

**Germination of achenes of *Chaptalia texana* Greene (Silverpuff) a perennial Asteraceae****O. W. Van Auken**

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[oscar.vanauken@utsa.edu](mailto:oscar.vanauken@utsa.edu)**ABSTRACT**

Some of the germination requirements of *Chaptalia texana* Greene (Silverpuff), a perennial Asteraceae, were examined. *Chaptalia texana* is found in central and western Texas, in southern New Mexico, northern, central and southern Mexico. In central Texas it seems to occur in savanna communities, below the canopy of *Juniperus-Quercus* (juniper-oak) mottes or woodlands, but infrequently in adjacent grasslands. Mostly population densities were low, and it appears to have an aggregated or clumped distribution with a high density under some woodland canopies and low density away from the canopies. Flowering seems to occur year round, though mainly when temperature and rainfall are moderate. Achenes of *C. texana* were slightly dormant, but started to germinate seven days after initial collection with 50% germination in 7.5 days. Initial germination immediately after collection, pappus removal and 16 days of incubation at 25°C in low light was 100±0% ( $\bar{x} \pm SD$ ) by day 12. Germination decreased to 82±4% with dry storage of 12 weeks at 25°C and was expected to decrease to approximately 49% after 36 weeks of dry storage at 25°C. Achenes with pappus intact and incubated at 25°C had 95±2% germination. However, this was not significantly different from achenes with pappus removed. *Chaptalia texana* had very little or very slight innate dormancy and a majority of achenes could survive at moderate temperatures and moisture for over six months. Achenes would probably not germinate in summer or winter because of enforced dormancy at high summer or low winter temperatures and low soil moisture in summer. Published on-line [www.phytologia.org](http://www.phytologia.org) *Phytologia* 95(4): 255-263 (Nov. 1, 2013). ISSN 030319430

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When and where a species will grow, flower and produce seeds is dependent on the habitat and a particular set of environmental conditions typical of that habitat. The factors would usually include specific temperature, rainfall, photoperiod, and probably the presence or absence of neighbors (Begon et al. 2006; Smith and Smith 2012). Seed germination and growth, especially the timing of germination and early growth seem to be very important to understanding the adaptations of a species to its environment and where it will be found (Baskin et al. 1995). Seeds of almost all flowering plants are initially dormant when shed from the parent (Begon et al. 2006). Regardless, seeds of every species respond to a characteristic set of environmental conditions. Conditions required for germination should be followed by another set of conditions favorable to seedling survival, growth, and reproduction (Fenner 1985). These germination and growth requirements probably include a specific temperature range, specific light levels, photoperiods, salt levels, nutrients and nutrient levels, possible seed scarification, red/far-red ratios, or some combination of factors (Mayer and Poljakoff-Mayber 1989; Bewley and Black 1994).

*Chaptalia texana* Greene or silverpuff (sunflower or Asteraceae family, Fig. 1) apparently can flower year-round in some parts of its range (Nesom 1995), but winter frosts and hot-dry summer conditions typically suppress or stop its growth and flowering during part of the year along the southern edge of the Edwards Plateau region of central Texas (personal observation). *Chaptalia* is a genus of about 56 species, with two species in the southern United States, and the remainder in Mexico, Central and much of South America (Correll and Johnson 1979; Nesom 1995). *Chaptalia texana* is found in central and western Texas, in southern New Mexico, northern, central and southern Mexico (Nesom 1995;

USDA 2009). In central Texas it occurs in savanna communities, below the canopy of *Juniperus-Quercus* (juniper-oak) motts or woodlands, but not in the adjacent grasslands (Nesom 1995; Van Auken and Bush 2013). *Chaptalia texana* is an herbaceous perennial and grows as a rosette in the woodland, and mostly not the grassland phase of some of these central Texas savanna communities (Correll and Johnston, 1979;



Figure 1. Photographs of *Chaptalia texana* plants with the rosette growth form below a *Juniperus-Quercus* woodland in central Texas. “A” shows a flower bud on a long scape (upper-left-center) and two inverted white tomentose leaves (lower left), “B” shows an inflorescence in seed on an elongated scape. Photographs were taken by Kelly Jo Stephens.

Enquist 1987; USDA 2009). It seems to be a secondary species found below the canopy of some of these woodlands. Many of the species of *Chaptalia* appear to be associated with the canopy of various species of *Quercus*, *Pinus*, *Juniperus* or some combination of them usually in a woodland, savanna or edge community (Nesom 1995).

Previous studies suggested that *C. texana* is a shade adapted species that can grow and carry out photosynthesis in the shade below a woodland canopy (Van Auken and Bush 2013). The physiological differences between plants of full sun compared to those found in shady habitats are fairly well known and have been used to delineate species habitat preferences (Begon et al. 2006; Valladares and Niinemets 2008). *Chaptalia texana* has maximum photosynthetic rates higher than typical understory plants at high light levels (Hull 2002). This is an interesting conundrum because photosynthetic rates suggest that this species should be found in grasslands and results do not explain why it is not found in grasslands of these central Texas or other savannas. However, gas exchange rates or growth rates of any of the other species of *Chaptalia* have not been identified. In addition, no ecological studies of the successional status, disturbance requirements, densities or resource requirements of this species have been identified. Thus, its ecological niche and factors affecting its distribution are not well recognized.

When a species is found in a given habitat, it is because that species can tolerate or requires the environmental conditions present in that habitat. However, sorting out the characteristics or factors that determine why a species is present or dominant where it is found and not in other habitats is much more challenging (Begon et al. 2006). Various grasses do not grow with *C. texana* in the canopy understory and at the same time *C. texana* does not seem to grow with or occur with various grasses in open central Texas grasslands or savannas (Van Auken and Bush 2013). It seems that light levels would be the obvious factor controlling this distribution, yet there seem to be other factors.

Before some of the above can be studied or tested using controlled conditions, factors that seem to determine *C. texana*'s germination and early growth should be understood so seedlings might be available for ecological studies. This would allow transplant or manipulation studies to be carried out to understand specific requirements and niche characteristics of this species. Purposes of the experiments completed and reported here were to examine possible dormancy and some of the factors responsible for promoting germination of *C. texana*. In general, I hypothesized that *C. texana* would have minimal innate dormancy, but that temperature and storage could be important in breaking dormancy and promoting germination. I investigated germination of *C. texana* at one temperature and relatively short storage times, as well as effects of the presence or removal its pappus.

## MATERIALS AND METHODS

To examine seed dormancy in *Chaptalia texana* (Fig. 1), the storage temperature and time required to promote germination or break dormancy was examined. Mature *C. texana* achenes (seeds) were collected in October and early December 2012 in San Antonio, Texas, USA (Bexar County, 98°36'W, 29°37'N). Collected achenes or seeds were placed in plastic bags at room temperature (25 °C). Immediately after achenes were collected, all that were to be placed in an experiment were visually inspected for fullness. Wrinkled or unfilled achenes were discarded. Some full achenes had their pappus removed. Initial germination was examined without any temperature or storage treatment. The experiment was repeated twice, once in October and a second time in early December. There were three replicates in each experiment and the pappus of all achenes was initially removed by breaking at the attachment point to the achene. Each replicate included 20 achenes placed on one, 7.0 cm diameter, Whatman® number one qualitative filter paper, that was placed in a 100 mm diameter X 15 mm deep disposable polystyrene petri dish. The filter paper was moistened with 5 ml of deionized water, and then the petri dishes were closed and placed in 17.8 cm X 20.3 cm plastic bags to retard moisture loss. They were kept at 25°C in low light ( $250 \mu\text{M}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ , Li-Cor® LI-188 integrating quantum sensor) for 15-18 days depending on the experiment and the germination response. All petri plates were examined every day and any achenes that had germinated (radical emerged at least 1 mm) were counted, the number was recorded, and germinated achenes were removed, placed in fiber pots with soil or discarded.

All stored achenes were kept dry and at a temperature of 25°C with some stored for three months. Initially and after 2.5 weeks and three months storage treatment time, germination was tested as above with the pappus removed. An additional study was completed with achenes with pappus attached. Each replicate was 20 achenes placed on one, dry, 7.0 cm diameter, Whatman® number one qualitative filter paper in a 100 mm diameter X 15 mm deep disposable polystyrene petri dish as above. This experiment was started 2.5 weeks after the achenes were collected. There were three replicates of 20 achenes each with the pappus intact and three with the pappus removed. Germination was observed and conditions were as indicated above and the experiment was completed in 16-18 days.

Data was analyzed using the SAS JUMPRO statistical package (SAS-Institute 2011). The experiments were analyzed as one-way ANOVAs with days of germination or time (storage time) as the independent variables. If significant differences between mean number of germinations and the

independent variables were detected, a Tukey-Kramer HSD multiple comparison test was employed for pair wise comparisons among individual treatments. All germination data was arc-sine transformed prior to analysis in order to normalize the distributions (Kleinbaum et al. 1988).

## RESULTS

Initial dormancy of *Chaptalia texana* achenes was examined by testing their ability to germinate as soon as they were harvested. Initial mean germination was  $100\pm 0\%$  ( $\bar{x} \pm SD$ ) with 7.5 days of germination treatment on wet filter paper in petri plates at  $25^{\circ}\text{C}$  in low light re quired to reach the mean  $T_{50}$  (number of days to 50% of final germination) (Fig. 2). Achene germination started on the seventh day

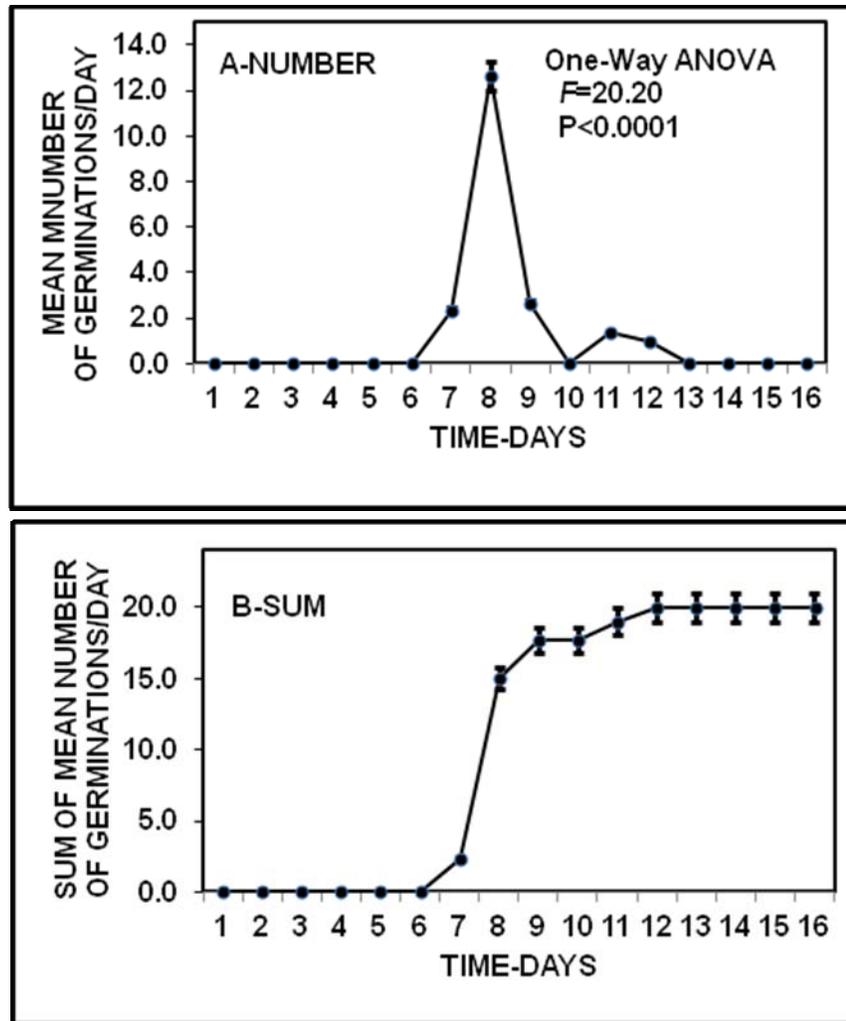


Figure 2. Mean number of achenes germinating per day (A) and the running mean of total germinations (B) for *Chaptalia texana* subjected to a germination test immediately after harvest. There were three replications with 20 achenes/replication. Conditions were  $25^{\circ}\text{C}$  and low light in petri plates. Final total was 100% (60/60 achenes) germinating. Germination started on day seven with a maximum on day eight.  $T_{50}$  or the number of days to 50% of final germination was 7.5 days. Achenes were harvested on 12-3-2012 and the germination test was started the same day. The one-way ANOVA was significant, but the number of germinations on day eight was the only day that the number of germinations was significantly different from all the others (Tukey- Kramer HSD test,  $P<0.05$ ).

of treatment and all achenes germinated by the 12<sup>th</sup> day of treatment. The one-way ANOVA was significant, but the number of germinations on day eight was the only day that the number of germinations was significantly different from all the others, which were not different from each other (Tukey-Kramer HSD test,  $P < 0.05$ ). The presence or absence of the pappus on the achenes did not change the total number of germinations (one-way ANOVA,  $F = 6.0$ ,  $P = 0.07$ ) (Fig. 3). If the pappus was attached, final germination was  $95 \pm 5\%$  and started on day 10 and was at a maximum the same day with slight declines on the 11<sup>th</sup> and 12<sup>th</sup> days. The mean  $T_{50}$  was 10.5 days (Fig. 3A). If the

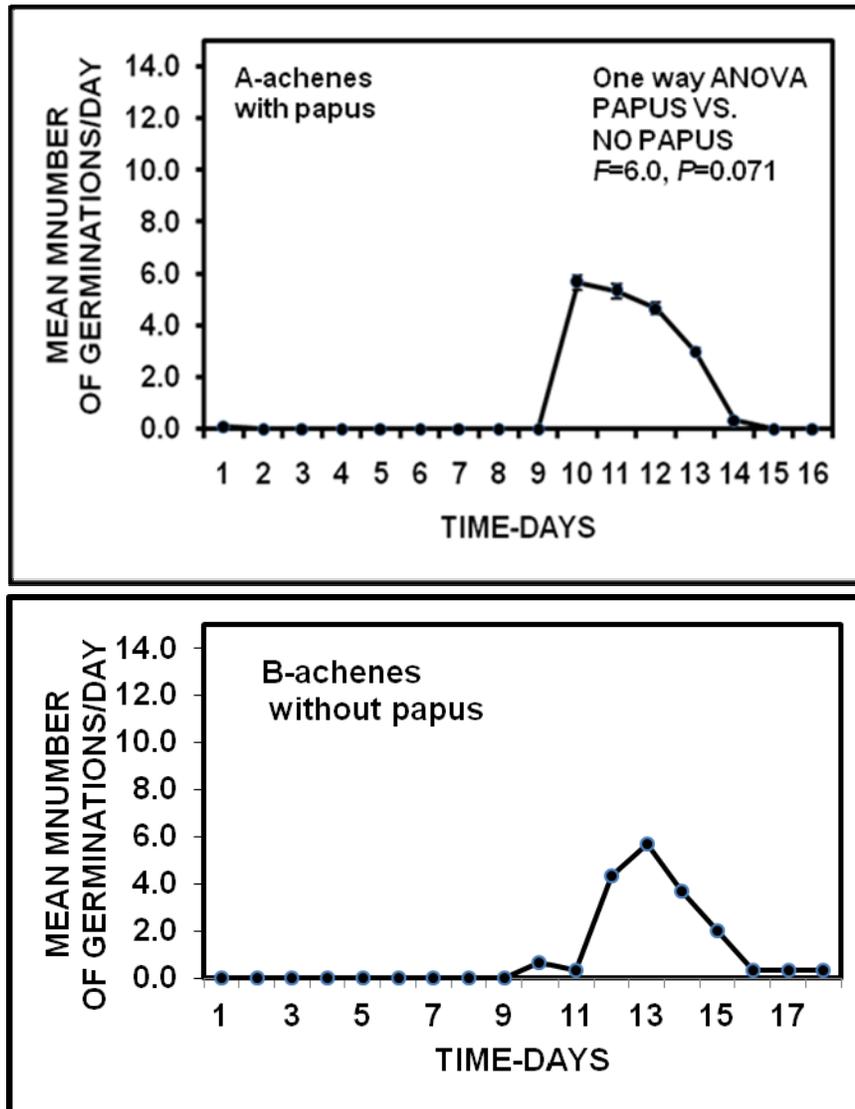


Figure 3. Mean number of achenes germinating for *Chaptalia texana* per day with pappus intact (A) or the pappus removed (B). There was no significant difference in total number of germinations between the two treatments (one-way ANOVA). There were three replications/treatment with 20 achenes/replication. The germination test was started 2.5 weeks after harvest. Conditions were 25°C and low light in petri plates.

pappus was removed, final germination was  $88 \pm 5\%$ . Germination started on day 10 with a maximum on day 13. The mean  $T_{50}$  was 12 days (Fig. 3B). With dry storage at 25°C and in low light, germination dropped to  $88 \pm 5\%$  in two and one half weeks and then to  $82 \pm 4\%$  in 12 weeks (Fig. 4). Simple linear

projections suggest that after 36 weeks of dry storage in low light that germination of *C. texana* achenes would be approximately 49%.

## DISCUSSION

Seeds of flowering plants usually show some degree of dormancy and that includes members of the family Asteraceae (Begon et al. 2006). Non-dormant seeds would appear to be an exception. The beginning of dormancy occurs while the seeds are still attached to the parent when metabolic activity of the seeds dramatically slows. Germination of the seed and breaking of dormancy is critical to a plant's reproductive success, especially in unpredictable or fluctuating environments (Baskin et al. 1995). Breaking dormancy and thus germination for a given species would be in response to a characteristic set of environmental conditions typical of their habitat and could include specific temperatures, light levels, photoperiods, salt levels, nutrients, scarification, red/far-red ratios, or combination of these factors (Harper 1977; Taiz and Zeiger 1998; Smith and Smith 2012). Once seeds germinate, the subsequent environmental conditions should be favorable to seedling survival, growth, and reproduction (Fenner 1985).

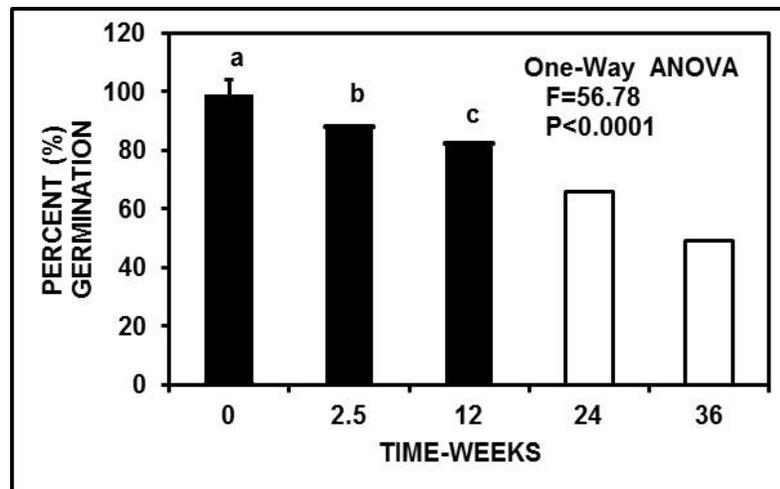


Figure 4. Mean percent germination of *Chaptalia texana* achenes after 0, 2.5, and 12 weeks of dry storage at 25°C and low light. Solid black bars are actual measurements and white bars are linear projections to 24 and 36 weeks. The line at the top of the zero week bar is one standard deviation of the mean. The percent of achenes germinating in the different storage times was significant (one-way ANOVA) and the different letters at the top of the bars indicate significant differences between storage treatments (Tukey Kramer-HSD test,  $P < 0.05$ ).

Seeds are dormant when they fail to germinate in spite of the presence of environmental conditions necessary for germination (Taiz and Zeiger 1998). There are three general types of seed dormancy that include innate, induced, and enforced dormancy (Nikolaeva 1977; Mayer and Poljakoff-Mayber 1989; Bewley and Black 1994; Taiz and Zeiger 1998; Begon et al. 2006). Seeds produced during the current growth year that fail to germinate under normally favorable growth conditions are innately dormant. These innately dormant seeds have an inhibitory mechanism that must be overcome before germination will begin. The mechanisms could be mechanical, chemical, or morphological and could include seed coat impermeability, light or temperature sensitivities, chemical inhibitors, or after-ripening requirements (Nikolaeva 1977; Mayer and Poljakoff-Mayber 1989; Bewley and Black 1994; Taiz and Zeiger 1998; Begon et al. 2006). Non-dormant seeds could be induced into dormancy when conditions that reduce seedling survival are present. The third type of dormancy is enforced dormancy and is caused by environmental conditions unfavorable to seedling growth and survival (Nikolaeva 1977; Mayer and

Poljakoff-Mayber 1989; Bewley and Black 1994). The three general types of dormancy may occur alone or in sequence, and possibly in the same seed or seed type.

*Chaptalia texana* achenes (seeds) demonstrated slight or little innate dormancy. Once collected and placed on wet filter paper with pappus removed at 25°C and low light, 100% of the achenes germinated. Germination started after seven days and all achenes germinated by day 12. Predicted 100% dormancy or 0% germination as soon as the seeds were mature and released from the parent (Begon et al. 2006) lasted seven days. However, most of this time could have been required for embryo and radical growth as well as escape from the achene coverings. Thus, innate dormancy in *C. texana* appears to be slight or minimal and easily overcome. Results were similar for a number of other south-central Texas Asteraceae (Baskin et al. 1998). Innate dormancy, when present, was broken with a short period of cold stratification (Baskin et al. 1992; Baskin et al. 1995; Baskin et al. 1998).

The presence of a pappus on achenes of *C. texana* had little effect on germination. The pappus is important for dispersal, but apparently not for germination success. However, as storage time increased, germination success decreased (Fig. 4). Estimated germination after 36 weeks was 49%. The achenes that did not germinate appeared to lose viability and were covered with fungal growth. Loss of viability could have been due to moisture loss by the stored achenes, but this was not examined.

*Chaptalia texana* along the southern edge of the Edwards Plateau region of central Texas appear to flower year round and mature achenes would be dispersed accordingly (Enquist 1987; Nesom 1995). June, July, and August as well as December and January in central Texas are times of environmental extremes. Monthly high temperature and precipitation means (NCDC 2000) in the San Antonio area for June-August are 33-35°C and 9.4-5.5 cm respectively, with some years having no rainfall in one or more of these months. In addition, mean high minimums are approximately 26°C. Thus, maturity and dispersal of *C. texana* achenes in summer, if at all, occurs under conditions of high temperatures and low rainfall. Germination of *C. texana* achenes during south Texas summers is probably low and moisture limited. With low rainfall conditions in summer, most achenes would likely not germinate due to enforced dormancy initiated by moisture limitations.

Germination results suggest that with sufficient moisture during summer in south Texas all *C. texana* achenes could germinate. However, because of potentially high drought induced seedling mortality in summer, those achenes that germinated immediately following dispersal would probably not survive. If substantial yet infrequent summer rainfall events triggered those achenes to germinate, the subsequent high temperatures, inconsistent rainfall and soil moisture would probably reduce seedling growth and survival close to zero. With flowering in fall and achene dispersal at that time, survival would be greater.

Decreased temperatures and increased rainfall in early fall would insure that the shallow central Texas soils (Taylor et al. 1966) would remain moist for a longer period of time (Fay et al. 2003; Wayne and Van Auken 2004) and that would probably increase *C. texana* seedling survival and plant growth. Therefore, the greatest *C. texana* seedling survival probably occurs in those years in which rainfall events in June, July, and August are infrequent and small, enforcing dormancy upon all *C. texana* achenes until temperatures are cooler and rainfall more frequent in September and October (NCDC 2000).

*Chaptalia texana*'s usual growth form is a basal rosette. This is a growth form used by many winter annuals to get an early start in the spring when temperatures increase and photoperiods get longer (Fenner 1985; Baskin et al. 1992; Bewley and Black 1994; Baskin et al. 1998). However, I know of no studies concerning growth and survival of *C. texana* seedlings or mature plants as basal rosettes. Their survival may have something to do with poor detection resulting in little consumption by large herbivores, but this is undocumented at this time.

Seedling success of *C. texana* is not assured after achenes germinate. The highest probability occurs after achene germination when a set of conditions follow that are favorable for seedling survival, growth, and reproduction (Fenner 1985). Nevertheless, beyond abiotic factors, various positive, negative, or neutral biotic factors (facilitation or competition), are often cited as playing major roles in determining species success, community composition and structure (Harper 1977; Connell 1983; Callaway 1995; Bertness and Leonard 1997; Callaway and Walker 1997; Holmgren et al. 1997; Bush and Van Auken 2010; Smith and Smith 2012).

Competition may be a major factor determining a plant or species establishment success, and then determining where it is found in the future (Harper 1977; Connell 1983; Schoener 1983; Smith and Smith 2012). Competition from associated grassland species or inherent lack of competitive ability may cause *C. texana*'s apparent restriction to juniper-oak canopies (Van Auken and Bush 2013). Nonetheless, *C. texana* does not appear to be a true understory or shade species. It has high photosynthetic rates when exposed to high light levels, but it seems to be restricted to areas below the canopy in low light because it cannot compete with the grasses growing in the open grassland. There seems to be another environmental factor or a combination of factors that limit the growth of *C. texana* to shaded understory habitats and prevent it from growing in open grassland habitats or disturbed grassland habitats. This is an interesting conundrum because photosynthetic rates suggest that this species should be found in grasslands and open savannas and results do not explain why it is not found in these habitats. A similar pattern has been reported for a native mustard (Crucifer), but the restriction is caused by herbivory (Leonard and Van Auken 2013). These theories or ideas have never been tested or demonstrated for *C. texana*. It appears that soil water may be limiting the growth of *C. texana* in grasslands because of water use by potentially more drought tolerant grasses, which keeps *C. texana* restricted to canopy habitats where the grasses cannot grow or compete because of low light levels and their high light requirements.

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#### LITERATURE CITED

- Baskin, C. C., J. M. Baskin and O. W. Van Auken. 1992. Germination response patterns to temperature during after ripening of achenes of four Texas winter annual Asteraceae. *Can. J. Bot.* 70: 2354-2358.
- Baskin, C. C., J. M. Baskin and O. W. Van Auken. 1995. Temperature requirements for dormancy break and germination in achenes of the winter annual *Lindheimera texana* (Asteraceae). *Southwest. Nat.* 40: 268-272.
- Baskin, C. C., J. M. Baskin and O. W. Van Auken. 1998. Role of temperature in dormance break and/or germination of autumn-maturing achenes of eight perennial Asteraceae from Texas. *Plant Spec.* 13 :13-20.
- Begon, M., C. R. Townsend and J. L. Harper. 2006. *Ecology: from individuals to ecosystems*. Blackwell, Malden, MA.
- Bertness, M. D. and G. H. Leonard. 1997. The role of positive interactions in communities: lessons from intertidal habitats. *Ecology.* 78: 1976-1989.
- Bewley, J. D. and M. Black. 1994. *Seeds: physiology of development and germination*. Plenum Press, New York, NY.
- Bush, J. K. and O. W. Van Auken. 2010. Competition between *Schizachyrium scoparium* and *Buchloe dactyloides*: The role of soil nutrients. *J. Arid Env.* 74: 49-53.

- Callaway, R. M. 1995. Positive interactions among plants. *Bot. Rev.* 61: 306-349.
- Callaway, R. M. and L. R. Walker. 1997. Competition and facilitation: a synthetic approach to interactions in plant communities. *Ecology* 78: 1958-1965.
- Connell, J. A. 1983. On the prevalence and relative importance of interspecific competition: evidence from field experiments. *Amer. Nat.* 122: 661-696.
- Correll, D. S. and M. C. Johnson. 1979. Manual of the vascular plants of Texas. Texas research foundation, Renner, TX.
- Enquist, M. 1987. Wildflowers of the Texas Hill Country. Lone Star Botanical, Austin, TX.
- Fay, P. A., A. K. Knapp, J. M. Blair, J. Carlisle, B. T. Danner et al. 2003. Rainfall timing, soil moisture dynamics, and plant responses in a mesic tallgrass prairie ecosystem *in* J. F. WELTZIN and G. R. MCPHERSON (eds). *Precipitation regimes and terrestrial ecosystems: a North American Perspective*. University of Arizona Press, Tucson, Arizona.
- Fenner, M. 1985. Seed ecology. Chapman and Hall, NY.
- Harper, J. L. 1977. Population biology of plants. Academic Press, NY.
- Holmgren, M., M. Scheffer and M. A. Huston. 1997. The interplay of facilitation and competition in plant communities. *Ecology*. 78: 1966-1975.
- Hull, J. C. 2002. Photosynthetic induction dynamics to sunflecks of four deciduous forest understory herbs with different phenologies. *Inter. J. Plant Sci.* 163: 913-924.
- Kleinbaum, D. G., L. L. Kupper and K. E. Muller. 1988. Applied regression analysis and other multivariable methods. PWS-Kent Publishing, Boston.
- Leonard, W. J. and O. W. Van Auken. 2013. Light levels and herbivory partially explain the survival, growth and niche requirements of *Streptanthus bracteatus* A. Gray (Bracted Twistflower, Brassicaceae), a rare central Texas endemic. *Nat. Areas J.* 33: 276-285.
- Mayer, A. M. and A. Poljakoff-Mayber. 1989. The germination of seeds. Pergamon Press, New York.
- NCDC, 2000 Climatic Data, edited by N. O. A. ADMINISTRATION. U. S. Department of Commerce, Washington, D.C.
- Nesom, G. L. 1995. Revision of *Chaptalia* (Asteraceae: Mutisieae) from North America and continental central America. *Phytologia*. 78: 153-188.
- Nikolaeva, M. G. 1977. Factors controlling the seed dormancy pattern Pp. 51-74 *in* A. A. Kahn (ed.), *The physiology and biochemistry of seed dormancy and germination*. North-Holland Publishing Co., New York.
- SAS-Institute. 2011. JMP pro. SAS Institute, Inc., Cary, NC.
- Schoener, T. W. 1983. Field experiments on interspecific competition. *Amer. Nat.* 122: 242-285.
- Smith, T. M. and R. L. Smith. 2012. *Elements of Ecology*. Pearson Benjamin Cummings, New York.
- Taiz, L. and E. Zeiger. 1998. *Plant Physiology*. Sinauer Associates, Sunderland, MA.
- Taylor, F. B., R. B. Hailey and D. L. Richmond. 1966. Soil survey of Bexar County, Texas. USDA, Soil Conservation Service, Washington, D.C.
- USDA. 2009. Plants Database, Plants Profile, *Verbesina virginica* L. var. *virginica*, White Crownbeard. United States Department of Agriculture, Natural Resources Conservation Service. Website <http://plants.usda.gov/java/profile?symbol=veviv>. [accessed 22 September 2009].
- Valladares, F. and U. Niinemets. 2008. Shade tolerance, a key plant feature on complex nature and consequences. *Ann. Rev. Ecol. Syst.* 39: 237-257.
- Van Auken, O. W. and J. K. Bush. 2013. Unusually high gas exchange rates for *Chaptalia texana* (Silverpuff, Asteraceae) a herbaceous understory species of woodlands of central Texas Savannas. Madrono (Submitted).
- Wayne, E. R. and O. W. Van Auken. 2004. Spatial and temporal abiotic changes along a canopy to intercanopy gradient in central Texas *Juniperus ashei* woodlands. *Tx. J. Sci.* 56: 35-54.