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Dynamics of reproductive growth of lesquerella (*Physaria fendleri*) over different planting dates[☆]

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ABSTRACT

Vegetative and reproductive growth information of lesquerella (*Physaria fendleri*), a new oilseed crop targeted for bio-products, is important to understand especially in the early commercialization stage of this new crop. The objective of this study was to determine the effect of fall, winter, and spring planting dates over three years on the ontogeny of the crop including biomass, floral buds, flowers, and siliques. Fall plantings always produced more than the other plantings due to the extended season. Winter and spring plantings had less biomass and produced fewer buds, flowers, and siliques. The compensation of lower crop management costs and a shorter growing season could make winter a viable option for planting in the southwest. Spring planting could become viable if seed shatter due to summer rains could be reduced. The information will help decide growing regions suitable for crop production and determine what reproductive stages could be manipulated to improve seed yields.

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1. Introduction

Lesquerella [*Physaria fendleri* (Gray) O'Kane & Al-Shehbaz, formerly *Lesquerella fendleri* (Gray) Wats.] (Al-Shehbaz and O'Kane, 2002) is a potential oilseed crop native to the southwestern U.S. and northern Mexico. The seed hydroxy fatty acids (HFA) combined with the yield potential of this species makes it a valuable option for industrial uses including lubricants, motor oils, nylon-11 production, greases, coatings, cosmetics and additives for biofuels (Roetheli et al., 1992; Goodrum and Geller, 2005; Isbell and Cermak, 2002). India is by far the largest exporter of castor oil (*Ricinus communis* L.) followed by China and Brazil and the U.S. is a leading importer of the oil (Anonymous, 2010; PCCO, 2010). Ricinoleic HFA of castor and lesquerolic HFA of lesquerella have similar chemical structures. Ricinoleic HFA is composed of 18 carbons (C18:1-OH) compared to 20 carbons in lesquerolic HFA (C20:1-OH) (Hayes et al., 1995). Castor is no longer produced in the U.S. due to the seed meal (the seed portion remaining following oil extraction) containing ricin, a deadly compound.

Like other crops in the Brassicaceae family, lesquerella produces bright yellow flowers indeterminately along inflorescences throughout the reproductive growth stage. The flowering period of a fall planted lesquerella crop can extend from late February until harvest in early June (>150 days). The crop is generally planted in the fall in the southwestern U.S. when soil temperatures begin to cool. Germinated plants remain in a vegetative stage during winter until temperatures warm in February. Plants then begin to branch and transition to a reproductive stage until harvest in June. Other planting dates have yet to be considered for this crop.

Physaria fendleri may produce 30 seeds in a single silique depending in part on successful outcross pollination by bees and other insects (Mitchell, 1997). A 1000-seed-weight of this small-seeded crop is 0.6 g. A single branch may contain up to100 siliques. Branching in this species is prolific and environmentally influenced,

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Table 1
Planting date, replications, and number of weekly samples for three plantings of lesquerella in 2006–2007, 2007–2008, and 2008–2009 growing seasons.

Growing season	Planting date treatment	Planting date	Replications	Weekly samples
2006–2007	Fall	October 10, 2006	4	10
	Winter			
	Spring	March 8, 2007	4	8
2007–2008	Fall	September 28, 2007	3	16
	Winter	November 30, 2007	3	3
	Spring	February 15, 2008	3	9
2008–2009	Fall	October 6, 2008	3	9
	Winter	January 8, 2009	3	7
	Spring	February 6, 2009	3	6

although the crop height is only 0.4 m (Dierig and Crafts-Brandner, in press).

Delph (1986) studied the effect of limited water resources and pollinator availability on fruit and seed production of *Physaria gordonii* in native populations. Flowering in this study increased to a peak and then fell off rapidly while seed pods (siliques) decreased throughout the season. Pollinators were not a limiting factor to silique or seed set in this study. However, additional irrigation to plants increased fruit and seed production by extending the growing season.

Egli (2005) reviewed temporal distribution of flowering and fruit set in soybean [*Glycine max* (L.) Merrill] literature to consider its potential role in regulating yield. Day length and date of planting were the main influences on length of flowering, while high temperatures contributed to greater flower numbers. Flowers and immature pods are reported to be the most vulnerable to reproductive failure (pods that do not survive to maturity) due to environmental stresses, stage of development and stem position, and genetic heritability. Combined reports from a number of studies showed an R^2 value of 0.83 describing the relationship between flowers and pods per plant at maturity (Egli, 2005).

Flowering time in oilseed rape (*Brassica napus* L.) spanned an average of 26 days and more than 75% of the siliques resulted from flowers which opened within 14 days of anthesis (Tayo and Morgan, 1975). The rate of supply of carbon assimilates to the inflorescences is critical for seed yield. In the same study, the number of siliques was reduced with shading. When the supply of carbohydrates to the apically positioned flowers or siliques was increased, they developed larger, or in greater numbers (Tayo and Morgan, 1979).

Improving yield proves to be difficult in indeterminate, outcrossing, long season crops such as lesquerella especially since the characteristics of an optimum profile for the plant has not been defined. Harvest index has been used as a selection tool for improved oil content and yield in lesquerella (Dierig et al., 2006b). However, there are many examples of yield-component compensation without increases in photosynthesis and sink characteristics capacity (Egli, 2005).

Decisions for agronomic management such as irrigation timing, fertilizer application, and harvesting of the lesquerella crop depend on the stage of growth and development. The ability to regulate the patterns of reproductive growth to improve seed yield is the goal of any breeding program. In this study our objectives were (1) to characterize the temporal distribution of plant biomass, floral buds, flowers, and siliques in lesquerella, and (2) determine the effects of dates of planting on growth and production.

2. Materials and methods

2.1. Field and data measurements

Experimental plots were established in all three years in a randomized complete block design with three replications at a seeding rate of 12 kg/ha^{-1} at the University of Arizona, Maricopa Agricultural Experiment Center (MAC) located near Phoenix, Ariz (33.067547°N, 111.97146°W). The experiments took place over three planting seasons including 2006–2007, 2007–2008, and 2008–2009 (Table 1). Plots were planted from all three seasons and are summarized in Table 1. Plots were planted using a Brillion planter with a roller ring which broadcasts seed and lightly presses seed beneath the surface. Lesquerella variety WCL-LO3 was used for all experiments (Dierig et al., 2006a). Plots were flood irrigated throughout the growing season. Prowl H_2O, a pre-emergent herbicide was used prior to planting and plots hand-weeded during the growing season.

After crop emergence, multiple 1 m^2 locations within each plot were randomly selected and flagged for destructive harvests for biomass and plant counts. An area within the meter square area, 0.125 m^2, was also marked for counts of total numbers and weights of buds, flowers, and siliques (seed pods). When floral buds were first evident in plots, destructive harvests and measurements began and continued throughout the season until the end of the season when the entire field was harvested with a grain combine.

Marked areas in the field were hand harvested in the mornings during the reproductive stage of crop development. To collect plant samples, square frames of PVC tubing were constructed and used to delineate the 1 m^2 and the 0.125 m^2 areas. Plants were counted and hand harvested from both areas, put into bags and brought to the laboratory for counts and weights of buds, flowers, siliques, and biomass in the same day. Roots were cut from plants before weighing. Reproductive parts were removed from plants and counted. Plants and reproductive parts were oven-dried with forced air for 48 h at 80 °C and then re-weighed to obtain dry weights.

Plants per plot were counted but were not reported here. There was a high amount of variability in population densities within a planting time treatment. The variability was evenly distributed across treatments. Populations fell within the population range given by Brahim et al. (1998) of around 1 million plants per ha.

Weather data were obtained from a weather station on the MAC farm which is part of a state wide system called AZmet: The Arizona meteorological Network (http://cals.arizona.edu/azmet/06.htm).

2.2. 2006–2007 field experiment

In the 2006–2007 growing season, a field at MAC was planted on October 10, 2006 (fall planting). The soil type was a Trix clay loam soil, classified as fine loamy, mixed (calcareous) hyperthermic, Typic Torryifluvent. The field layout consisted of two plots 30 × 250 m with 1 m^2 marked areas randomized by harvest date throughout the plots. Each week, four replications of marked areas were harvested beginning on March 12, 2007. Plots were flood irrigated by siphoning tubes from a canal along the southern edge of the field. After six weeks of sampling (March 12 19, 26, April 2, 16 and 23) the experiment on that field was discontinued due to irrigation mismanagement (over-watering) causing many plants to prematurely die. A similar field 2 km east at MAC was used to