Weed Management Strategies for Conservation Tillage in the 1990's

A. Douglas Worsham[1]

Introduction

Surveys in past years among no-tillage and conservation-tillage practitioners and professional workers usually indicated that obtaining adequate weed control was the greatest problem encountered in no-till and the greatest deterrent to expansion of this practice (22). This led Worsham and Lewis to state in the Proceedings of the 8th Southern No-Tillage Conference that weed management was the key to successful no-tillage crop production (24).

Now, however, a survey recently conducted by the National Conservation Tillage Information Center revealed that grower resistance to change was the major deterrent to adopting conservation tillage methods. Weed control was the second most important problem.

Weed management strategies for no-tillage and conservation-tillage cropping systems will be similar in the early 1990's as they have been for the past several years. These strategies in no-tillage depend almost entirely on foliar and surface-applied herbicides because mechanical seedbed preparation, soil-incorporated herbicides, and postemergence mechanical cultivation are eliminated. Some use of soil-incorporated herbicides and cultivation in row-crops could still be made in conservation-tillage systems, depending on the amount of surface residue left after minimum tillage seedbed preparation.

Currently, for example, most no-tillage cropping systems in the southern U.S. employ a mixture of a "burndown" herbicide plus one or more residual herbicides. The burndown herbicide kills emerged grass and broadleaf weeds and any cover crop present at or before planting. Residual herbicides are needed to control weeds germinating from seed later in the season. To complete the weed management program, a postemergence herbicide or herbicides may also be needed for additional control of broadleaf weeds, grasses, or both. In some crops, such as in soybeans, postemergence grass and/or broadleaf herbicides may be substituted for residual herbicides.

Many of these strategies should change or shift in emphasis in the 1990's. Some predictions as to changes in weed management strategies will be made in following sections of this paper.

Weed Management Tools and Changes for the 1990's

The time proven weed management tools of crop rotations, crop competition, cultivation and seedbed preparation, and herbicides will remain with us through the 1990's. There will be changes, however, even within these weed management tools.

Rotations: Crop rotation will play a greater role in weed management in the future. There will be a general public demand and acceptance by growers for a reduction in pesticide use, including herbicides. More legislative or regulatory agency regulations will be enacted. Therefore, there will be more reliance on non-chemical methods of weed management, including rotations, to help reduce weed problems.

Crop Competition: Greater use of crop competition will help fulfill the prediction made above. Growers will move toward planting all row crops in more narrow rows, making greater use of cover crops to suppress weeds (more details will be given on this aspect later) and planting cover crops to more dense stands.

Cultivation and Seedbed Preparation: Currently the presence of certain weeds, mainly perennials, causes cultivation or tillage to be recommended for seedbed preparation. New herbicides now expected to be on the market within a few years and possible yet undiscovered herbicides may make this recommendation obsolete. With better no-till drills becoming more widespread in use, more crops, including winter cover crops, will be planted satisfactoriIy without tillage. Tillage for successful establishment of fall-seeded cover crops has been recommended in the past. These new developments should allow for a system of continuous no-till crops in many areas, thus allowing growers to realize the full, long-term benefits of no-tillage.

[1]Crop Science Department, North Carolina State University, Raleigh, NC 27695.

Another innovation in the machinery area is the development of "no-tillage" cultivators. These implements are designed to operate to control weeds in soils with mulch present, leaving the mulch on the surface to conserve soil and moisture.

Herbicides: There will be an overall reduction in total herbicide use, partially the result of new regulations and partially made possible by the adoption of the new practices described in the previous sections and the advent of new herbicides which are being used in fractions of an ounce per acre. However, there will still be heavy reliance on herbicides in no-tillage and conservation-tillage systems.

There will be a move toward more reliance on postemergence herbicides applied on an as-needed basis instead of routine applications of soil-applied herbicides at planting. New herbicides, some of which will be discussed later, will allow a total postemergence approach to weed management in more crops, particularly corn.

Current Management Strategies

In the chapter on weed management in the N.C. State University publication, "Conservation Tillage for Crop Production in North Carolina", there is a detailed discussion of weed management programs covering control of existing vegetation, residual weed control and postemergence weed control in corn, soybeans, grain sorghum and cotton (7). Weed management systems in forage and vegetable crops are covered in other chapters in the same publication.

These recommendations are still current except for a few additions in corn and soybeans: Buctril or Brominal postemergence in corn; Roundup + Prowl + Scepter; Roundup + Squadron or Turbo; Gramoxone Extra + Prowl + Scepter, or Gramoxone Extra + Squadron preemergence in soybeans; and Pursuit postemergence in soybeans.

All situations which may be encountered in weed management inconservation tillage productionof these crops are adequately covered in the previously mentioned publication and will not be repeated here.

Future Weed Management Strategies

The 1990's will see tremendous changes in weed management strategies in conservation tillage cropping systems as well as conventionally tilled systems. Some of these changes in conservation tillage crops will be in the areas of: (1) new herbicides, (2) more use of allelopathic (phytotoxic) cover crop mulches to suppress weeds, and (3) genetically engineered crops which will have tolerance to different herbicides.

New Herbicides: The first new herbicides to be marketed in the early 1990's that will have a significant impact on no-till corn will be the over-top grass herbicides Accent, from duPont, and Beacon, from Ciba-Geigy. A major advantage will be that no-till or conservation-till corn can be planted into johnsongrass-infested fields. A standard surface applied herbicide can be used at planting for other weeds and johnsongrass can be controlled postemergence. Both compounds have activity on annual grasses and some broadleaf weeds. Use of these compounds, and in some cases, with the addition of a broadleaf herbicide, will for the first time allow a total postemergence approach to weed management in corn. The major advantage of these new herbicides in conservation cropping systems, however, is the fact that in johnsongrass infested fields, preplant soil-incorporated herbicides will not be required, thus allowing more soil-conserving, crop production practices.

Since these new herbicides will be used at rates of fractions of an ounce per acre and are moderate in soil mobility, they should pose less potential for groundwater contamination and be more environmentally acceptable.

Another herbicide expected to be marketed in the early 1990's as a non selective 'burndown' chemical in no-till crops is Ignite, from American Hoechst. This herbicide is moderately translocated and is faster acting than Roundup. It is expected that this herbicide will fill a gap in controlling certain weeds present at planting that are tolerant or require higher rates of Roundup or Gramoxone Extra.

While it is expected that there will be a great reduction in the number of new herbicides reaching the market in the 1990's, those that do will probably be "new generation" compounds used at extremely low rates and more environmentally acceptable.

Use of Allelopathic Cover Crops: With growers meeting full compliance of the conservation requirements of the 1985 Food Security Act by 1995, more and more will turn to conservation- or no-tillage. With this move, there will be more use of cover crops in general. Also, since North Carolina's requirement to meet conservation tillage on highly erodible land is 50% ground cover, ad compared to 30% for the rest of the U.S., more use will have to be made of cover crops. Research and farmer experience in North Carolina and in a few other states has shown that a considerable degree of early-season weed suppression can be gained by use of certain winter annual cover crops.

The presence of crop residues has been reported to both increase and decrease crop yields and not tilling to increase certain difficult-to-control weeds (7). However, other reports indicated that the presence of certain mulches can reduce the biomass of certain weeds and allow for higher crop yields (1,13,15,25). Research to date indicates that both mulch and the lack of soil disturbance contributes to the suppression of weeds in no-till cropping systems (15).

Crop and weed scientists traditionally have viewed allelopathic interactions in agriculture as detrimental (14). Many of the world's weeds have been reported to have allelopathic properties which reduce crop growth and yield. In fact, 13 of the world's 18 "worst weeds" have been reported to produce allelochemicals (10). Allelopathic potential has now been suggested for about 90 species of weeds (11).

In recent years, however, more attention has been given to possibilities of exploiting allelopathy to aid in weed management. This approach gains importance as growers try to adopt crop production methods which rely less on high chemical (pesticide) inputs (25). Cover crops of wheat, barley, oats, rye, grain sorghum, and sudangrass have been used effectively to suppress weeds, primarily annual broadleaf weeds (1,12,13,15,17).

Weed suppression has also been noted in the U.S. from residues of several winter annual legume crops. White et al. (21) reported inhibition of several weeds from field residues and leachates of crimson clover and hairy vetch. Teasdale (18) showed some weed suppression from hairy vetch residues, but concluded that other methods of weed control would be needed. Enache and Ilnicki (6) concluded, however, that subterranean clover had a definite potential for controlling weeds in corn. Else and Ilnicki *(5)* studied growth and species composition of weeds in four mulch and tillage systems, with A living subterranean clover mulch provided nearly complete weed control. Evidence of allelopathic activity was found in extracts of clover leaves and in dead residue. The authors concluded that some mulches can, in the presence of a corn crop, provide adequate weed control without the use of herbicides or mechanical control.

Among five no-tillage systems studied by Shilling et al. (17) using desiccated small grains for weed suppression, rye generally provided the best broadleaf weed control (Table 1). Rye has also been particularly effective in studies by Putnam and DeFrank (12), Barnes et al. (2), and Worsham (23). The high biomass production of shoots and roots, winter hardiness, and phytotoxicity of the residues make this grass cover crop very effective in no-tillage soil conservation cropping systems.

Chou and Patrick (4) identified nine acids from ether extracts of decaying rye residues in soil. Phenylacetic, 4-phenylbutyric, vanillic, ferulic, *p*-coumaric, p-hydroxybenzoic, o-coumaric, and salicylic acids all inhibited the growth of bioassay plants. Two different groups of investigators isolated compounds from water extracts of above-ground rye mulch that inhibited weed growth in laboratory bioassays. Shilling et al. (15,16,17) found ß-phenyllactic acid (PLA) and *p*-hydroxybutyric acid (HBA) provided 20 to 60% inhibition of common lambsquarters and redroot pigweed. Barnes et aL(2) isolated two hydroxamic acids, 2,4-dihydroxy-l,4(2H)-benzoxazin-3-one (DIBOA) and 2(3H)-benzoxyazolinone (BOA), with phytotoxicity on a large number of weed test plants. These two compounds were more phytotoxic than PLA or HBA and DIBOA was shown to maintain toxicity for an extended period following addition to soil.

Table 1. Effects of Small Grain Mulch and Tillage on Weed Control at Two Locations Over Two Years in North Carolina[a]

Mulch type[b]	% Weed Control[d]	
	Broadleaf[e]	Grass[f]
Rye	85 ab	70 b
Wheat	74 c	61 bc
Barley	75 c	54 bc
Oats	80 bc	64 b
None	63 d	41 d
None[c]	90 a	81 a

[a]Modified from Shilling et. al. (17).
[b]All treatments had 6 lb/A diphenamid and 3 lb/A glyphosate applied to kill grain and provide residual weed control.
[c]Tilled and rebedded prior to transplanting tobacco and cultivated twice.
[d]Means within a column followed by the same letter are not significantly different. Ratings are in early-season.
[e]Redroot pigweed, common lambsquarters, and common ragweed.
[f]Large crabgrass and goosegrass.

The collective allelochemical action of rye mulch on weed suppression in the field is outstanding. Barnes et al. (2) reported that weed biomass in a cover crop of living rye was reduced 90% over unplanted controls. A mulch of 40-day-old spring-planted rye gave 69% reduction. Shilling et al. (15) found rye mulch and root residues to give over 90% early-season reduction in the biomass of common lambsquarters, redroot pigweed, and common ragweed in no-till planted soybean, sunflower, and tobacco compared to tillage and no rye. Liebl and Worsham (8) reported significant reductions in morningglory and prickly sida in field studies involving wheat mulch and isolated ferulic acid as the most phytotoxic compound from foliar wheat extracts.

Weston et a1 (20) investigated the apparent allelopathic effects of sudex on weed and vegetable species. Two major phytotoxins, *p*-hydroxybenzoic acid and p-hydroxybenzaldehyde, were isolated and identified from shoot tissue. These compounds are potentially the enzymatic breakdown products of the cyanogenic glycoside dhurrin.

Recent discoveries concerning microbial transformation of certain allelochemicals from wheat and rye may be significant in increasing phytotoxicity of these residues to weeds. Liebl and Worsham (8) reported that ferulic acid in the presence of prickly sida seed carpels was decarboxylated by a bacterium living on the seeds to a styrene derivative, 2-methoxy-4-ethenylphenol. The styrene was more phytotoxic to prickly sida than ferulic acid and may play an important role in control of this weed in natural conditions under wheat mulch.

More recently Muraleedharan et al. (9) isolated a microbially transformed allelochemical, 2,2'-epidioxy-1,l’-azobenzene [2,2’-oxo-l,l’-azobenzene] (AZOB) from a soil supplemented with 2,3-benzoxazolinone (BOA). AZOB was more toxic to curly cress and barnyardgrass than either DIBOA or BOA. Although there were no detectable amounts of the biotransformation product in soil under rye residues, the implications of such phytotoxic bio-magnification of allelochemicals may be very significant in helping to explain allelopathic weed suppression under field conditions.

Although there is great promise in using cover crops and mulches to aid in weed control, much research needs to be done to gain full advantage of the system. Some problems that need attention are the lack of suppression of perennial weeds and annual and perennial grasses, the cost of establishing and killing the cover crop, allelopathic effects on the crop itself (19), and compatibility of rotations.

Our work in North Carolina over a number of years has indicated that leaving a small grain mulch and not tilling gives 75 to 80% early-season control of a number of annual broadleaf weeds (Table 2). Removing straw, tilling and replacing straw gives 60% control. Removing straw and not tilling gives 40 to 50% control and removing straw and tilling the soil, without herbicides, gives little or no control of these weeds. It was concluded that not tilling accounted for some weed control, but having straw alone contributed even more. Not tilling plus having a straw mulch gave the highest degree of weed control.

Table 2. Effects of straw management and tillage on weed suppression in no till planted crops in North Carolina.[a] (25)

Straw and tillage treatment	% Control[b]	
	Rye Mulch[c]	Wheat Mulch[c]
Remove straw & till soil	9 a	30 a
Remove straw, no-tillage	43 b	50 b
Remove straw, till & replace	60 c	60 c
Leave straw, no-tillage	76 d	81 d

[a]Average results from research in corn, soybeans, sorghum, and tobacco, 1980-1986
[b]Early-season ratings on redroot pigweed, common lambsquarters, common ragweed, morningglory sp., prickly sida, sicklepod
[c]Means within a column followed by the same letter are not significantly different.

Shilling et al. (17) reported research in which they attempted to partition the weed control effects from tillage alone, no-tillage, and no-tillage plus mulch with and without a prcemergence herbicide in tobacco (Table 3). Tillage alone without herbicide gave 8% early-season control of broadleaf weeds and 47% control of annual grasses. Adding a soil-applied herbicide gave 52 and 67% control of broadleaf weeds and grasses, respectively. Not tilling, without herbicide or mulch, gave 68 and 71% control. The no-till treatment without mulch plus herbicide yielded 87 and 94% control. Rye mulch, no-till without herbicide gave 79 and 54% control, respectively, of broadleaf and grass weeds and rye mulch plus herbicide in no-till gave 97 and 80% control. Results from the same treatments with wheat, oats and barley were similar. These results confirm the need for not tilling plus having a mulch to achieve the highest degree of weed control without a preemergence herbicide.

Farmers interested in reducing or eliminating chemical inputs in cropping systems often ask if the allelopathic cover crops or mulches will do the whole weed control job so herbicides won’t be needed. Our experience in North Carolina indicates that most of the time herbicides are still needed, especially postemergence herbicides in late-season. The allelopathic suppression effect usually is adequate only for the first few weeks for a crop. In research plots, however, we have been able to grow crops and attain adequate weed control with only a heavy mulch of killed rye. These crops have been corn, soybean, grain sorghum and sunflower. The rye cover was killed before planting with a herbicide. In 1989, corn soybeans and grain sorghum were grown in a killed rye cover crop without the need of additional herbicides. We believe that the unusually wet season allowed the allelopathic weed control results to be more effective than usual. Additional research on this aspect was begun in 1990 with corn, tobacco, cotton and soybeans in cover crops of rye, crimson clover, hairy vetch and subterranean clover.

Table 3. The effects of mulch, tillage, and diphenamid on weed control in flue-cured tobacco at two locations in North Carolina.[a]

	% Weed control [b]	
Treatment	**Broadleaf**	**Grass[d]**
Tilled no herbicide	**8 e**	**47 c**
Tilled plus herbicide	**52 d**	**67 bc**
No-till, no herbicide	**68 bc**	**71 abc**
No-till plus herbicide	**87 ab**	**94 a**
No-till, rye mulch, no herbicide	**79 bc**	**54 bc**
No-till, rye mulch plus herbicide	**91 a**	**80 ab**

[a]Modified from Shilling et al. (17)
[b]Ratings taken four weeks after transplanting. Means within a column followed by the same letter are not significantly different.
[c]Redroot pigweed, common lambsquarters, and common ragweed.
[d]Goosegrass and large crabgrass.

Use of Genetically Altered Crops: Sometime during the 1990's we may see the release of crop varieties which have been genetically altered to be tolerant to herbicides that they were previously sensitive to. These endeavors are in various stages of development, with some having reached the field testing stage (3). Ciba-Geigy has field-tested a line of tobacco tolerant to the triazine herbicides, although they do not plan to commercialize this discovery. DuPont has ficld-tcsted tobacco and soybeans tolerant to certain sulfonylurea herbicides. American Cyanamid, working with biotechnology and seed companies, is developing corn tolerant to imidazolinone herbicides (3). Monsanto is working to produce various crops tolerant to Roundup. American Hoechst is interested in developing crops tolerant to Ignite. Various other biotechnology companies are working on Roundup tolerant tomato, corn, and cotton; bromoxynil tolerant sunflower; atrazine tolerant canola; and corn tolerant to Treflan (3).

The development and marketing of some of these new crop varieties should make the control of some difficult to control weeds easier in conservation and no-till cropping systems. The anti-synthetic pesticide forces, however, are mounting increasing opposition to this approach. A bill may be introduced in Congress to prohibit any federal funds from being used for this purpose.

Literature Cited

1. Barnes, J. P. and A. R. Putnam. 1983. Rye residues contribute weed suppression in no-tillage cropping systems. J. Chem. Ecol. 9:1045-1057.

2. Barnes, J. P., A. R. Putnam, and B. A. Burke. 1986. Allelopathic activity of rye (*Secale cereale* L.). *In* A. R. Putnam and C. S. Tang (Eds.), The Science of Allelopathy. John Wiley and Sons, New York, pp.271-286.

3. Bublitz, Ann E. 1987. Impact of biotechnology on weed science. Pages 1-6 in Proc. 5th Annual Meeting of the Weed Sci. Soc. of N.C., T. J. Monaco and A. R. Bonanno, eds. Weed Sci. Soc. of N.C.

4. Chou, C. H. and Z. A. Patrick. 1976. Identification and phytotoxic activity of compounds produced during decomposition of corn and rye residues in soil. J. Chem. Ecol. 2:364-387.

5. Else, M. J. and R. D. Ilnicki. 1989. Crop and mulch system effects upon weeds in corn.(Abstr. No. 157), WSSA Abstracts 29:68.

6. Enache, A. and R. D. Ilnicki. 1988. Subterranean clover: a new approach to weed control. Proc. N.E. Weed Sci. Soc. 42:34.

7. Lewis, W. M., A. D. Worsham, and A. C. York. 1989. Weed Management in Conservation Tillage. Pages 28-39. In. Conservation Tillage for Crop Production in North Carolina. M. G. Cook and W. M. Lewis, Eds. N. C. Agric. Ext. Serv. Bulletin AG-407.

8. Liebl, R. A.; Worsham, A. D. 1983. Inhibition of pitted morningglory *(Ipomoea lacunosa L.)* and certain other weed species by phytotoxic components of wheat *(Triticum aestivum L.)* straw. J. Chem. Ecol, 9-1027-1043.

9. Muraleedharan, G. N., Whitenack, C. J., Putnam, A. R.1989. 2,2'oxo-1,1'-azobenzene: a microbially transformed allelochemical from 2,3-benzoxa-olinone: I. J. Chem. Ecol., 15, (In Press).

10. Patterson, D. T. 1986. Allelopathy. In "Research methods in Weed Science" (Camper, N.D., Ed.); 3rd ed., Weed Science Society, Champaign, IL. pp. 111-134.

11. Putnam, A. R. 1988. Allelopathy: problems and opportunities in weed management. In "Weed

11. Putnam, A. 10.1988. Allelopathy: problems and opportunities in weed management. In "Weed Management in Agroecosystems: Ecological Approaches" (Altieri, M. A. and Liebman, M., Eds.) CRC Press, Inc., Boca Raton, FL. pp. 77-88.

12. Putnam, A. R. and J. De Frank. 1983. Use of phytotoxic plant residues for selective weed control. Crop Protection 2:173-181.

13. Putnam, A. R., J. De Frank, and J. P. Barnes. 1983. Exploitation of allelopathy for weed control in annual and perennial cropping systems. J. Chem. Ecol. 9:1001-1010.

14. Putnam, A. R. and L. A. Weston. 1986. Adverse impacts of allelopathy in agricultural systems. *In* "The Science of Allelopathy" (Putnam, A. R., and Tang, C. H., Eds.), John Wiley and Sons, New York. pp. 43-56.

15. Shilling, D. G., R. A. Liebl, and A. D. Worsham. 1985. Rye (*Secale cerale* L.) and wheat (*Triticum aestivum* L.) mulch: The suppression of certain broadleaved weeds and the isolation and identification of phytotoxins. *In* A. C. Thompson (Ed.) The Chemistry of Allelopathy: Biochemical Interactions Among Plants. ACS Symp. Ser. 268. American Chemical Society, Washington, D.C. pp. 243-271.

16. Shilling, D. G., L. A. Jones, A. D. Worsham, C. E. Parker and R. F. Wilson. 1986a. Isolation and identification of some phytotoxic compounds from aqueous extracts of rye (*Secale cereale* L.) J. Agric. Food Chem. 34633-638.

17. Shilling, D. G., A. D. Worsham, and D. A. Danehower. 1986b. Influence of mulch, tillage, and diphenamid on weed control, yield, and quality in no-till flue-cured tobacco (*Nicotiana tabacum*). Weed Sci. 34:738-744.

18. Teasdale, J. R. 1988. Weed suppression by hairy vetch residue. Proc. N.E. Weed Sci. Soc. 42:73.

19. Waller, G. R., E. G. Krenzer, J. K. McPherson, and S. R. McGown. 1987. Allelopathic compounds in soil from no tillage vs conventional tillage in wheat production. Plant Soil 98:5-15.

20. Weston, L. A, R. Harmon, and S. Mueller. 1989 Allelopathic potential of sorghum-sudangrass hybrid (Sudex). J. Chem. Ecol. 15:1855-1865.

21. White, R. H., A. D. Worsham, and U. Blum. 1989. Allelopathic potential of legume debris and aqueous extracts. Weed Sci. 37:674-679.

22. Worsham, A. D. 1980. No-till corn -- Its outlook for the 80's. Proc. Ann. corn and Sorghum Res. Conf., Amer. Seed Trade Assoc. 35:146-163.

23. Worsham, A. D. 1984. Crop residues kill weeds: allelopathy at work with wheat and rye. Crops Soils 37:18-20.

24. Worsham, A. D. and W. M. Lewis. 1985. Weed management: Key to no-tillage crop production. Proc. South. Region No-Till Conference. Pages 177-188. Univ. of Ga. Agric. Exp Sta., Athens, GA.

25. Worsham, A. D. 1989. Current and potential techniques using allelopathy as an aid in weed management. Pages 275-289. In. Phytochemical Ecology: Allelochemicals, Mycotoxins, and Insect Pheromones and Allomones (C.H. Chou and G. R. Waller, Eds.), Institute of Botany, Academia Sinica Monograph Series No. 9, Taipei, Taiwan.