Harvest Season Influences Fertilizer Effects on Seed Production of Lanceleaf Coreopsis[1]

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Abstract

Seasonal and fertilization effects on seed production were investigated for a north Florida ecotype of lanceleaf coreopsis (*Coreopsis lanceolata* L.) grown in containers. Since containerized ecotypes of native, herbaceous species are frequently grown using nutrient regimes lower than those for production of typical garden plants, Osmocote 18N–2.6P–10K (18–6–12; 8–9 month formulation) was incorporated into the soilless substrate at one-half the low, low and medium label rates for container-grown plants [1.8, 3.6, and 5.4 kg/m^3 (3.0, 6.0, and 9.0 lb/yd^3], respectively. Seed were harvested in June, and then again from July–October after plants had been cut back and reflowered. Seed production was greatest for the June harvest based on the number and mass of filled seed per seed head as well as the number of mature seed heads per plant. Number of mature seed heads was directly related to fertilizer rate but this effect varied by harvest season. Seed head production was substantially more responsive to increasing fertilizer rate for the June harvest than for the July–October harvest, which was one of the primary reasons for greater seed production in June. There were also 37% more filled seed per seed head for the June harvest than for the July–October harvest. Seed in June were 67% viable but only 21% of the viable seed germinated. The July–October seed were only 24.7% viable but half of them germinated. Seed harvested during July–October germinated faster than seed harvested in June.

Index words: native wildflower, seed germination, seed production, tickseed.

Significance to the Nursery Industry

Seed production of regionally adapted native wildflowers is an enterprise that is an alternative to production of traditional ornamental commodities. Demand for this type of seed has risen over the past 10–20 years largely due to concerns about the ecological impacts that cultivars or selections of native species would have on existing indigenous populations. However, formal, non-proprietary evaluation of cultural practices is very limited since this is a specialized commodity. In this study, an ecotype of lanceleaf coreopsis was grown in containers and fertilized in the spring at rates that ranged from slightly less to slightly greater than those frequently used for production of ecotypes of native, herbaceous species. The yield in June, after the first flush of flowers, was much greater than that for the July–October harvest after plants had been cut back and reflowered. The main reason for the greater seed production in June was that seed head production was substantially more responsive to increases in fertilizer rate. Interestingly, seed harvested in June were more viable but seed harvested from July–October were less dormant and germinated faster. The tendency for this species to naturally flower less in summer and fall and/or nutritional stress probably caused the lower yields for the July–October harvest. Seasonal and fertilization effects might be issues to consider with seed production of ecotypes of other native wildflower species that have extended flowering seasons.

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Introduction

Lanceleaf coreopsis (*Coreopsis lanceolata* L.) is a native wildflower found throughout much of the United States (24). The range of this short-lived perennial extends south into central Florida (25). In Florida, naturally occurring plants of this semi-evergreen to evergreen species are about 15–20 cm tall (6–8 in), with inflorescences extending another 15–20 cm (6–8 in) above the foliage. In a common garden study, the wild lanceleaf coreopsis of Florida differed from the garden variety in that foliage, clump size, and flower diameter of the garden variety were about two to three times greater (18). The Florida lanceleaf coreopsis also flowered the first spring after sowing the previous fall while the garden variety only flowered sporadically (18). Flowering of natural populations in Florida is from March to June, with generally infrequent flowering in summer and fall (5; J. Norcini, unpublished observation). Lanceleaf coreopsis is self-incompatible (22).

There is a growing demand for seed of regionally adapted (i.e., local ecotypes) native wildflowers and grasses for use in roadside plantings, ecological restoration, and revegetation projects (4, 9). Seed source can affect survival, growth, and/or flowering of native wildflower species (14, 19). The importance of seed origin has not only been recognized by the research community but by those involved with managing our nation's roadsides (8).

Because seed origin is becoming such an important issue, field production of local ecotypes of native wildflower and grass seed has become a commercially viable niche industry, especially in the Midwest and West (4, 9, 15). Production in these areas primarily resulted from the demand for seed in Conservation Range Programs and restoration and rehabilitation of native prairies (9, 15). Production in the lower South was extremely limited until recently because the strong demand for this type of seed did not begin until the late 1990s. In response to this demand, Florida now has a small but expanding industry devoted to production of Florida ecotypes of native wildflowers. Efforts to establish a similar niche industry in Louisiana have recently begun (Jackie Carlisi, Univ. of Louisiana, Lafayette; personal communication).

One of the major impediments has been and continues to be the lack of information about cultural practices that will improve yields. This was an important issue noted by Minnesota growers (15) as well as growers in Florida (Joan Wood, Wildflower Seed and Plant Growers Assoc., Inc.; personal communication). Since this is a niche industry, nonproprietary information about cultural practices is very limited, with the majority of it being anecdotal in nature (e.g., 10, 17). An extensive literature search revealed only two studies in refereed journals that dealt directly with commercial seed production practices for coreopsis species (11, 20). Effects of harvesting date and method for a north Florida ecotype produced in a nonfertilized/irrigated field site were examined by Norcini et al. (20). Mechanical harvesting was more efficient than manual harvesting but yields were substantially greater for manually harvested seed. It was also noted that harvest date (late June and late August) had minimal effects on yield or quality. Germination, which was conducted using Association of Official Seed Analysts (AOSA) specifications (1), ranged from about 14 to 30%, but no correction was made for the percentage of viable seed so percent germination was underestimated. Johnson and Whitwell (11) evaluated seed production potential of 29 native wildflower species field plots that were fertilized and irrigated. Seed were purchased from a large, commercial grower that markets seed nationwide. They concluded that lanceleaf coreopsis had poor seed production potential because the germination rate was <45%. However, seed production potential most likely would have been rated as 'moderate' had the germination rate (43%) been corrected for the percentage of viable seed and the seed tested according to AOSA standards (1).

In order to gain further insight about the seed production potential of a regional ecotype of lanceleaf coreopsis, seed was harvested from containerized plants at two times during the growing season. The soilless substrate was amended with a controlled release fertilizer at three rates in order to gather some preliminary information about fertilization rates on yield and quality. This study was conducted under these conditions so that nutrients available to individual plants were uniform and moisture was nonlimiting.

Materials and Methods

Seed origin. Seed (achenes) of lanceleaf coreopsis were collected in 1996 and 1997 from several native upland populations located in the Florida panhandle (AHS Heat Zone 9; USDA Hardiness Zone 8b). A pooled sample of seed was sown on an unfertilized soil [Fuquay fine sand (Arenic, Plinthic Kandiudults); 0.5–2% OM; 0–5% slope] at the North Florida Research and Education Center, Monticello (30.5°N, 83.9°W) in February 1998. The pH and nutrient levels of a composite soil sample prior to sowing seed were pH 5.6 and 1.5N–21.8P–37.4K mg/kg soil (University of Florida/IFAS Soil Testing Laboratory). In August 1998, seed were harvested, cleaned, and stored in the dark at 5.6C (42F) at 40% relative humidity.

Plant culture and fertilizer treatments. Seed from the 1998 harvest were sown on January 18, 2002, on the surface of flats containing MetroMix 200 (Scotts-Sierra Horticultural Products Co., Marysville, OH). They were lightly covered (1–2 mm) with MetroMix 200 and placed in a glasshouse on a propagation mat (Pro-Grow Supply Corp., Brookfield, WI) that was set at 21C (70F). Seedlings were fertilized with 50 mg/liter (ppm) N of Peters 15N–13.2P–12.4K (15–30–15; Scotts Co.) on February 1. Single seedlings were transplanted to cell packs [1204; Cassco, Montgomery, AL; vol. 75 ml (2.5 oz)] on February 5. Weekly fertilization continued from February 14 through the end of March.

On April 2, seedlings [8.9 ± 0.3 cm tall (3.5 ± 0.1 in); 14.8 ± 0.4 cm wide (5.8 ± 0.1 in)] were transplanted individually into a soilless substrate in 3.8-liter (#1) containers. The substrate was composed of 1.9-cm (0.75 in) shaker-screened pine bark (Georgia-Florida Bark & Mulch, Capps, FL), Canadian sphagnum peat (Berger Peat Moss Inc., St. Modeste, Quebec, Canada), and rescreened 6B gravel (Martin Aggregates, Chattahoochee, FL) at a ratio of 3:1:1 (by vol); it was amended with Micromax (Scotts-Sierra Co.) at 1.1 kg/m^3 (1.9 lb/yd^3). The soilless substrate was divided into thirds; each third was amended with Osmocote 18N–2.6P–10K [18–6–12; 8–9 month formulation at 21C (70F); Scotts-Sierra Co.] at one-half of the low label rate [1.8 kg/m^3 (3.0 lb/yd^3)], low label rate [3.6 kg/m^3 (6.0 lb/yd^3)], or medium label rate [5.4 kg/m^3 (9.0 lb/yd^3)]. These rates were from slightly less to slightly greater than those frequently used for container production of ecotypes of native, herbaceous species (16). There were 20 single pot replications per fertilizer rate, each containing a single plant. Pots were arranged in a completely randomized design about 46 cm (1.5 ft) apart on an outdoor, full sun container bed that was covered in black plastic. Overhead irrigation (pH 7.8) was applied at the rate of 9 mm (0.4 in) per day. Containers were hand weeded as necessary.

Seed harvest. Plants began flowering in early May. Seed were harvested from the first eight mature seed heads on each plant from June 4 to 21. For plants on which there were more than eight seed heads of equal maturity, up to 14 seed heads per plant were harvested so as to avoid any bias when deciding which seed heads to harvest. Seed heads were defined as mature when the pedicel directly under the head appeared dry and brown. At this time, the phyllaries appeared brown and dry but were not open to allow seed loss. On July 1, remaining mature seed heads were excised and counted. Plants then were cut back to a height of 15.2 cm (6 in). Plants began to rebloom shortly thereafter. Mature seed heads were harvested from July 30 to October 14. The harvest was terminated on October 14 when it was apparent that some plants were not going to produce eight mature seed heads. The number of mature seed heads per plant collected for seed varied from 0 to 12. Shortly after October 14, any remaining mature seed heads were excised and counted.

Harvested seed heads were placed in dated coin envelopes and oven dried [31–34C (88–93F)] for 2–3 days. Inert material was removed, and the filled, dried seed were counted and weighed. Number and mass of filled seed (per mature head) were recorded. After filled seeds were counted and weighed, they were subjected to a germination test at 20/30C (68/86F) according to AOSA specifications (1); germination tests were started within 2 weeks of harvest. Viability of nongerminated seeds was determined with a tetrazolium (TZ) test (7); embryos that were white, plump, and otherwise appeared normal were also counted as viable (Carol Baskin; personal communication). Some seed appeared to have no embryo, or a very under-developed embryo with no to little endosperm; these seed were classified as unfilled. To

Table 1. Significant harvest season effects on seed yield and quality of a north Florida ecotype of lanceleaf coreopsis grown in containers.[z]

	Seed quality parameter					
Harvest season	Filled seed/ seed head (no.)	Mass filled seed/ seed head (mg)	Mature seed heads (no.)	Germination of viable seed at 7 days (%)	Germination of viable seed at 21 days (%)	Total viable seed (%)
June[y]	45.0	72.0	161.9	4.6	21.1	67.1
July-October[y]	32.9	36.1	28.6	19.8	49.2	24.7
Significance[x]	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

[z]For all analyses, except germination, the plant averages over seed heads were used (n = 20 for June; n = 18 to 20 for July–October, depending on treatment). For germination, the individual seed head data were used; sample size varied as noted below.

[y]June 4–20: 8–14 seed heads harvested per plant ; July 30–October 14: harvest was terminated on October 14 when it was apparent that some plants were not going to produce eight mature seed heads, 0–12 seed heads harvested per plant.

[x]F-test *P* value.

confirm that these seed were unfilled, they were included in the germination and TZ tests for the June harvest, and examined under 25× magnification. For the July–October harvest, we were able to visually recognize unfilled seed. All unfilled seed were discarded for both harvests, so all results only refer to filled seed.

The significance of main and interactive effects was determined using the General Linear Model (GLM) procedures of SAS (21). In these analyses, the plant averages over seed heads was used for all responses except for percent germination. Analyses of germination responses used the individual seed head percentages. No arcsine transformation of germination percentages was required since the equal variance assumption was not violated. When F tests of harvest season main effects were significant, no mean separation test was necessary since there were only two means. Although there were no significant main effects for fertilizer rate, when harvest season × fertilizer rate effects were significant, fertilizer rate effects were subjected to regression analyses by harvest date. Regression models were fitted sequentially. The quadratic term was added to the model only if its inclusion was significant at $\alpha = 0.05$.

Results and Discussion

Seed production of lanceleaf coreopsis was greatest for the June harvest based on the number or mass of filled seed per seed head as well as the number of mature seed heads per plant (Table 1). There were 37% more filled seed per seed head for June than for July–October, and seed mass per seed head for June was double that of July–October (Table 1). Number of filled seed per seed head for the June harvest was about the same as for Michigan and Indiana ecotypes (~41 to 51) (2). Number of mature seed heads was directly related to fertilizer rate but this effect varied by harvest season (Table 2). Mature seed head production was much more sensitive to increases in fertilizer rate in June than in July–October (Table 2). However, the medium fertilizer rate was suboptimal for mature seed head production (and hence, seed production) since the response included only a significant liner component and not a significant quadratic one. Based on the predicted number of seed heads per plant (Table 2) and the average number of seeds or seed mass per seed head (Table 1), estimated per plant yields for the June harvest ranged from 4,561 seed [7.3 g (~0.02 oz)] to 10,020 seed [16.1 g (~0.04 oz)] for the one-half low to medium fertilization rates, respectively. Estimated yields for the July–October harvest based on the predicted number of seeds and seed heads (Table 2) as well as the average seed mass per seed head (Table 1) ranged from 123 seed [0.15 g (<0.001 oz)] to 1,940 seed [1.9 g (~0.004 oz)] for the one-half low to medium fertilization rates, respectively.

The harvest season × fertilizer effect on number of mature seed heads per plant may have been confounded by plant

Table 2. Significant harvest season × fertilizer rate effects ($P = 0.001$) on seed yield of a north Florida ecotype of lanceleaf tickseed grown in containers.[z]

	Fertilizer rate (kg/m^3)[y]			
Harvest season[x]	1.8	3.6	5.4	P[w]
Number of filled seed				
July–October harvest[v]				
Observed means	29.6	32.0	37.1	
Regression model	25.4 + 2.1R (r^2 = 0.14)			0.004
Number of mature seed heads				
June harvest				
Observed means	104.0	156.6	225.2	
Regression model	40.7 + 33.7R (r^2=0.56)			<0.001
July–October harvest				
Observed means	6.4	23.8	54.9	
Regression model	–20.1 + 13.5R (r^2 = 0.44)			0.004
Uniformity of seed ripening (days)[u]				
June harvest				
Observed means	2.7	2.6	1.2	
Regression model	3.70 – 0.43R (r^2=0.07)			0.050
July–October harvest				
Observed means	23.4	13.0	8.6	
Regression model	29.8 – 4.11R (r^2 = 0.24)			0.002

[z]For all analyses, the plant averages over seed heads were used (n = 20 for June; n = 18 to 20 for July–October, depending on treatment).

[y]Osmocote 18N–2.6P–10K [18–6–12; 8-9 month formulation at 21C (70F)] at 50% of the low Osmocote label rate, low rate, or medium rate [1.8, 3.6 or 5.4 kg/m^3 (3.0, 6.0, and 9.0 lb/yd^3), respectively].

[x]June 4–20: 8–14 seed heads harvested per plant; July 30–October 14: harvest was terminated on October 14 since it was apparent that some plants were not going to produce at least eight mature seed heads, 0–12 seed heads harvested per plant.

[w]Significance of F-Test.

[v]Fertilizer rate had no effect on number of filled seed for the June harvest.

[u]Number of days from the first to last mature seed head harvested on a given plant within a fertilizer treatment.

size, although plant size was not measured in our study. Plants at the medium rate were visibly the largest (taller, wider, more leaves) and those at the lower rates were the smallest. The same trend was observed in previous work that involved containerized lanceleaf coreopsis (J. Norcini; unpublished data). The significance of the larger plant size is that the individual ramets that comprised the overall plants likely produced more flowers and hence more seed. Kumar and Kaur (12) noted that plant height, width, branching, and seed production of field-grown coreopsis were greatest at the highest N fertilization rate.

Seed ripening was very uniform for the June harvest when averaged among plants within a fertilizer treatment. There was a linear effect of fertilizer rate on the uniformity of seed ripening; however, it was a very poor relationship ($r^2 = 0.07$) so the practical significance of this effect was minimal (Table 2). Regardless of fertilizer rate, less than 3 days was needed to harvest 8 to 14 mature seed heads from any single plant within a treatment. Considering all plants for the June harvest, no more than 18 days were required to harvest at least eight mature seed heads. This 18-day harvest period concurs with the 2- to 4-week seed ripening period of field-grown lanceleaf coreopsis (11). In contrast, seed ripening was much less uniform for the July–October harvest. The response of ripening uniformity to fertilizer rate was still linear but the uniformity of seed ripening was more sensitive to changes in fertilizer rate than in June (Table 2). For any single plant within a treatment, 23.4 days was required to harvest at least eight mature seed heads from plants fertilized at 1.8 kg/m^3 (3.0 lb/yd^3) but only 8.6 days was needed to harvest at least eight mature seed heads from plants fertilized at 5.4 kg/m^3 (9.0 lb/yd^3) (Table 2). Moreover, some plants did not produce any mature seed heads even after 11 weeks.

Seed harvested during June was 67.1% viable compared to only 24.7% for seed harvested from July–October. However, July–October seed was less dormant than seed harvested in June. Of the viable seed harvested in July–October, nearly 50% germinated while only about 21% of viable seed harvested in June germinated (Table 1). In addition, July-October seed germinated faster as evidenced by the germination rates at 7 days (Table 1). Differences in germination rates seemed to coincide to our field observations of mid-fall through mid-winter germination of this species under low input landscape conditions. It would be advantageous for delayed germination of seed produced early in the summer so that most seed do not germinate under hot summer conditions when seedling survival is at greater risk. Goldenmane coreopsis [*Coreopsis basalis* (A. Dietr.) S.F. Blake], another spring flowering species in north Florida, also germinates in mid-fall under low input conditions (J. Norcini; unpublished observation). Other species of Asteraceae exhibit similar flowering and seed germination patterns (3). Differences in seed germination also might have been due to what Ellner (6) termed a 'sibling-competition model'. The relatively high level of seed production during June would mean a concomitant increase in competition among siblings if most seed germinated. However, the greater level of seed production could be offset by a corresponding increase in seed dormancy thereby spreading out germination over time and reducing competition among siblings.

The significant harvest season main effects (Table 1) and harvest season × fertilizer rate interactive effects (Table 2) were most likely related to one or more of the following issues. First, lanceleaf coreopsis tends to flower less during late summer and fall than in spring and early summer (5) so there was probably inconsistent flowering and seed production within and among treatments from July–October. Hence, it's not surprising that seed production was greatest in June (Table 1), and also that the effect of fertilizer rate on responses related to yield and uniformity of ripening varied by harvest season (Table 2). Secondly, plant resources (nutrients, photosynthate, etc.) during July–October might have been allocated towards vegetative growth. Plants cut back in July might have directed nutrients and photoassimilates primarily to new vegetative growth, rather than flowers, which also might help to explain reduced flowering of plants at the low fertilizer rate (Table 1). In addition, plants might have been nutrient stressed—although no plants exhibited any visual foliar symptoms of nutrient deficiency—since they were not refertilized. Nutrient levels in the soilless substrate might have been low due to high container substrate temperatures and the associated increase in fertilizer release rate. Lloyd (13) suggested that if available resources fall below a minimum threshold level, maternal investment in reproduction is withdrawn, even at the primordium level. And finally, pollen limitation (23) might have played a role in reduced seed yield for the July–October harvest.

In conclusion, fertilizer enhanced seed production of lanceleaf coreopsis mainly by increasing mature seed head production, although the magnitude of this effect varied by season of harvest. Best yield and quality were for seed harvested in June after the first flush of flowers. Results of this study can be used as the basis for evaluating harvest season and fertilizer rate effects on seed production of lanceleaf coreopsis under commercial field conditions.

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