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Weed Seedbanks and Seedling Emergence in a Two and Three Crop Narrow Strip Intercropping/Rotation System

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Weed populations in agronomic settings are, in part, a reflection of the cropping system utilized. The goal of this project was to gain an understanding of the weed population dynamics in a narrow strip intercropping (NSI) rotation by assessing the weed seedbank, weed emergence, and seedling establishment over the growing season for a corn-soybean (two-crop), and a corn-soybean-oat+berseem clover (three-crop) system. Field research was conducted in 1994 and 1995, near Nashua, IA, and each crop was grown in 4.6 m wide strips. Giant foxtail and total weed seed densities were significantly lower in the three-crop NSI rotation system than in the two-crop system. NSI rotation system affected total preplant weed emergence. Preplant density ranged from 103 to 433 weeds m^{-2} in the two-crop system, while density ranged from 3 to 99 weeds m^{-2} in the three-crop system. There were no consistently significant differences in weed seedling emergence after crop planting due to NSI rotation system when individual species were examined. Changes in Iowa cropping systems may result from a better understanding of these system dynamics.

INDEX DESCRIPTORS: berseem clover (*Trifolium alexandrium*), corn (*Zea mays*), crop rotation, narrow strip intercropping, oat (*Avena sativa*), ridge-till, seedbank, soybean (*Glycine max*), weed emergence.

Traditional corn-soybean rotation systems used in Iowa and many other regions of the United States require significant inputs of fertilizers and pesticides for the production of high crop yields and may leave the soil susceptible to erosion and water loss. Significant resources are also expended to control weeds in these systems. In Iowa, for example, common weed control practices in corn and soybean generally involve multiple pre- and post-planting tillage operations and the application of herbicides. The estimated herbicide costs for 1999 were approximately \$74.13 to \$86.49 ha^{-1} (Duffy and Vontalge 1999).

The lack of significant temporal and spatial diversity inherent in corn-soybean systems can influence the agricultural ecosystem leading to the development of a well-adapted, difficult-to-manage weed complex (Liebman and Dyck 1993). Management difficulties can arise due to weed population shifts, the development of herbicide resistance, and/or government regulations and restrictions on herbicide application (Liebman and Gallandt 1997). This weed complex can then persist through the development of a characteristic reserve of weed seeds in the soil, referred to as the weed seedbank.

An understanding of weed population dynamics starts with enumeration of seedbanks because the seedbank provides the potential weed species that will be influencing the crop (Buhler et al. 1997, Forcella et al. 1992). Those non-dormant seeds in the seedbank at the onset of the next growing period have the possibility of becoming weeds that pressure the crop. Seed enters the seedbank as the result of seed rain from the previous weeds and by importation through the action of wind, water, or other vectors. Processes that affect seedbank dynamics include loss through predation, degradation, germination, or dispersal (Fig. 1). Potential weed pressure will be impacted by anything that prevents weed seed from entering the seedbank, increases the loss of seed from the seedbank, or influences the ability of weed seed to germinate and develop. Management practices have major impacts on these processes and represent opportunities for regulating seedbank characteristics in crop production systems (Schweizer and Zimdahl 1984, Wilson 1988).

Alternative cropping systems may increase temporal and spatial diversity and create environments that are unfavorable for the proliferation of stable weed populations (Liebman and Gallandt 1997). Liebman and Dyck (1993), in a review of the impact of crop rotation and intercropping on weed population density and biomass, found that crop rotation resulted in lower emerged weed densities than did monoculture in 21 of 27 studies. They also reported that intercropping with at least two main crops resulted in a weed biomass that was lower than in all of the component sole crop monocultures in 12 studies, intermediate between component sole crops in 10 studies, and higher than all sole crops in two studies. Other benefits traditionally associated with crop rotations include enhanced soil moisture and insect and disease control, increased nitrogen fixation with the use of leguminous plants, improved soil structure, and increased organic matter content (Geyer-Allely 1994).

Intercropping has been practiced for many years with various crops. In many regions of the world it is still a common form of crop production. Narrow strip intercropping (NSI) is one alternative to conventional production systems (Fig. 2). In NSI, crops with diverse growth requirements and patterns are planted in alternating, contiguous strips that are wide enough to allow independent mechanical operations, yet narrow enough for there to be interaction between the strips (Andrews and Kassam 1976). It is possible that when NSI is coupled with crop rotation, the benefits may be enhanced relative to the benefits derived from either system separately. By including crops in the rotation that differ in agronomic charac-

[4] Mention of a specific variety does not imply endorsement of this variety to the exclusion of other varieties that may be suitable.

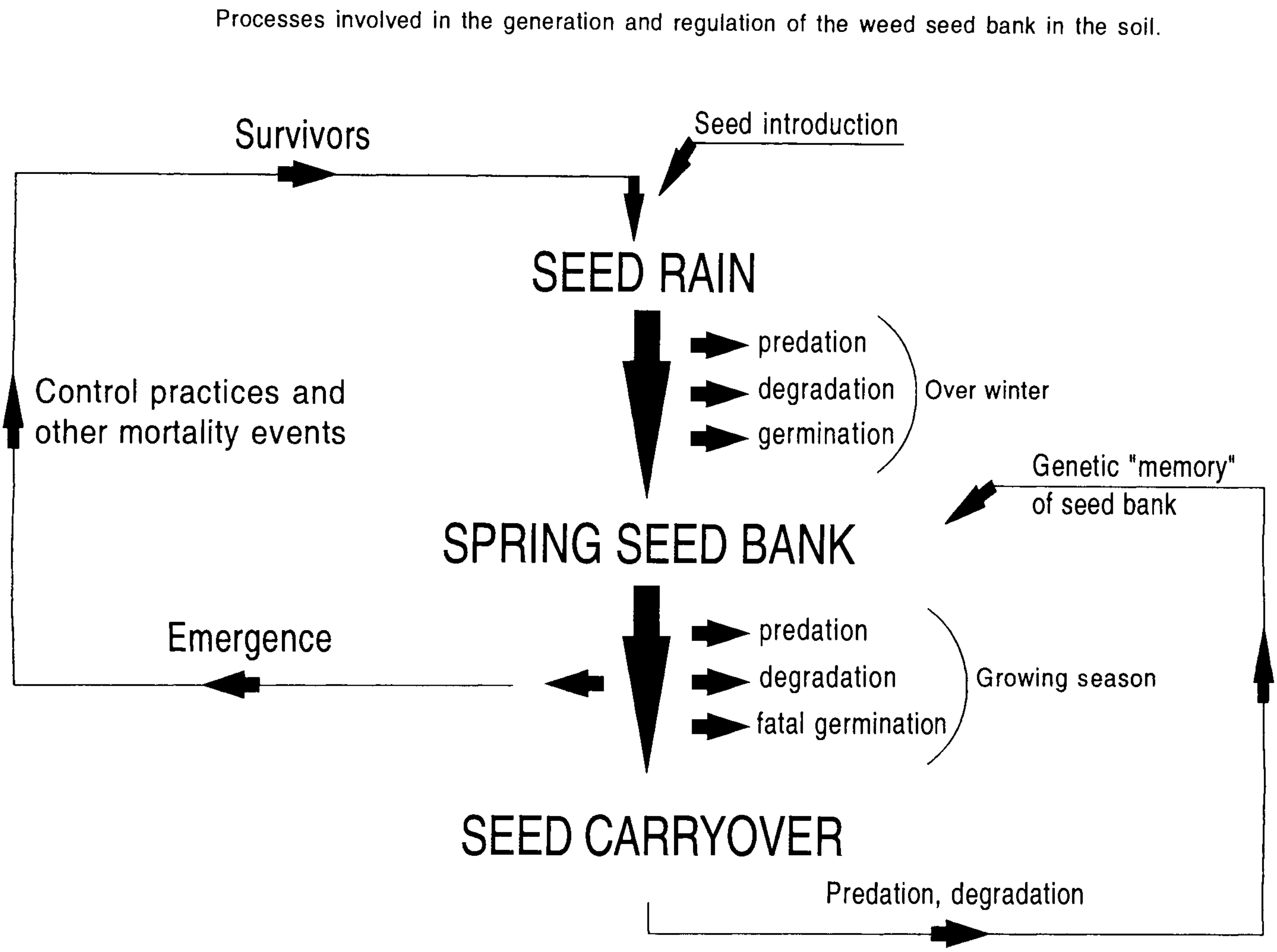

Fig. 1. Seedbank dynamics illustrating sources of input and loss.

teristics and requirements, weed populations may not proliferate to the extent that they would if only crops with similar agronomic characteristics and requirements were included (Liebman and Dyck 1993, Liebman et al. 1996).

The goal of this project was to gain an understanding of the weed population dynamics in a NSI rotation system by assessing the weed seedbank, weed emergence, and seedling survival over the growing season for a corn-soybean, and a corn-soybean-oat+berseem clover rotation system. A better understanding of these dynamics will provide the basis for further research that in turn may result in changes in Iowa cropping systems that increase profitability while promoting sustainability and resource conservation.

METHODS

The weed population dynamics of an established NSI research site at Iowa State University's Northeast Iowa Research Center (Nashua, IA) were investigated in 1994 and 1995. Soils at the site belong to the Kenyon series (fine-loamy, mixed, mesic Typic Hapludolls) with less than 5% slope. Two-crop (corn-soybean) and three-crop (corn-soybean-oat+berseem clover) NSI rotation systems were evaluated (Fig. 2). Each crop was grown in strips that were 4.6 m wide by 61.0 m long, replicated four times. Rotations were the main plots with four replications in a block, and each block consisted of a complete set of two or three crop strips with a border strip on each side of each rotation (Choromanska 1995, Ghaffarzadeh 1997). Because of high soil test values, no phosphorous and potassium fertilizers were applied. Nitrogen was added as urea (168 kg ha^{-1}) to the corn plots in mid-June. Crop planting dates and other cultural practices were typical for the area. Oat (Troy[4]) was sown in mid-April in twenty 0.19 m wide rows using a no-till drill at the rate of 135 kg ha^{-1}. Berseem clover (Bigbee) was planted concurrently with the oats at a rate of 17 kg ha^{-1}. Corn (Golden Harvest 2343) was seeded in early May in six 0.76 m wide rows at 59,400 seeds ha^{-1}. Soybean (Sansegaard S01237) was seeded in mid-May in six 0.76 m wide rows at 396,000 seeds ha^{-1}. A ridge tillage system was used for corn and soybean production. Ridge tillage involves planting and growing the crop on the tops of ridges that are produced by the cultivation of the previous crop. Ridge tillage requires little pre-planting soil disturbance, but generally the ridge top is shaved off using a sweep. This allows planting into a 25 to 30 cm wide band of fresh soil and also removes from the row most weed seeds that fell on the soil surface the previous year (Exner et al. 1996). Forcella and Lindstrom (1988) found that the planter sweep removed 80 to 100% of the weed seed from ridges in a corn-soybean rotation. Other management

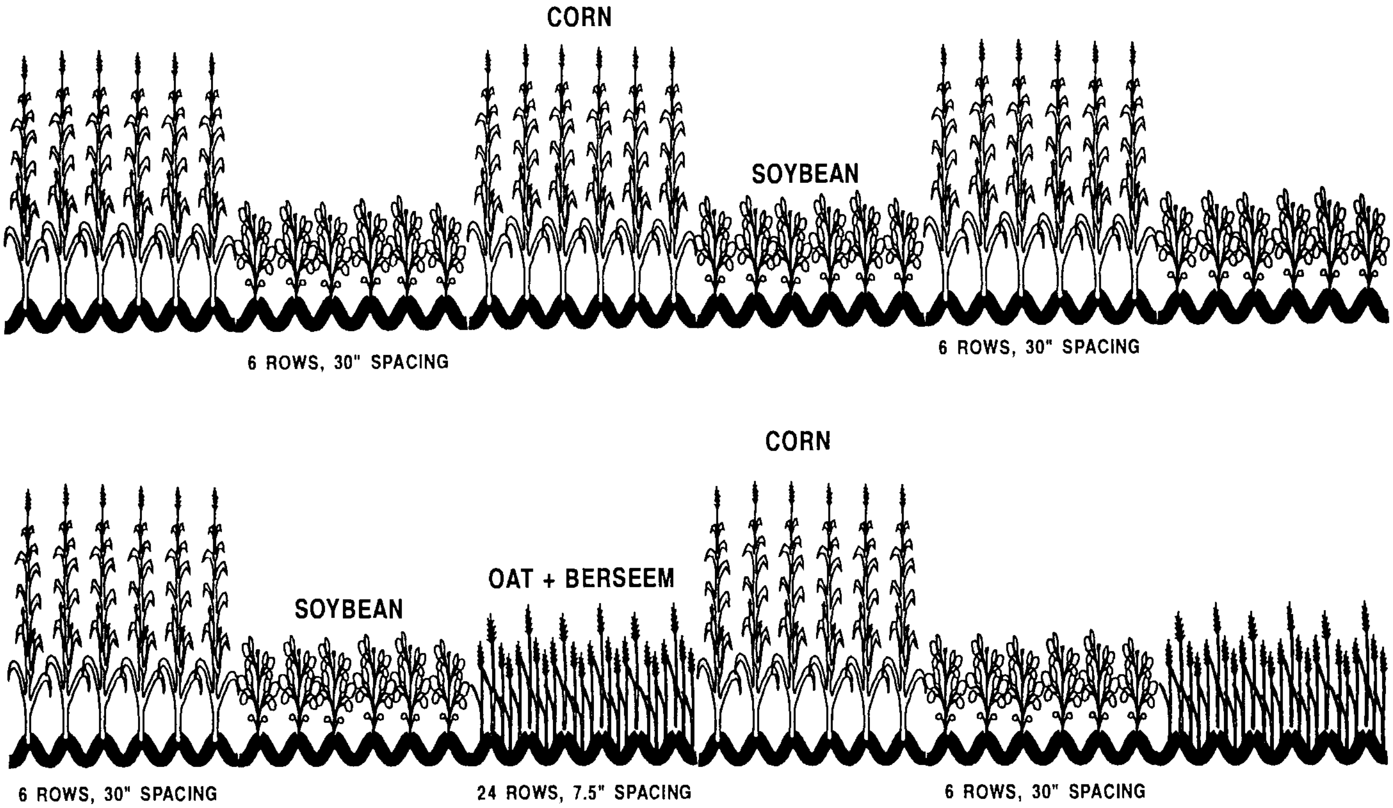

Fig. 2. Illustration of two-crop and three-crop NSI rotation system plantings at the Iowa State University field station in Nashua, IA. (Constructed by M. Ghaffarzadeh).

Table 1. Effect of NSI rotation system on mean[a] seed densities (m^{-2}) in the surface 10 cm of soil at Nashua, IA.

YEAR	NSI ROTATION SYSTEM	GIANT FOXTAIL WEED SEED (m^{-2})		TOTAL WEED SEED (m^{-2})	
		CORN	SOYBEAN	CORN	SOYBEAN
1994	Corn-Soybean	7370a	12375a	12045a	17160a
	Corn-Soybean-Oat/B. Clover	4180b	660b	6490b	4070b
1995	Corn-Soybean	4840a	2915a	7315a	3520a
	Corn-Soybean-Oat/B. Clover	3410b	1155b	3850b	1650b

[a]Means followed by the same letter within columns and years did not significantly differ according to an F test at $P < 0.05$

Table 2. Effect of NSI rotation system on mean[a] weed seed densities (m^{-2}) in the surface 10 cm of soil at Nashua, IA.

YEAR	NSI ROTATION SYSTEM	CORN (m^{-2})			SOYBEAN (m^{-2})		
		COM. LAMBSQ.	PIGWEED	PENN. SMART.	COM. LAMBSQ.	PIGWEED	PENN. SMART.
1994	Corn-Soybean	330a	1375a	55a	495a	1045a	220a
	Corn-Soybean-Oat/B. Clover	55a	550a	0a	0a	550a	0a
1995	Corn-Soybean	330a	1210a	550a	165a	110a	110a
	Corn-Soybean-Oat/B. Clover	165a	0b	0b	110a	220a	0a

[a]Means followed by the same letter within columns and years did not significantly differ according to an F test at $P < 0.05$

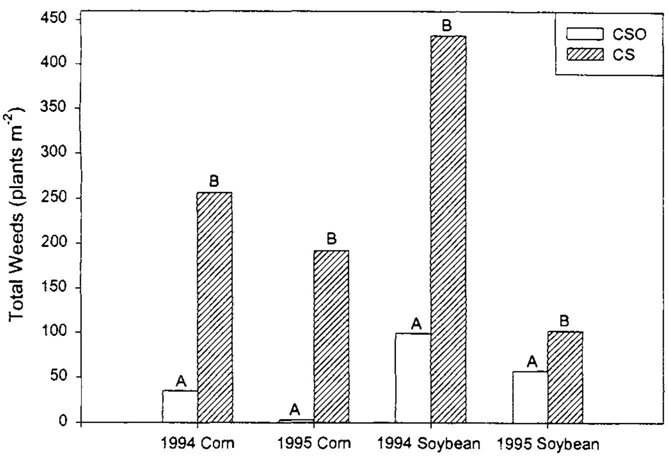

Fig. 3. Effect of NSI rotation system and crop on preplant total weed emergence (m^{-2}) at Nashua, IA. Statistically significant differences between rotations within each year are indicated by different letters (T-test, alpha = 0.05).

practices for the ongoing rotation study were as reported in Sawchick (1994) and Choromanska (1995).

Soil samples were collected prior to the initiation of weed emergence (19 April 1994 and 19 April 1995) for enumeration of the weed seedbank. Twenty, 5 cm diameter by 10 cm deep cores were collected in an M-shaped pattern from each plot. The samples were collected without regard to surface topography. Samples were composited by plot and stored at −5°C until analysis (Buhler and Mester 1991, Forcella et al. 1992). Seeds were extracted using the K_2CO_3 flotation and centrifugation method (Buhler and Maxwell 1993). Seeds were then enumerated by species, and counts converted to seeds m^{-2} surface area.

Prior to crop planting, three 0.4 m^2 areas were randomly selected within each plot, and emerged weeds were counted by species. After crop planting, weed emergence data were collected weekly from 6 randomly-established, untreated (no herbicide) 0.1 m^2 areas in the corn and soybean strips in each plot. Counting quadrats were centered over the crop row. All counts were taken from these marked areas, and seedlings were removed following each count. Percent emergence was calculated based on the individual species mean of two seed counts in each of four replications. Data were analyzed in t-test using SAS (alpha = 0.05). Means were compared using Fisher's Protected LSD. Because there were significant year effects, results are presented separately for each year.

RESULTS AND DISCUSSION

Weed seed densities differed greatly between the two NSI rotation systems. In 1994 and 1995, giant foxtail (*Setaria faberi* Herrm.) and total weed seed densities were significantly lower in the three-crop NSI rotation system than in the two-crop NSI rotation system (Table 1). Total weed seedbank in corn in the three-crop system was 46 and 47% less than in the two-crop system 1994 and 1995, respectively. Total seedbank in soybean plots responded similarly, with a 76 and 53% reduction in the two years. Giant foxtail dominated the seedbank, but seed of common lambsquarters (*Chenopodium album* L.), Pennsylvania smartweed (*Polygonum pensylvanicum* L.), and pigweed (*Amaranthus* spp.) were also found. There were no statistically significant differences observed in seed density of species, other than giant foxtail, between two- or three-crop systems in soybean in either year (Table 2). In corn, statistically significant differences in weed seed density by system were only observed in 1995 for Pennsylvania

Table 3. Mean weed seed, weed emergence, and percent emergence form the seed bank at Nashua, IA.

			FOXTAIL			PENN. SMART			VELVETLEAF			COM. LAMBSQ.		
YEAR	NSI ROTATION SYSTEM[a]	CROP	SEEDS (dm^2)	WEEDS (dm^2)	%	SEEDS (dm^2)	WEEDS (dm^2)	%	SEEDS (dm^2)	WEEDS (dm^2)	%	SEEDS (dm^2)	WEEDS (dm^2)	%
1994	C-S	Corn	17,026	158	0.9	159	2	1.3	0	0	0.0	796	0	0.0
	C-S	Soybean	28,643	316	1.1	477	4	0.8	0	1	—	1,114	1	0.1
	C-S-O+B	Corn	9,707	74	0.8	0	3	—	0	1	—	159	1	0.6
	C-S-O+B	Soybean	1,591	27	1.7	477	11	2.3	0	1	—	0	2	—
1995	C-S	Corn	1,125	117	10.4	1,273	2	0.2	106	1	0.9	743	4	0.5
	C-S	Soybean	6,789	130	1.9	212	0	0.0	0	1	—	424	0	0.0
	C-S-O+B	Corn	7,850	124	1.6	0	0	0.0	0	0	0.0	0	2	—
	C-S-O+B	Soybean	2,652	109	4.1	0	1	—	0	1	—	0	1	—

[a] C-S (Corn-Soybean), C-S-O+B (Corn-Soybean-Oat+Berseem Clover)

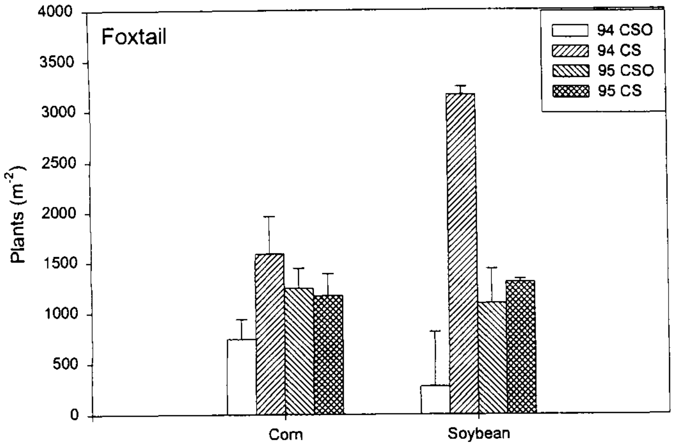

Fig. 4. **Effect of NSI rotation system and crop on mean foxtail emergence postplanting (m^{-2}) at Nashua, IA. Error bars represent standard error of the mean.**

smartweed and pigweed (Table 2). Thus, differences in the total weed seedbank were primarily the result of differences in giant foxtail.

Total preplant weed emergence was significantly affected by NSI rotation system for both crops in both years (Fig. 3). The weed density prior to planting in the three-crop NSI rotation system ranged from 3 to 99 plants m^{-2}. Conversely, the weed density prior to planting in the two-crop NSI rotation system was much higher, ranging from 103 to 433 plants m^{-2}. Giant foxtail was primarily responsible for differences as expected from the seedbank analysis (Table 1).

When the percent emergence from the seedbank is calculated, total emergence was below 2% for all weeds except on three occasions (Table 3). Total Pennsylvania smartweed emergence in soybean in 1994 was 2.3% in the three- crop NSI rotation system versus 0.8% in the two-crop NSI rotation system. Total giant foxtail emergence in 1995 in corn was 1.6 % in the three-crop NSI rotation system versus 10.4% in the two-crop NSI rotation system, and in soybean it was 4.1% in the three-crop NSI rotation system versus 1.9% in the two-crop NSI rotation system. This low percentage of emergence is not unexpected. Forcella et al (1992) found that viable seed in the seedbank ranged from 10 to 50%, and of the viable seed, 75% may be dormant.

There were no consistently significant differences in weed seedling emergence during the growing season, due to NSI rotation system, when individual species were examined. Total giant foxtail emergence was lower in the three-crop NSI rotation system than in the two-crop NSI rotation system for both corn and soybean in 1994, however in 1995 there was no significant difference in total postplanting giant foxtail emergence in either crop (Fig. 4). The similarity in foxtail emergence in 1995 may have been related to hail damage suffered by the crops. This hail damage opened the canopy allowing light to reach the soil surface, and may have stimulated seed germination. Emergence of Pennsylvania smartweed, common lambsquarters, and velvetleaf (*Abutilon theophrasti* Medikus.) (Fig. 5a-c) was significantly lower than that of giant foxtail. Pennsylvania smartweed emergence was less in the three-crop NSI rotation system in 1995 in corn, and in the two-crop NSI rotation system in 1994 in soybeans. Total common lambsquarters emergence was less in the two-crop NSI rotation system in 1994 in corn and in 1995 in soybeans. There were no significant differences observed in velvetleaf emergence in corn in 1994 or in soybean in either year. In the 1995 three-crop NSI rotation system corn plots, no velvetleaf plants

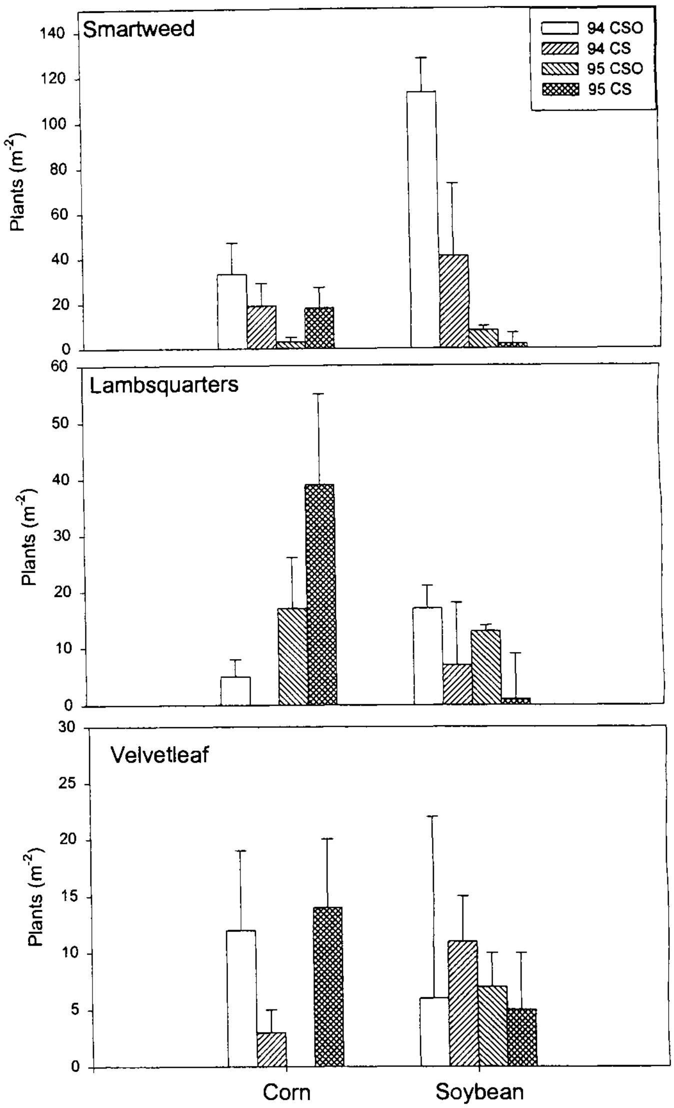

Fig. 5a–c. **Effect of NSI rotation system and crop on mean emergence of smartweed (a), lambsquarters (b), and velvetleaf (c) postplanting (m^{-2}) at Nashua, IA. Error bars represent standard error of the mean.**

emerged, however an average of 14 velvetleaf m^{-2} emerged in the two-crop NSI rotation system corn plots. We also examined the impact of the previous crop on weed emergence, but there was no significant effect.

The inclusion of an oat+berseem clover crop in the NSI rotation system reduced the size of the weed seedbank. Preplant total weed emergence was lower in the three-crop NSI rotation system than in the two-crop NSI rotation system, particularly in 1994 when the seedbank was much smaller. No general trend for postplant weed emergence was observed. The temporal diversity inherent in NSI rotation systems may have decreased weed populations. It is also possible that the oat+berseem clover cover crop may have reduced weed densities by increasing surface mulch the year following its production, although the effects of mulch are highly variable. Soil surface cover measured before corn planting in a concurrent study was 52 to 79% (Sawchick 1994). Mester and Buhler (1991) found that mulch increased germination of surface planted giant foxtail and velvetleaf seed, while Buhler et al. (1996) and Mohler and Teasdale

(1993) found that residue reduced emergence. Berseem clover has an advantage over other leguminous cover crops grown in Iowa because it is winter-killed and does not interfere with corn planting or production the following year. It is possible that volatile allelopathic compounds identified in the residue of Berseem clover (Bradow and Connick 1990) may have inhibited weed germination and growth in corn the following year. Additional research will increase our understanding of these dynamics. This in turn may result in changes in Iowa cropping systems that increase profitability while promoting sustainability and resource conservation.

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