PEST CONTROL: HERBACEOUS WEEDS

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Keywords: Mechanical control, biological control, Integrated Weed Management (IWM), cultural control, agriculture, weeds, pests.

Contents

Summary

Herbaceous weeds that are not controlled can cause substantial reductions to crop yields as well as negatively affect crop quality regardless of the production system and geographic location. The management of herbaceous weeds in agricultural production is thus necessary and can be laborious, time consuming, and costly. The management of weeds in these systems is currently achieved through the use of a number of strategies including cultural (managerial), mechanical, biological, chemical, and a combination of these methods. This review provides information on our current knowledge and understanding of the impact of largely non-herbicidal strategies for managing weeds in crop production systems and offers insight into future prospects for each of these tactics.

1. Introduction

The control of herbaceous weeds (hereafter referred to as weeds) in agricultural production systems has been a main concern of farmers since the earliest days of agriculture. Weeds represent the most economically serious pest complex reducing world food and fiber production. Regardless of the cropping system used or agricultural region of the world, effective weed management strategies are constantly being sought to maintain crop yields and crop quality as well as reduce the deleterious effects of weeds in subsequent years. This on-going quest to optimize weed management strategies is largely due to the apparent ability of agricultural weeds to adapt to all agronomic systems.

The control of weeds in crop production areas of the world was carried out primarily by manual and mechanical means before the appearance of the first hormonal herbicides in

Europe and North America in the early 1950s. Although manual, cultural, and mechanical control of weeds are still mainstays of crop production practices in many developing regions of the world, weed control efforts in industrialized regions have been heavily dependent on the use of synthetic herbicides. The wide adoption of herbicides in these areas has been due to several factors including their greater efficacy compared with most alternative methods, ease of use, and relatively cheap cost. However, the dramatic rise in the appearance of herbicide-resistant weed biotypes over the last decade (currently a total of 273 biotypes have been identified from 59 different countries), increasing herbicide costs, and long-standing concerns about the environmental and human health effects of herbicide use, have increased suspicion about the effectiveness, safety, and sustainability of this heavy reliance on herbicides.

Weeds are a serious threat to the sustainability and profitability of agricultural production around the world. Crop yield losses from weed competition can be substantial and depend on several factors including, crop and weed species present, timing and duration of competitive interactions, and resource availability. Worldwide, it is estimated that a 10% loss in agricultural production can be directly attributed to the competitive effect of weeds despite their intense control within most crop production systems. Yield losses in rice systems of West Africa have been reported to range from 28 to 100% if weeds are not controlled, with the greatest reductions occurring on nutrient impoverished soils.

The control of weeds in agricultural production is estimated to cost the United States (USA) economy more than $15 billion annually, which surpasses the combined costs of controlling diseases and insect pests. Herbicides constitute 85% of all pesticides applied annually in the USA. Nearly all (greater than 95%) of the corn and soybean acreage in the USA receives herbicide applications. Left unchecked, weeds cause dramatic reductions in food production that eventually can destabilize economic and social systems. Hence, there is an urgent need to develop and refine weed management strategies in agricultural production that are effective, safe and economically viable.

The overall objective of this paper is to review current knowledge and understanding of the impact of largely non-herbicidal strategies for managing weeds in crop production systems and to provide insight into future trends for each of these tactics.

2. Review of Current Management Strategies

2.1. Cultural Control

Cultural weed control includes a large and diverse group of tactics whereby weed populations are managed through the design of the cropping system. Cultural weed control procedures include crop rotation to disrupt weed life cycles, integration of livestock grazing into cropping systems for reduction of weed biomass and prevention of seed set, irrigation and fertilization practices that direct resources to the crop rather than the weeds, and increased crop competitiveness through dense planting, adjustment of row spacing, use of competitive cultivars and choice of planting times that favor crops relative to weeds. Although any one cultural tactic is unlikely to effectively control all weed problems by itself, the cumulative impact of multiple tactics acting on different stages of the weed life cycle can potentially reduce weed populations substantially.

Crop rotation improves weed management both by disruption of weed life cycles and by allowing opportunities for use of a wider range of herbicides than are possible with continuous monoculture. The most effective rotations for managing weed populations include crops that differ in planting and harvest dates, competitive ability and management practices. For example, the traditional practice of rotating grain crops with clean cultivated row crops like sugar beet decreased weed density in the grain crop and increased grain yield. Since annuals are rarely able to set seed in a forage crop, the seed bank of annual weeds tends to decline during the sod phase of rotations that include perennial forages. Similarly, spring germinating annual weeds face severe competitive pressure from a fall sown cereal crop, while fall germinating species are usually killed by seedbed preparation for spring planted crops. Crop rotation also facilitates variation of herbicide mode-of-action, thereby avoiding buildup of species resistant to any given herbicide.

Grazing animals can be used to destroy weeds before or after crop planting. They can also be used to suppress competing vegetation in orchards and young forestry plantations. Manipulation of timing, type of grazing animal and stocking rate can be used to control weeds in pastures.

Substantial improvement in the competitive balance between crops and weeds can be accomplished by careful timing and placement of fertilizer and irrigation water. Because weeds tend to have smaller seed reserves, and more rapid nutrient uptake than crops, delaying application of part of the fertilizer until the crop is established tends to starve weeds and favor the crop. For example, delaying half the application of NPK in pot experiments can reduce weed biomass by as much as 50% while increasing maize biomass by as much as 70%.

Similarly, delayed fertilizer application can improve rice production in fields heavily infested with barnyardgrass (*Echinochloa crus-galli*). Placing fertilizer in a deep band next to the crop row directs a larger percentage of the nutrients to the crop relative to broadcast fertilization. In Denmark, greater than 50% reduction in weed biomass and a 28% increase in barley yield have been reported when fertilizer was banded instead of broadcast. Also, the biomass of annual weeds in tomatoes irrigated by subsurface drip irrigation without herbicides was as low or lower than in furrow or sprinkler irrigated tomatoes that received napronamide and pebulate. Releasing the water deep in the soil profile kept the surface soil too dry for weed seed germination.

An extensive literature has demonstrated that weeds decrease with increased planting density. Theory indicates that weed growth should also decrease with more uniform spacing, and this is reflected in a slight majority of field studies. For example, increasing spring wheat planting density by 50% relative to the usual rate and changing from 13 cm rows to a square-grid sowing pattern can result in a 60% reduction in weed biomass.

Use of competitive crop cultivars that either suppress weed growth or tolerate the presence of weeds is another means for improving crop yields under weedy conditions. Unfortunately, characteristics that confer competitiveness, like tall stature, sometimes conflict with those that confer high yield, such as high harvest index. Nevertheless, recent work has shown that competitive ability differs even among high yielding cultivars.

Although the potential for breeding competitive crop cultivars is great, few studies have actually attempted to breed for crop competitiveness. Other methods for enhancing the competitive ability of crops include use of transplants rather than direct seeding, for example in tomatoes and rice, and use of planting dates that maximize early crop growth rates.

Understanding of the ecological processes underlying cultural weed management tactics remains limited. For example, studies of the effects of crop rotation on weeds are relatively few, and most of these have not provided the detailed information on weed population dynamics that is needed to explain divergence in composition and weed density between rotation treatments.

With regard to weed management through manipulation of crop nutrition, an important emerging area of research involves comparison of the effects on weed-crop competition of mineral versus organic sources of plant nutrients. For all cultural weed management procedures, much work is needed to adapt methods to particular regions and even to particular farms.

Cultural management is a knowledge intensive rather than input intensive approach that can be facilitated by improving the ability of farmers to learn through systematic experimentation with their cropping practices.

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Biographical Sketches

Antonio (Toni) DiTommaso is an Assistant Professor of Weed Science in the Department of Crop and Soil Sciences at Cornell University. He received his B.Sc.(Agr.) and PhD degrees from McGill University in Montréal, Canada and his M.S. degree from Queen's University in Kingston, Canada. His research focuses on the seed biology/ecology and population dynamics of weeds from both cropping and non-cropping systems, biological weed control, and integrated weed management. He is co-author of the bilingual English/French educational CD weed guide *Weed Identification, Biology and Management*. He has served on numerous regional, national, and international weed science society committees and boards.

Charles L. Mohler received a B.A. in biology from University of Oregon and a PhD in ecology from Cornell University. His early career addressed the quantitative study of forest composition and the population dynamics of succession. Since 1986 his research has related primarily to the ecology of agricultural weeds and ecological methods of weed management. Most of this work has focused on the effects of tillage, cultivation, and crop residue on the population dynamics of annual weeds. He is coauthor with Matt Liebman and Charles Staver of *Ecological Management of Agricultural Weeds*, which was published in 2001 by Cambridge University Press. He is currently an Associate Editor of the journal Weed Science.

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