Effects of Storage Period and Rhizome Breaking on *Oxalis triangularis* subsp. *popilionacea* Growth and Development©

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***Oxalis triangularis* subsp. *popilionacea* (syn. *regnellii*) (oxalis), a specialty potted bulb crop grown for the St. Patrick's Day holiday in the United States, is asexually propagated using rhizomes. Little information exists regarding oxalis rhizome storage and handling and subsequent greenhouse forcing. This paper describes the effects of storage period and rhizome propagule source on growth and development of oxalis.**

Storage period had a significant effect on several *O. triangularis* subsp. *popilionacea* growth parameters. Days to leaf emergence decreased by nearly a week as storage duration increased from 0 weeks to 5 weeks; while time to flower was unaffected. The number of leaves and flower cymes increased as storage period increased, along with leaf dry weight, more than doubling from 0.33 g with zero storage weeks to 0.85 g after 5 storage weeks.

Whole, intact rhizome propagules produced fuller plants compared to both basal and apical rhizome sections, producing 30% more leaves. Twice as many flower cymes were produced from intact rhizome propagules. Basal rhizome portions emerged between four and six days later than other rhizome propagules and flowered at least eight days later than all other rhizome treatments. Dry weights were greatest from plants grown from whole rhizomes, 0.44 g, but were not different than plants grown from basal rhizome pieces, 0.34 g.

INTRODUCTION

Oxalis triangularis subsp. *popilionacea* (oxalis), also known as the shamrock plant, is a specialty potted bulb crop grown for its clover-like leaves and white flowers. Oxalis is marketed primarily for the St. Patrick's Day holiday in the United States (Dole and Wilkins, 2005; Miller, 1997).

Oxalis is asexually propagated through small, slender rhizomes, comprised of tiny modified leaf scales (Ingram, 1959) and maintains a supply of food reserves (presumably carbohydrates) for perrenation, serving as a survival mechanism. Commercially, rhizomes are produced in the Netherlands and the United States (California and Oregon) (De Hertogh, 1996). In total, there are approximately 6000 to 8000 m^2 (P. Van Leeuwen, pers. commun.) of *O. triangularis* subsp. *popilionacea* (and *O. triangularis*) produced in the Netherlands. There are likely similar production numbers in the United States (M.A. Mellano, pers. commun.). Commercially, rhizomes are harvested from August to October. Oxalis rhizomes can be relatively long and delicate and are easily broken during harvest and processing.

After lifting, rhizomes are separated, graded, and stored in a cool environment at 1–5 °C until shipment in November or December (De Hertogh, 1996; Dole and Wilkins, 2005). Some geophytic species require a dormant period for proper growth and development, whereas others do not require a dormant period. Dole and Wilkins (2005) report that rhizomes can be stored for 10+ months in moist peat, while Mellano (pers. commun.) suggests a much shorter storage period of 1 to 2 months. In our research, we have stored oxalis rhizomes longer than 2 months and up to 4 months, with no ill effects during greenhouse growth.

Because little information exists regarding oxalis rhizome storage and handling, along with subsequent greenhouse forcing, we conducted experiments investigating (1) different storage durations and (2) rhizome propagule breaking effects on subsequent growth and development of *O. triangularis* subsp. *popilionacea* rhizomes.

MATERIALS AND METHODS

Storage Experiment. Oxalis rhizomes were harvested weekly, for 6 weeks, from actively growing oxalis plants in the greenhouse (21 °C). Rhizomes were carefully washed then placed in plastic bags with moist vermiculite and stored in a dark cooler at 3 °C. After the 6th week, rhizomes that had been previously harvested and stored in the cooler were removed. Ten uniform rhizomes (2.15 g ± 0.5) were selected and one rhizome was planted per 10-cm pot using a commercial greenhouse medium substrate (LC1; Sun Gro Horticulture Ltd., Vancouver, Canada). Pots were placed in the greenhouse and grown at 21 °C for 6 weeks. Plants were fertilized at each watering with 250 $mg \cdot L^{-1}$ N 20N–2.2P–16.6K (Jack's Professional LX Water Soluble Fertilizer 21N–$5P_2O_5$–$20K_2O$. All Purpose; J. R. Peter's Inc., Allentown, Pennsylvania).

Breaking Experiment. Oxalis rhizomes that had been stored for 6 weeks in the dark at 3 °C were used in this study. Rhizomes of similar size were selected and gently broken in half to obtain apical and basal portions of ~3 cm. Whole intact rhizomes of ~6 cm were also selected and grown as the control, in addition to whole intact rhizomes that were equal in size to the apical and basal portions (~3 cm). Six rhizomes were planted and grown for 6 weeks in conditions as described for the dormancy experiment.

Data Collection and Statistical Analysis. Data collected for both experiments included days to shoot emergence (DTE) which was recorded when the first leaf was visible above the media surface; the number of days to flower (DTF), recorded when the first flower fully opened; the total number of leaves; and the total number of flower cymes per pot. Plant height was recorded (for the dormancy study only) after 6 weeks and above ground tissues were harvested and oven dried at 70 °C for at least 48 h after which dry weight was determined. One-way analysis of variance tests were conducted to identify differences in the measured parameters in response to storage periods and rhizome propagule portions. General linear or quadratic regression lines were applied as appropriate based on r^2 values.

RESULTS AND DISCUSSION

Rhizome Storage Experiment. Storage period had a significant effect on DTE (Fig. 1). As storage duration increased, DTE decreased. Rhizomes stored for 5 weeks emerged after 10 days compared to 16 days for rhizomes given no storage.

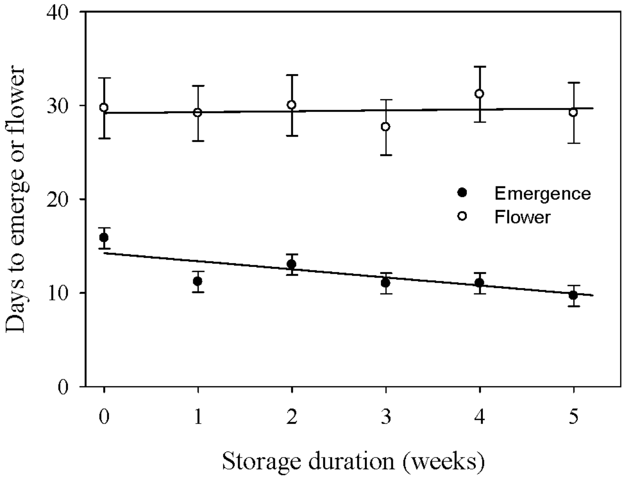

Figure 1. Effects of pre-plant storage at 3 °C on days to shoot emergence and first flower in *Oxalis triangularis* subsp. *popilionacea.* The regression equations, associated *P* values for the associated F statistic, and r^2 values are as follows; emergence: y = -0.8637x +14.2401 (P = 0.0052) (r^2 = 0.21); flowering: y = 0.0952x +29.1846 (P = 0.8944) (r^2 = 0.00).

Similar results were observed by Armitage et al. (1996) when *O. adenophylla* was stored at 5 °C (dry or wet) for at least 6 weeks. Storage period had no effect on DTF (Fig. 1). The number of leaves and flowers increased as storage period increased (Fig. 2, 4). Rhizomes stored for 5 weeks produced more than twice as many leaves than rhizomes stored for 0 or 1 week. Leaf dry weight also increased linearly as storage period increased, more than doubling from 0.33 g with 0 weeks to 0.85 g after 5 weeks storage (Fig. 3).

Rhizome Breaking Experiment. Whole, intact rhizomes produced fuller, more marketable plants compared to both basal and apical rhizome sections (Fig. 5). Basal rhizome portions emerged between 4 and 6 days later than other rhizome treatments (Fig. 6). Similarly, basal rhizomes flowered at least 8 days later than all other treatments (Fig. 6). Whole, intact rhizomes produced at least 30% more leaves and twice as many flowers when compared to the short and split rhizome portions (Fig. 7). Decapitation, or removal of the apical meristem, has been used in many plant species to overcome apical dominance and promote lateral bud development. In our study, the basal rhizome propagules produced significantly more dry matter; however, the number of leaves was not significantly different. The number of axillary buds that developed was not recorded. Leaf dry weights were greatest from plants grown from whole rhizomes, 0.44 g, but were not different than plants grown from basal rhizome pieces, 0.34 g (Fig. 8).

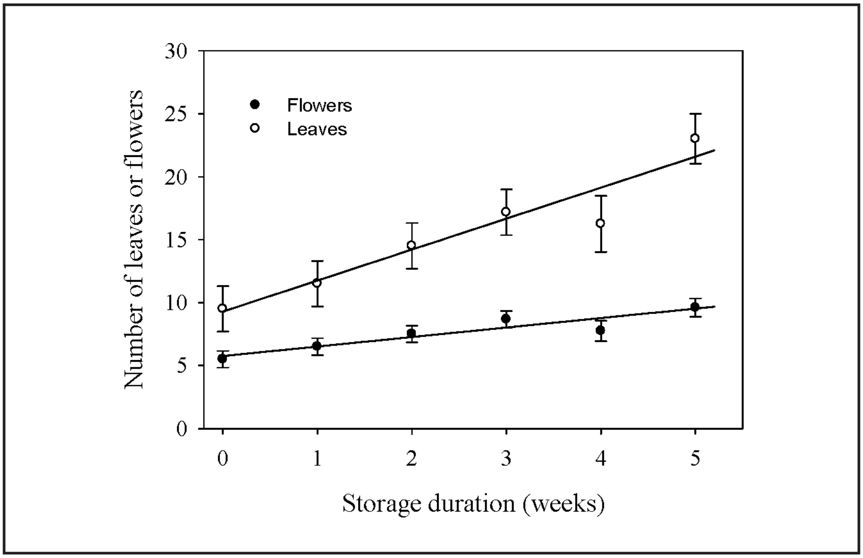

Figure 2. Effects of pre-plant storage at 3 °C on flower and leaf numbers in *Oxalis triangularis* subsp. *popilionacea.* The regression equations, associated *P* values for the associated F statistic, and r^2 values are as follows; flowers: y = 0.7536x +5.757 (*P* = <0.0001) (r^2 = 0..40); leaves: y = 2.4607x +9.289 (*P* = <0.0001) (r^2 = 0.49).

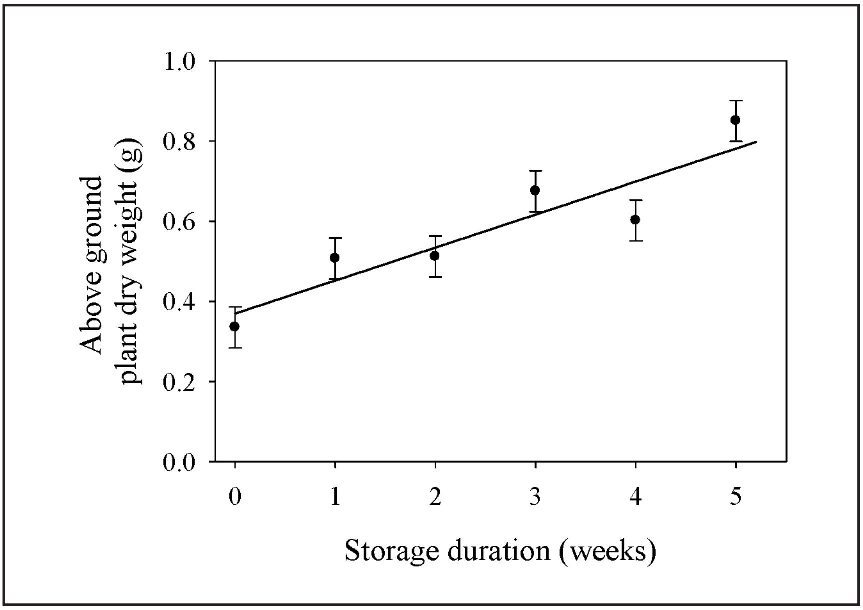

Figure 3. Effects of pre-plant storage at 3 °C on leaf dry weight in *Oxalis triangularis* subsp. *popilionacea.* The regression equation, associated *P* value for the associated F statistic, and r^2 value are as follows: y = 0.0824x +0.369 (*P* = <0.0001) (r^2 = 0.53).

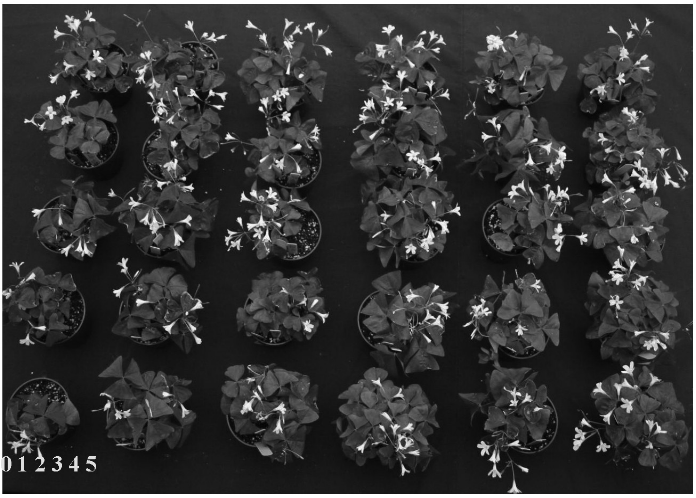

Figure 4. Effects of pre-plant storage at 3 °C on growth and development of *Oxalis triangularis* subsp. *popilionacea* forced in the greenhouse at 21 °C. L to R; 0, 1, 2, 3, 4, and 5 weeks of storage.

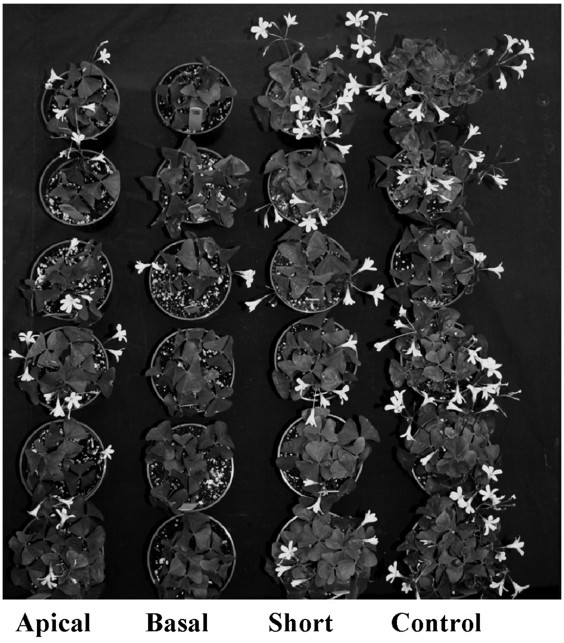

Figure 5. Effects of rhizome propagule type on growth and development of *Oxalis Oxalis triangularis* subsp. *popilionacea* plants after 6 weeks. Control rhizomes were ~6 cm. Apical and basal rhizome propagules were obtained by breaking ~6 cm rhizomes. Short rhizomes (~3 cm) were grown to compare to broken rhizomes.

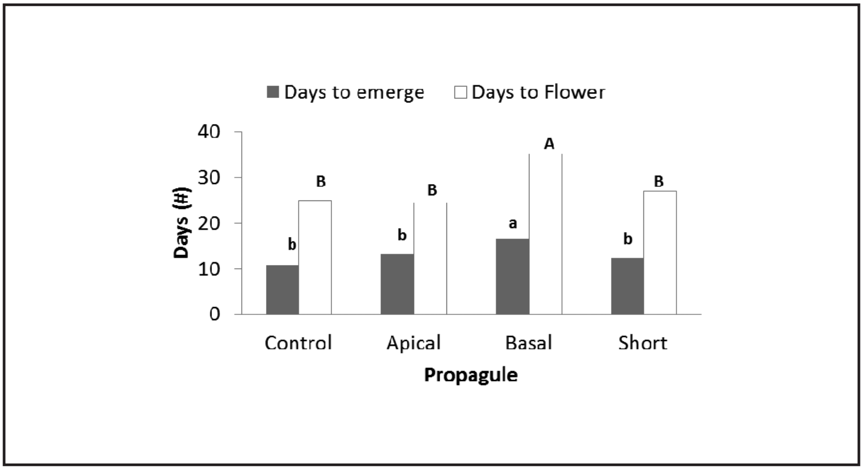

Figure 6. Effects of rhizome propagule type on days to emerge and flower for *Oxalistriangularis* subsp. *popilionacea* plants after 6 weeks of growth. Control rhizomes were ~6 cm. Apical and basal rhizome propagules were obtained by breaking ~6 cm rhizomes. Short rhizomes (~3 cm) were grown to compare to broken rhizomes. Values are means of 6 plants. Means followed by different letters are significantly different by Tukey's honestly significant difference test at $P \leq 0.05$.

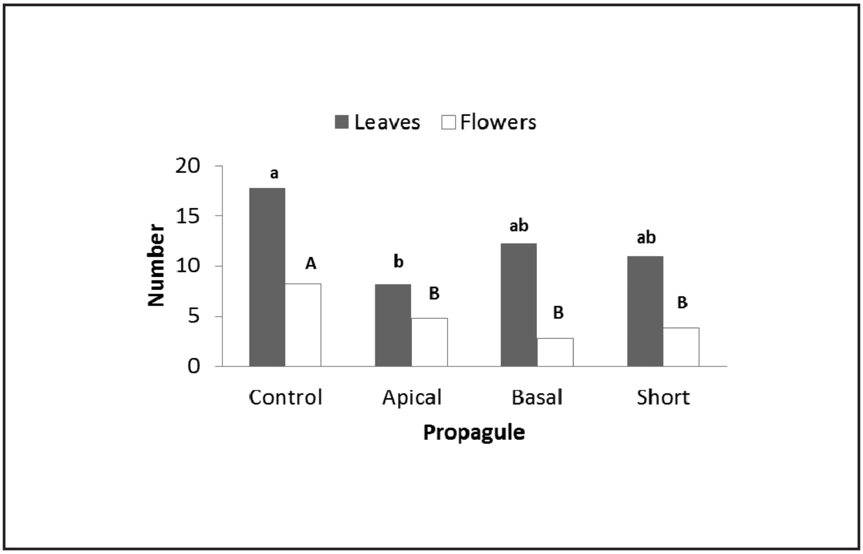

Figure 7. Effects of rhizome propagule type number of leaves and flower cymes for *Oxalis triangularis* subsp. *popilionacea* plants after 6 weeks of growth. Control rhizomes were ~6 cm. Apical and basal rhizome propagules were obtained by breaking ~6 cm rhizomes. Short rhizomes (~3 cm) were grown to compare to broken rhizomes. Values are means of 6 plants. Means followed by different letters are significantly different by Tukey's honestly significant difference test at $P \leq 0.05$.

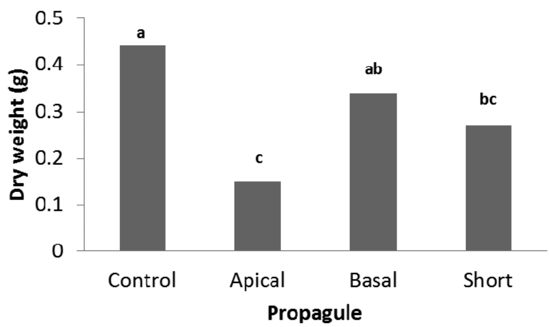

Figure 8. Effects of rhizome propagule type on leaf dry weight for *Oxalis triangularis* subsp. *popilionacea* plants after 6 weeks of growth. Control rhizomes were ~6 cm. Apical and basal rhizome propagules were obtained by breaking ~6 cm rhizomes. Short rhizomes (~3 cm) were grown to compare to broken rhizomes. Values are means of 6 plants. Means followed by different letters are significantly different by Tukey's honestly significant difference test at $P \leq 0.05$.

CONCLUSIONS

Pre-plant storage period had a positive effect on growth and development of oxalis, with more leaves and flowers produced as storage duration increased from 0 to 5 weeks. Careful handling of plant material is always important, as to reduce physical damage and potential pathogen problems. Some oxalis rhizomes can grow to be several centimeters in length and could potentially break during processing. Our results indicate subsequent growth can be achieved from either the apical or basal portion, without significant delay in growth and development. However, because oxalis is primarily marketed as a foliage plant, more leaves are beneficial and the greatest growth, both in terms of leaf number and flower stem production was from intact rhizomes. The value of the flower with oxalis is less important; however more flowers have the potential to attract more customer interest. It is unclear how longer storage periods or storage at other temperatures may affect growth and development of *O. triangularis* subsp. *popilionacea*, and should be investigated in future studies. It is plausible that plant growth hormones have little significant effects on subsequent growth and development of oxalis, namely axillary branching. Carbohydrates and their role in plant development may be more influential and would be interesting to investigate.

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