EFFECT OF TILLAGE ON *SENNA OBTUSIFOLIA* AND *XANTHIUM STRUMARIUM* POPULATION, INTERFERENCE AND SEED BANK

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SUMMARY

Two of the most troublesome weeds in the southern United States are *Senna obtusifolia* and *Xanthium strumarium*. A field experiment was conducted to determine the influence of tillage practice and interference level on seed production potential, emergence pattern and soil seed bank of *S. obtusifolia* and *X. strumarium* and to determine the dominant species after introduction into a weed-free field. Interference level did not influence the soil seed bank except for *S. obtusifolia* under tilled conditions. Under tilled conditions, *X. strumarium* was the dominant species, and *S. obtusifolia* was dominant under no-till conditions. Soil seed bank loss was greater for both species with tillage. Three years after initial seed deposition, the remaining *S. obtusifolia* seeds were 100% viable while *X. strumarium* burs were not viable. Thus, under no-till conditions, the *X. strumarium* soil seed bank was depleted while *S. obtusifolia* was not.

INTRODUCTION

Senna obtusifolia L. and *Xanthium strumarium* L. are among the most troublesome weeds in many fields of the southern United States (Elmore, 1986). Once the weeds are introduced and established, a producer is confronted with the potential for a severe weed problem for many years. *X. strumarium* is more competitive than *S. obtusifolia* (Monks and Oliver, 1988); however, other factors may regulate the population and determine the dominant weed species when both species are established on an equal basis.

The lifespan of weed seed in soil is important since potential weed problems exist as long as weed seed remain viable (Egley and Chandler, 1978). An understanding of seed bank function requires knowledge of the numbers of seed present at a given time and knowledge of the soil seed bank dynamics. Seed bank dynamics are affected by both rate of input (direct deposit by the plant and by dispersal from humans, wind, rain, birds and other animals) and rate of output (loss through germination, deep burial, predation, disease and death) (Fenner, 1985). Understanding emergence patterns and extent of seedling emergence from the seed bank aids in weed control and estimation of crop yield loss.

Soil tillage reduces the number of weeds but may increase germination of weed seed in the soil seed bank (Roberts and Neilson, 1981). In contrast, no-till systems typically have high populations of small-seeded annual weeds. The objectives of the present work were 1) to determine the influence of tillage practice and interference level on seed production potential, emergence pattern and soil seed bank of *X. strumarium* and *S. obtusifolia* and 2) to determine the dominant species after initial introduction into a previously weed-free field.

Materials and Methods

A field study was conducted at the Main Agricultural Experiment Station, Fayetteville, Arkansas, from 1991 through 1994. The experimental design was a split-plot with a three by two factorial of subplots and four replications. Main plots were no-till and tilled. Tilled plots were tilled 10 to 12 cm deep each year following actual or anticipated seed production in mid-November and in early April prior to weed emergence with a Triple-K seedbed cultivator with rear rolling baskets. The factorial subplots were three weed populations: *S. obtusifolia* alone, *X. strumarium* alone and *S. obtusifolia* plus *X. strumarium*; and two seed deposition levels: harvested in the year of establishment (1991) for initial seed production determinations or allowed to produce seed and deposit to the soil for one year (1991). Each plot was 5 m^2 with a 1-m border between plots. The soil was a Taloka silt loam (fine, mixed, thermic Mollic albaqualfs) with 25% sand, 62% silt, 13% clay, 1% organic matter and a pH of 6.7.

Initial Seed Production Determination.

In the year of establishment (1991), each plot consisted of four single-seed-source weed seedlings transplanted 2 May 1991 and allowed to grow to maturity and deposit seed. The distance between plants was 2 m. Plots with *S. obtusifolia* plus *X. strumarium* had two seedlings of each species planted alternately in the plot. All plants received the same cultural practices and were protected from wind breakage by staking, allowing plants to grow and produce seed as uniformly as possible.

At the end of the growing season, plants were harvested for seed or bur production. *X. strumarium* burs were counted for each plant. *S. obtusifolia* pod length was measured, and number of seeds per pod was determined by the following linear equation:

$$Y = -0.0329 + 1.766 X, r^2 = 95$$

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where Y = number of *S. obtusifolia* seed in each pod, and X = pod length in cm. Bur or pod counts and lengths were determined in the field in all plots not harvested the first year.

Seed Production for One Year

In 1992, all seedlings were allowed to grow to maturity. Two 0.5- by 0.5-m permanently positioned sub-sample markers were placed in each plot. From the subsamples, the number of emerged seedlings and seedling mortality were recorded every two weeks during the growing season. At the end of the season, entire plot seed production was determined for one set of seed deposition plots while the other set was left undisturbed. For *S. obtusifolia*, number of pods per plot was counted. For both weed species, all plants were cut at the soil line for shoot fresh and dry weights (data not shown). Four 1,000-g subsamples for each species were air dried at 45 C for eight days. *S. obtusifolia* pods were separated from the plants and counted, and average pod length was determined. The number of seeds per pod was calculated from the equation developed in 1991 and was multiplied by the actual pod count to estimate total *S. obtusifolia* seed production per plot. Plants in each plot were harvested at the end of the season for fresh weights (data not shown). *X. strumarium* burs were separated from the subsample before drying. The total bur production per plot was calculated by counting the burs per subsample and multiplying by the total dry weight. In 1993 and 1994, all emerged seedlings were counted and removed every two weeks during the growing season.

Soil Seed Bank Sampling

In November 1994, three years after initial seed deposition, soil samples were taken to estimate *S. obtusifolia* and *X. strumarium* soil seed bank numbers. Each 5-m^2 plot was divided into 25 1-m grids, and 25 soil samples were taken from the upper right corner of each grid with a 10.5-cm-diameter soil probe at a 20-cm depth. Each soil sample was passed through a descending series of sieves with screen sizes of 4.75 mm to collect *X. strumarium* burs, 2.0 mm for *S. obtusifolia* seed and 1.0 mm for escaped *S. obtusifolia* seeds. Water was run through the screens to enhance sample movement. Seeds or burs were separated and counted according to species as an estimate of number remaining in the soil.

General Procedures

During the experiment, unwanted weeds were removed by spraying sethoxydim (Poast-Plus™, 120 g ai/L, BASF) at 0.22 kg ai/ha plus 1% v/v crop oil for grass control. Hand hoeing in tilled plots and hand clipping in no-till plots were used for broadleaf weed control. Glyphosate (Roundup™, 360g ae/L, Monsanto) at 0.84 kg ae/ha was sprayed after each seedling count in 1993 and 1994 to control existing vegetation.

Data were subjected to analysis of variance. Means were separated by Least Significant Differences (LSD) at the 5% level of probability.

RESULTS

S. obtusifolia and *X. strumarium* initiated flowering 1 July and 3 September, respectively, in 1991. At the end of the first season, *S. obtusifolia* produced an average of 11,420 seeds/plant, and *X. strumarium* produced an average of 4,469 burs or 8,938 seeds (achenes)/plant. For the remainder of the paper, *X. strumarium* reproductive potential will be presented as achene number.

Seed production data were similar for intraspecific and interspecific interference levels except for the number of seeds deposited to the seed bank. With intraspecific interference, 1,827 and 1,430 seeds/m^2 were deposited for *S. obtusifolia* and *X. strumarium*, respectively, and only half that amount with interspecific interference. Thus, interference data were combined and averaged in order to present seed production potential.

In 1992 *X. strumarium* seedlings began emerging by the end of May and ceased at the end of June, eight weeks after emergence (WAE) while *S. obtusifolia* seedling emergence began at the same time but continued until August (16 WAE). Similar emergence was noted in 1993 and 1994. *X. strumarium* was larger than *S. obtusifolia* under both tilled and no-tilled conditions (data not shown).

During the growing season, seedling mortality was 9.3% of the population for *X. strumarium* under tilled conditions (data not shown). *S. obtusifolia* seedling mortality varied with interference level. Seedling mortality was 5.6% with intraspecific interference and 17% with interspecific interference. The increase was due to the dominance of *X. strumarium* in interspecific plots because of initial rapid emergence and plant size under tilled conditions. *S. obtusifolia* and *X. strumarium* seedling mortality was not observed in no-till plots due to low plant populations and lack of interference.

By the end of the growing season, 165 and 202 seedlings/m^2 emerged for *X. strumarium* and *S. obtusifolia*, respectively, under tilled conditions, while under no-till conditions only 10 and 29 seedlings/m^2 emerged for *X. strumarium* and *S. obtusifolia*, respectively (Table 1). For both species, approximately 15% of the initial soil seed bank emerged under tilled conditions. Under no-till conditions only 0.2 and 0.08% of the *S. obtusifolia* and *X. strumarium* had emerged, respectively.

In 1992, *X. strumarium* bur production was reduced 42%, and *S. obtusifolia* seed production was reduced 78% under no-till intraspecific conditions compared to tilled conditions (Table 2). Under interspecific, no-till conditions, *X. strumarium* bur production was reduced 46%, but *S. obtusifolia* seed production increased 40%. The reduction in *X. strumarium* interference allowed the remaining *S. obtusifolia* plants to grow larger and produce more seeds than in tilled plots, where *S. obtusifolia* seed production was decreased by *X. strumarium* interference. Thus, no-till significantly reduced *X. strumarium* emergence and seed production potential while increasing potential of *S. obtusifolia*.

In 1993 *S. obtusifolia* seedling emergence was similar under both tillage conditions while *X. strumarium* seedling emergence continued to decline under no-till conditions (Table 1). Percent emergence from the seed bank increased the second year after initial seed deposition to approximately 19% for both species under tilled conditions. However, under no-till conditions *X. strumarium* emergence declined to only 0.03% while *S. obtusifolia* emergence increased to 14%, from 0.2% the previous year. The equivalent seedling emergence for *S. obtusifolia* under both tillage conditions indicates that once a soil seed bank reaches a certain level, only a given number of seeds will emerge due to the number of safe sites (Harper, 1977).

In 1994, the loss of *S. obtusifolia* seed through emergence under no-till was two times greater than under tilled conditions (Table 1). Thus, the initial delay in seed emergence under no-till conditions was being corrected by seeds getting better soil-seed contact, allowing germination of readily germinable seeds. Emergence of *X. strumarium* was negligible regardless of tillage. Not allowing *X. strumarium* to reseed following initial seed production resulted in 29% emergence over a three-year period under tilled conditions; however, only 1% germinated under no-till conditions. *S. obtusifolia* emergence (34%) over the three years was similar to that of *X. strumarium* under tilled conditions; however, under no-till conditions, 24% of the *S. obtusifolia* seed emerged. *S. obtusifolia* seeds were still showing a strong emergence pattern in 1994, indicating that *S. obtusifolia* has a harder seed coat than *X. strumarium*.

The estimated *S. obtusifolia* seed remaining in the soil after three years was 906 and 1,042 seeds per m^2 under tilled and no-tilled conditions, respectively (Table 1), or by soil sampling 54 and 72% of the estimated seed bank under tilled and no-tilled conditions, respectively. Germination tests indicated that 100% of these seeds were viable and would germinate. Seed loss averaged 46 and 28% under tilled and no-tilled conditions, respectively. The estimated number of *X. strumarium* achenes remaining in the soil averaged 756 and 1,058 achenes per m^2 under tilled and no-tilled conditions, respectively (Table 1). Under intraspecific conditions, seed reserve in the soil estimated by soil sampling was 65 and 93% of the achenes remaining under tilled or no-tilled conditions, or a 35 and 7% loss, respectively. Under interspecific interference, there was only a 10 and 5% bur loss under tilled and no-tilled conditions, respectively (data not shown). The increased loss under intraspecific conditions was probably due to more immature seeds being produced under high densities in tilled plots and greater moisture stress in no-till. None of the remaining achenes were viable.

DISCUSSION

The loss of seeds and burs was due to decay, predation, dispersal, immature seed, mechanical destruction and sampling error (Ball and Miller, 1989; Fenner, 1985; Kremer and Spencer, 1989). The higher loss under tilled conditions indicates that microbial decay and insect predation increase with greater soil seed contact.

Emergence potential is critical in terms of competitiveness because the species emerging first has the potential to dominate throughout the season. A high percent emergence early in the season is also an advantage in terms of colonizing an area ahead of other competitors. The dominance of *X. strumarium* over *S. obtusifolia* under conventional tillage is due to the following: 1) tillage creates an adequate seedbed for both species, but *X. strumarium* grows faster than *S. obtusifolia* and shades *S. obtusifolia* plants earlier, reducing *S. obtusifolia* growth and emergence; 2) the dispersal ability of *X. strumarium* is much greater than that of *S. obtusifolia*, so *X. strumarium* can invade the *S. obtusifolia* area; 3) *X. strumarium* has a longer vegetative growth period than *S. obtusifolia*, allowing a longer competitive period; and 4) *X. strumarium* seedling emergence is greater than that of *S. obtusifolia* during the first emergence flush. However, a large number of *S. obtusifolia* seed remained in the soil from initial seed production. So, if *X. strumarium* is controlled, *S. obtusifolia* seeds that remain in the soil profile will have a chance to emerge and cause a new weed problem for the producer.

S. obtusifolia was as competitive as *X. strumarium* under no-till conditions. In 1992, it was expected that *S. obtusifolia* would be the dominant species within the next one or two years under no-till conditions, and 1993 and 1994 results verified that observation. In fact, *S. obtusifolia* became the dominant species because *X. strumarium* burs needed adequate soil-seed contact for germination. The bur prickles prevented soil-seed contact under no-till conditions. In contrast, *S. obtusifolia* seed is smaller and has a smooth, waxy surface for better soil contact and can penetrate soil cracks for improved germination. Thus, the *S. obtusifolia* plant population increased over the years, while the *X. strumarium* plant population was reduced under no-till.

Seed viability and germination tests indicated that the *X. strumarium* soil seed bank was reduced tremendously one to three years after initial seed deposition and remaining *X. strumarium* achenes were very sensitive to decay in or on the soil surface. The loss of viability results in a quick depletion of the *X. strumarium* soil seed bank. The *S. obtusifolia* soil seed bank was not depleted after three years. *S. obtusifolia* seeds have hard seed coats and are more resistant to decay than *X. strumarium* burs in or on the soil surface. Thus, *S. obtusifolia* can pose a more serious problem than *X. strumarium*, especially as no-till practices are adopted.

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Table 1. Effect of tillage on *X. strumarium* and *S. obtusifolia* seed bank potential after four years averaged over interference level.

Species	Tillage level	Initial seed deposition	Plants 1992	Seedlings 1993	Seedlings 1994	Seeds remaining
		-----no/m^2-----				
X. strumarium		1,072				
	Till		165	150	1	756
	No-till		10	4	1	1,058
S. obtusifolia		1,370				
	Till		202	219	44	906
	No-till		29	194	105	1,042
LSD(5%)			100	120	50	250

Table 2. Effect of tillage on *X. strumarium* and *S. obtusifolia* seed production in 1992 (LSD1-to compare species or interference levels at same tillage level and LSD2-to compare same species or interference at different tillage levels).

Species	Tillage level	Interference level: Intraspecific	Interference level: Interspecific
		---------no./m^2--------	
X. strumarium	Till	880	780
	No-till	510	420
S. obtusifolia	Till	8,940	920
	No-till	1,930	1,290
LSD 1 (5%) 1,800 and LSD 2 (5%) 2,000			