REGENERATION POTENTIAL OF DISTAFF THISTLE IN CENTRAL TEXAS

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ABSTRACT

Seed production and seed reserves in the soil were determined for distaff thistle (Carthamus lanatus) at two grazed range sites in central Texas. Seed production ranged from 345 to 376 seeds/ft². Seed bank density ranged from 16 to 23 seeds/ft², with 84% or more of the seed occurring in the top 1 inch of soil. Greater than 58% of the seeds extracted from soil samples were viable as determined by a tetrazolium test. Persistent testa halves (seed coat segments), remaining in the soil after germination, ranged from 37 to 72/ft², with 91% or more occurring in the top 1 inch of soil. Seeds were harvested from one site and exposed to different light/dark and dark/light regimes over a 14-day period to determine light requirements for germination. Seeds exposed to at least 12 h of light per day during initial imbibition had mean germination times of about 3.4 days and greater than 80% cumulative germination. Light enhanced the germination responses of seeds kept in darkness during the first 7 days of the 14-day period. A small portion (10%) of non-dormant seeds germinated in total darkness.

Key words: Rangeland, soil disturbance, light-sensitive seed, seed bank, germination.

INTRODUCTION

Distaff thistle (Carthamus lanatus), an introduced, overwintering annual from the Mediterranean region (Correll and Johnston, 1970), is presently found on a variety of disturbed rangelands in 21 counties of central Texas, and is spreading rapidly. Distaff thistle is a serious weed problem in parts of California, Australia, Argentina, Chile, and Morocco (Holm et al., 1979). Dense stands of this prickly weed can decrease forage production and reduce livestock access to more palatable forage species.

Seeds germinate late summer through fall in response to increasing precipitation and decreasing temperatures. Plants overwinter in a rosette stage, and main stem elongation occurs in early spring. Flowering and seed production can extend into mid-summer, depending on available soil moisture (Figure 1). Distaff thistle populations may be controlled by properly timed herbicide, mechanical, or burning treatments (Meadly, 1957; Quinlivan and Pearce, 1964). Due to the prolonged dormancy of seeds in the soil (Pearce and Quinlivan, 1968), the control strategy should consider the effects of soil disturbance on plant regeneration. Soil disturbance brings the light-sensitive seeds to the soil surface, fulfilling the light requirement for germination (Wright et al., 1980), and setting the stage for the establishment of a new stand.

Research on the regeneration potential of distaff thistle on disturbed rangeland in central Texas is nonexistent. A field study was conducted to characterize seed production and seed bank reserves, and a laboratory study was conducted to determine the effect of length of light exposure on germination response.

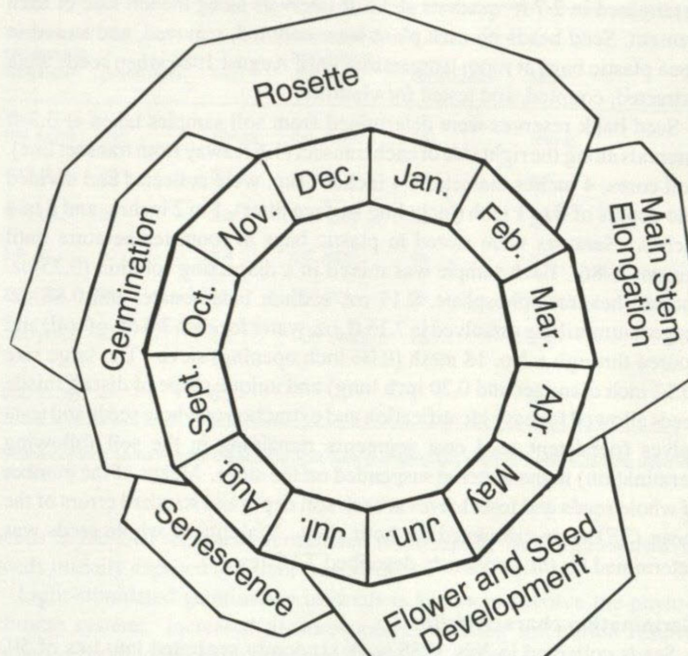

Figure 1. Life cycle of distaff thistle (Carthamus lanatus) in central Texas.

MATERIALS AND METHODS

Study sites

The field study was conducted in 1985 and 1986 on two adjacent range sites at the Goodrich Ranch in Burnet County, Texas, near the eastern edge of the Edwards Plateau resource region. The adobe range site, at an elevation of 1,590 ft, is dominated by distaff thistle, threeawns (Aristida spp.), hairy tridens (Erioneuron pilosum), red grama (Bouteloua trifida), fall witchgrass (Leptoloma cognatum), bur clover (Medicago hispida), and upright prairie coneflower (Ratibida columnaris). The soil is a Brackett sandy loam (fine-loamy, carbonatic, thermic, shallow, typic Ustochrepts). The redland range site, located 330 ft downslope from the adobe site, is dominated by distaff thistle, Texas wintergrass (Stipa leucotricha), silver bluestem (Bothriochloa saccharoides), buffalograss (Buchloe dactyloides), tumble windmill grass (Chloris verticillata), and upright prairie coneflower. The soil is a stony loam (clayey, mixed, thermic, lithic Rhodustalfs). Vegetation composition on both range sites indicated that retrogression had occurred as the result of heavy livestock use (Soil Conservation Service, 1979). Average annual rainfall for the area is 30 inches. May and September are the peak rainfall months (National Oceanic and Atmospheric Administration, 1986). The mean frost-free period for the area is 230 days.

Seed population dynamics

Preliminary seed production data were obtained from distaff thistle plants in a 23x23 ft plot on the adobe site in July 1985. Seed heads on all 474 plants in the plot were counted, removed, placed in open plastic bags, and stored at room temperature until September 1985. Seeds were then counted and tested for viability by a 2, 3, 5 - triphenyl tetrazolium chloride (TTC) test (Copeland, 1978). Four replicates of 25 undamaged seeds each were soaked in distilled water for 24 h at 78°F, bisected and placed in a 1% solution of TTC for 24 h at 78°F in complete darkness. Percent viability was determined by visually evaluating intensity of staining and staining patterns under a 10-power lens.

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Three randomly located 100 ft-long transects were established in representative distaff thistle populations on the adobe and redland sites in July 1986, just prior to seed dissemination. Plant population density was determined in 2.7 ft^2 quadrats at 3.3-ft intervals along the left side of each transect. Seed heads on each plant were counted, removed, and stored in open plastic bags at room temperature until August 1986 when seeds were extracted, counted, and tested for viability.

Seed bank reserves were determined from soil samples taken at 3.3-ft intervals along the right side of each transect (1.6 ft away from transect line). Soil cores, 4 inches diameter x 4 inches deep, were collected and divided into depths of 0 to 1 inch (including surface litter), 1 to 2 inches, and 2 to 4 inches. Samples were stored in plastic bags at room temperature until August 1986. Each sample was mixed in a dispersing solution (0.35 oz. sodium hexametaphosphate, 0.17 oz. sodium bicarbonate, and 0.88 oz. magnesium sulfate dissolved in 7.15 fl. oz. water for each 3.5 oz. of soil) and poured through a No. 18 mesh (0.04 inch opening) sieve. The large size (0.12 inch diameter and 0.20 inch long) and unique shape of distaff thistle seeds allowed for easy identification and extraction of whole seeds and testa halves (persistent seed coat segments remaining in the soil following germination) in the material suspended on the sieve. Means of the number of whole seeds and testa halves at each soil depth and standard errors of the mean (SE) were calculated for both sites. Viability of whole seeds was determined by the previously described TTC test.

Germination characteristics

Seeds collected in July 1985 were randomly separated into lots of 50, making no distinction for size, color, or presence of pappus hairs. Each seed lot was placed on a piece of chromatography paper supported on polyurethane foam (0.25 inch thick) in a plastic tray (5x5.5x1.5 inches). Five cotton wicks extended into a 7.15 fl. oz. reservoir of distilled water, maintaining wetness of the paper. Trays were wrapped with clear polyethylene film to reduce evaporation and stabilize relative humidity (Berkat and Briske, 1982). Half of the trays were wrapped in two layers of aluminum foil to exclude light. All trays were placed in a controlled environment at the beginning of the light period (60/78°F night/day temperature regime with a 12-h photoperiod, simulating conditions in central Texas in September/October). A light intensity of 1,000 foot-candles was maintained at tray level. Seeds were exposed to light treatments of: 1 day light/13 days dark (1L); 3 days light/11 days dark (3L); 5 days light/9 days dark (5L); 7 days light/7 days dark (7L); 14 days light (14L); 1 day dark/ 13 days light (1D); 3 days dark/11 days light (3D); 5 days dark/ 9 days light (5D); 7 days dark/ 7 days light (7D); and 14 days dark (14D).

Germinated seeds were counted under a green safety light every day over the 14-day period. Seeds were considered germinated when the cotyledons were exposed and radicle length was 0.2 inches or greater (Copeland, 1978). Germination rates were estimated by calculating the mean time in days taken for nondormant viable seeds to germinate (Ellis and Roberts, 1978).

Trays were arranged in a completely randomized design with four replications per treatment. The entire experiment was repeated, and data from both trials were combined for statistical analysis. Cumulative germination percentages (adjusted by an arcsine transformation to normalize percentage values before analysis) and mean germination time values were analyzed by analysis of variance. Treatment means were compared by least significant difference ($P<.05$).

RESULTS AND DISCUSSION

Seed population dynamics

Prior to seed dispersal in July 1986, mean plant density along line transects at the adobe site was 10 plants/ft^2 with 1.4 seed heads/plant and 28 seeds/seed head. Mean plant density at the redland site was 11 plants/ft^2 with 1.3 seed heads/plant and 29 seeds/seed head. With 92% viable seed at both sites, the extrapolated estimate of viable seed production was 345 and 376 seeds/ft^2, respectively, for the adobe and redland sites. Plant population density and seed production can vary from year to year at the same site. Prior to seed dispersal in July 1985, mean plant population density on the 23x23 ft pilot plot adjacent to the line transects established later on the adobe site was 1 plant/ft^2 with 5.5 seed heads/plant and 29 seeds/seed head. With 95% viable seed, the extrapolated estimate of viable seed production was 140 seeds/ft^2, less than half the estimated viable seed production from line transects in 1986.

Distaff thistle seeds were most abundant near the soil surface at the two study sites. Seeds recovered from the 0 to 1 inch depth comprised 96 and 84%, respectively, of the total number of seeds occurring in the 4-inch deep soil cores at the adobe and redland sites (Table 1). Most distaff thistle seeds remained near the soil surface due to their large size and the presence of numerous rigid pappus hairs (30 to 50 hairs, up to 0.35 inch in length). Seeds buried at depths greater than 1 inch may have been incorporated by livestock hoof action, cached by rodents, covered by soil during erosional deposition, or may have fallen into cavities left after plant removal or decomposition.

Seed densities at all three soil depth increments were greater at the redland site than the adobe site (Table 1). Seed bank differences at the two sites can be explained, in part, by differences in soil depth and by topographic orientation. The coring apparatus regularly penetrated through the shallow top-and subsoil horizons into limestone parent material at the adobe site, but only penetrated into the friable topsoil horizon at the redland site. During occasional heavy thunderstorms, soil and associated surface-lying seeds (including distaff thistle) were transported down-slope from the adobe site to the redland site.

Table 1. Density, viability, and frequency of occurrence of whole seeds, and density and frequency of occurrence of testa halves of distaff thistle (Carthamus lanatus) from three soil depths at two range sites in Burnet County, Texas, 1985.

Range site	Soil depth	Density of whole seeds[a]	Viability of whole seeds	Frequency of samples with whole seeds	Density of testa halves[a]	Frequency of samples with testa halves
	(inches)	(no./ft^2)	(%)	(%)	(no./ft^2)	(%)
Adobe	0-1	15±3	78	38	35±8	41
	1-2	0	-	0	1±0.3	6
	2-4	1±0.3	100	4	1±0.3	4
	0-4	16		42	37	42
Redland	0-1	19±4	65	53	66±13	70
	1-2	2±1	58	8	2±1	11
	2-4	2±1	73	8	4±2	16
	0-4	23		54	72	71

Greater than 78% of the seed recovered from soil cores at the adobe site and 58% of the recovered seed at the redland site were viable as determined by a tetrazolium test (Table 1). Distaff thistle seeds buried at similar depths in a loamy sand in Western Australia (warm Mediterranean climate) remained viable for 5 to 6 years (Pearce and Quinlivan, 1968).

Densities of testa halves in soil cores followed the same trends as those of whole seeds. Testa halves were more abundant near the soil surface at both sites, and densities at all three soil depth increments were greater at the redland site than the adobe site (Table 1). Persistent testa halves, when divided by two, provide an indication of the number of seeds that may have germinated over the past several years. Accordingly, about 18 and 33 seeds/ft^2 may have germinated in the top 1 inch of soil of the adobe and redland sites, respectively. The presence of testa halves at 1 to 2 and 2 to 4 inches indicates that limited germination may have occurred at greater depths, however, the seedlings may not have reached the soil surface and survived.

In an Australian study (Pearce and Quinlivan, 1968), 96% of the original distaff thistle seeds planted in the top 1 inch of soil emerged as seedlings over a 4-year period, whereas only 3.4 and 1.2%, respectively, emerged from the 1 to 2 and 2 to 4 inch soil depths.

Several consecutive soil cores along each transect contained seed and testa halves at each soil depth increment while several subsequent consecutive soil cores were completely devoid of seed and testa halves. The uniform sampling pattern along the line transects may have underestimated clustered seed reserves (Bigwood and Inouye, 1988). Such clustered spatial distributions have been observed in other seed bank studies, and can have ecological ramifications in terms of seed predation or density-dependent competition among establishing seedlings (Bigwood and Inouye, 1988).

These results and results from the distaff thistle seed burial study in Western Australia (Pearce and Quinlivan, 1968) demonstrate that distaff thistle does form a persistent seed bank (Thompson and Grime, 1979). Persistent seed banks: confer potential for regeneration where disturbance of established vegetation is temporally and/or spatially unpredictable (e.g. livestock grazing); permit populations to establish themselves rapidly without immigration if environmental conditions prevent or greatly reduce seed production for one or several years; and represent an overlapping of generations, increasing genetic variability and stability within populations (Baskin and Baskin, 1985; Thompson and Grime, 1979). The most consistent feature of species forming persistent seed banks is the inhibition of germination by darkness, which may be enforced or perhaps induced by burial in the soil (Wesson and Wareing, 1969).

Germination characteristics

In general, earlier and longer exposure to light enhanced the germination of distaff thistle seeds (Table 2). Highest cumulative germination, approaching the viability (95%) of the seed population, was attained in the 14L treatment which received 12 h of light each day of the 14-day trial. Cumulative germination decreased slightly as length of initial exposure to light decreased from 14 days to 3 days (14L to 3L treatments). Germination after 1 day of exposure to light (1L treatment) was markedly lower than the treatments with longer initial light exposures. Seeds in the 1L treatment may not have been sufficiently hydrated to respond to the 12 h light period during the first day of imbibition before being placed in the dark for the remaining 13 days of the germination trial. Distaff thistle seeds from a population in New South Wales, Australia required up to 24 h for complete imbibition (Wright et al., 1980) and several other herbaceous dicots with light sensitive seed from temperate climates required 24 hours or more for complete imbibition and maximum photoresponsivity (Frankland and Taylorson, 1983). Cumulative germination percentages of seeds initially exposed to 1 and 3 days of darkness (1D and 3D treatments) were slightly lower than those of seeds in the 3L, 5L, and 7L treatments. Germination decreased significantly as the length of initial exposure to darkness increased from 3 to 14 days (3D to 14D treatments). Some seeds in the 5D, 7D, and 14D treatments may have passed the period of light sensitivity (beyond 24 h) associated with full imbibition and remained in a dormant state. The low percentage of seeds germinating in complete darkness in the 14D treatment were considered to be non-dormant. Similar trends in germination were reported for a distaff thistle population in New South Wales (Wright et al., 1980).

Mean germination time was most rapid and differed little for seeds in the 1L, 3L, 5L, 7L, and 14L treatments, and was significantly slower for seeds in the 1D, 3D, 5D, 7D, and 14D treatments (Table 2). All treatments initially exposed to light initiated germination on day 2 and completed germination by day 5. As the length of initial exposure to darkness increased by 2-day intervals for treatments 1D to 7D, mean germination time increased by approximately 2 days. Upon exposure to light, seeds in these treatments required about 3 days to attain maximum germination. The non-dormant

Table 2. Cumulative germination and mean germination time (MGT) of distaff thistle (Carthamus anatus) seeds exposed to different light/dark and dark/light treatments in a controlled environment with a 12 hour photoperiod.

Sequence of exposure to light/dark[a]	Germination	MGT	Sequence of exposure to dark/light[a]	Germination	MGT
(no. days)	(%)	(days)	(no. days)	(%)	(days)
1/13 (lL)	80	3.2	1/13 (lD)	86	4.0
3/11 (3L)	89	3.3	3/11 (3D)	85	5.9
5/9 (5L)	90	3.4	5/9 (5D)	74	8.2
7/7 (7L)	91	3.5	7/7 (7D)	73	10.2
14/0 (14L)	93	3.3	14/0 (14D)	10	4.5
LSD (0.05)	4	0.3		4	0.3

[a]Alpha-numeric terms in parentheses are light/dark and dark/light treatment abbreviations used in the text.

seeds in the 14D treatment germinated more rapidly than light-sensitive seeds initially exposed to a dark treatment.

Light-stimulated germination of seeds is known to involve the phytochrome system. Increased photoresponsivity during imbibition results from rehydration of phytochrome molecules in dry seeds (Frankland and Taylorson, 1983). The photoconversion of the Pr form of phytochrome (absorbs red wavelengths) to the Pfr form (absorbs far-red wavelengths), along with greater amplitudes of temperature fluctuation and changes in plant hormone levels, may stimulate germination by altering membrane properties (Baskin and Baskin, 1985). Distaff thistle seeds on or near the soil surface have the greatest chance for germination because: available soil moisture for imbibition is greatest near the surface after small rainfall events, physiologically significant amounts of light rarely penetrate more than 0.2 inches through soils (Tester and Morris, 1987), and diurnal temperature fluctuations are greater near the surface than at a depth of 3 or 4 inches.

Management implications

An understanding of seed production potential, seed reserves in the soil, and environmental factors that influence germination should allow managers to better determine expected densities of distaff thistle under certain environmental and management conditions, the type and amount of control required, and the response of distaff thistle populations following vegetation or soil manipulation (Roberts, 1986). Distaff thistle plants from these populations in central Texas have the potential to produce large numbers of seed that develop persistent seed banks and characteristically germinate near the soil surface over an extended period in the fall and early winter.

Prevention of seed development should be the primary consideration when planning control measures for distaff thistle. Herbicides are best applied during the young rosette stage (Figure 1) after all germination and seedling development has taken place. 2,4-D (2,4-dichlorophenoxy acetic acid) amine and ester formulations have satisfactorily controlled distaff thistle in Western Australia (Meadly, 1957; Quinlivan and Pearce, 1964) and at the adobe site in central Texas (Thompson, 1986). Mowing is an option if site conditions permit close cutting and the operation is timed properly. If plants are mowed too early (March), seed may develop on the regrowth, while late mowing (June/July) may not prevent seed development (Meadly, 1957). In addition, seeds have been observed to mature if plants are cut at the flowering stage (Figure 1) without being destroyed. After plants have flowered, burning may be the best method for destroying the current seed crop and removing dense stands. If revegetation is being considered, the seedbed should be prepared in the fall and seeding should be delayed as long as possible to allow distaff thistle seedlings to be controlled by herbicides. Based on seed longevity and germination requirements, the most economical approach may involve minimizing soil disturbances and implementing grazing practices that maintain a good vegetation cover on rangelands, because other control methods will have to be repeated over several years to control seedlings developing from persistent seed banks.

LITERATURE CITED

Baskin, J.M. and Baskin, C.C. (1985). The annual dormancy cycle in buried weed seeds: A continuum. Bio Science 35:491-498.

Berkat, O. and Briske, D.D. (1982). Water potential evaluation of three germination substrates utilizing polyethylene glycol 20,000. Agron J. 74:518-521.

Bigwood, D.W. and Inouye, D.W. (1988). Spatial pattern analysis of seed banks: An improved method and optimized sampling. Ecology 69:497-507.

Copeland, L.O. (1978). Rules for testing seeds. Proc. Assoc. Offic. Seed Analysts. J. Seed Tech. 3(3).

Correll, D.S. and Johnston, M.C. (1970). Manual of the vascular plants of Texas. Texas Research Foundation, Renner, TX.

Ellis, R.H. and Roberts, E.H. (1978). Towards a rational basis for testing seed quality. In: P.D. Hebblethwaite (Ed.), Seed production (pp. 605-636). Butterworths, London.

Frankland, B. and Taylorson, R. (1983). Light control of seed germination. In: W. Schropshire and H. Mohr (Eds.), Photomorphogenesis (pp. 428-456). Encyclopedia of Plant Physiology, New Series Vol. 16A. Springer-Verlag, N.Y.

Holm, L., Pancho, J.V., Herberger, J.P. and Pucknett, D.L. (1979). A georgraphical atlas of world weeds. John Wiley & Sons, N.Y.

Meadly, G.R.W. (1957). Weeds of Western Australia: Saffron thistle (Carthamus lanatus (Tourn.) L.) J. Dep Agric. West. Aust. 6:197-201.

National Oceanic and Atmospheric Administration. (1986). Climatological data, Texas, Vol. 91. National Climatic Data Center, Asheville, N.C.

Pearce, J.R. and Quinlivan, B.J. (1968). The long-term field germination of saffron thistle (Carthamus lanatus L.) and the life span of dormant seeds in the Geraldton Region, W.A. J. Aust. Inst. Agric. Sci. 34:231-232.

Quinlivan, B.J. and Pearce, H.A. (1964). Saffron thistle. J. Dep. Agric. West. Aust. 5:346-348.

Roberts, H.A. (1986). Seed persistence in soil and seasonal emergence in plant species from different habitats. J. Appl. Ecology 23:639-656.

Soil Conservation Service. (1979). Soil survey of Blanco and Burnet counties. USDA, Soil Cons. Ser., Temple, TX.

Tester, M. and Morris, C. (1987). The penetration of light through soil. Plant, Cell and Environ. 10:281-286.

Thompson, C.L. (1986). Results of 1986 agricultural demonstrations - Lampasas County. Result demonstration handbook. Texas Agric. Ext. Serv., Texas A&M Univ., College Station, TX.

Thompson, K. and Grime, J.P. (1979). Seasonal variation in seed banks of herbaceous species in ten contrasting habits. J. Ecology 67:893-921.

Wesson, G. and Wareing, P.F. (1969). The induction of light sensitivity in weed seeds by burial. J. Exp. Bot. 20:413-425.

Wright, G.C., McWilliam, J.R. and Whalley, R.D.B. (1980). Effects of light and leaching on germination of saffron thistle (Carthamus lanatus L.). Aust. J. Plant Physiol. 7:587-594. f