Conservation and re-establishment of Florida panhandle goldenasters (*Chrysopsis*): I. Reproduction characteristics and germination requirements

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ABSTRACT

Goldenasters (*Chrysopsis* (Nutt.) Elliott [Asteraceae]) are southeastern US native sunflowers that are important components of imperiled plant communities. However, information is limited regarding their conservation and restoration. We investigated reproduction characteristics and germination requirements for 3 *Chrysopsis* taxa: 2 forms of Godfrey's goldenaster (*Chrysopsis godfreyi* Semple f. *godfreyi* and *Chrysopsis godfreyi* f. *viridis* Semple) and Cruise's goldenaster (*Chrysopsis gossypina* ssp. *cruiseana* (Dress) Semple). The total number of inflorescences per plant, heads per inflorescence, heads per plant, and seeds per head were counted for plants growing in coastal back dunes in the Florida panhandle. The number of seeds per plant was estimated. Initial viability and germination tests were conducted by a seed testing laboratory. Effects of photoperiod (0 or 12 h) and temperature on germination were also evaluated. Reproductive characteristics did not differ among the 3 taxa, but there were differences in seed viability and germination. Seeds of *C. godfreyi* f. *viridis* and *C. gossypina* ssp. *cruiseana* had high (>70%) viability compared to *C. godfreyi* f. *godfreyi* (<50%). We observed a significant interaction between temperature and light for all 3 taxa. The highest germination percentages (50–56%) for *C. godfreyi* f. *godfreyi* were recorded in winter and early spring/late fall temperatures with light. Similarly, the highest germination percentages (58–71%) for *C. godfreyi* f. *viridis* and *C. gossypina* ssp. *cruiseana* were recorded in winter, early spring/late fall, and early fall/late spring temperatures in light. We recommend collecting seeds in the late fall to winter and immediately sowing with light exposure.

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KEY WORDS
Godfrey's goldenaster, Cruise's goldenaster, seed viability, coastal dune restoration, Asteraceae

NOMENCLATURE
Semple (1981)
USDA NRCS (2019)

CONVERSIONS

(°C x 1.8) + 32 = °F
1 ml = 0.034 oz
1 cm = 0.4 in
1 m = 3.3 ft

Photos by the authors

Goldenasters (*Chrysopsis* (Nutt.) Elliott [Asteraceae]) are herbaceous to subshrub, annual to biennial to perennial plants (Semple 1981). Most occur in xeric, nutrient-poor plant communities (Wunderlin and Hansen 2011) and support insect (Matthews and others 1990; Schaefer and others 1990; Tschinkel and Domínguez 2017) and other animal diversity (Thill and Martin 1986; MacDonald and Mushinsky 1988). The genus contains rare, threatened, and endangered species (Wunderlin and Hansen 2011). All 11 species of *Chrysopsis* are native to Florida, 7 of which are endemics that occur in the central or panhandle region of the state (Wunderlin and Hansen 2011; eFloras 2019). Because of their rarity and value to fauna and dune stabilization, we recommend goldenasters for inclusion in coastal restoration projects.

The current experiments include 2 species representing 3 taxa found within the panhandle of Florida coastal back dunes: *Chrysopsis godfreyi* Semple f. *godfreyi*, *Chrysopsis godfreyi* f. *viridis* Semple, and *Chrysopsis gossypina* ssp. *cruiseana* (Dress) Semple. Godfrey's goldenaster (*C. godfreyi* f. *godfreyi* and *C. godfreyi* f. *viridis*), first identified in 1978, is a rare state-endangered coastal dune plant endemic to a few counties in the central and western panhandle of Florida and coastal Alabama (Semple 1978; DeLaney and Wunderlin 2002; USDA NRCS 2019). It is most common on barrier islands, and it sometimes forms large colonies that assist in sand stabilization on back dunes (Semple 1978; USDA NRCS 2019). Likewise, Cruise's goldenaster (*C. gossypina* ssp. *cruiseana*) is a rare and state-endangered plant found in dunes and scrub within the western Florida panhandle (Wunderlin and Hansen 2011; USDA NRCS 2019; Wunderlin and others 2019) (Figure 1). According to Semple's (1978) account, 2 forms of Godfrey's goldenaster exist, f. *godfreyi* and f. *viridis* (Figure 1). The 2 forms are distinguished by leaf pubescence with forma *godfreyi* exhibiting long, woolly hairs and forma *viridis* exhibiting sticky, glandular pubescence on leaves. *Chrysopsis gossypina* spp. *cruiseana* displays thin pubescence on the basal leaves, the tips of some leaves, and (or) on the youngest leaves, but not throughout the entire stem. *Chrysopsis godfreyi* f. *viridis* appears green in color and has stipitate, glandular trichomes that exude a sticky oil. *Chrysopsis godfreyi* f. *godfreyi* is densely covered with pubescence on all stems and leaves, producing a silvery-white appearance because of the large amount of hairs present.

Information regarding seed propagation of *Chrysopsis* species is limited. In a field study, the federally endangered Florida goldenaster (*Chrysopsis floridana* Small) had significantly higher emergence (>75%) in bare, disturbed soil with 30% shade compared to 35 to 45% emergence in full sun or 50% shade (Lambert and Menges 1996). Even lower emergence percentages (<35%) occurred when seeds were placed in undisturbed soil with or without litter, regardless of light level. Exposure to liquid smoke, but not wet or dry heat, increased final germination percentage and time to germination for *Chrysopsis highlandsensis* DeLaney & Wunderlin (King and Menges 2018). Weekley and others (2008) reported 2% field emergence and 20% laboratory germination for *Chrysopsis highlandsensis* based on previously unpublished work by Menges and Weekley, but details of the germination conditions were not provided. Barbour (2007) reported low germination of 19% for *Chrysopsis gossypina* (Michx.) Elliott, but no details of the germination conditions were provided. Barbour (2006) also reported *Chrysopsis gossypina* to have poor field emergence (1%) but fair lab germination of 36% when exposed to 20/30 °C diurnal 8 h light/16 h dark photoperiod, noting that 40% germination was achieved after seed cleaning procedures were employed. Similarly, *Chrysopsis gossypina* germinated at 30% when placed in a Petri dish and left at room temperature on a windowsill within a laboratory (Glitzenstein and others 2002). Information regarding flower and fruit production is lacking for most *Chrysopsis*, however, and the germination requirements for most species are not well understood. In this experiment, we describe reproductive characteristics and investigate the effects of photoperiod and temperature on germination for 3 taxa of *Chrysopsis* found on back dunes (stable dunes inland of foredunes and beach) in the Florida panhandle.

METHODS

Reproductive Characteristics

A total of 150 heads (capitula) containing single-seeded fruits (achenes), hereafter referred to as seeds, from 33 individuals (10–12 of each taxa) were collected during December 2009 from 2 sites (Pensacola and Perdido Key) in the western panhandle of Florida. The Pensacola site is within the Naval Air Station Pensacola (30.35 N, 87.32 W; elevation 9 m) and the Perdido Key site is within Perdido Key State Park (30.30 N, 87.47 W; elevation 7 m). The dominant plant species present at both sites were woody goldenrod (*Chrysoma pauciflosculosa* (Michx.) Greene [Asteraceae]), goldenasters (*Chrysopsis* spp.), sand live oak (*Quercus geminata* Small [Fagaceae]), and myrtle oak (*Quercus myrtifolia* Willd. [Fagaceae]). The Pensacola site additionally had false rosemary (*Conradina canescens* (Torr. & A. Gray ex Benth.) A. Gray [Lamiaceae]), ground cherry (*Physalis angustifolia* Nutt. [Solanaceae]), and jointweeds (*Polygonella* Michx. [Polygonaceae]).

Up to 5 non-fractured, fruit-bearing heads were collected from each inflorescence (flowering stem originating from the rosette). Heads were placed in paper envelopes, sealed, and stored in a growth chamber at approximately 23 °C prior to further characterization. Seeds were separated from flower heads by hand, graded, and counted. Class 1 seeds (normal) were defined as fully developed, light to dark tan in color, and having no signs of herbivory (Figure 2A). Class 2 seeds (abnormal) were defined as underdeveloped or having evidence of herbivory, and thus were not used further for experimentation

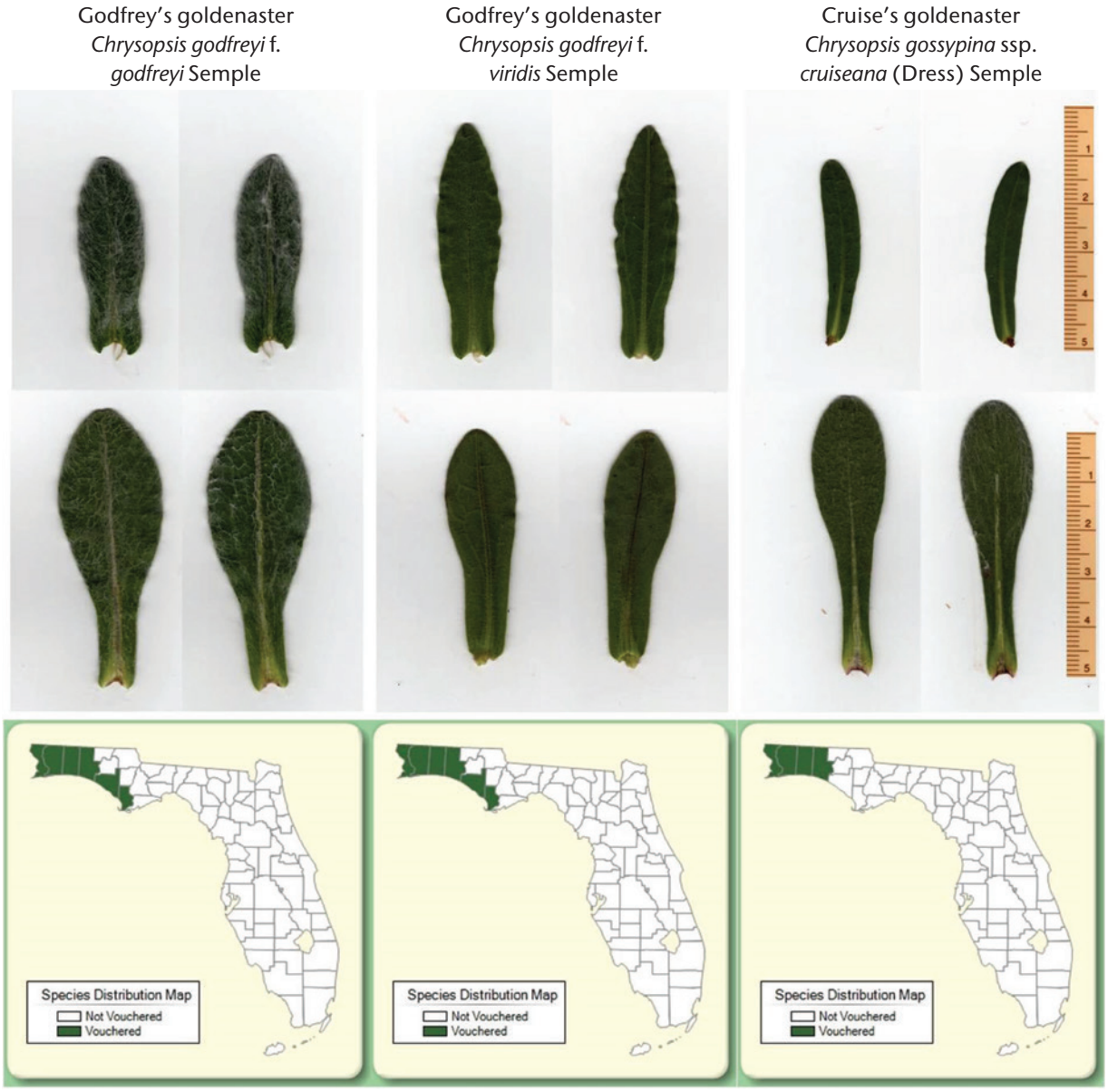

Figure 1. Scans of upper (cauline) (*top row*) and basal leaves (*bottom row*) of elongated inflorescences and Florida distribution maps (Wunderlin and others 2019) of vouchered specimens of Godfrey's goldenaster and Cruise's goldenaster. Scale = 5 cm.

(Figure 2B). Cleaned seeds (separated from heads by hand) were air-dried at 22 °C and relative humidity ~40% for 48 to 72 h before analysis.

The total number of inflorescences per plant, heads per inflorescence, heads per plant, and seeds per head were recorded. The number of seeds per plant (heads per plant × seeds per head) was estimated for each taxa.

Viability Tests and Initial Germination

In accordance with the Tetrazolium Testing Handbook, Contribution No. 29, Association of Official Seed Analysts rules (Peters 2007), pre-germination viability tests (tetrazolium (TZ) tests) were replicated twice on a subset of 100 seeds per taxa (2 forms of *C. godfreyi* and *C. gossypina* spp. *cruiseana*). TZ

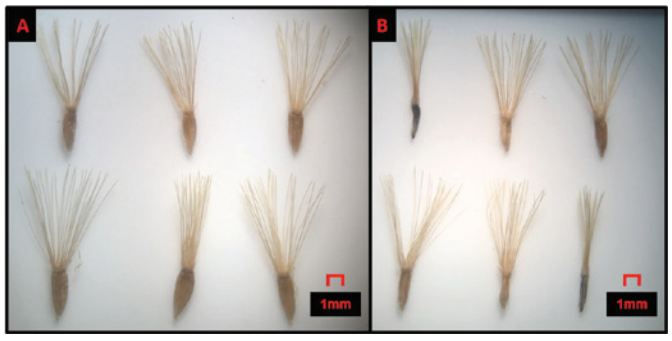

Figure 2. Seeds (achenes) of Cruise's goldenaster (*Chrysopsis gossypina* ssp. *cruiseana*). Class 1 seeds (A) fully developed, light to dark tan in color, with no signs of herbivory; Class 2 seeds (B) show color and size irregularities, and signs of herbivory.

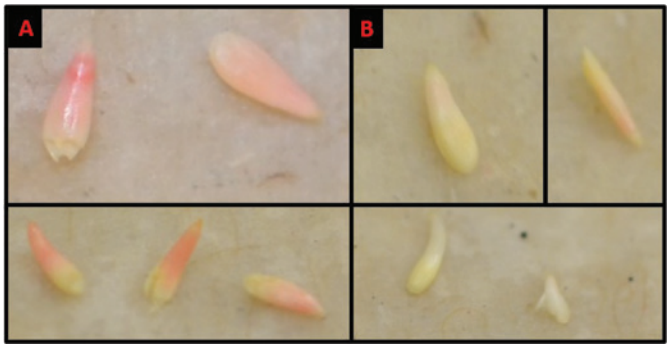

Figure 3. Viable (A) and nonviable (B) staining patterns for seeds of Cruise's goldenasters (*Chrysopsis gossypina* ssp. *cruiseana*) exposed to 1% tetrazolium for 24 h.

tests were performed by MidWest Seed Service Inc, Brookings, South Dakota. Seeds were pretreated by placing them between moist blotter paper saturated with deionized water and allowing them to imbibe moisture overnight at 20 to 25 °C. Seeds were then cut longitudinally and stained for 18 to 24 min at 30 to 35 °C in 1.0% tetrazolium (2,3,5-triphenyl tetrazolium chloride) solution with positive staining patterns confirming seed viability. Seeds that stained substantially pink were considered viable (Figure 3A) whereas seeds with little or no staining were deemed nonviable (Figure 3B).

An additional 400 seeds per taxa were subjected to germination tests (4 replications of 100 seeds per test) at 30/20 °C (8 h photoperiod at 30 °C followed by 16 h darkness at 20 °C) for 28 d by MidWest Seed Service Inc. Seeds were arranged in germination boxes (containing 2 layers of moistened blotter paper saturated with deionized water) that were placed in incubators equipped with cool-white fluorescent lamps. Germination (radicle emergence) was recorded after 28 d. Seeds that did not germinate were subjected to post-germination viability tests (as described previously), and the data were used to calculate percent germination of viable seeds [(number of seeds germinated/number of viable seeds) × 100)]. Water was added to seeds as needed.

Germination Response to Photoperiod and Temperature

We conducted a germination trial on 2 September 2010 to test the effects of photoperiod and temperature on germination of Class 1 seeds for each of the 3 *Chrysopsis* taxa. A randomized complete block design was used for this experiment with a factorial arrangement of treatments with 2 levels of light exposure (photoperiod) and 4 levels of temperature regime (4 day/night corresponding to high/low temperatures). Seeds were incubated with 0 or 12 h of white fluorescent light at a photosynthetic photon flux of 22 to 30 µmol/$m^{2/s}$. Darkness was achieved by double wrapping boxes in aluminum foil. Temperature treatments included 20/10 °C, 25/15 °C, 30/20 °C, and 35/25 °C corresponding to average high/low winter, early spring/late fall, early fall/late spring, and summer temperature regimes for Florida, respectively. Seeds were exposed to light during high temperatures.

Seeds were soaked in a Physan 20 (Marlin Products Inc, Tustin, California) fungicide solution (1.0 ml of Physan 20 per 500 ml of deionized water) for 5 min to reduce the amount of surface contaminants (Physan 20 was tested in preliminary trials and determined to have no effect on final germination). Surface disinfected seeds were then placed in 10.9 × 10.9 cm transparent polystyrene germination boxes (Hoffman Manufacturing Inc, Albany, Oregon) containing 2 sheets of germination paper (Hoffman Manufacturing Inc) that were saturated with 15 ml of ultrapure water. An additional 5 to 10 ml of deionized water was added to germination boxes as needed. Germination boxes containing seeds were then placed in temperature- and light-controlled chambers equipped with cool-white fluorescent lamps (Model818; Precision Scientific, Winchester, Virginia). The experimental unit was a germination box with 50 seeds, and 4 replications were used for each temperature and photoperiod treatment and taxa. Germination (seeds with radicle emergence) 8 wk after sowing and a germination percentage per box were calculated.

Statistical Analysis

An analysis of variance was performed on the total number of inflorescences per plant, heads per inflorescence, heads per plant, the estimated number of seeds per plant, germination, and viability using the SAS PROC GLM procedure (SAS Institute, Cary, North Carolina) with a Tukey correction (alpha = 0.05). Prior to analysis, mean germination percentage data for the initial germination test were transformed using the arcsine of the square root. Nontransformed data are presented.

For germination under varying temperature regimes and photoperiods, mean percent germination data were recorded and transformed using the arcsine of the square root. Analysis of variance was performed using the aov function, and means separation (alpha = 0.05) was performed using the lsmeans package in R v. 3.3.1. Nontransformed data are presented.

RESULTS

Reproductive Characteristics

With the exception of seeds per head (P = 0.0028), reproductive characteristics did not significantly differ between taxa (P = 0.1979 – 0.8724; Table 1). The number of seeds produced per head for *C. godfreyi* f. *godfreyi* (118) was lower than the number produced by both *C. godfreyi* f. *viridis* (137) and *C. gossypina* ssp. *cruiseana* (148). Estimated number of seeds per plant was 6082 to 7949.

TABLE 1

Comparison of reproductive characteristics and seed production traits among 3 Chrysopsis *taxa collected from Naval Air Station-Pensacola and Perdido Key State Park in Florida.*

Characteristic	*Chrysopsis godfreyi* f. *godfreyi* (*n* = 12)	*Chrysopsis godfreyi* f. *viridis* (*n* = 11)	*Chrysopsis gossypina* ssp. *cruiseana* (*n* = 10)	*P* value
Inflorescences per plant	5 ± 1 a[z]	6 ± 1 a	4 ± 1 a	0.1979
Heads per inflorescence	11 ± 1 a	11 ± 2 a	12 ± 2 a	0.8724
Heads per plant	59 ± 14 a	62 ± 17 a	40 ± 8 a	0.3993
Seeds per head	118 ± 7 b	137 ± 6 a	148 ± 10 a	0.0028
Estimated seeds per plant[y]	6778 ± 1401 a	7949 ± 1920 a	6082 ± 1538 a	0.6653

[z] Means separation by least significant difference test procedure (alpha = 0.05) with a Tukey correction. Means ±1 standard error of the mean; means in the same row with the same letter are not significantly different.

[y] Estimated number of seeds per plant was calculated (heads per plant × seeds per head).

TABLE 2

Seed (achene) characteristics and viability for 3 Chrysopsis *taxa (*n = *200 for all characteristics except germination [*n = *400]).*

Characteristic[z]	*Chrysopsis godfreyi* f. *godfreyi*	*Chrysopsis godfreyi* f. *viridis*	*Chrysopsis gossypina* ssp. *cruiseana*	*P* value
Seed characteristics				
Normal seeds	40.5 ± 1.7 b[y]	55.0 ± 2.9 a	53.5 ± 1.8 a	0.0036
Dormant seeds	10.5 ± 1.3 a	6.2 ± 0.7 a	10.5 ± 1.8 a	0.1270
Total viable seeds	51.0 ± 2.9 b	61.2 ± 2.6 a	64.0 ± 2.8 a	0.0145
Abnormal seeds	1.7 ± 0.4 a	2.2 ± 0.7 a	1.0 ± 0.00 a	0.4059
Nonviable seeds	47.2 ± 3.3 a	36.5 ± 2.7 ab	35.0 ± 2.8 b	0.0342
Viability and germination				
Pre-germination viability	48.0 ± 13.9 a	73.2 ± 21.0 a	74.5 ± 21.6 a	0.1753
Germination of viable seeds	79.7 ± 1.4 b	89.7 ± 1.6 a	83.7 ± 2.5 ab	0.0461

Notes: Numbers reported are means (%) ± the standard error of the mean.

[z] Seed characteristic: Normal = (Class 1 seeds) fully developed, light to dark tan in color, with no signs of herbivory; Abnormal = (Class 2 seeds) underdeveloped with color and size irregularities or evidence of herbivory; Total viable seeds = normal seeds (seeds deemed viable) + dormant seeds (nongerminated seeds deemed viable from additional TZ test); Germination and viability: pre-germination viability = separate seed sets used to conduct TZ test; seeds were cut longitudinally and stained for 18 to 24 h at 30 to 35 °C in 1.0% tetrazolium (2, 3, 5-triphenyl chloride) solution with positive staining patterns confirming seed viability; Germination of viable seeds = percentage of all viable seeds that germinated.

[y] Means ±1 standard error of the mean; means separation by least significant difference test procedure (alpha = 0.05) with a Tukey correction. Means in the same row with the same letter are not significantly different.

Viability Tests and Initial Germination

Differences occurred in the proportion of viable and nonviable seeds between taxa (Table 2). Mean percentage of normal seeds was lower (40.5%) for *C. godfreyi* f. *godfreyi* than for the other 2 taxa (53.5 to 55.0%) (P = 0.0036; Table 2). Percentage of dormant (dormant = nongerminating seeds deemed to be viable according to the TZ test) and abnormal seed did not differ significantly between the 3 *Chrysopsis* taxa (P = 0.1270 and 0.4059; Table 2). Percentage of nonviable seed differed for *C. gossypina* ssp. *cruiseana* (35.0%) and *C. godfreyi* f. *godfreyi* (47.2%) (P = 0.0342; Table 2). Percentage of viable seeds (normal + dormant) was significantly lower (P = 0.0145) for *C. godfreyi* f. *godfreyi* (51.0%) than for the other 2 taxa (61.2 to 64.0%), and the percentage of viable seeds that germinated differed (P = 0.0461) between the *C. godfreyi* f. *viridis* (89.7%) and *C. godfreyi* f. *godfreyi* (79.7%). Results from the pre-germination viability (TZ) tests were highly variable but generally suggest that the mean percentage of viable seeds sampled from the natural populations of *C. godfreyi* f. *godfreyi, C. godfreyi* f. *viridis*, and *C. gossypina* ssp. *cruiseana* were 48.0%, 73.2%, and 74.5%, respectively.

Germination Response to Photoperiod and Temperature

There was a significant interaction between the main effects of photoperiod and temperature on germination for all

TABLE 3

Analysis of variance table for main effects of temperature and photoperiod and their interaction on the germination of 3 Chrysopsis *taxa recorded 8 wk after sowing.*

Main effects[z]	df	Sum sq	Mean sq	*F* value	*P* value
Chrysopsis godfreyi f. *godfreyi*					
Temperature	3	0.3271	0.109	53.11	<0.0001
Photoperiod	1	1.0047	1.0047	489.33	<0.0001
Temperature × Photoperiod	3	0.2025	0.0675	32.87	<0.0001
Chrysopsis godfreyi f. *viridis*					
Temperature	3	0.3308	0.1103	17.83	<0.0001
Photoperiod	1	1.5887	1.5887	256.88	<0.0001
Temperature × Photoperiod	3	0.1405	0.0468	7.572	0.0001
Chrysopsis gossypina ssp. *cruiseana*					
Temperature	3	0.3804	0.1268	52.88	<0.0001
Photoperiod	1	1.8624	1.8624	776.70	<0.0001
Temperature × Photoperiod	3	0.1254	0.0418	17.43	<0.0001

[z] Main effects: Temperature = 4 regimes in which temperature changed every 12 h mimicking Florida's winter (20/10 °C), early spring/late fall (25/15 °C), early fall/late spring (30/20 °C), and summer (35/25 °C) average high and low temperatures; Photoperiod = 12 h light exposure during high temperatures and no light exposure for dark treatments.

3 *Chrysopsis* taxa indicating that germination responses within the seasonal temperatures differed between seeds exposed to light and seeds kept in the dark ($P < 0.0001$; Table 3). Hence, for each taxon, we present mean germination for each seasonal temperature for both photoperiod treatments (Figure 4).

For *C. godfreyi* f. *godfreyi,* the highest germination percentage was for seeds with light exposure at 20/10 °C (50%) and 25/15 °C (56%), with significantly less but still substantial germination with light exposure at 30/20 °C (41%) (Figure 4). Seeds did not germinate well in the dark (<10%) at all temperatures tested, and a similar response was noted for seeds at 35/25 °C with light exposure.

The highest germination for *C. godfreyi* f. *viridis* occurred with light exposure at 20/10 °C (58%), 25/15 °C (64%), and 30/20 °C (62%) (Figure 4). Germination percentages were similar between light-exposed seeds at 35/25 °C (24%) and dark-exposed seeds at 20/10 °C (14%) and 25/15 °C (11%), while dark-exposed seeds at warmer temperatures (30/20 °C and 35/35 °C) had <5% germination.

The highest germination for *C. gossypina* ssp. *cruiseana* occurred with light exposure at 20/10 °C (67%), 25/15 °C (71%), and 30/20 °C (62%) (Figure 4). Germination percentages were similar for light-exposed seeds at 35/25 °C (31%) and dark-exposed seeds at 20/10 °C (22%), while dark-exposed seeds in warmer temperatures (25/15 °C, 30/20 °C, and 35/35 °C) had <12% germination (Figure 4).

DISCUSSION

Differences in the number of seeds produced per flower head can be caused by genetic variation, differing environmental conditions such as resource availability, and (or) various biological stressors such as competition at the time of seed development. Some studies have shown that increased pollen levels resulted in a greater number of seeds (Galen and Weger 1986; Lalonde and Roitberg 1989). *Chrysopsis godfreyi* f. *godfreyi*, which had fewer seeds per flower head, was most commonly found near a tree line or next to large, shrubby vegetation, whereas *C. godfreyi* f. *viridis*, and *C. gossypina* ssp. *cruiseana* were found on the edge of swales or in less densely vegetated areas of back dunes (Hooton 2011). Locations in the landscape

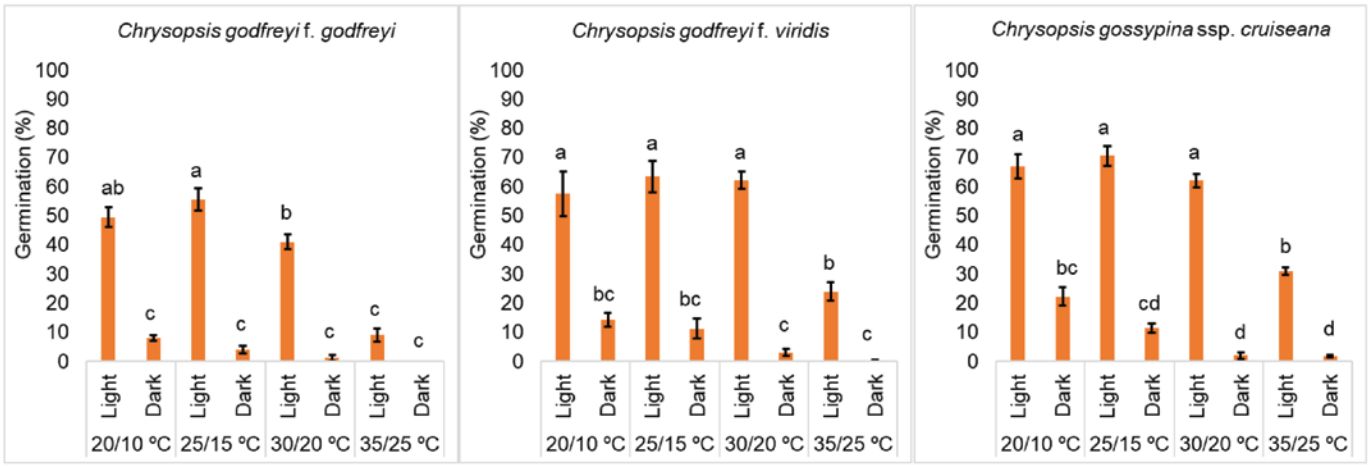

Figure 4. Effects of temperature and photoperiod on germination of 3 *Chrysopsis* taxa. Temperature changed every 12 h mimicking Florida's winter (20/10 °C), early spring/late fall (25/15 °C), early fall/late spring (30/20 °C), and summer (35/25 °C) average high and low temperatures; light = 12 h light exposure during high temperatures and dark = no light exposure. Means ±1 standard error of the mean; Means separation within each taxa by least significant difference test procedure (R v. 3.3.1, alpha = 0.05); bars with the same letter do not differ.

may have influenced (possibly reduced) the number of pollinators visiting *C. godfreyi* f. *godfreyi* plants. Another possibility is that those plants had fewer resources available. McGinley and Charnov (1988) found that the relationship between seed number and size was influenced by the amount of carbon and nitrogen available for seed production.

Characteristics of germination can vary within a species based on genetics, the environment, or an interaction of genetics and the environmental conditions at the time of seed maturation (Baskin and Baskin 2014). While no difference was observed in dormancy between the 3 taxa, there were variations in the percentage of normal, nonviable, and viable seeds and germination of viable seeds. The viability of seeds collected is an important consideration for restoration projects. If only a small percentage of seeds are viable for a species of interest, more seeds must be collected to reach the target number of individuals. For our study, all seeds tested were collected at the same time and were subjected to the same conditions. Also, the seeds were collected from random individuals across a large area of the habitat, so it is unlikely that age of the parent plant differed between the 3 *Chrysopsis* species. However, several studies have indicated that environmental conditions required for germination may vary between populations of a species (Groves and others 1982; Fady 1992; Baskin and Baskin 2014). Varying individual sensitivities to salinity, soil pH, photoperiod, and temperature have also been observed (Baskin and Baskin 2014).

Van Loenhoud and Duyts (1981) found that ideal light and temperature requirements for germination of 11 taxa of dandelion (*Taraxacum* F.H. Wigg. [Asteraceae]) differed significantly. Among the temperature regimes and photoperiods tested here, it appears that all 3 taxa favor a 12 h photoperiod with alternating temperatures consistent with fall and winter in Florida. Given the harsh environment of coastal dunes, fall and winter likely allow seeds to experience less direct heat stress and more exposure to moisture due to reduced evaporation at those times.

CONCLUSIONS

Our work demonstrates that germination for the 2 forms of *Chrysopsis godfreyi* and the subspecies of *Chrysopsis gossypina* respond differently to seasonal temperature regimes and to differing light exposure treatments. This differential in germination characteristics further supports Semple's conclusion that *C. godfreyi* represents 2 forms and the 3 taxa represent 2 species of *Chrysopsis*. Moreover, distinct leaf and floral morphologies of the 3 taxa naturally occur within the same landscape. Therefore, efforts should be made to include all 3 taxa in revegetation of coastal dune habitats within their native ranges. Our results suggest that optimal seasons for germination of all 3 *Chrysopsis* in Florida are fall and winter. Seeds can be collected in the late fall or winter across a range of individuals to capture genetic variability and then immediately sown for greatest germination. Additionally, because C. *godfreyi* f. *godfreyi* has a lower proportion of viable seeds that germinate, it may be necessary to collect additional seed heads of this taxa compared to the other 2 taxa to produce the same number of plants. Floral and seed production characteristics, probable seed viability, and germination characteristics provided herein may assist land managers in understanding the quantity and quality of seeds required to achieve plant production and restoration goals.

Maintaining species diversity and genetic diversity are important restoration goals, which make experiments on coastal dune species such as *C. godfreyi* and *C. gossypina* necessary to better understand potential sources of variation that influence plant recruitment. Additionally, when multiple, distinct ecotypes or subspecific taxa exist, it will be necessary to incorporate all of them in management plans and restoration efforts.

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