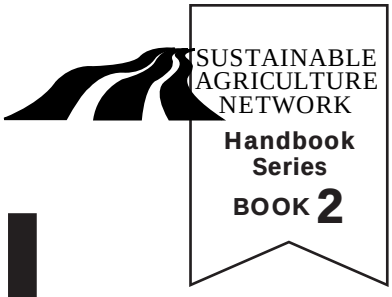


# STEEL IN THE FIELD

## A Farmer's Guide to Weed Management Tools

EDITED BY GREG BOWMAN

A publication of the Sustainable Agriculture Network
with funding by the
Sustainable Agriculture Research and Education Program
of CSREES, U.S. Department of Agriculture

**Sustainable Agriculture Network**
**Beltsville, Maryland 20705**

Printed in 2002 by the Sustainable Agriculture Network (SAN), with funding from the Sustainable Agriculture Research and Education (SARE) program of the CSREES, U.S. Department of Agriculture. This book was supported by USDA-CSREES project award no. 2001-48546-01236. Contact SAN before reproducing any part of this book.

SAN is the national outreach arm of USDA's SARE program. Since 1988, SARE has worked to advance farming systems that are profitable, environmentally sound and good for communities. For more information about SAN and SARE, see www.sare.org or contact:

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Material for this book was researched, written, illustrated, edited and produced by the Rodale Institute, Kutztown, Pa., with revisions added by SAN in 2001. The book concept, format and selection of featured farmers and content reviewers were developed under the auspices of the Sustainable Agriculture Network.

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Other SAN Handbook Series titles in print include Book 3: Managing Cover Crops Profitably; Book 4: Building Soils for Better Crops; and Book 5: How to Manage the Blue Orchard Bee as an Orchard Pollinator.

**Library of Congress Cataloguing-in-Publication Data**

Steel in the Field: a farmer's guide to weed management tools /
edited by Greg Bowman.
p. cm. — (Sustainable Agriculture Network handbook series; 2)
Includes bibliographical references and index.
ISBN 1-888626-02-X (alk. paper : soft cover)
1. Agricultural implements. 2. Weeds—Control.
I. Bowman, Greg, 1952 - . II. Series.
S676.S69 1997
681'.7631—dc21 97-8406
CIP

2 4 6 8 9 7 5 3

Printed in the United States of America on recycled paper ♻



Every effort has been made to make this book as complete and as accurate as possible and to educate the reader. This text is only a guide, however, and should be used in conjunction with other information sources on weed-, herbicide- and farm management. No single tool or weed control strategy will be appropriate and effective for all conditions. The editor, authors and publisher disclaim any liability, loss, or risk, personal or otherwise, which is incurred as a consequence, directly or indirectly, of the use and application of any of the contents of this book.

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Graphic design, interior layout and cover type design by Jerry O'Brien. All interior illustrations by John Gist. Cover illustration by Franklin Fretz. Farmer narratives on Rich Bennett and Jack Erisman written by Christopher Shirley. All others by Greg Bowman. Text editing by Craig Cramer. Copy editing by Cheryl Lachowski. Indexing by Manuscript Doctors (Nancy Hopkins.)

Printing by Jarboe Printing, Washington, D.C.

# Acknowledgments

Dairy farmer John Merrill's frustration with trying to find a rotary hoe—and someone anywhere close to New England who knew how to operate one—was the origin of this book. He shared this information hole with his colleagues on a committee of the Sustainable Agriculture Research and Education (SARE) program. Like many other SARE groups, this committee was a cross-section of farmers, educators, researchers and farm specialists. They agreed that farmers needed a nuts and bolts book on how to find and use weed management tools profitably and sustainably.

Beth Holtzman, communications specialist for the Northeast Region SARE program, and Fred Magdoff, coordinator of SARE's Northeast Region, developed the question into a concept. Both individuals were patient and supportive in seeing this project through.

I repeatedly interviewed the farmers who are featured in this book. Each gave generously of his time, experience and on-farm research findings, formal or informal. These innovators are the real authors of this book. Many frequently open their farms to other members of regional sustainable farming networks where real farmer-to-farmer exchange takes place.

Providing unfailing good sense was Dale Kumpf of Henke Machine/Buffalo Farm Equipment. He knows farmers throughout the U.S. and Mexico who are familiar enough with their farms to know when steel is ideal. Richard R. Johnson and Al Higley at Deere and Company—and the dozens of Deere specialists they linked me to at the right moments—provided images, specifications, insight, statistics and technical explanations that could only come from a world-class corporation. Ralph Moore of Market Farm Implement, Somerset, Pa., shared repeatedly of his deep working knowledge of horticultural tools, as he does daily with farmers across the U.S.

Vern Grubinger at the University of Vermont recommended farmer contacts and tools. Richard Parish, Dan Ball and Thomas Lanini at the state universities of Louisiana, Oregon and California at Davis, respectively, provided important perspective on crops, tools and farmers in their regions. I frequently consulted Rick Exner of the Practical Farmers of Iowa.

Helping to distill and express all this shared wisdom was Craig Cramer, who has yet to see a sustainable farming sentence he couldn't improve. He and the reviewers listed at the back of the book immensely enhanced this effort. Errors that remain are mine. These individuals lent their expertise without compensation simply to make this book as valuable as possible to the people who choose to make sustainable farming work in these United States.

To all these and many others, many thanks.

Greg Bowman
Kutztown, Pa.
January, 1997

# Publisher's Foreword

Controlling weeds with reduced reliance on herbicides is one of the main challenges facing farmers interested in moving toward a more sustainable agriculture. Some are concerned about the potential health implications of handling herbicides. Others worry about groundwater contamination. Still more farmers and ranchers have seen the escalating costs of bringing new, less environmentally harmful chemicals to market and have witnessed the development of "super weeds" that are resistant to commonly used herbicides. Therefore, finding alternative weed control strategies remains of great practical importance.

In some ways, cultivating for weed control is almost a lost art. Herbicides seemed to work so well for so long that many farmers abandoned mechanical means of control. But now, with new implements and improved versions of the basic rotary hoes, basket weeders and flame weeders of 50 years ago, we are seeing improved efficiency and renewed interest in mechanical cultivation.

Farmers are employing many techniques to control weeds, including careful selection of crops in rotations, using cover crops to compete with and smother weeds and, of course, mechanical cultivation.

This book will provide you with information about how each implement works in the field in sustainable weed management systems. It also rates each tool's usefulness in certain conditions, what problems other farmers have identified with that tool and where to obtain more information.

First published in 1997, this revised 2002 version of *Steel in the Field* includes updated tool sources with World Wide Web sites, updated contact information for our list of experts and current tool prices. Thanks to SAN's Jennifer Butler for leading the revision effort.

You may want to travel to farms or research sites to see these implements in use. (See p. 118 for a list of experts.) We hope this book will help reduce the legwork in finding the right set of implements that works well on your farm.

After you read the book, let us know what you think! We've included an evaluation sheet on p. 123.

Andy Clark, Coordinator
Sustainable Agriculture Network
April 2002

# Contents

# Cultivation in Context: Renewed tools for better farming

## Spend less. Manage more. Take control.

Here's a deal for you. Invest in a few pieces of well-chosen steel, diversify your crop mix for higher-value marketing, and harvest a higher return to your bottom line through big savings on herbicide.

Interested? I thought so.

Keep in mind, whether you farm 1 acre or 1,000 acres, you can save in many ways—not just in dollars and cents. The tools and techniques you read about in this book will also pay off in less liability, greater management flexibility, less trouble with herbicide-resistant weeds and reduced off-farm environmental impacts.

Thinking about weed control changed dramatically in the years following World War II. Scientists working for the Allies developed growth-regulating compounds known today as 2,4-D and MCDA. When these chemicals "leaked" into the biological research community, it soon became clear they could be formulated to kill broadleaf weeds and not harm corn. These herbicides helped to reduce the need for cultivation and led to greater plant populations per acre. Check planting in wide rows of aligned hills (to allow cultivating across rows) gave way to drilled corn in narrower rows.

Herbicides, affordable hybrid corn seed and inexpensive nitrogen fertilizers opened new production frontiers throughout the '50s. The arrival in the '60s of atrazine and other herbicides that provided control for a wide range of weeds led to the wholesale abandonment of mechanical weed control (MWC) in some areas.

Tough-to-mount and painfully-boring-to-operate cultivators frequently became fencerow architecture. Farm-country cultivating skills and wisdom dwindled as herbicides simplified decision-making. Researchers can trace the origin of herbicide-resistant weeds, as well as "new" weeds, to the very areas where cultivation ceased.

However, mechanical weed control is still important to many farmers. While national aggregate sales of cultivating equipment slowly declined through the '80s and '90s, use of cultivators remains fairly common in scattered areas. Many farmers cultivate in some row-cropping regions of the Midwest and South. Vegetable farmers, especially in California, keep farmshop welders at work creating custom tools that fit their specialized needs. And ridge-till farming (see page 34) usually means at least an annual ridge-forming cultivator pass.

The current interest in mechanical and flame weed control tools as a preferred technology began long ago with farmers who decided—for a range of reasons—not to abandon their "steel" for herbicides. A few individuals never switched. Many contemporary tool users blend physical and chemical weed management modes. Some depend primarily on mechanical controls, using partial rates or "banding" herbicide in a swath just over the row area. Others use full broadcast rates and continue to cultivate to ensure top yields—or just because it feels right.

While the "other-than-herbicide" group of farmers has grown significantly in the past 30 years, it is still a distinct minority. Yet, out of necessity, these farmers have preserved weed management skills and developed sophisticated tools to produce crops profitably.

Steel used appropriately can cut herbicide costs. But an integrated mechanical tool approach wins in other ways, too. It deals effectively with herbicide-resistant weeds, perennial weeds in no-till fields, and soil types that respond positively to occasional tillage within a no-till system. Mixing in the optimum combination of tools and cultural weed management preserves the effectiveness of herbicides through limiting their use. When farmers bring together *improved* tools with all these factors, many find that an integrated, steel-based approach is their least risky, most profitable option.

There are even signs of a watershed in how mainline agricultural researchers will view the

weed control future. Orvin C. Burnside is a veteran weed scientist at the University of Minnesota. In 1993, he authored a perspective piece titled "Weed Science—The Step Child" (*Weed Technology*, Vol. 7, Issue 2, pp. 515-518). He wrote:

> Public weed scientists need to undertake a "crash program" to develop alternative weed control technologies that will be needed if herbicide use is reduced because of the economics of weed management, public concern, or government regulation. There needs to be a paradigm shift away from over dependence on herbicides that presently are our primary weapons in weed control.

Later, Burnside called for a systems approach using preventive, mechanical, cultural, biological, chemical and integrated strategies in his address to the North Central Weed Science Society's 1995 annual meeting.

If these professionals pursue research into biological and mechanical strategies as aggressively as they have herbicides, many farmers featured in this book are ready to help. These visionary, self-funded agriculturists have practical, farm-tested techniques to share and plenty of new ideas to test and refine.

Expectations of tillage have changed dramatically in 50 years. Farmers are under critical scrutiny from their neighbors and regulators to keep streams clean and topsoil in place. Yet, as they devote more management to meet rising environmental standards, farmers wonder how to find new ways to make their operation profitable.

To win acceptance in the '90s by farmers who know it only by its negative reputation, mechanical weed control has to show it can meet these challenges. This strategy has its own demands and limits, but also offers its own assurances. Through market incentives or crop diversification options, some operators decide that the benefits of not using herbicides justify the trade-off of mastering broader management skills. Other operators see well-managed herbicides and steel tools as equally useful and acceptable, and invest in learning how to fine-tine the combination.

## Facing the Questions

Sure, steel and flame tools can kill weeds. But can they become the foundation of a weed management strategy that works profitably across a range of conditions?

Inevitably, those new to mechanical weed control will ask some of these questions:

- Is it economically efficient?
- Is it as effective as herbicides?
- Is it dependable?
- Is it unwise, because of soil erosion, moisture loss or increased compaction?

The answers must be considered in light of each farmer's "big picture" approach to crop and soil management. No single tool will provide season-long, year-in/year-out success. But the same is true for herbicides. An appropriate selection of weed management implements can succeed as part of an integrated system with two fundamental requirements: **weed competition is suppressed and rows are straight.**

## CULTIVATION PAYS WELL

Farmer Ron Rosmann of Harlan, Iowa, works with the Iowa State University "weed team" of agricultural specialists. About his experience with an aggressive, high-residue cultivator and an electro-hydraulic guidance system, he says: "Over 14 years, assuming herbicide costs at $20/acre, after subtracting a $20,000 investment in cultivation equipment, I've saved $70,000 on herbicides. Look how long that initial investment can work for you, compared to herbicides you have to apply every year. ...Some bigger farmers think they don't have time to cultivate, but it's the net return that they should be looking at." ("Harlan farmer considers cultivation critical," by Elizabeth Weber, editor, *Leopold Letter,* Leopold Center for Sustainable Agriculture, Vol. 8, Number 4, Winter 1996, (515) 294-3711.)

Managing overall weed pressure includes making this year's crop more competitive against weeds and preventing weed seeds or reproductive tissue from building up in the soil. "Cultural management" steps of crop production include crop rotation, the timing of planting, the soil's biological health and soil physical quality, cover crops (varied rooting depth and soil environment), variety selection, and crop spacing to outcompete weeds.

Some growers achieve uniformly parallel rows with a traditional row-marker disk on an outrigger arm on their planter, while others turn to some type of guidance system. Consistent row alignment allows close-to-the-row settings and high speed. Straight rows and guidance systems change the whole economic picture of mechanical weed control—and how the driver feels by evening. They greatly increase how many acres per day your cultivator can cover, without increasing labor or cultivator costs. Close cultivation decreases how wide the herbicide band needs to be, and allows crop canopy to shade out weeds sooner in the season. Speed makes it easier to throw weed-smothering soil into the rows during late-season passes.

So, how about MWC—with straight rows and a handle on weed pressure—compared with current herbicide-only systems?

**Is MWC economically efficient?**

In the Corn Belt, annual herbicide costs (material, application and labor) in 1996 were in the area of $20 to $25 per acre for corn and $25 to $30 per acre for soybeans. An all-mechanical, no-herbicide approach might take two rotary hoeings (at about $2 each) and two cultivations (at about $4 each for a 6R30 unit—one covering six rows, 30 inches apart). That's $12 per acre, figured at $9.25 per hour for labor.

That total jumps to $22 per acre in dryland, contoured grain sorghum. Further, the "opportunity cost" of labor in critical times varies greatly.

Cost per acre also varies by scale. Agronomists at the University of Wisconsin estimated in 1990 that it cost $3.30 per acre for a farmer to rotary hoe once if the farmer had 100 acres of row crops, but only $1.65 if the farmer had 500 acres.

In mechanical and chemical systems, efficiency varies with weather, planting, crop conditions and the skill of the farmer. An emergency mechanical or herbicide "rescue treatment" can be significant. The unplanned trip will be efficient if it costs less than the yield loss that weeds would have caused.

A mixed approach holds the most promise for the most growers. Banding herbicides places the chemical in a limited-width strip over the row, usually 10 to 15 inches wide. A single herbicide application, banded preemergence, followed by a single late-season cultivation, can manage weeds as effectively as broadcast herbicide-only and with less than half the material, for less money and with reduced herbicide exposure to humans and the environment.

That's the assertion of Mark Hanna, an Iowa State University agricultural and biosystems engineer who led a four-year study. He says the mix would save an average of $9 per acre for Iowa corn growers, and should apply to wide-row soybeans as well. ("No-till study offers new incentive to cultivate," *Leopold Letter*, Vol. 8, No. 4, Winter 1996, Leopold Center for Sustainable Agriculture.)

In fields with moderate to heavy weed pressure with 10-inch herbicide bands, watch weed pressure closely. An earlier, additional cultivation may be needed to keep the crop competitive.

Dairy operators face excruciating labor demands at first cultivation because of haying. Ways to stretch out the cultivation window include staggered plantings of corn and soybeans to prevent large blocks from being ready at once, and diversifying into small grain or vegetable crops to further spread out the work load.

**Is MWC effective at controlling weeds?**

How about in-row weeds and escapes in the "guess-row" area between planter passes?

MWC must be part of a weed management system. Because it deals with biological observation, crop stages and implement adjustments, mechanical weed control is an acquired skill. Farmers say it is art *and* science. They report that effectiveness of an integrated, mechanical-based weed strategy increases over time. Sustainable soil management brings gradual improvements year to year, and farmers learn new techniques.

The total effect becomes greater than the sum of the parts—fewer weeds in more mellow soil are

out-maneuvered by synchronized crop rotations and disrupted by more expertly applied tillage or flaming. Close attention to fertility balance to lessen deficiencies and excesses gives crops more advantage. Narrower rows and precision seed placement increase the canopy effect.

In-row weeds deserve particular attention. Start early if you want to win. Management steps that hold weeds back in the days just after planting give crops a competitive advantage. When the crop is large enough to withstand soil flow, tools that move soil into the row can smother small, in-row weeds. This requires soil that "flows" and rows straight enough to keep cultivation speed high. Specialized in-row weeding tools developed originally for vegetables actually move between crop plants.

**Is MWC dependable?**

Wet fields, dry fields and schedule conflicts can hobble any weed control program. More options cover more contingencies. Sometimes cultivation can rescue a failed herbicide treatment. Other times a spot spray or postemergent herbicide pass can save a crop that remains too wet to cultivate.

Experienced farmers committed to mechanical weed control report they are no more vulnerable to **economic losses** from weeds than their neighbors with well managed herbicide programs. Some years they even fare better, but they would have a harder time guaranteeing a cosmetically perfect field, year after year.

Having the tool and labor capacity to cover crop acres within tight windows is a matter of weighing the odds then making a choice. Keep careful records on acres per day per tool and on hours per field. Figure the total time required compared with your average weather window. Scaling up tool capacity has to be a part of taking on more acres of the same crop with similar planting dates. Sequencing planting dates or changing crops are other options.

Wet years will come, but they don't have to doom mechanical controls. Once you decide how small a cultivation time window you're willing to work in, line up tools and drivers for the critical times. Emergency decisions are eased if you know the limits of your tools and the relative costs of weed-induced production losses. Marketing plans, weed characteristics and alternate crop use all play a part.

**Is it unwise?**

What about soil erosion, moisture loss or increased compaction?

Poorly managed tillage can cause these problems, as well as waste fossil fuel and harm crop growth. Mistakes include using the wrong tool or using the right tool at the wrong time, too often, in the wrong way, in the wrong place or at an improper orientation to field slope.

The general rule for MWC tillage is that it be as **shallow,** as **infrequent,** as **specific to the weed** problem, and as **limited in soil impact** as possible. Where following these guidelines still results in muddy water, dry root zones, damaged crop roots or compacted row areas, MWC is not appropriate as applied. You may seek assistance from an individual in your region or specialty from the "Contacts" list on page 118.

You make the difference by selecting the right tool and using it wisely. Occasional tillage—even moldboard plowing done properly—can actually decrease erosion by increasing moisture infiltration rates.

Cover crops, compost, manure and other organic matter incorporated into biologically active soil bring measurable changes. Properly managed, additional organic matter can increase infiltration and water-holding capacity, thereby reducing erosion potential.

A cultivation pass before a rain shower will have less impact where soil has greater tilth and soaks up more water. The same tool used the same way across the road on "tighter" soil will create channels and probably lead to more erosive water movement.

Where soil moisture is usually marginal, soil and residue disturbances should be minimized. Local soil types, precipitation patterns and crop systems give specialized weeding tools a role. Cases include shattering the soil crust after planting but before crop emergence, or intentionally creating a slightly compacted zone just under the soil surface to retain moisture.

A controlled traffic field plan (running equipment wheels in the same row middles season to season), using deep-rooted rotation crops and staying out of the field in wet conditions help to minimize compaction.

## Maximizing The Benefits

MWC that works offers clear advantages for sustainable farming. These include four opportunities.

**Develop weed control customized to your farm.** Remember, tools are only part of a site-specific, self-sufficient system. Their highest use comes mixed with years of on-farm observation of your soils, crops and weather. Start where you are, learning from other farmers with related tools, crops, soils, weeds and farming goals. As you work with more of these variables, your system becomes more flexible and more adapted to your farm—in sum, more site-specific and more sustainable.

**Reduce annual expense for consumable purchased inputs.** Yearly costs for herbicides can be reduced as tool use increases. Most weed tools work years after they're paid for. Spray equipment does, too. Herbicides you buy every growing season.

Reasonable maintenance and appropriate use lets you run cultivators for many seasons. Sweep wear is gauged in thousands of acres, with replaceable blades minimizing the new steel needed for a clean cut. Moving parts in some weed tools increase soil action as well as maintenance needs, but still give long service.

**Mesh weed management with crop rotation and soil tilth improvement.** Tillage that replaces herbicides uncouples crop selection from any limits of chemical carryover. This freedom maximizes cropping opportunities. It increases options when you are re-planting an alternative crop in the event of a crop failure or a weather catastrophe. You can interplant crops or use narrow-strip tillage of several crops without concern about herbicide drift causing damage.

Adding small grains or forage crops to a rotation reduces the size of the niche for annual weeds by shifting the seasonal opening for weed growth. Plus these crops can add biomass to the soil when residue is unharvested. Pre-plant tillage can serve dual purposes of incorporating covers and preparing a seed bed. Rotating warm- and cool season crops is another way to put weeds on the defensive.

Innovative farmers are exploring no-till planting into cover crops left on the surface. These operators use chemical or mechanical means to kill covers, then plant seed or vegetable transplants with tools that create openings just big enough for the job. This route suppresses weeds, preserves moisture and creates habitat for beneficial insects. Carefully incorporating sufficient cover crops with tillage can significantly improve soil water retention, which reduces surface run off with its erosive tendency. Extra organic matter added over time also increases a soil's tendency to flow better when tilled because it becomes more granular and less cloddy. Covers can suck up moisture as they mature, which can be a problem in dry years.

**Profit from new, high-value markets for non-chemically produced crops.** A MWC-based, non-herbicide system often offers relief from pesticide applicator's licensing; incurring new environmental liability from chemical surface runoff, groundwater contamination or spray drift; health risks to applicators or family members; and any accidental contact with livestock or non-target crops.

Opportunities are increasing for food crops grown under more ecologically sustainable management. More buyers—local, regional and national—pay premium prices for vegetables, fruits and grains grown under integrated pest management systems, or even from fields that receive no herbicides for the current cropping season. Organic dairies need grains and hay—and prefer them to be regionally grown. Exporters need high quality, specially grown grains and soybeans for customers in Europe and Japan. Local food buyers, from families to restaurants, seek out vegetables, grains and livestock raised in ways that seem to be more ecologically safe.

Even without a market that rewards a shift to lower pesticide use, you gain a positive conversation starter with consumers and neighbors. You have new chances to win support for your farming operation from local non-farmers interested in environmental issues. Explain the alternative measures you're taking to produce profitable crops. Highlight the extra effort you give to understanding your farm's complex ecological balance.

Every farmer has a unique range of skills, economic situations and natural resources. Choosing the most sustainable mix—for weed management and for an overall, whole-farm approach—is a privilege and a responsibility that should stay as close to home as possible. When your tools fit your system, you're the one in charge.

# ABCs of mechanical and cultural weed management

In a sustainable farm plan, each type of implement is only one part of a long-term weed management strategy. Any tool will disappoint when it's asked to do more than it was designed to do. A successful strategy distributes weed-limiting and weed-killing roles into complementary parts. The benefits of crop diversity and soil improvements in lowering weed pressure increase over time. This trend lessens the economic hit when weed control steps face difficulty.

Critical principles of sustainable, integrated weed control using steel or flame include:

**A. Give the crop the advantage.**
Steel tools succeed best when you focus on weed prevention, lessening the vigor and number of weeds that need to be killed. Delayed planting is a key here. Crops germinate quicker in warmer soil. They spend fewer days in the ground before they begin to outgrow weeds or form a shady canopy that sets back weeds.

Intensive, early season weeding is a second distinguishing feature of a system based on mechanical weed control (MWC). It keeps crops ahead by hitting weeds as soon after germination as possible—long before they are a physical threat to the crop. Causing weeds to die by physical means (tearing, cutting, root drying or flaming) is much easier and more efficient when the weeds are tiny and vulnerable. By the time they threaten the crop with shading and competition for soil moisture and fertility, they are much more difficult to kill with cultivation. Postemergent herbicide application gives a little more leeway.

**B. Keep weeds on the defensive.**
Weed seeds wait each spring for heat and light to induce germination. Don't wake them up unless you have a way to take them out.

Several farmers in this book describe their version of a "stale seedbed." (See stories about Jim Cavin, Rich de Wilde, Carmen Fernholz and Paul Muller.) They do one or two shallow tillage passes to stimulate germination of surface weed seeds before crop-planting time. Irrigation or warm, moist soil conditions spur weed seed germination that triggers a control pass with tillage or flame. By minimizing subsequent tillage at planting that would stimulate new weed seeds, the crop comes up through pre-weeded soil.

Any planter can be less of a weed-helper if it is tooled to leave soil as loose as possible over the seed row, while still creating good seed-soil contact. Packer wheels at the surface press light-stimulated weed seeds into moisture. Ridge-till planters move fresh weed seed from the rows by skimming the top inch or so of topsoil from the row to the middles, where cultivators can attack weeds more easily.

Your crops can out-compete weeds through well-planned crop rotations. Manage the crop sequence to minimize ecological openings for weeds. Mix crop rooting depth, root type (taprooted or fibrous), and seasonal surface cover. Vary the timing and depth of tillage. In mature, sophisticated rotations, crops emerge in ideal conditions while weeds struggle to find an opening to survive.

**C. Accept weeds that don't really matter.**
Separate how you *feel* about weeds in your fields from their potential to diminish production. Agronomically, weeds are an economic problem only if they decrease yield—now or in the future—by more than the cost of managing them. If the aesthetics of a clean field are important, you need to be honest about the extra cost.

Weed species vary in how much of a threat they pose to crop vigor. Some winter annuals provide soil protection. Some annual weeds in forage crops provide nutrition for livestock or abundant residue to build soil. Weeds that don't go to seed in a cover-crop stand count as biomass to soil microbes and warrant only your watchful eye.

"Eradication of all weeds is a virtual ring in the nose of farmers," claims organic farmer Terry Jacobson of Wales, ND. That goal can tempt farmers to over-control with chemicals or excess tillage, he says.

Jacobson wants to learn more each season about weeds. He wants to know which ones he can live with, which ones are worth containing and which ones are telling him where he needs to make improvements in crop or soil management. ■

# How to Use This Book

A single tool can be used in many ways. So don't be limited by this book's presentation of tools in three general sections by cropping system:

**Agronomic row crop tools** (for corn, soybeans, grain sorghum and cotton) include broadcast tillage implements for early weed control, and tools that work between the rows as crops mature.

**Horticultural crop tools** include implements for bedded vegetables and for in-row weeding between plants or trees.

**Dryland crop tools** control weeds efficiently in vast fields while managing residue and conserving moisture during the fallow times between cropping periods.

Each section has two parts: **"The Tools"** (technical information on each of its featured tools) followed by **"The Farmers"** (narratives illustrating how farmers fit tools to their conditions).

The technical sections, outlined in detail below, feature drawings of important design elements. You learn here—at a glance—the *facts* of the tool. In their narratives, farmers explain how they integrate tools with the other parts of their weed management system—planting time, soil building, crop rotation and tillage mode. They provide you with the rest of the story—the *art* of the tool. Selecting the right technology is only part of the equation. A tool's wise use and adaptation to each farm are at least as important in making it part of a sustainable system.

### The Tools

Two **bar graphs** begin the full-page entries. The top bar shows the estimated crop height range where the tool is most effective. The lower bar shows the estimated height range of weeds that the tool can handle.

The intensity of shading within the bars indicates the degree of certainty of the recommendation, i.e. the darker the shading, the more sure the effect. *These are general guides reflecting a range of experiences. Actual effectiveness will vary according to your conditions and operating methods.*

A tool **overview** summarizes how a tool works, its roles and important applications for weed management.

In **design features,** the mechanical and engineering highlights of the tool's shape, components and features are detailed.

Under **model for comparison** is a particular size of the tool—in some cases specifically outfitted—that is used for price comparison between makers. The 2001 list price figures were submitted by participating sources who also provided average PTO horsepower and field operating speed.

**Width range, all makers/all models** shows the widest and narrowest of all versions of a tool offered. **Sources** lists the reference number of commercial contacts found in "Tool Sources" at the rear of the book. **Farmers** shows where to find the tool described in a farm narrative. Some tools were not used by any of the interviewed farmers.

### The Farmers

Each farmer's narrative opens with general information about farm size, crops, soils, tillage style and cropping systems. **Weed management highlights** show the cultural steps and the tools used by the farmer. **Boldface type** highlights each farmer's first description of a tool that is illustrated in the Technical Section.

### The Toolshed

**Farmer sidebars** add details to the narratives. **Reviewers** lists experts whose advice improved this book. The **Glossary** provides working definitions for tool-related terms. **Horticultural tool sources** includes contact information for specialty tractors suitable for cultivating (high clearance, offset fuselage, rear motor, light frame). **Publications and information** tells you how to learn more. **Contacts** gives ways to reach individuals willing to share of their knowledge.

**Tool Sources** is a numbered listing of tool manufacturers, North American distributors of foreign tools, and regional suppliers. The index lists tool text references, tool illustrations, farmers, tool parts, weeds varieties, tillage modes and cropping practices. ■

# I. Agronomic Row Crops

## The Tools

A flexible combination of tools, timing and technique to suppress early season weeds is the foundation of an integrated row-crop weed management program. Broadcast weeding tools, used in conjunction with cover crops and primary tillage, offer an alternative to herbicides at planting to control weed competition.

Rotary hoes, flex-tine weeders, spike-tooth harrows and rolling bar baskets all provide shallow, thorough stirring of the soil that kills sprouting and emerging weeds the full width of the tool. The action knocks soil from weed roots, causing them to die. Control is best when field conditions are hot, dry and sunny.

Flame weeding just prior to and just after crop emergence is also effective in establishing early control in some crops. Of the entire group of broadcast tillage or flaming tools, only specially designed rotary hoes work well in fields with appreciable crop residue.

Post-plant treatment for weed control *before crop emergence* is a delicate, time sensitive maneuver. It depends on the ability of an implement to kill surface weeds without mortally disturbing the germinating crop. For pre-emergent treatments to be effective, the crop must be planted deeper than the working depth of the broadcast tillage tool. Postemergence, the crop must be more firmly rooted than competing weeds to survive the weeding pass.

Years of crusted spring soils boost rotary hoe sales. In these times, the tool's flicking and shattering of soil particles to kill weeds takes second place to its ability to aerate a rain-packed soil surface. Extra weight helps crust penetration but makes gauge wheels a necessity. A pair of these supporting tires, one under either side of the rotary hoe toolbar, maintains even penetration by the hoe points. On rough fields, the tires prevent gouging by the hoe wheels on one end of the toolbar.

Rotary hoes are not good weeders in tilthy, soft soils. In these conditions, the dragging action of soil-stirring harrows and tine weeders tend to be more effective.

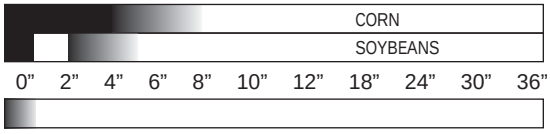
The rotary hoe is an effective and efficient tool within a sharply limited window of weed size. Once weeds form true leaves or you can see them while driving by from your tractor seat, many will survive. Doubling back to cover the same field a second time—in the same or opposite direction immediately, or in several days when re-rooting of weeds begins—often boosts effectiveness if weed pressure is strong, residue interferes, or cloudy, humid conditions slow weed kill.

Crops at large vary in their tolerance of rotary hoeing, with species having a strong but flexible center stem surviving best. Row crops—and even tomatoes—can survive rotary hoeing at 8 to 12 inches tall if an emergency pass is needed to control small weeds before a cultivator is available.

**Note:** This book presents tools in three categories by crop type where they are commonly used. Many tools are employed effectively in diverse systems. The farmer narratives show how the same tool works well in different crops and for different purposes.

# Standard Rotary Hoe

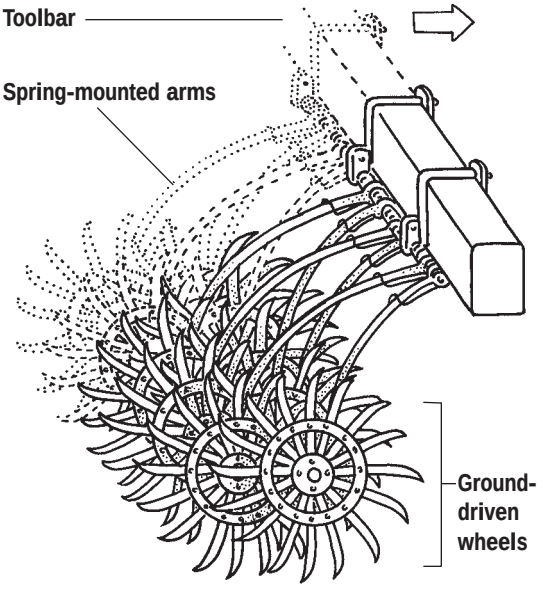
CROP height range estimate (must be large-seeded)




WEED height range (annuals) estimate

suitable  less suitable  unsuitable

Match tillage timing, depth and location to crop root growth. Weed control varies with soil conditions and weed density.




**Overview:** In clean-tilled or low-residue fields, the sharp-edged, rounded teeth on rotary hoe spokes aggressively uproot weeds in the pre-emergent, white-root stage. Hoes work before or after crops are up, as long as crop seed is more deeply rooted than weeds and crop tissue damage is not too severe. Rotary hoes are used for “broadcast” cultivation, i.e. lightly tilling their full width at 1" to 2" deep without regard to crop rows. Faster speed enhances surface aggressiveness but decreases penetration. Rotary hoes have a vertical entrance and surface shattering action ideal for aerating crusted soils. Increase corn seeding rate about 2 percent per intended mechanical pass to compensate for possible plant population reductions.

**Design Features:** Curved steel spokes radiating as a flat wheel from a hub are rotated forward by ground contact. The curvature accelerates the exit of a tooth tip from the soil, sharply kicking up soil and weeds. Rigid or folding toolbar; 18" to 21" wheels; 16 teeth per wheel; wheels on 3.5" centers. One or two wheels per arm, with most models using down-pressure springs for consistent penetration on uneven surfaces. **Cautions:** worn tips greatly decrease effectiveness. Replace worn hub bearings as needed for smooth operation. Bolt attachments, rather than rivets, makes bearing replacement easier. Residue, corn rootballs, stones, sticks and plastic can plug wheels. Adding knives to cut residue or increasing spacing between wheels can improve performance in these conditions. (See next page.)

**Options:** Gauge wheels (recommended); extra down-pressure springs for crusted soil. (Other options for extending hoe use are described on the next page.)

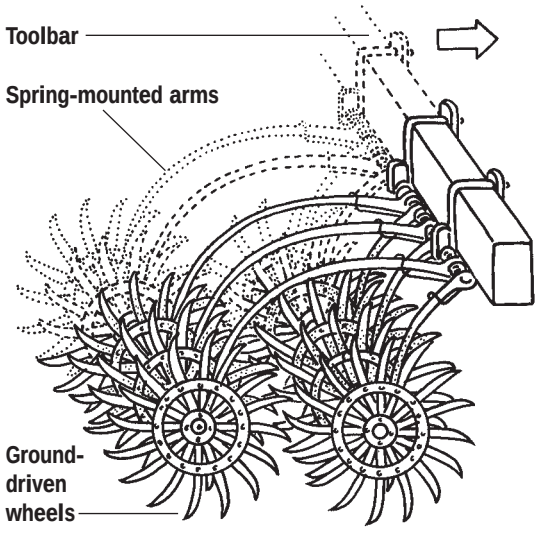
▶ **Model for comparison:** 21', rigid-frame
**Rec. PTO HP:** 75 to 90  **Speed:** 5 to 15 mph  **List price:** $4,700 to $6,100

**Width range** (all makers/all models): 10' to 42'

**Sources:** 14, 18, 21, 68, 86
**Farmers:** Berning, Cavin, de Wilde, Fernholz, Kenagy, McKaskle, Spray

**TIPS:** Don’t hoe bean crops from the brittle “crook” stage to three days later. Don’t expect a rotary hoe to kill green weeds—they’ve usually developed too deep a root system.

# High-Residue Rotary Hoe




**Working ranges same as for standard hoe**

**Overview:** Same operating principles as standard rotary hoe (previous entry), but works in fields with up to 60 percent residue *as long as teeth still are able to penetrate into the soil surface.* Optional knives and spacers help to cut residue and reduce plugging. (See below.)

**Design Features:** Greater clearance for residue flow than standard hoe; built with more distance between front and rear wheels as well as between the toolbar and soil surface. Wheels are self-cleaning.

▶ **Model for comparison:** 21', rigid-frame
**Rec. PTO HP:** 80 to 100 **Speed:** 5 to 15 mph **List price:** $5,700 to $6,330

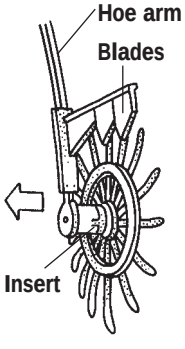
**Width range** (all makers/all models): 15' to 41'

**Sources:** 18, 86 **Farmers:** Erisman, Thacker, Thompson

# Rotary Hoe Accessories

### Bearing Protector and Residue-Knife Kit

**Overview:** An insert extends the wheel axle, moving each wheel closer to the adjoining arm where two stationary sickle-bar mower blades shred residue brought up by wheels.




**Design Features:** Allows hoeing in heavier residue.

**Price:** $25 per wheel unit.

**Source:** 21,36

### Replacement Tooth Tips

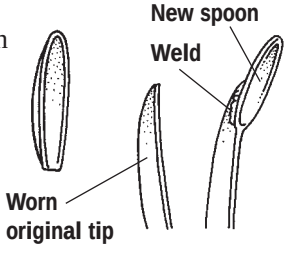
**Overview:** Weld-on "spoons" restore aggressive soil penetration after original teeth wear down.

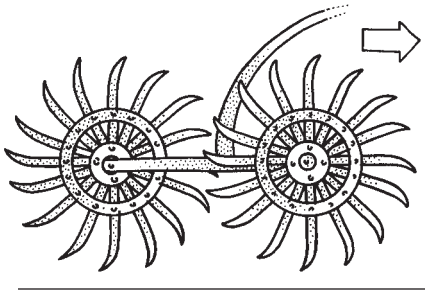
**Design Features:** Rolled steel: 0.75" wide, 0.12" thick, and 2.37" long. Weld freehand or with jigs.

**Price:** $1.75 per spoon ($28 per wheel).

**Source:** 86

**Farmer:** Spray



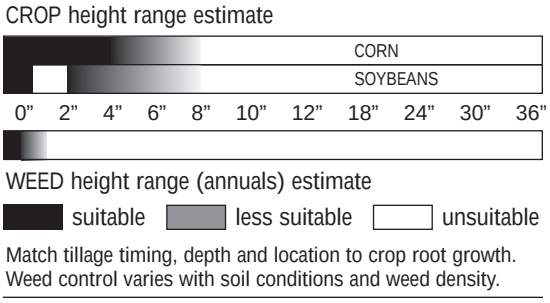
**Extender Arms** (for Deere Rotary Hoes)

**Overview:** Doubles rocker-arm length to improve residue flow, allowing operation in heavier residue.

**Design Features:** Sets wheels so that wheels self-clean.

**Price:** $14.56 per arm. **Source:** 21, 86

# Flex-Tine Weeder



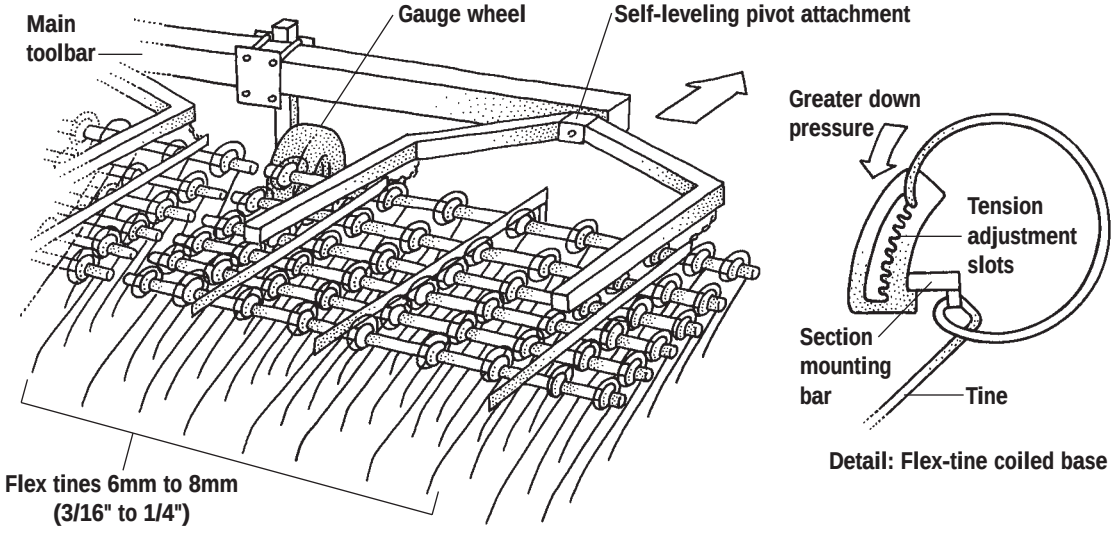

**Overview:** Spring wire tines scratch the soil surface to uproot tiny weed seedlings. Up to 25 tines per toolbar foot are mounted in a staggered fashion on three or six mounting bars, resembling the layout of a spike-tooth harrow. The bent tines vibrate rapidly and glide around or over obstructions. A tine weeder works in loose or lightly crusted soil with no long-stemmed residue. When used postemergence, crops must be well-rooted. Excellent within its limits for high speed, preemergence and early postemergence broadcast weeding. Stiffer tines break through heavier crusts but lose some of their vibrating action.

**Design Features:** Coiled-loop or other spring mounting may allow five to nine position tension adjustment. This tensioning, tine diameter selection (sized 6mm to 8mm, or about 3/16" to 1/4"), three-point hitch height and gauge wheel setting combine to determine degree of soil penetration. Many makers allow individual tines to be raised up over crop rows while other tines are down for inter-row, postemergence cultivation. Well suited for cultivation of hilled crops such as potatoes, as tines can be adjusted to follow contour of field. There are many brands of weeders in Europe, where the tools are often used in small grains or to incorporate cover-crop seed. Frame clearance of 14" to 18" varies with tine length.

▶ **Model for comparison:** 10' wide, or maker's smallest model
**Rec. PTO HP:** 30 **Speed:** 4 to 8 mph **List price:** $1,800 to $2,940

**Width range** (all makers/all models): 50" to 45'
Larger models, 30' to 45', overall average $6,600

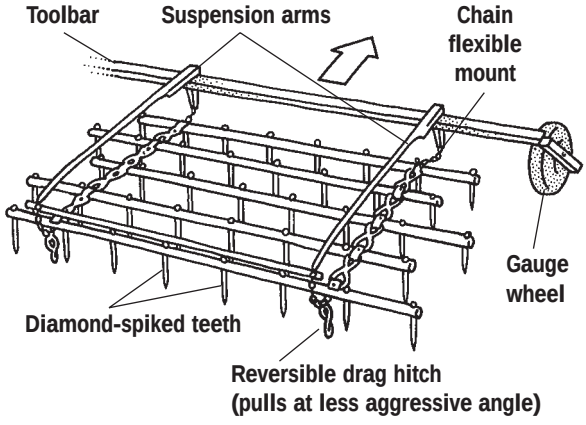
**Sources:** 39, 48, 53 **Farmers:** Chambers, deWilde, Haines, Reeder



# Spike-Tooth Harrow

Crop, weed ranges similar to flex-tine weeder.

**Overview:** Pointed metal spikes stir soil to a depth of 1" to 1.5". For weeding, works much like a rotary hoe or flex-tine harrow (See "Harrows and hoes to the rescue," below.) Used widely for seedbed preparation.




**Design features:** The high-carbon steel spikes (0.5" or 0.62" square, about 8" long) are set to run corner-forward as a diamond, and are bolted into "bars" of round pipe or square tubes. Five to nine bars in sequence pull about 10 teeth per running foot through the soil. Some units are reversible: one direction sets teeth nearly vertical for cultivating and deeper penetration, the other direction lays the teeth almost flat for a leveling action. Other units have a handle for adjusting the angle from 10 to 85 degrees.

▶ **Model for comparison:** 33' trailer type, flexing bar brackets
**Rec. PTO HP:** 80 **Speed:** 5 to 10 mph **List price:** $4,680 to $5,200

**Width range** (all makers/all models): 4' to 76'

**Sources:** 31 (spreading-action tine), 33, 44, 45, 56, 64 **Farmers:** Erisman, Spray

## HOES AND HARROWS TO THE RESCUE

Flex-tine weeders, spike-tooth harrows and rotary hoes can be set so that they perform shallow tillage weeding about the same as each other in non-crusted soils. But in heavily crusted soil, flex-tines may not penetrate at all and the harrows can dislodge then push soil chunks with weeds intact, damaging shallow-rooted crops.

In North Dakota, research with 20 crops showed the rotary hoe and a light spike-tooth had about the same impact on crops. Use was preemergence at crop-specific times then again at about two weeks after planting.

Both tools work preemergence in small grains until shoots (coleoptiles) reach the tillage zone depth of 0.5" to 1". They can be used postemergence after grains show their first true leaf through the 3-leaf stage. Later use will inflict yield-reducing stress on the crop. Postemergent use is not recommended for amaranth, canola, crambe, mustard and oats. Stand reduction occurs in buckwheat, flax, lentils and proso millet. Stand reduction is possible in safflower.

In general, a one-pass mechanical treatment followed by weed scouting and a species-specific, reduced-rate herbicide can provide suitable weed management at the same or lower cost as herbicides alone, according to agronomist Greg Endres of NDSU. For a 1997 chart listing mechanical weed control recommendations for 21 crops, write "Harrow List," NDSU/Carrington Research Extension Center, Box 219, Carrington ND 58421, fax (701) 652-2055.