



# Evaluation of the impact of tillage/cropping systems on soil microflora and weed seedbank predation

**Abstract:** *Soil erosion and pesticide use are critical issues in sustainable agriculture. With a view to decreasing the amount of pesticides used for weed control, researchers assessed the impact of tillage, cropping systems and weed management regimes on seasonal and long-term weed and weed seedbank population dynamics, especially in Conservation Reserve Program land being returned to production.*

## Background

The Conservation Reserve Program (CRP) was established in 1986 as a voluntary program to help reduce soil erosion and adjust production of some agricultural commodities. After ten years, farmers were allowed to put the land to other uses or to potentially re-enroll in the program. In 1996, Iowa had more than 2 million acres under CRP, and surveys indicate that 40 to 50 of the producers intend to return some of the land to row-crop production. The southern one-third of the state has the largest area in CRP, while the central tier and the upper third have considerably less. Thus research on lands under CRP that may return to production is needed to determine how to minimize environmental disruption and contamination from cropping systems.

When tillage systems are altered, an immediate change in the crop-weed relationship occurs. Tillage systems influence weed seed germination rates and the efficacy of weed control tactics, thus affecting weed populations. This change is not fully understood and likely represents a major impediment to the successful implementation of conservation tillage systems. Growers may abandon no-till systems because of weed problems that occur due to a lack of knowledge about changes in weed ecology. Further, it is possible that growers who are successful practitioners of

no-till make inappropriate use of herbicides because of the same knowledge void.

*Effect of tillage, cropping systems, and weed management on weed seedbank* The fate of a weed seedbank is controlled by several factors, including seed germination, predation from vertebrates and invertebrates, and infection by soil microorganisms. Other factors include dormancy and loss of viability, which are influenced by the physiological status of the seed and the environmental conditions in the soil.

Predicting potential weed emergence is a fundamental need in the development of integrated pest management and strategies for weed control. If growers could predict the composition and density of weed seedlings that will emerge during a growing season, they could plan and implement appropriate control measures only when and where necessary.

Crop and weed management programs are closely linked and influence changes in the soil weed seedbank. Tillage systems influence weed seed germination rates and herbicide efficacy, thus affecting future weed populations. Tillage also impacts the physical location of the weed seedbank.

*Effect of set-aside on weed seedbank* Surveys of weeds present can provide quantitative

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information on weed communities for evaluating changes in weed flora over time, developing integrated management strategies, or mapping weed population. It is fair to predict that the weed seedbank in the land coming out of CRP is likely to be moderately high for some species and low for others. Information on weed seedbank composition of the land under CRP is therefore very important to those who will be advising producers on how to manage the weeds in land brought back into production.

Ideally, formerly cultivated areas that have been seeded to winter pasture grass should exhibit fewer weed species characteristic of farmed land because the annual weed seed rain (weed seeds produced annually by the weeds present in the field) typical of cultivated land is very much curtailed in land under CRP. However, the likelihood that weed seeds will remain dormant deep in the soil profile is very high.

In non-cultivated areas like CRP lands, many weed seeds will not germinate because crucial cues to break dormancy are lacking. Thus, the majority of all buried weed seeds will die within a few years, but significant numbers of seeds of some species in suitable microsites can survive for decades. Seeds buried at greater depths tend to remain dormant longer, but fewer of them can germinate successfully and emerge as seedlings. In CRP soils, it is suspected that the species with persistent seedbanks may become a problem when the land is returned to row-crop production.

The objectives of this research project were to assess the impact of tillage, cropping systems, and weed management tactics on short- and long-term field weed population dynamics, seedbank, and soil fungi.

## **Approach and methods**

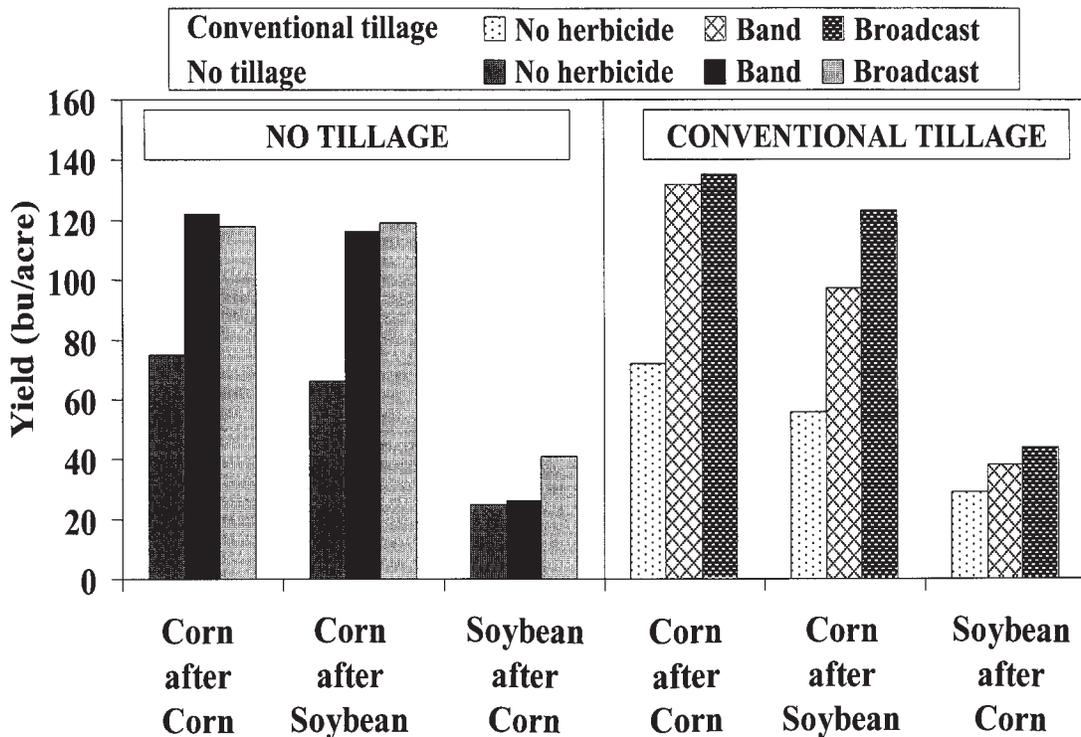
Field experiments were conducted during the summers of 1994 through 1997 at the Iowa State University McNay Research Center near Chariton, on land previously under CRP for eight years. The CRP cover was a mixed seeding of big bluestem, smooth brome grass, and yellow sweetclover.

No-till and conventional tillage formed the main plots, whereas crop rotations (continuous corn and soybean/corn rotation) and weed management regimes (no herbicide, banded, and broadcasted herbicides) formed the sub-plots. Plots measured 100 by 15 ft, and 50 ft of the two center rows were harvested to determine yield.

Tillage systems were established in spring 1994 and maintained for the duration of the study. The entire experimental area was mowed and hay was collected. Following regrowth to about 15-cm, the no-till plots were sprayed with glyphosate one week prior to planting. Moldboard plowing was followed by two rounds on disc cultivation on the conventional tillage plots in 1994. In succeeding springs, a rotary mower was used to distribute residue from the preceding crop over the plots before a field cultivator was used to create a smooth seedbed ready for planting. Corn and soybean plots were treated with herbicides on banded, broadcast, and glyphosate treatment sites. Cultivation was done 20 days after planting (DAP) each year and hand weeding was used to remove weeds in banded and broadcast plots to keep them as clean as possible. Plants on each side of the two center rows were counted 21 DAP to determine crop stand.

*Field weed counts* Weeds were counted at 29, 68, and 120 DAP and recorded by species. Three sub-samples per plot were counted in a 30 by 30 cm area chosen at random.

*Soil sampling and weed seed recovery* Soil



A four year corn and soybean yield as affected by tillage, crop rotation and weed management

sampling for seedbank characterization was done during the spring and fall of each year beginning in 1994. Soil samples were processed for seed recovery, then seeds were dried and recorded by species.

*Soil sampling in state CRP and adjacent cultivated land* In 1997 and 1998, soil samples were taken from 63 of 99 Iowa counties to categorize the weed seedbanks in CRP and adjacent cultivated land. The CRP land contained in this survey was considered to be highly erodible (HEL). Its erosion potential is considered to be equal or greater than eight times the rate at which continued soil productivity can be maintained. Samples were grouped using the nine state cropping districts and counties, and the same number of samples were taken from each region even though the lower one-third of the state has more area

under CRP than the central and upper tiers.

*Statistical analyses* Field weed count analysis was done for individual weed species and grouped categories (broadleaf, grass, and total). Broadleaf weeds included field bindweed, common lambsquarters, common waterhemp, Pennsylvania smartweed, Venice mallow, horsenettle, common ragweed, horseweed, prickly sida, and eastern black nightshade. Grass weeds categorized were giant foxtail and yellow foxtail. Weed seedbank analysis was done for state CRP and adjacent cultivated land.

## Results and discussion

*Managing the CRP cover* The glyphosate applied in the spring of 1994 failed to com-

pletely eradicate the CRP cover in the no-till plots, leaving these plots with high infestations of big bluestem. Plots that received no herbicide treatment had the highest big bluestem population and the broadcast herbicide plots had the lowest. These results indicate that a single dose of glyphosate applied during the spring to kill the CRP cover will not provide an acceptable control level in a no-till environment. This suggests that application of glyphosate in late fall, followed by a second dose (as needed) in the following spring may be a better strategy to effectively manage the CRP cover.

*Corn and soybean establishment* Tillage affected corn population significantly in 1995 with no-till plots averaging 19 percent fewer plants than conventional tillage plots. Also corn in no-till plots took two to three days longer to emerge than in conventional tillage plots, most likely because of cooler soils and thick residue ground cover. There was no difference between soybean populations under different tillage treatments. First-year soybean establishment was better than that of corn, suggesting that this would be a better rotation choice for land coming out of CRP. Tillage did not affect corn plant population in 1995 and 1996, but in 1997 conventional tilled (CT) plots averaged 19 percent fewer plants than the no-till plots. Also, crop rotation affected the corn plant stands in 1995 when corn rotated with soybeans produced 32 percent fewer plants than continuous corn. Excessive early season rainfall hurt corn production under all tillage regimes in 1995.

*Weed population changes over time* There was a yearly variation in weed density with a continued buildup of giant foxtail and common waterhemp. The continued increase in weed density suggested that different weed management tactics had not reached equilibrium.

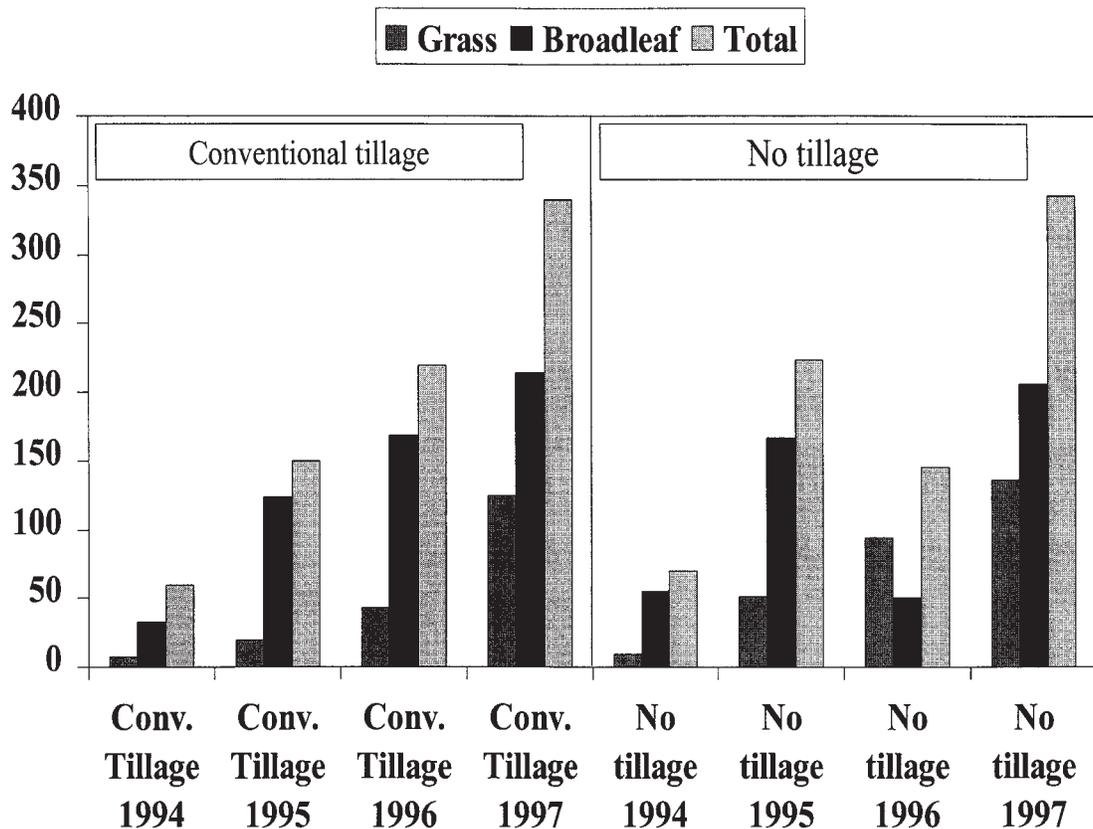
*Effect of tillage on weed counts* Tillage did not influence individual weed populations from 1994 through 1997. However, tillage effects were observed in broadleaf weeds in 1994 and 1996 and for total weeds in 1995. Tillage did not affect grass weeds in any of the years, but there was a general increase in weed population over time with no-till (NT) plots having a higher population.

Common waterhemp comprised an average of 50 and 44 percent of the broadleaf weeds observed in NT and CT plots, respectively. This difference can be attributed to the late emergence tendencies of common waterhemp compared to other annual weeds. Tillage differences in weed seed placement also may have contributed to the differences.

*Seasonal weed population dynamics* A three-year average indicate that there was a seasonal decline in weed density regardless of the weed management program used. There were more weeds at 29 DAP and fewer at 120 DAP, perhaps due to hand weeding, natural thinning, and seasonal weed aging. Plots under the no-herbicide program had the most weeds in all four categories.

Overall, weed management regimes had the greatest impact on weed populations. When compared to the no-herbicide treatment, banded and broadcast treatments reduced the total weed population by 80 and 89 percent, respectively, at the 29 DAP. The same treatments cut the total weed population by 78 and 92 percent at 68 DAP. The broadcast treatment appears to be preferable to the banded treatment according to these results.

*Effect of weed management regime* Weed management practices had the greatest impact on the number of weeds, with no-treatment plots showing higher weed populations than band or broadcast treatment plots. Weed density increased over time, perhaps because yield, weed populations, and soil characteristics do



Effect of tillage on weed population dynamics averaged across cropping systems and management regimes

not reach equilibrium until the management regime has been established at least four to 10 years.

*Corn and soybean yields* Tillage affected the soybean yield in no-till plots in 1994. Soybean plots within no-herbicide and banded herbicide treatments resulted in similar yields, and broadcast treatment yields were somewhat greater. No difference in yield was recorded for soybeans raised under conventional tillage in 1994. Similar results were obtained in 1996, however, with an increase in soybean yield possibly due to crop rotation effects and better control of big bluestem in the no-till environment.

Tillage did not significantly alter corn yield in any of the years, though conventional tillage plots tended to produce slightly more corn. Problems experienced with soil quality, weather, and animal damage may have affected yields in several instances.

Weed management regimes had the greatest impact on corn yield. In this study, the no-herbicide treatment had the lowest corn yield throughout, regardless of the tillage used, due to the higher weed populations during the growing season. Banding and broadcast treatments produced similar corn yields most of the time.

The eight years of CRP inactivity caused patchy weed distribution in the fields and there was a great variation in weed population and distribution among plots. This also could be associated with differences in seed dormancy and longevity in the soil among different weed species. Therefore, spot application of herbicides might be appropriate for efficient management of certain weeds. Unlike corn, there was no problem establishing soybeans in the first year of this study, indicating that a rotation starting with soybeans would be preferred in lands previously under CRP. Soybeans also allow use of cultural weed management strategies that may help reduce herbicide usage. Tillage affected both weed population and yield, with conventional tillage generating better yields than no-till. However, because this land was taken out of production due to concerns about soil erosion, conventional tillage may not be an environmentally appropriate option.

*Seedbank characterization* Weed seedbank populations reflect the effects of seed biology as well as past and current management practices. Seeds of 13 weed species were recorded at the McNay location from 1994 to 1997 with broadleaf weeds surviving at a higher rate compared to grasses after eight years under the CRP. On average, common lambsquarters and pigweed species comprised 82 percent of the total weed seedbank.

Prevailing weather conditions and crop performance in the previous year played a very significant role in the changes of weed seedbank at this location. Grass weed species seedbank totals continue to increase yearly with the highest total recorded in 1997. There was an almost 19-fold increase in foxtail species from 1994 to 1997.

Poor weed control in 1995 due to high rainfall at the beginning of the season resulted in higher seedbank totals for yellow sweetclover, field pennycress, common lambsquarters, and *Amaranthus* in 1996. Venice mallow and

common ragweed, which had been controlled well in previous years, were first recorded in 1996 and their populations remained relatively unchanged in 1997. Poor corn and soybean stands in 1995 also contributed to a favorable environment for weed seed production. Better weed control in 1996 produced a decline in the total weed seedbank for 1997.

*Effect of tillage and crop rotation* Even though tillage and crop rotation are known to influence the species composition of the seedbank, there were no tillage and crop rotation main effects, nor any interactions shown in this study. It has been estimated that weed populations and soil characteristics do not reach equilibrium until the management regimes have been established for four to ten years. Similarly, in order for rotation to affect weed seedbank composition, the rotation must include crops that differ in planting and maturation dates, competitiveness, and associated management practices. In this study, both corn and soybeans were planted at the same time each year so there were no differences between the cropping systems.

*Effect of weed management regimes* Except for a few instances, the no-herbicide treatment plots had the highest seedbank totals throughout this study. Band and broadcast herbicide treatments had similar effects on foxtail weed species seedbanks in 1994, 1996, and 1997. There was an average annual increase of 177 (non-herbicide) and 121 percent (banded herbicide) for the pigweed species seedbank between 1994 and 1997. In contrast, the broadcast herbicide treatment showed a 31 percent decline in weed seedbank for pigweed species (which includes common waterhemp) in the same period.

*Effect of time of soil sampling on seedbank* Time of soil sampling for weed seedbank characterization tended to have a large influence on the weed seedbank for foxtail species, common lambsquarters, pigweed species, field

pennycress, yellow sweetclover, yellow woodsorrel, and witchgrass. The foxtail and common waterhemp species seedbanks were higher in the fall sampling each year and low in the spring, reflecting the effect of annual seed-rain on the seedbank. Predation by small animals and insects that use weed seed for food is believed to affect the seasonal differences in seedbank totals.

*Weed seedbank diversity and riches* The study of community diversity considers the number of species within a community and an assessment of the proportional representation of these species. The no-herbicide treatment tended to have a more diverse grass weed seedbank compared to band and broadcast herbicide treatments. Total seedbank diversity was similar for the three weed management regimes from 1995 through 1997.

Even though the use of herbicides tends to reduce the weed seed density, it does not eliminate weed species. In this study, the use of band and broadcast herbicides reduced the total weed density, but did not affect the number of broadleaf weed species. The no-herbicide treatment tended to have a greater number of grass species, whereas the broadcast has the least, and banded was intermediate. Total weed species were similar in the band and broadcast treatments and lower in the no-herbicide in 1995 through 1997. Weed community richness was higher in the no-herbicide treatment for grass seedbank and lower in the broadcast treatment. This suggests that herbicides used in this study were very effective on grass species. Overall, broadleaf weed seedbank seemed to be affected differently by weed management compared to grass species. Band and broadcast treatments are likely to lower the number of weed species, increase weed species evenness, and maintain species richness.

*Weed seedbank characterization in CRP and adjacent cultivated land* Weed seeds for 18

species were recorded both in the CRP and cultivated fields in different proportions. However, statistical analysis indicated only seedbanks for foxtail species, common lambsquarters, and pigweed species were significantly different between CRP and cultivated land. Of the 126 fields sampled in the survey, only 17 had CRP land with a larger foxtail seedbank than in adjacent cultivated land. Eighteen CRP fields had larger concentrations of common lambsquarters and pigweed species seedbanks than adjacent cropped land. The fields showing differences in weed seedbanks were mainly distributed in the central Iowa district. However, these differences could be associated with individual field management during and after CRP cover establishment. These results indicate that even though producers try to prevent the last weed from forming seed, cultivated land seems to have a larger seedbank than adjacent CRP land.

Only three counties of the 63 surveyed showed differences in the number of weed species between CRP and adjacent cultivated land. This is an indication that weed seedbank variability is due mainly to weed fertility and not species variability.

*Soil fungi population response to treatments* Tillage and cropping system did not have any influence on the population density of isolated fungi in this study. However, there were differences attributed to years, time of soil sampling, and weed management regimes without any interactions. Forty-four different fungi species were found in the soil taken from the McNay research center from 1994 to 1997.

*Trichoderma* and *Penicillium* had the largest population within the fungi imperfecti with 23 percent each in 1994, 17 and 31 percent in 1995, 24 and 22 percent in 1996, and 26 and 25 percent in 1997, respectively. *Fusarium* had 10 percent of the total fungi imperfecti in 1994; 13 percent in 1995 and 1996; and 11 percent in 1997.

Fall soil sampling tended to produce a larger fungi count than in spring. Increase in numbers for some fungi species is due to their known ecological functions. The population of *Aspergillus* species, which are known to degrade atrazine in the soil, was high in the fall and low in spring sampling from 1994 to 1997.

Weed management regimes did not influence fungi population in 1994. In 1995, however, the population of *Humicola* spp was high in the no-herbicide treatment. In the third year of the study (1996), things started to change. The population of *Acremonium kiliense* was high in the broadcast herbicide treatment both in 1996 and 1997. Overall, the fungi population density was high in the no-herbicide plots and similar results were obtained for band and broadcast regimes.

### Conclusions

Tillage and crop rotation did not directly influence weeds and the weed seedbank dynamics in this study. On the contrary, weed management tactics had the largest impact on weed and weed seedbank dynamics. Use of band and broadcast herbicides resulted in similar

weed and weed seedbank populations. The land coming out of CRP is likely to have a higher broadleaf weed seedbank and lower percentage of grass species. Weed management seems to have the greatest impact on weeds and weed seedbank populations.

### Impact of results

Growers have a better understanding of the weed management problems when retiring CRP land and placing it back into crop production. This study clearly indicates that there are opportunities to improve the efficiency of weed management and herbicide use in this cropping system.

### Education and outreach

Results from these preliminary studies have been used in numerous Extension meetings with growers and agrichemical dealers. More than 2,500 people attended events where these research findings were presented. Abstracts about this study have appeared in publications of the North Central Weed Science Society and the Weed Science Society of America.

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