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Weed Seed Decline and Buildup in Soils Under Various Corn Management Systems Across Nebraska[1]

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ABSTRACT

The weed seedbank in the soil makes weed control necessary every year in crop production. Research was initiated to determine if a farmer could reduce weed control practices after several years of excellent weed control. Experiments were conducted at five locations across Nebraska to determine the demise of weed seed in continuous corn (*Zea mays* L.) where weed seed production had been eliminated for 3 yr (1975–1977) and then four weed management levels were superimposed for another 3 yr (1978–1980). Soils were Cumulic Haplaquolls, Typic Argiudolls, Udic Agriustolls, Typic Haplustolls, and Aridic Haplustolls. Within 1 yr (1978) after weed eradication had stopped, the average number of weed seeds that germinated increased over the four weed management levels; and weed competition to corn was evident within 2 yr (1979). Weeds have the potential to rapidly increase and reinfest a field once there is a lack of vigilance in the weed control program. Thus, the weed seedbank assures a continuity to the weed problem that will require more than eliminating weed seed production for several years. If a farmer has achieved 3 yr of perfect weed control on a given field, he still must expect weed problems in subsequent crops because of seed longevity in soil.

Additional index words: **Broadleaf weeds, Grass weeds, Seedbank, Seed dormancy, Seed longevity, Weed competition, Weed management.**

THE weed seedbank in the soil makes weed control a problem every year in crop production as contrasted with the invasive nature of many of the other crop pests (1, 5, 9, 10, 11, 12, 14). Thus, the farmer knows that a weed problem one year will yield a similar or greater problem the next year depending on the number and viability of weed seeds produced.

Over the past 40 yr, many weed species shifts have been observed in response to increasingly selective herbicides (2, 3, 10, 13, 14). For example, the advent of 2, 4-D [(2,4-dichlorophenoxy) acetic acid] in 1944 for broadleaf weed control in grass crops has decreased broadleaf species, while grass species have increased to fill the void (16). Beginning in 1954 dalapon (2,2-dichloropropanoic acid) was used for selective control of grass weeds in certain broadleaf crops. The introduction of CDAA (2-chloro-*N*,*N*-di-2-propenylacetamide) in 1956 selectively controlled grass weeds in grass crops. In 1958 2,4-DB [4-(2,4-dichlorophenoxy) butyric acid] was introduced to control broadleaf weeds in broadleaf legumes. Atrazine [6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-traizine-2,4-diamine] was sold in 1959 for broadleaf and grass weed control in grass crops. In 1960 chloramben (3-amino-2,5-dichlorobenzoic acid) was introduced for broadleaf and grass weed control in broadleaf crops. Each of these steps represented greater selectivity in herbicide development over the years. We are now in the era where most weeds can be controlled selectively in most crops, and new herbicides are introduced each year. We are also experiencing and beginning to expect improved weed control each year.

The repercussions of these weed control developments will occupy the attention of weed scientists for many decades (3, 7, 15, 17). However, as weed control methods improve and annual weed seed production is greatly reduced or eliminated, we must evaluate the importance of this drawdown of the seedbank and its impact on future weed control programs (1, 4, 5, 6, 8, 9, 11, 12). The soil seedbank is reduced as weed seed production or invasion is reduced and as weed seeds germinate or decay.

As the seedbank is depleted the grower may be able to reduce some weed control practices and still maintain crop yields. We must determine how quickly the weed seedbank buildup occurs under different weed management systems. It may be economical to consider the complete elimination of weed seed production by soil fumigation to destroy the seedbank. Weed scientists may be approaching the ultimate weed control method as they contemplate ridding our soils of its weed seedbank. How quickly the weed seedbank will increase by weed invasion after its demise will be determined by the effectiveness of our preventative weed control programs.

The objectives of this research were to determine (i) weed seed demise in continuous corn (*Zea mays* L.) during 3 yr of zero weed seed production, and (ii) weed seed buildup and associated corn production during the subsequent 3 yr while utilizing four different weed management levels.

MATERIALS AND METHODS

Research was conducted at Concord, Lincoln, Clay Center, North Platte, and Scottsbluff, NE, during 1975 through 1980. Soil type at Concord was a Colo silty clay loam (fine silty, mixed, mesic Cumulic Haplaquoll) with 38% clay, 4.0% organic matter, pH of 6.5, and cation exchange capacity (CEC) of 26 cmol kg^{-1}; Lincoln was a Sharpsburg silty clay loam (fine, montmorillonitic, mesic Typic Argiudoll) with 42% clay, 3.3% organic matter, pH of 5.5, and CEC of 22 cmol kg^{-1}; Clay Center was a Hastings silt loam (fine, montmorillonitic, mesic Udic Argiustoll) with 25% clay, 3.0% organic matter, pH of 6.5, and CEC of 18 cmol kg^{-1}; North Platte was a Cozad silt loam (fine-silty, mixed, mesic Typic Haplustoll) with 19% clay, 1.5% organic matter, pH of 7.4, and CEC of 15 cmol kg^{-1}; and Scottsbluff was a Tripp very fine sandy loam (coarse-silty, mixed, mesic Aridic Haplustoll) with 16% clay, 1.6% organic matter, pH of 7, and CEC of 11 cmol kg^{-1}.

Concord and Lincoln, in eastern Nebraska, were dryland sites and the other three were irrigated as needed for corn production. Fertilizer was applied as needed for corn production according to Agronomy Department Soil Testing Laboratory soil tests from each location. Designated plots were plowed 20 cm deep each fall after corn harvest, but prior to taking soil samples in November for weed seed germination determinations.

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The experimental design was a randomized complete block with a split-plot treatment arrangement and three replications. Main plots initiated in 1975 were either plowed or not plowed and each was 9 by 36 m. Corn was grown on the experimental areas all 6 yr, but no weeds were allowed to produce seed during the 1975–1977 growing seasons. Weed growth in adjacent areas was also controlled to reduce weed seed movement onto the plot area by wind, water, or animals. Weed control during these years included preemergence applications of atrazine at 2.8 kg ha^{-1} plus alachlor [2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxy-methyl)acetamide] at 2.8 kg ha^{-1}, cultivation at 3 and 5 weeks after planting, postemergence application of 2,4,-D amine at 0.4 kg ha^{-1}, occasional postemergence directed applications of paraquat (1,1′-dimethyl-4,4′-bipyridinium ion) at 0.6 kg ha^{-1}, and handweeding as needed to control any weeds that escaped the aforementioned treatments. An adapted corn hybrid was planted at each location in 76 cm rows at an appropriate stand for dryland (37 000 plants ha^{-1}) or irrigated (59 000 plants ha^{-1}) corn.

In 1978, each main plot was divided into four subplots, each 4.5 by 18 m. Between 1978 and 1980, weed control treatments superimposed on the four subplots consisted of (i) no cultivation or herbicide, (ii) no cultivation + alachlor preemergence at 2.8 kg ha^{-1}, (iii) two cultivations plus atrizine preemergence at 2.8 kg ha^{-1}, and (iv) two cultivations plus alachor + atrazine at 1.7 + 1.1 kg ha^{-1}. These four weed management levels represent no weed control, mainly grass but some small seed broadleaf weed control, broadleaf and some grass weed control, or both grass and broadleaf weed control, respectively. The irrigated locations of Clay Center, North Platte, and Scottsbluff also received a layby cultivation in early July to facilitate furrow irrigation.

In addition to the indigenous weed seed reservoir in the soil at each experimental site, 5 to 20 kg ha^{-1} of weed seed were spread on the soil surface before plowing and prior to seedbed preparation in 1975. No additional weed seed was added to the soil after 1975. Weed species added to the experimental areas were: common lambsquarters (*Chenopodium album* L.) and green foxtail [*Setaria viridis* (L.) Beauv.] at Concord; velvetleaf (*Abutilon theophrasti* Medic.) and green foxtail at Lincoln; Pennsylvania smartweed (*Polygonum pensylvanicum* L.) and shattercane [*Sorghum bicolor* (L.) Moench] at Clay Center; redroot pigweed (*Amaranthus retroflexus* L.) and bristly foxtail [*Setaria verticillata* (L.) Beauv.] at North Platte; and hairy nightshade (*Solanum sarrachoides* L. Sendtner) and barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] at Scottsbluff, NE.

Soil samples were taken in weed-free corn plots during 1975–1977 and in the four weed control treatments during 1978–1980. About 1 November each year, 25 composite soil samples were taken per plot at the 0- to 20-cm depth. Weed seed germination tests were run on 454 g of air-dry soil per plot by spreading soil on a 46- by 48-cm germination paper (Anchor Paper, St. Paul, MN) placed on trays. Paper and soil were wetted by wick action with tap water. Trays were placed in a germinator operated at 20°C for 16 h of darkness and 30°C for 8 h of fluorescent light at 100% relative humidity. Germinated seed were recorded as either grass or broadleaf weeds at 7-day intervals over a 4-week germination period. After the third-week count, soil was air-dried for 3 days, remoistened with tap water, and again placed in the germinator for 7 days before the final germination count. The number of dormant seed were not determined.

In 1978, the four aforementioned weed control treatments were superimposed on the prior weed-free corn plots. Corn injury notes and percent weed control were taken about 45 days after corn planting. Corn population was determined about 2 months after planting by counting plants in 13 m^2 per plot. Weeds were clipped in August from 5 m^2 per plot and expressed as kg ha^{-1} of oven-dry top growth. Corn yields were harvested in October by combining 26 m^2 per plot and expressed as kg ha^{-1} of oven-dry shelled corn.

Analyses of variance were computed on all data. Differences among treatments were computed using Least Significant Difference (LSD) tests at the 5% level of significance.

RESULTS AND DISCUSSION

Weed Seed Demise and Buildup in Soil. Weed seed populations in soil at the Nebraska test sites dropped during 1975–1977 when weed seed production was prevented, but seed populations rapidly increased when four weed management levels were initiated in 1978 and continued on through 1980 (Table 1). The two locations in eastern Nebraska (Lincoln and Concord) accounted for the largest share of the weed seed buildup during 1978–1980, followed closely by Clay Center in east central Nebraska, while North Platte and Scottsbluff in western Nebraska showed a very slow increase in the seedbank (Fig. 1). Grass weed seed predominated at Lincoln and Concord, but broadleaf weed seeds were most common at Clay Center, North Platte, and Scottsbluff (Table 1).

Plowing reduced total weed seed populations in the soil as compared with nonplowed plots (Table 1). Grass seeds were reduced more by plowing than broadleaf seeds. Of the four weed management systems initiated

Table 1. Effect of 3 yr with no weed seed production (1975–1977) followed by the initiation of four levels of weed management for 3 yr (1978–1980) in continuous corn on weed demise and corn grain yield at Concord, Lincoln, Clay Center, North Platte, and Scottsbluff, NE.

Main treatments		Germinated weeds† Broad-leaf	Grass	Total	Weed yield	Corn yield
		no./454 g of soil			kg/ha	
Year						
1975		14	4	18	–	–
1976		9	1	10	–	–
1977		7	1	8	–	–
1978		9	17	26	200	8 250
1979		13	12	25	900	6 870
1980		10	15	25	800	5 140
LSD 0.05		5	7	9	300	360
Nebraska Location, 1980						
Concord		8	17	25	1 160	3 550
Lincoln		24	34	58	1 570	1 750
Clay Center		12	5	17	–	10 640
North Platte		6	2	8	120	6 770
Scottsbluff		3	1	4	30	9 210
LSD 0.05		4	8	9	300	480
Plowed Annually, 1980						
No		12	14	26	730	6 270
Yes		10	11	21	680	6 780
LSD 0.05		NS	2	4	NS	270
Weed management treatments 1978–1980	Herbicide rate, kg/ha		1980			
Unsprayed check	–	15	13	28	1 480	5 880
Alachlor	2.8	11	11	22	840	6 460
Atrazine + 2 cultivations	2.8	8	11	19	200	6 970
Alachlor + atrazine + 2 cultivations	1.7 + 1.1	6	12	18	300	6 780
LSD 0.05		3	NS	8	260	380

† Approximate number of germinated seed/ha can be calculated by multiplying the number of germinated weeds/454 g of soil by 5 × 10^6.

in 1978, the two most effective in reducing weed seed production were atrazine at 2.8 kg ha^{-1} plus two cultivations and alachlor + atrazine at 1.7 + 1.1 kg ha^{-1} plus two cultivations. Treatments containing atrazine showed a marked drop in broadleaf weed seed as compared with the unsprayed check. Alachlor at 2.8 kg ha^{-1} caused a significant drop in broadleaf but not grass weeds as compared with the unsprayed check. In this study, alachlor was more effective in controling small seeded broadleaf weeds such as redroot pigweed and tall waterhemp [*Amaranthus tuberculatos* (Moq.) J. Sauer] than late emerging grass weeds.

A farmer cannot decrease his weed control program after 3 yr of eliminating weed seed production, because the weed seedbank in the soil is ample to rapidly replenish the seedbank. Thus, a weed control program of a farmer must be continued beyond 3 yr of crop production without weeds to achieve corn production without weed competition.

Weed Yields. Average weed growth was lower in 1978, the first year after eliminating weeds for 3 yr than weed growth in 1979 or 1980 (Table 1). The two sites in eastern Nebraska (Lincoln and Concord) showed markedly increased weed growth in comparison to sites in western Nebraska (North Platte and Scottsbluff). Rainfall increases as one goes from west to east in Nebraska and the diversity and density of weed species increases accordingly (1). Plowing did not affect overall weed growth (Table 2). The unsprayed check, utilized from 1978–1980, had the most weed growth, followed by alachlor at 2.8 kg ha^{-1}, which was higher than the two cultivated treatments receiving atrazine. Some weeds escaped the best cultivation plus herbicide weed control systems that were utilized. Thus, unless the soil seedbank has been exhausted it would be difficult to dispense with most weed control methods.

Corn Growth. Corn stands were not affected by plowing or weed control treatments, and location differences were due to planting rates needed for dryland or irrigated corn (data not shown). Corn injury showed less injury on plowed (5% on a 0 to 100% injury scale) than nonplowed (12%) plots and on unsprayed (5%) vs. herbicide-treated (10%) plots, but the differences were so small as to be insignificant as far as subsequent corn growth and yield were concerned (data not shown).

Corn Yield. Average corn yields decreased each year from 1978 to 1980 because weed populations increased (Table 1). Corn yields on dryland sites (Lincoln and Concord) were lower than those on irrigated sites (Clay Center, North Platte, and Scottsbluff) because water stress was greater without irrigation. Annual plowing increased corn yields over that from nonplowed plots. Average corn yields were highest on cultivated plots receiving atrazine because weed yields were least on these plots. Plots receiving alachlor at 2.8 kg ha^{-1} had lower corn yields than the aforementioned plots, but they were higher than the unsprayed plots.

Complete weed control must be maintained in excess of 3 yr to hold the soil seedbank to a minimum level. Also, the weed seedbank rapidly increased once pressure on the weeds was released. If a farmer has achieved perfect weed control for 3 yr and then returns to a conventional weed control program, the weed seedbank in the soil will build up within the year and significant corn competition will return the second year. Weeds have the potential to rapidly increase and reinfest a field once there is a lack of vigilance in the weed control program (3, 5, 9, 10, 12).

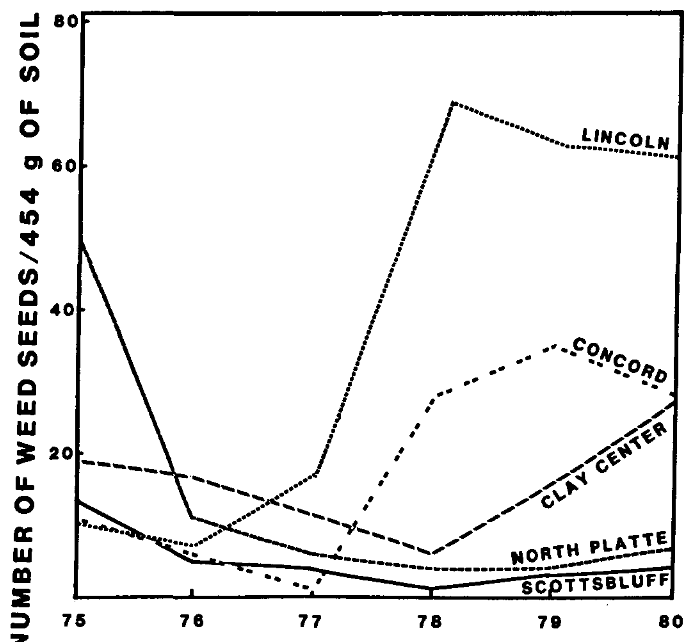

Fig. 1. Weed seed germination in composite soil samples taken each November in corn plots maintained weed-free from 1975–1977 and then grown under four levels of weed management during 1978–1980 at Concord, Lincoln, Clay Center, North Platte, and Scottsbluff, NE.

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