full bloom and flower and plant diameter for 15 exacum cultivars and breeding lines produced in two glasshouses during winter and summer growing seasons. Genotype $\times$ season interactions were significant ($P < 0.01$) for all four characteristics. Genotype rankings for time to flowering and plant diameter varied greatly depending on the growing season; evaluation during the target growing season is recommended when selecting among exacum genotypes for these characteristics.

In plant improvement programs, the amount of genotypic variance due to genotype $\times$ environment interaction determines whether genotypes are tested in multiple environments (Comstock and Moll, 1963). Research on many field crops has demonstrated that genotype $\times$ environment interaction is significant for some characteristics (Chakrown et al., 1990; Fernandez and Chen, 1989; Shellie and Hosfield, 1991). Although floricultural crop breeders usually test genotypes under multiple environments, few genotype $\times$ environment interaction studies have been conducted.

For *Gerbera hybrida* cut flower yield, Byrne et al. (1987) reported that selection response will be overestimated if genotype $\times$ environment interaction is not taken into account when estimating heritability. In addition, Teynor et al. (1989a, 1989b) found that chrysanthemum [*Dendranthema $\times$ grandiflorum* (Ramat.) Kitamura] clone flower color could be classified differently depending on environment (field and glasshouse); thus, they recommended evaluating flower color under multiple environments.

Breeding programs have improved exacum (a flowering, potted plant) growth habit and time to flowering (Harbaugh, 1991; Irwin,

1984; Wolf and Craig, 1988), although further improvements are desired. Research on the environmental effects on these characteristics so far has focused on one or a few genotypes. For two inbred exacum lines, Williams et al. (1983) reported that irradiance level influences foliar characteristics and the number of days to flowering. They suggested that the response to irradiance level explained the seasonal variation in exacum flowering time. Supplemental irradiance (30 W·m⁻²) during winter also reduced the production period of 'Best Blue' exacum (Andersen and Aabrandt, 1988). In addition, Harbaugh and Waters (1982) reported that fertilizer rate influenced foliar chlorosis and floral display ratings of 'Elfin' exacum plants in low-irradiance, simulated home conditions.

Although seasonal variations in exacum flowering time and morphological characteristics have been noted (Larson, 1981; Williams et al., 1983), the importance of the interaction between exacum genotype and growing season has not been reported. Therefore, the objective of this investigation was to determine the importance of the genotype $\times$ season interaction for days to first flower and full bloom and flower and plant diameter in exacum in winter and summer growing seasons.

The experiment with 15 exacum genotypes (cultivars and breeding lines) (Table 1) was conducted from Oct. 1989 through June 1990

(winter environment) and Feb. through Sept. 1990 (summer environment). Genotypes were grown in two glasshouses in each season. For winter, temperatures averaged 17C in one glasshouse and 19C in the other; for summer, temperatures averaged 22C in both glasshouses.

About 14 weeks after seeds were sown, seedlings of each genotype were planted, one per 1.05-liter pot, in a soilless medium (Pro-mix BX; Premier Brands, Stamford, Conn.) supplemented with 80 g of a fritted micronutrient mixture/m³ (Micromax; Sierra Chemical, Milpitas, Calif.) and 2 g of Osmocote 14N-6.1P-11.6K (controlled-release fertilizer) per pot. Standard cultural practices were used (Irwin, 1984). Genotypes were arranged in a split plot (in time) in a randomized complete-block design at a density of 27 pots/m², two blocks per glasshouse, at Beltsville, Md.

Five plants that were surrounded by competitive plants were evaluated for each genotype in each block. The number of days to the opening of the first flower and full bloom ($\approx 25\%$ of the plant canopy covered with flowers) was recorded. At full bloom, flower (an average of measurements made on three flowers) and plant (an average of the two widest measurements) diameters were recorded.

Data were averaged over the five plants for analysis of variance. Seasons and genotypes were reconsidered fixed effects, and glasshouses and blocks were considered random effects. If nonsignificant ($P \leq 0.05$), interactions involving glasshouses were pooled with error terms.

Differences between growing season were significant for flower diameter but not for the other three characteristics (Table 1). Average flower diameter for each genotype was smaller in summer than in winter (Table 2).

For all four characteristics, variation due to glasshouses was nonsignificant, although variation among genotypes was highly significant ($P < 0.01$) (Table 1). Genotype 505 required an average of 30 days longer to reach full bloom than genotype CE (Table 2). However, genotype 505 had a larger average flower diameter than the other genotypes. This result suggests that genotype 505 may be polyploid (Erb et al., 1981; Semeniuk, 1978). Plant diameter ranged from an average of 245 mm for genotype CE to ≈ 283 mm for genotypes 42E and 42Y and cultivar Blue Champion.

Seasonal difference in time to flowering was absent when averaged over genotypes

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Table 1. Mean squares from the combined analysis of variance for days to first flower and full bloom and flower and plant diameter for 15 exacum genotypes grown in two glasshouses during two seasons.

Source	df	Days to		Diam	
		First flower	Full bloom	Flower	Plant
Season	1	420 ^{ns}	373 ^{ns}	132.0**	3818 ^{ns}
Glasshouse	1	29 ^{ns}	44 ^{ns}	0.1 ^{ns}	648 ^{ns}
Error ^a (A)	5	358	461	0.8	743
Genotype	14	609**	594**	12.4**	1460**
Genotype $\times$ season	14	386**	240**	0.9**	618**
Error (B)	83 ^b	59	44	0.3	188

^aInteractions with glasshouses were not significant and were pooled with error terms.

^bOne degree of freedom was subtracted from Error (B) due to estimated values for one missing plot.

^{ns,**}Nonsignificant or significant at $P = 0.01$, respectively.

Table 2. Phenotypic means for days to first flower and full bloom and flower and plant diameter for 15 exacum genotypes grown during two seasons.

Genotype	Source ²	Season							
		Winter				Summer			
		Days to		Diam (mm)		Days to		Diam (mm)	
		First flower	Full bloom	Flower	Plant	First flower	Full bloom	Flower	Plant
Petite	J	195	212	19.5	252	188	208	17.3	249
CE	S	194	215	19.7	250	183	203	17.4	240
Michigan White	S	200	222	18.8	249	197	221	17.3	273
3057A	S	199	222	19.8	252	211	232	17.1	286
42E	S	201	224	19.7	272	219	239	18.0	294
3033	S	206	227	20.3	267	206	227	18.3	267
Royal Blue	S	198	223	20.4	259	200	222	17.7	276
4002A	S	216	237	18.6	240	200	234	17.4	266
Best Rosa	R	200	223	20.7	252	187	206	18.8	250
White Champion	S	197	219	19.8	259	220	241	17.8	294
Blue Champion	S	193	220	21.1	283	195	220	18.8	283
Little Champ	S	195	216	20.4	268	191	220	16.9	251
42Y	S	194	219	21.9	284	212	231	19.3	283
505	S	207	230	23.4	263	236	248	22.4	300
Blue Chip	J	198	223	20.8	278	207	232	19.0	284
LSD ($P = 0.05$)									
Within seasons		11	9	0.8	19	11	9	0.8	19
Between seasons		13	12	0.8	21	13	12	0.8	21

²J = J & L Plants, Amarillo, Texas; S = Earl J. Small Growers, Pinellas Park, Fla.; R = Rosendals EX-PLANTS Aps., Assens, Denmark.

(Table 1). For some genotypes (e.g., CE), significantly fewer days to first flower and full bloom were required in summer than winter (Table 2). However, other genotypes (e.g., 42E) flowered earlier in winter than summer. These differences are reflected in the significant genotype $\times$ season interaction for days to first flower and full bloom (Table 1). For days to first flower, the genotype $\times$ season mean square was $\approx 60\%$ of that for genotypes. Genotype rank for days to first flower changed dramatically for some genotypes with growing season. For example, genotype 42Y was ranked second in winter but 12th in summer. Lower irradiance levels during winter may increase flower production time in exacum (Larson, 1981; Williams et al., 1983); however, the influence of various environmental factors may be genotype-dependent. There were also large changes in rank in winter vs. summer growing seasons for days to full bloom and plant diameter; these changes are reflected in highly significant genotype $\times$ season interactions (Table 1). For flower diameter, the mean square for genotype was 14 times larger than the mean square for genotype $\times$ season interaction. Nevertheless, the genotype $\times$ season source of variation for flower diameter was highly significant (Table 1).

The exacum genotypes in this study interacted with growing season more than with glasshouse environment for days to first flower and full bloom and for flower and plant diameter. Therefore, time to flowering and flower and plant diameter should be evaluated in winter and summer if the objective is to select an early flowering genotype with a large flower

and small plant diameter for a particular growing season.

A target environment for glasshouse floral crops can be difficult to define, especially for those crops that are grown year-round under natural daylength and irradiance at a variety of latitudes. Further investigations are needed to examine the magnitude of the genotype $\times$ environment interaction for economic characteristics in a wide range of environments for all major floricultural crops. Evaluating genotypes in more than one environment was found to be important for *Gerbera hybrida* cut flower yield (Byrne et al., 1987) and chrysanthemum flower color (Teynor et al., 1989a, 1989b). This method also is recommended for evaluating exacum time to flowering and flower and plant diameter.

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