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Seed production of cut-leaved teasel (*Dipsacus laciniatus*) in central Missouri

Diego J. Bentivegna[1] & Reid J. Smeda[2]

[1]*CERZOS, CCT-Bahía Blanca (CONICET), Camino La Carrindanga Km 7, B8000FWB Bahía Blanca, Argentina; e-mail: dbentive@criba.edu.ar*
[2]*Division Plant Science, University of Missouri, Columbia, MO 65211, USA; e-mail: SmedaR@missouri.edu*

Abstract: Cut-leaved teasel is an invasive weed in Missouri that reduces the diversification of native species along roadsides and impairs traffic visibility. Teasel is a biennial and grows as a rosette in the first year and flowers the second year. Reproduction is only by seed. Field studies were conducted in 2004 and 2005 at two locations to assess the seed production of cut-leaved teasel. From a natural stand, fifteen plants were tagged at the onset of flowering. Selected plants included those considered growing in a group and those growing alone; a plant was considered alone when no other plant was adjacent for at least 60 cm. Whenever a seedhead completed flowering, it was covered with a cellophane bag and harvested one month later. Linear regression was used to correlate the weight of seeds from a single seedhead and number of seeds to estimate the total seed production per seedhead. The number of seedheads per plant varied from 3 to 56. On average, plants growing alone had 64% more seedheads per plant than plants occurring in a group. Seed numbers in the primary seedhead ranged from 511 to 1,487. Total seed production per plant ranged from 1,309 to 33,527. Seed production was 61% greater for plants growing alone versus those growing in a group and was more prolific in 2005 than in 2004. In addition, seed production per plant varied between locations for plants growing alone, but seed yield per plant was similar for plants growing in groups. Colonization of teasel in new areas is facilitated by higher seedhead numbers per plant and total seed production compared to reproduction of plants in areas of intraspecific competition.

Key words: *Dipsacus laciniatus*; invasive; noxious weed; seed production; teasel

Introduction

Cut-leaved teasel (*Dipsacus laciniatus* L.) is a native plant of southern Europe that was introduced into the United States from Europe in the 1700's for the processing of wool (Bobrov 1957; Mullins 1951; Rodale 1984). Teasel has spread rapidly over the last 30 years along highway corridors, where dispersal has been aided by mowing equipment (Hoffman & Kearns 1997). Teasel has a competitive advantage over other species in roadside habitats, because plants can tolerate saline soil created by the spread of in winter months (Beaton & Dudley 2004). Today, cut-leaved teasel is considered a noxious weed in several states including Colorado, Iowa, New Mexico, Oregon, and Missouri (Rector et al. 2006; USDA 2006).

Teasel colonizes undisturbed areas along roadsides, conservation areas, railroads and cemeteries (Solecki 1993; Werner 1975b). Cut-leaved teasel's negative impacts include displacing native species, increasing soil erosion by reducing water penetration into the soil, and reducing traffic visibility (Rand Swanigan, personal communication). In conservation and natural areas teasel could cause the suppression or elimination of desirable species by altering the nutrient and hydrological cycles (Huenneke & Thomson 1994; Solecki 1993; Werner 1977). The taproot changes the soil moisture levels by reducing water infiltration in relation to fibrous roots, thus increasing runoff and erosion (Lacey et al. 1989).

Seeds germinate throughout the year but mainly during the fall and spring. Following emergence, teasel develops a rosette with a large taproot extending down to 75 cm in the first year. In the second year, rosettes bolt and produce a flowering stalk reaching 2.5 meters (Werner 1975b). Biennial plants die after flowering and seed maturation (Jurica 1921; Solecki 1993; Werner 1975b).

The type of inflorescence is a head or capitulum borne at the end of branches and the fruit is an achene. The method of flowering is unique because it begins at the middle of the capitulum and extends upward and downward simultaneously (Jurica 1921). The number of seed per head varies directly with the size of the capitulum (Werner 1975b) and the number of heads per plant varies with the size of the plant. In fact, vigorous plants are more likely to have larger seedheads (Hedberg & Hedberg 1977). Poorer soil fertility and greater plant density decreased the number of branches and ultimately reduced total seed production (Caswell & Werner 1978). Seeds do not require stratification, scarification, or specific light conditions for germination (Solecki 1993). High germination rates (30 to 80%) and prolonged viability (more than 7 years) are important characteristics contributing to the success of teasel (Glass 1991; Roberts 1986).

Neither teasel plants nor the seeds possess morphological characteristics for dispersal by wind or animals (Werner 1975b). Thus, more than 99% of the seeds fall within 1.5 m of the parent plant, producing dense populations (Werner 1975a). Seeds can float on water and this dispersal mechanism was cited by several authors (Glass 1991; Neubert & Caswell 2000; Werner 1975b). Even though dispersed seeds were near the parent plant, Caswell & Werner (1978) suggest that colonization of new sites was the result of elevated levels of reproduction.

Seed production of teasel was reported to be over 3,300 seeds per plant for *D. sylvestris* in Michigan (Werner 1975b) and 3,000 seeds per plant for *D. sylvestris* and *D. laciniatus* in Illinois (Glass 1991). In the southern Midwest, there are no reports on the extent of seed production for individual plants or demonstrations of the impact of intraspecific competition on seed production. Studies identifying seed production per seedhead as well as the number of seedheads per plant are also lacking. The quantification of seed production in cut-leaved teasel in central Missouri may lead to improved understanding of the importance of reproduction in the life cycle of teasel and at the same time generate useful information regarding future control strategies.

The objectives of this study were to quantify numbers of seedheads, total seed per primary seedhead, and total seed production for cut-leaved teasel plants both growing alone and in a group.

Material and methods

Research was conducted in 2004 and 2005 at two locations in central Missouri including the Bradford Research and Extension Center located 10 km east of Columbia, MO and

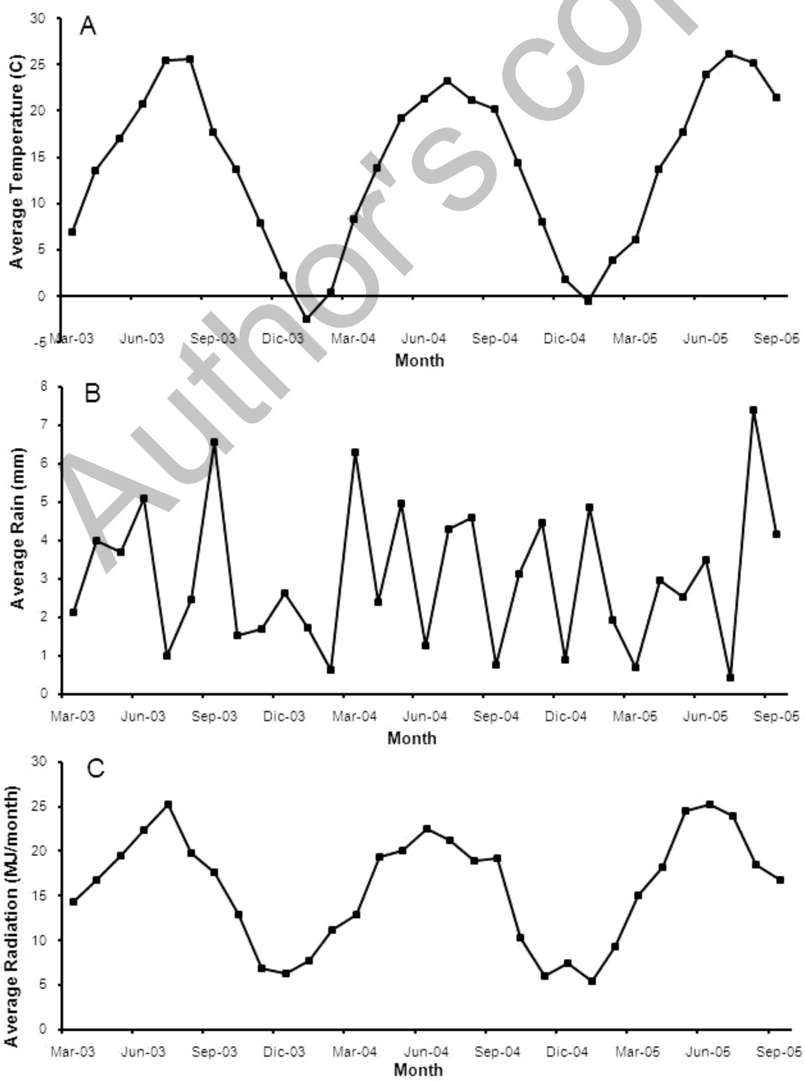

Fig. 1. Monthly means of air temperature (A), total rainfall (B), and total solar radiation (C) registered for the Bradford seed production study. The second Missouri site (Highway) was 15 km away.

along Highway 63 located 7 km north of Columbia, MO, USA. These will be referred to as the Bradford and Highway locations, respectively. Soil characteristics of the two sites are shown in Table 1. At the onset of flowering, a total of fifteen plants were tagged in two different plant densities (hereafter termed growth habits), some in a group and some growing alone. A plant was considered alone when no other teasel plant was closer than 60 cm, while a plant was considered in a group when there were at least two flowering teasel plants within 60 cm. When a capitulum completed flowering, late August to early September, the seedhead was covered with a cellophane bag to prevent seed loss and harvested one month later.

At harvest, all seedheads produced by teasel plants were harvested and counted. To determine seed number and weight, seeds were extracted by hand and cleaned using a mesh screen with 0.125 cm holes. Total weight of the seeds from each seedhead was recorded at room temperature (20 °C) and 50% relative humidity. To estimate seed production, seed weight was regressed against the number of seeds from eleven randomly selected individual seedheads for each year, location, and growth habit. All estimates of seed weight and seed number were combined to form one regression equation. This equation was then used to estimate seed yield from each seedhead and plant for all site years.

Table 1. Chemical and physical soil properties at Highway and Bradford locations in Missouri during seed production study.

Soil Property	Bradford	Highway
pH	5.9	7.5
Organic Matter	2.9 %	2.1 %
texture	Silt loam	Clay loam
Sand	20 %	22.5 %
Silt	57.5 %	40 %
Clay	22.5 %	37.5 %
Phosphorous (kg ha^{-1})	12.3	25.8
Potassium (kg ha^{-1})	167	375
Magnessium (kg ha^{-1})	612	1055
Calcium (kg ha^{-1})	4062	13168
CEC (meq/100 g)	14.5	33.7
Depth to rock	$\geq$ 40 cm	$\leq$ 20 cm

Weather conditions during the growth cycle were recorded from the Missouri Historical Agricultural Database at the University of Missouri (Fig. 1).

Data from each location, growth habit and year were tested for homogeneity of variance by plotting residuals. Normality was assessed using PROC UNIVARIATE with a

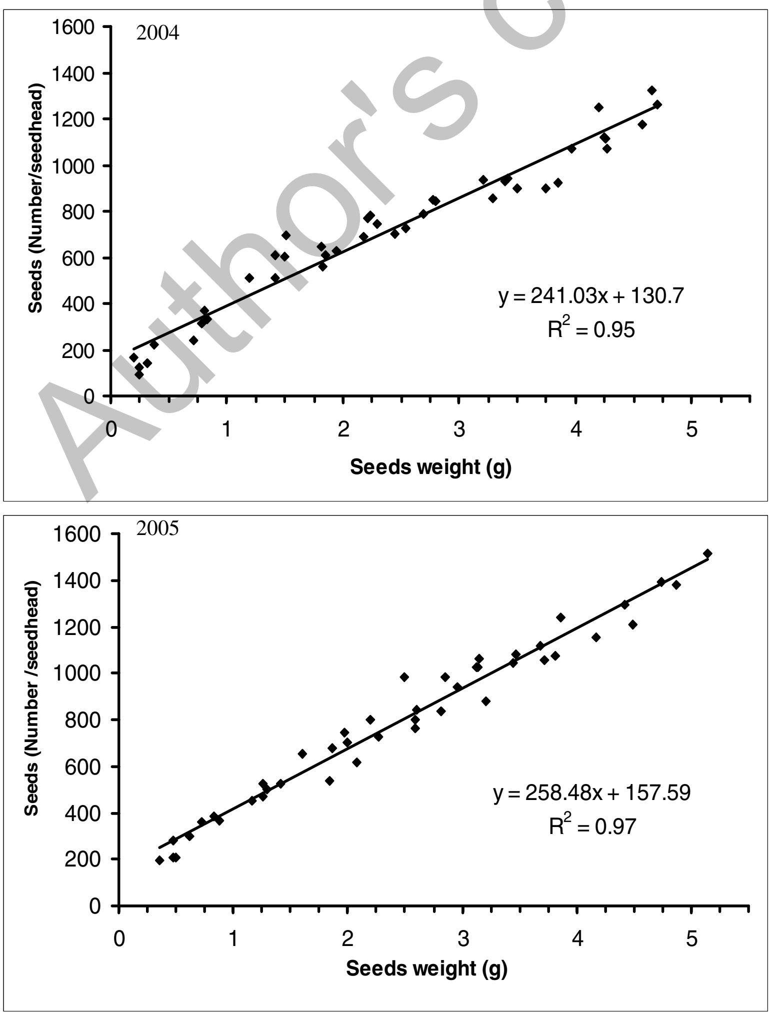

Fig. 2. Number of seeds produced per individual seedhead regressed against seed weight of cut-leaved teasel (*Dipsacus laciniatus* L.) in 2004 and 2005.

Table 2. Mean, standard deviation (Std. dev.), minimum (Min) and maximum (Max.) number of seedheads, seed production by primary seedhead, and total seed production at Highway and Bradford locations in 2004 and 2005 for cut-leaved teasel plants grown alone or in a group.†

		Bradford				Highway			
		Alone		Group		Alone		Group	
		2004	2005	2004	2005	2004	2005	2004	2005
Number of seedheads	Means	25.2	35.7	6.6	8.5	10.6	14.8	9.5	6.4
	Std. dev.	12.1	8.2	3.8	2	4.4	3.3	5.2	2.6
	Min.	11	23	3	5	5	10	5	3
	Max.	49	56	16	11	18	20	20	13
Seed production of the primary seedhead	Means	1008	1383	775	934	1010	1219	988	961
	Std. dev.	131	88	87	188	156	109	104	107
	Min.	780	1236	656	511	734	971	786	740
	Max.	1253	1487	954	1155	1266	1416	1158	1118
Total seed production	Means	12358	21986	3364	4720	5912	10010	5225	3873
	Std. dev.	5657	4752	2292	1431	2755	2877	2725	1351
	Min.	5467	14346	1309	2144	1894	5827	2292	2060
	Max.	22905	33527	9916	6604	9732	16540	10429	6640

† Abbreviations: alone, plant without another teasel plant closer than 60 cm; group, plant with at least two teasel plants within 60 cm.

probability ≤ 0.05 (SAS 2003). Analyses of seedhead number, total seed production per primary seedhead and total seed production were performed by the PROC GLM procedure of SAS (SAS 2003). Independent variables included location, year, and growth habit. Where significant interactions occurred, data were subjected to a one-way analysis. Means for main effects were separated by Fisher's Protected LSD at $P \leq 0.05$ (SAS 2003).

Results and discussion

The linear relationship between seed weight and the number of seed per seedhead fit the data well with an R^2 of 0.95 in 2004 and 0.97 in 2005 (Fig. 2). Small seedheads that produced less than 0.2 grams of seeds were eliminated from the seed estimation because they did not produce viable seeds as estimated by a tetrazolium test (Copeland 1976). Using the slope of the regression equation for each year, the mean number of seeds in one gram was 307. Comparing the number of seedheads, seed per primary seedhead and total seed production per plant variables among location, year, and growth habit, three-way interactions were not significant. However, two-way interactions between location-growth habit, location-year, and growth habit-year were significant for the number of seedheads, seed per primary seedhead, and total seed production per plant. The number of seedheads per plant, seed per seedhead, and total seed production were greater on average at Bradford compared to the Highway location, even though the soil fertility at Highway (P, K, Mg, and Ca) was higher compared to Bradford (Table 1). Other environmental variables such as depth to rock may be important in determining reproductive potential.

The number of seedheads per plant varied from 3 to 56 at the Bradford location and from 3 to 20 at the Highway location across years and growth habits (Table 2). The greatest number of seedheads per plant was

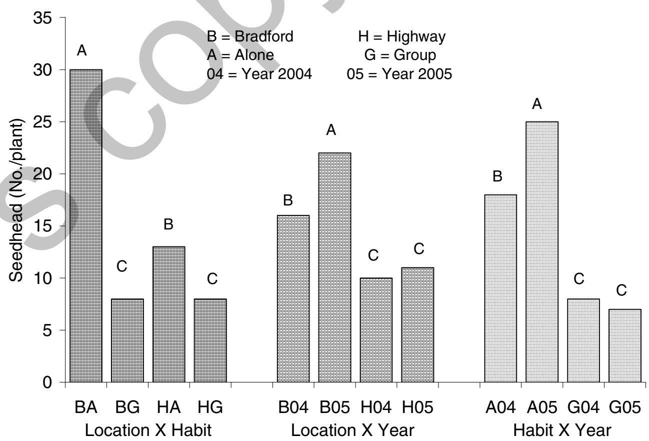

Fig. 3. Number of seedheads per cut-leaved teasel (*Dipsacus laciniatus* L.) plant for two-way interactions between location, growth habit, and year. Abbreviations: A (Alone), plant without other teasel plant closer to 60 cm; G (Group), plant with at least two flowering plants within 60 cm. Means followed by the same letter within a group are not significantly different according to Fisher's protected LSD test at $p \leq 0.05$.

for plants growing alone at Bradford (Table 2). Plants living alone had an average of 56% more seedheads per plant compared to plants occurring in a group. There was an effect of year in the number of seedheads per plant, which was greater for plants growing alone (2004 and 2005) and at Bradford (2004 and 2005) (Fig. 3). The morphology of teasel results in a single seedhead borne at the end of each stem.

The degree of branching, and consequently the number of seedheads produced by one plant, depends upon fertility levels in the soil (Chujo & Hanyu 1990; Jurica 1921). Previous research documented that one plant of *D. fullonum* usually supports 1 to 40 flowerheads (Cheesman 1998). Werner(1975b) reported the number of inflorescences ranged from 3 to 9 for *D. sylvestris*, but as few as 1 or as many as 35 were com-

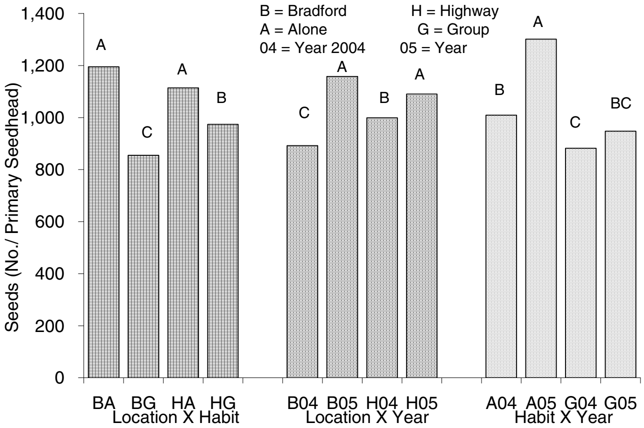

Fig. 4. Number of seeds per primary seedhead of cut-leaved teasel (*Dipsacus laciniatus* L.) across two-way interactions between locations, grow habits, and years. Abbreviations: A (Alone), plant without other teasel plant closer to 60 cm; G (Group), plant with at least two flowering plants within 60 cm. Means followed by the same letter within a group are not significantly different according to Fisher's protected LSD test at $p \leq 0.05$.

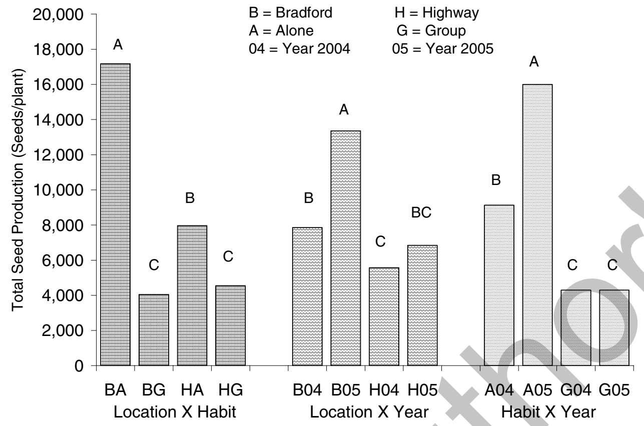

Fig. 5. Total seed production per cut-leaved teasel (*Dipsacus laciniatus* L.) plant for all two-way interactions between locations, grow habit and year. Abbreviations: A (Alone), plant without other teasel plant closer to 60 cm; G (Group), plant with at least two flowering plants within 60 cm. Means followed by the same letter within a group are not significantly different according to Fisher's protected LSD test at $p \leq 0.05$.

mon in a roadside population from Michigan. A population of *D. fullonum* in Japan was reported to produce from 60 to 100 seedheads per plant (Chujo & Hanyu 1990). Mullins (1951) illustrated in a population of *D. sativus* that values ranged from 3 to 100 seedheads per plant. Our results on the range of seedheads produced were similar to previous researchers, suggesting teasel can reproduce over a broad geography.

The number of seeds in the primary seedhead ranged from 511 to 1,487 for the Bradford location and 734 to 1,416 for the Highway location (Table 2). Plants growing alone (BA, HA) had a greater number of seeds per primary seedhead than plants growing in a group (BG, HG) (Fig. 4). There was a difference between years in the number of seeds per primary seedhead at both locations, with 10 to 31% more produced in 2005 than in 2004 (Fig. 4). Significant differences between years for number of seeds per primary seedhead were only for plants growing alone. Plants growing in a group likely extracted all the resources available in that environment, but intraspecific competition limited total seed production. On the other hand, plants growing alone took advantage of available resources and increased the production of seed in each primary seedhead.

Seed production ranged from 1,309 to 33,527 seeds per plant for the Bradford location and from 1,894 to 16,540 seeds per plant for the Highway location (Table 2). Across locations, seed production was 64% greater for plants growing alone (BA, HA) versus those growing in a group (BG, HG, Fig. 5). There were differences in seed production between Bradford and the Highway but only for plants growing alone (BA vs. HA). Total seed production at Bradford was greater in 2005 than 2004 and greater than the Highway location for both 2004 and 2005 (Fig. 5). Plants growing alone resulted in 2.1– and 3.6–fold more seed than plants growing in a group for 2004 and 2005, respectively (Fig. 5). Colder winter temperatures in 2004 compared to 2005 could have impacted the use of resources in rosettes and reduced seed production during 2004, especially for plants growing alone.

The number of seeds per plant in our study was more than those reported by Werner (1975b), who found that *D. sativus* plants produced an average of 3,333 seeds per plant in Michigan. Also, Caswell & Werner (1978) suggested that 2,500 seeds per plant of *D. sativus* were typical for Michigan. Similarly, Glass (1991) reported that a single plant of cut-leaved teasel produced up to 3,000 seeds in Illinois. Our results suggest the reproductive potential of *Dipsacus* plants is much higher than previously reported; seeds produced per seedhead and the number of seedheads per plant add to the biological data for this species.

Cut-leaved teasel seed production was more prolific in the absence of close competition compared to competing with other teasel plants (from 3,400 to 13,100 seeds more per plant). Plant reproduction occurs on numerous seedheads (up to 56 seedheads) that mature progressively depending upon the date of initial flowering. When a plant invades a new site, represented by plants growing alone, more seedheads and ultimately more total seeds were produced compared to plants in dense stands. Since seed dormancy following maturity has been found to be minimal (Bentivegna & Smeda 2011), a large number of seedlings is expected (up to 10,000) from each parent plant. This will contribute to the formation of teasel monocultures. Werner (1975b) identified that seed of teasel are located in open locules. As mowing is a common practice on roadsides, this is likely to facilitate spread to adjacent areas.

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