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Teaching/Education

Experiential Learning Activities in the Weed Science Classroom

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Considerable discussion has occurred among the weed science community regarding the potential benefits and limitations of integrated approaches to crop and pest management. This discussion also needs to occur in our weed science classrooms, where students from a wide range of academic disciplines are trained in the fundamentals of weed ecology and management. Although the inherent complexity of integrated crop and pest management can make this adaptation to our weed science courses challenging, the use of experiential learning techniques provides an effective means to promote understanding and retention of these concepts. This paper outlines several classroom activities based on the experiential learning approaches that have been implemented by the authors. The activities focus on (1) weed identification and natural history, (2) weed population processes, and (3) integrated management systems. For each activity, we offer our rationale for the exercise, an example of its implementation in the classroom setting, potential pitfalls, and student feedback regarding their perceptions of the activity's educational value. With this paper, we hope to provide examples that may be useful to other weed science educators wishing to incorporate more experiential learning activities into their courses and to initiate a dialogue between educators that can help our community improve and enliven weed science education.

Additional index words: Education; teaching; weed identification; integrated weed management; herbicide-tolerant crops; agricultural systems.

There has been a growing discussion on the benefits of integrated approaches to crop and pest management among the weed science community in recent years (Buhler 1999; Buhler et al. 2000; Cardina et al. 1999; Elmore 1996; Hall 1995; Swanton and Murphy 1996). Typically these discussions emphasize that integrated weed management (IWM) promotes the combination of numerous management strategies, such as improved crop competition, soil and crop fertility, and crop rotation, with mechanical and chemical weed control strategies to reduce weed interference in a way that is both economical for the farmer and environmentally and socially acceptable. Ideally, IWM considers the management of weeds in the context of other management issues (i.e., it is multidisciplinary), as well as balancing the long- and short-term trade-offs and implications of management tactics. For IWM to realize its full potential, a focus on weed science principles such as weed population dynamics and weed–crop–soil interactions is needed to provide a foundation for the development of new management strategies, and to facilitate more efficient implementation of existing control measures (Buhler 1999). The emphasis on IWM that has occurred in weed science research also needs to be mirrored in our weed science classrooms, where students from a wide range of disciplines are trained in the principles of weed biology, ecology, and management. Promoting a mechanistic understanding of weed ecology and management will allow students to apply these concepts to the multitude of situations they are likely to encounter in the future.

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In addition to modifying the content of our weed science classes to give students a broad understanding of weed management issues, the presentation style of course material has a profound effect on its relevancy and retention with the students (Davis 1993). Although the traditional lecture-style delivery of course material may be the most efficient with respect to time and effort of the instructor, this approach does not necessarily result in a comprehensive understanding of the course material, or in the students' ability to apply their knowledge to another set of circumstances. As an alternative, the experiential or active learning approach can provide a more satisfying and meaningful experience for both students and instructors. Experiential learning integrates fact-based knowledge with (1) concrete experiences, (2) reflective observation, (3) abstract conceptualization, and (4) active experimentation (reviewed by Atherton 2002). A major advantage of experiential learning is that it accommodates to students' different learning styles. Some students excel at fact-based learning, whereas others prefer to reflect or conceptualize. Likewise, students that may not do well in a typical classroom setting may be adept at hands-on experimentation. Although each experiential learning activity would not necessarily contain all four components outlined by Atherton (2002), having a suite of classroom and laboratory activities that emphasize these components of the experiential learning process would likely be the most practical and effective means to adapt this concept to a weed science curriculum.

This paper outlines several experiential learning activities that have been used in the introductory weed science classes at Washington State University, the University of Maine, the University of Wisconsin–Madison, and Cornell University. For each exercise we offer (1) our rationale for the exercise, (2) its implementation in the classroom, and (3) potential pitfalls associated with the exercise. We do not assume that the activities outlined in this paper are the only innovations that are occurring in weed science classrooms, or that similar activities have not been implemented by others. Rather, the broader objective of this paper is to expand the dialogue among weed science instructors on how to improve the educational experience for our students while making our role as educators more interesting and rewarding.

Weed Identification and Natural History

Weed identification is generally taught in undergraduate weed science courses, accounting for approximately 30% of the laboratory time in class (Lindquist et al. 1989). Instructors typically transfer their expert knowledge to the students by word of mouth or demonstration, or both. Students are often required to identify selected species by common name, binomial, family, and life cycle. Resources available to students may include regional weed identification guides, herbarium specimens, potted specimens in the greenhouse, and flagged examples that are visited during weekly "weed walks." The advantage of this expert knowledge approach is that it facilitates considerable instructor–student contact, often resulting in experiential accounts of the natural history and distribution of a particular weed. The major disadvantage of the expert knowledge approach, however, is that the students may forget the distinguishing characteristics of a weed they do not encounter on a regular basis, and therefore will need to find another expert to help them identify the weed in the future. Thus, whereas the expert knowledge approach helps students memorize a suite of weed species and their families, it does not necessarily provide the students a tool for weed identification that they can use later in their careers. Emerging weed identification software may be a useful complement to expert knowledge-based weed identification and taxonomy instruction.

XID Identification System. "1,000 Weeds of North America" is a PC-based interactive weed identification system developed by XID Services[1] and distributed in collaboration with the Weed Science Society of America. The software includes a series of menus containing plant traits of typical morphological characteristics (e.g., flowers, fruit, leaves, stems, roots) as well as general plant characteristics, such as plant aroma, life cycle, and height. Traits are listed by absolute types, numerical distinction (i.e., height, length, width), and by a series of objective and relative comparisons. Other features include tutorial, color photos of all species, sorting capability by geographical region, state/province level distribution maps, illustrated glossary of terminology, and page number references to over 40 weed reference books. Unlike a dichotomous key, which has a required starting point, XID users navigate through the menu structure and enter known traits for their particular specimen. As traits are entered, the comprehensive database is parsed, eliminating species lacking the selected traits. The ANALYZE feature is particularly useful, listing traits that best distinguish the remaining species. Future versions of XID will include additional weed species and weed biographies written by students from weed science classes across the country (Weed Biography section in this paper).

At Washington State University, four XID-based activities have been used to teach weed identification in the laboratory section of the introductory weed science course from 2003 to 2005. In the first laboratory session, students work through the XID tutorial, learning the basic function of the program using a limited database and a set of contrived examples to illustrate the functions. For this first activity, students are offered a range of plant part samples representing basic morphological characteristics, such as inflorescence type, leaf traits (type, shape, arrangement, venation, etc.), life form, and growth habit. The students must describe each plant part, and may use the XID glossary function to derive their answers. This activity reinforces the plant traits that are useful for identification. The second XID activity involves the identification of a suite of broadleaf and grass weeds chosen by the instructor; these generally include species that have many of the characteristics that were emphasized in the first activity. Students are required to use the XID program, but the use of various weed guides is encouraged for final verification. One to two laboratory periods (3 h each) are needed to complete the first two activities. The third XID activity is the weed collection, where the students are required to collect 15 specimens from not less than 10 plant families. They are encouraged, but not required, to use XID to identify their collected samples. To reinforce the use of XID, students are permitted to include an XID printout outlining the traits used to identify the weed. In this exercise, partial credit is given if the student uses many of the key traits, but fails to correctly identify the weed. Finally, the fourth XID activity is a weed identification exam in which students are presented with five unfamiliar species. Students are required to use the XID system, without the aid of any weed guidebooks, to identify the specimens. For one of the specimens, the sample includes a single leaf, compelling the students to closely scrutinize leaf characteristics. Species with large, distinctive leaves, such as common cocklebur (*Xanthium strumarium* L.), Japanese knotweed (*Polygonum cuspidatum* Sieb. & Zucc), and redroot pigweed (*Amaranthus retroflexus* L.) are well suited for this activity.

Student responses to the XID activities have been quite favorable. Students may experience some initial frustration learning all the operational mechanics of XID; however, they generally adapt quite rapidly. Initial assistance from the instructor and teaching assistant is essential, but sufficient time should be allotted for the students to master the program. When given sufficient time, students seem to enjoy the self-taught nature of the XID activities. Many of the students entering careers in agricultural education or extension appreciate the flexibility that a program such as XID affords them in future jobs. From the instructor's viewpoint, XID can greatly streamline weed identification teaching and provide an excellent opportunity for a student–instructor team approach to problem solving.

Weed Biography. In the fall terms of 2003 to 2006, weed science students at five U.S. universities participated in a coordinated national effort to supply detailed weed biographies for future releases of the XID weed identification software and informational system described above. Students in introductory weed science classes were each required to submit one weed biography, whereas students in upper-level weed science courses were required to submit two: one for an annual weed species and another for a biennial or perennial species. Students selected and registered their species from a web-based database of 1,366 weed species to ensure no duplication of efforts among participating students and institutions. A uniform format was established by the participating instructors, including the following major subject areas: botanical description, habitat and climatic requirements, origin and distribution, economic importance, ethnobotanical characteristics, and response to management. Students were encouraged to use peer-reviewed literature to complete their weed biographies, although information obtained from government and university Internet sites was also accepted.

Although the exercise required considerable editing by the instructor, students were motivated by authorship of their published biography, and the caliber and quality of many of their weed biographies were excellent. Most students viewed this experience as unique and beneficial. Several students noted that they appreciated the detailed and critical editing of their writing by the instructors, and were pleased to put effort into a project that would be used beyond the classroom. Here are the comments from one such student:

> "Probably the most favorable aspect of these biographies was the fact that they are reviewed and are to be published in a web format. I cannot begin to count the number of papers and projects I have done for classes that just end up collecting dust on my shelf. Your class is the only class I have taken, where student projects are slated to become published on-line (or anywhere) as the end project goal. It is a great way to introduce students to the review process and gets their names out there. Although I would imagine editing these weed biographies is more work for you, it stands out as something that i) not a lot of professors are doing here at UMaine and ii) is a great teaching tool with documented, reviewed results. With hundreds of weeds left in XID, I imagine this opportunity will be available in the years to come."
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> —A. Hoshide, University of Maine, December, 2003

Integrating Weed Identification, Biology, and Management in the Classroom. Instructors wishing to integrate both weed identification and important aspects of the biology/ecology and management of a species during laboratory and lecture sessions are often required to ask their students to consult at least several general weed science textbooks and several weed identification guides to obtain all the necessary information. If this information were contained within a single easily available and accessible resource, students would be able to more effectively learn important biological and ecological features of weeds and correctly identify them. This was the main impetus for the development of the *Weed Identification, Biology and Management*®[2] software (DiTommaso and Watson 2003). The software helps students gain knowledge of, and to recognize, over 100 important agricultural, environmental, and urban weeds common to North America. The software is designed to complement living plant material, herbarium specimens, and class lecture notes. Information on nomenclature, distribution, habitats, morphology, life history, biology, and management options are provided for each weed species. The software includes high-quality photographs of the seed, seedling, juvenile plant, flowering plant, flower close-up, and special features as well as photos in the field. This "complete life cycle" approach to the identification of weeds is a particularly useful feature of the program that is often not available from a single reference source. Other useful aspects of this resource include the classification of all species on the basis of flower color and seedling morphology and a grass key. In addition, technical taxonomic and botanical terms in each species description are linked to an illustrated glossary.

The *Weed Identification, Biology and Management*® software program has now been integrated into the teaching of the undergraduate weed science courses at both McGill and Cornell Universities during the last 2 yr and several other institutions over the past year. Students describe the ease of use, high-quality images, and biological and management information provided as key benefits of this novel teaching aid. In evaluating the usefulness of the program, several Cornell students who completed weed science courses at other institutions (where weed identification sessions focused on rote memorization of key distinguishing characteristics of weeds) indicated that using this comprehensive approach to weed identification, which also integrates information on the ecology and management of weeds, was a more effective and stimulating way to learn the material. Students have also emphasized that having their own copy of the program made their studying more effective and flexible. Weed identification test scores at Cornell corroborate the student comments that this tool and approach to learning weed identification skills has been successful. Test scores have increased by an average 20% during the 2 yr that students have had access to this program compared with scores for the 3 previous years when the program was not available. Although this software targets weeds of northeastern America, it may be a valuable tool for educators elsewhere who wish to develop and integrate weed identification, ecology, and management into educational materials, particularly with respect to regionally common weeds.

Alternative Class Structure. On the basis of a survey of 20 U.S. universities conducted from 1986 to 1987, Lindquist et al. (1989) found that weed identification was most commonly taught as a component of undergraduate courses in weed science. Only five of the 20 instructors surveyed taught a separate course in weed identification. Most instructors were less than fully satisfied with their teaching of weed identification and that greater effort should be dedicated to this teaching goal.

At the University of Maine, weed identification has been removed from the laboratory section of the senior-level course in weed ecology and management, and offered as separate two-credit course. This course meets once per week for a 3-h period that includes lecture, testing, and observation of specimens in the field. With this class format, students have more time to work with specimens and observe them in the field, thereby learning the species in the context of their habitat. In addition, intensive and repetitive observation of weed species reinforces the basic information about the biology of the weeds, such as life cycle, reproductive strategy, and plasticity. Perhaps the most important benefit of offering a separate weed identification course is that the laboratory time in this senior-level weed science course can be used to emphasize weed ecology and management.

The students' response to the weed identification course has been very positive. In particular, they enjoy the fact that the first 9 wk of the semester are predominantly occupied by "weed walks" in the field, which facilitates considerable interaction among the students and the instructor. The remaining weeks are dedicated to seed and seedling identification in the laboratory. An unexpected benefit of this offering has been the enthusiastic response from students in Landscape Horticulture, a popular undergraduate program at the University of Maine. Relatively few of these students take our senior-level weed science course, but many have made weed identification a common elective in their curriculum. Because fundamentals of ecology and basic aspects of management are also included in the weed identification course, these students gain some applied knowledge useful to careers in the horticulture industry.

Population Processes

Weed–Crop Interactions. The traditional method for teaching undergraduate students weed ecology concepts tends to model laboratory activities after scientific research procedures. In this case, students gain experience with the scientific method and an appreciation for the research and concepts upon which the exercise is based. Excellent examples of such laboratory exercises structured on the research model have been outlined by Gibson and Liebman (2003a, 2003b, 2004). These exercises help students understand weed–crop–soil interactions by decomposing a system into components. For example, in Gibson and Liebman (2004), burial depth is shown to influence both germination potential and recruitment of two weeds species. Similarly, a laboratory exercise has been developed at the University of Wisconsin–Madison, and used at the University of Maine, that demonstrates the incorporation of experiential learning principles to facilitate a systems-level understanding of weed community, recruitment, and their potential impact on crop productivity (Luschei 2002).

The primary objective of this novel experiment is to create a weed community that will create the greatest impact on the target crop. Factors regulating weed recruitment and seedling growth, such as temperature, light quality and quantity, and soil fertility, are reviewed with the students, and the relative niche adaptation of individual weed species is discussed. Groups of two to four students are challenged to apply this knowledge by competing to create a weed community that produces the greatest impact on the growth of a crop. Each student group is provided with six flats, three for a weed seed mixture of the group's choice and three to serve as the weed-free controls. Weed seeds are provided by the instructor.

To help illustrate the relation between seed size and seed number, each weed species is assigned a value on the basis of seed size. For example, small-seeded weeds, such as redroot pigweed, are assigned an arbitrary cost of $0.01 per seed, whereas medium-size-seeded weeds, such as giant foxtail (*Setaria faberi* Herrm.), cost $0.05 per seed. Large-seeded weeds, such as velvetleaf (*Abutilon theophrasti* Medic.) and ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq.], are $0.10 and $0.20 per seed, respectively. Groups have a total budget of $50.00 to purchase seed for their three flats. Groups are allowed to pick through seed lots looking for seed with the greatest potential vigor if they feel that might be an important factor driving the outcome of the experiment. With the potential to enhance seed performance, groups are allowed to physically or chemically pretreat seeds (e.g., sandpaper, wire brushes, acid, hydrogen peroxide, bleach). Hard red spring wheat is sown in two 2.5-cm-deep furrows at specified row spacing in each flat 1 wk after the weeds were planted. Fertilization and watering regimes may also be tailored to optimize weed interference.

Student groups count the number of emerged weeds by species once a week. Eight weeks after sowing the weed seed, the students count the number of wheat tillers and seedlings (by species) in each flat. The above-ground (wet) biomass of each weed species and each crop is also measured. The group with the highest mean yield loss, calculated as a percentage of the mean of the control flats, is then deemed the winner. At UW-Madison, winning students receive a "get out of a question free" card that can be used for any exam, a reward they seem to find much more desirable than an equivalent number of points. Student groups prepare a preliminary written report of their Materials and Methods and Results, which is distributed among the other student groups. These preliminary reports are used to prepare a formal paper that contains the following sections: (1) Introduction, (2) Materials and Methods, and (3) Discussion. The Introduction will describe the logic behind the group's choices in the Materials and Methods, whereas the Discussion will contrast the results and approach to the other groups' experiments. Students should consider issues of weed seed viability, emergence uniformity and timing relative to the crop, and the relation between seed size and competitiveness. Graduate students are required to perform more formal statistical analyses of the data, cite other published works to help develop their Discussion, and prepare a proper bibliography for their paper. Student reviews of the exercise indicate that most found the exercise stimulating and instructive. Students lacking the initial motivation require more discussion of the objectives and goal of the activity before it is initiated. The major pitfall with this activity has been assuring that flats are adequately drained and maintained.

Weed Seed Predation. There has been considerable interest and active research by the weed science community in seed predation and its implications for weed, crop, and soil management (Anderson 1998; Brust 1994; Cardina et al. 1996; Carmona et al. 1999; Cromar et al. 1999; Menalled et al. 1999; Reader 1990; Spafford-Jacob et al. 2005; Westerman et al. 2002). This subject area, however, does not tend to be covered in many of the traditional weed science textbooks. At the University of Wisconsin–Madison, students explore the concept of postdispersal seed predation using a laboratory investigation that makes use of the experiential learning approach. The first phase of the laboratory is exploratory, where students have the opportunity to test or explore some element of the process of weed seed predation that they have developed from lectures or discussions on seed predation, such as that featured in Radosevich et al. (1997). Students are asked to formulate a hypothesis regarding the impact of at least one factor (e.g., species, seed types, seed characteristics, habitats) on seed predation rate. The students' application of knowledge is then assessed by having them design an experiment to test their hypothesis. Students are provided with different types of materials, such as chicken wire, burlap, glue, sandpaper, sponges, flypaper, etc. that might serve to protect seed from predation or minimize the chances that seeds disappear for reasons other than predation. Likewise, many different types of weed and crop seed (varying in both size and shape) are provided. Students work individually with minimal guidance from the instructor to create an apparatus to address their hypothesis. This "hands-off" approach facilitates independent problem solving and student ownership of the process. Students are required to implement their 3- to 5-d experiment somewhere on the campus grounds or near their home.

The student grade on the first phase of the experiment is given for a short and informal report of their hypotheses, a detailed "Materials and Methods" description, and a summary of their initial results. This self-guided direct experience facilitates more deliberate and careful thought to the second phase of the laboratory in which students work together to further shape and revise their hypotheses.

In this second phase, students begin by discussing their respective methods and results from the first experiment with their classmates. From this discussion, the students design and carry out a second experiment that eliminates at least one possible explanation for the results they found during the first phase. Usually this involves increased replication or adding controls. Students then prepare a report on the phase one and two hypotheses, with detailed "Materials and Methods" and "Results." These written reports are distributed to all students. The final component of the experiment requires students to digest and explain the body of results from the entire class. They must deduce some generalities but temper them with logical alternative explanations.

Having sufficient structure built into this laboratory exercise to assure discussion and interpretation during the progression of the phases is essential. From the instruction standpoint, the fact that the laboratory emphasized the "detective-like" role of the researcher was helpful in engaging student interest. For example, seeds placed in shallow dishes will likely be recovered with litter or other organic matter, and searching through the debris for parts of seed hulls was both natural and interesting for students. The laboratory also offered students the opportunity to test creative new ideas that actually go beyond those covered in the class materials. For example, one student speculated that adding a few large (hence more visible), high-quality crop seeds to a batch of weed seeds would increase the weed seed predation rate by attracting additional granivores to the location. The major pitfalls associated with this activity included the inability to: (1) detect a difference between treatments due to removal of either all or none of the seeds, and (2) determine whether missing seed were consumed or dispersed. Encouraging the students to include adequate replication and experimental control helped to safeguard against these problems.

Engineered Herbicide Resistance in Crops. The benefits and risks associated with herbicide-tolerant crops (HTCs) have been extensively debated over the last decade and reviewed by Martinez-Ghersa et al. (2003). Proponents of these technologies cite improved weed control efficacy, higher crop yields, and reduced environmental impacts as some of the potential benefits. Opponents of these technologies, however, cite the development of herbicide-resistant weed populations, the HTCs becoming a weed in other crops, and a suite of ethical concerns associated with the use of biotechnology in agriculture as some of their major concerns. All points, both for and against HTCs, are valid, depending on one's assumptions and goals. As such, presenting a comprehensive view of the issues surrounding HTCs is essential to facilitate the shaping of the students' perspective on this issue.

At Washington State University, a semiformal debate format is used to allow the students to explore the issues associated with HTCs. This debate focuses on the glyphosate-resistant system by asking the students to debate the question "Is Glyphosate-Resistant Technology Sustainable and Appropriate?" The meanings of 'sustainable' and 'appropriate' are left deliberately vague to give the students the flexibility to use any or all of the agronomic, ecological, sociological, and ethical issues to make their case. In random order, students are required to select the team defending or criticizing glyphosate-resistant technology. Debate teams are assembled 4 wk before the scheduled debate, and two laboratory periods before the debate are allocated for the teams to work together to formulate their argument. Although these preparation periods consume considerable laboratory time, team members find it difficult to coordinate their schedules outside of the regular class hours. The students are encouraged to use all possible sources of information, particularly the scientific literature and personal testimony from scientists and practitioners. Each team is allowed 25 min to present their opening argument followed by a 15-min rebuttal from the other team. After these periods, the teams must answer questions from the audience, which may include other faculty members, graduate students, or university staff. Teams are evaluated on how well they document their case, the quality of their presentation, and how well they answer questions from the audience. Each team is assigned a grade by the instructor or teaching assistant, but students also evaluate their own team members. The students' final individual grade is based on their team's grade adjusted for the rating they receive from their teammates.

Student feedback regarding this activity has generally been positive. Nearly all students indicate that the debate expands their knowledge of the issues associated with HTCs and that the debate format better illustrates the complexities of the issues than could be accomplished with standard lectures. Students appreciate that they are responsible for the information they present, and for the structure (within limits) in which it is presented. The success of this activity is linked to giving the students sufficient time to prepare and conduct the debate, as well as time for discussion afterwards. From an instructor's viewpoint, the debate format facilitates the efficient presentation of the complex issues associated with HTCs.

Integrated Management Systems

Resistance and Integrated Management (RIM)—A Bioeconomic Model for IWM. IWM is the combination of cultural, mechanical, biological, and chemical management strategies to reduce the impact of weeds in a way that is economically and environmentally sustainable. Although the typical classroom lecture format is useful to outline the components of IWM and how they may fit together under different scenarios, a full appreciation of the interrelated nature of IWM, as well as the benefits and trade-offs among IWM systems, may be best achieved with hands-on experience. Many of our students, however, do not come from agricultural backgrounds and may not have a good understanding of agricultural production issues. In addition, understanding the agronomic, economic, and environmental complexities of IWM over the long term is a challenge for all students. Simulation crop management models may be a useful complement to hands-on management experience to expose students to IWM issues and their long-term implications.

The RIM model is a dynamic and deterministic crop management model that integrates economic, biological, and agronomic components (developed and described by Pannell et al. 2004). It includes approximately 500 biological, agronomic, and ecological parameters that may be adjusted by the user. The RIM model is set in the context of the dryland wheat-based systems of southern Australia where rigid ryegrass (*Lolium rigidum* Gaud.) is the dominant weed. The user may opt for a wide range of chemical, mechanical/physical, and cultural weed controls to manage rigid ryegrass in the context of a user-specified crop rotation, which may include wheat (*Triticum aestivum* L.), lupin (*Lupinus* spp.), canola (*Brassica napus* L.), legume forage and green manure crops, and fallow, among other options. The program tracks rigid ryegrass plant and seed bank populations, as well as economic returns, over a 20-yr period. Seed bank dynamics account for natural mortality of dormant seeds and removal of weed seeds with harvest. Fixed and variable input costs are preprogrammed in the RIM model according to current standards of the southern Australia production region, but can be modified by the user. Herbicide efficacy and the number of herbicide applications before herbicide resistance develops can also be set in the RIM model.

At Washington State University, the RIM model is used to provide students hands-on experience at creating an economically viable IWM system in the face of widespread herbicide resistance. In this laboratory exercise, the RIM User Guide within the program is printed and handed out to the students 1 wk in advance of the scheduled laboratory period to allow them to read about the RIM model before they attempt to use the program. An initial tutorial exercise is created that steps students through the basic functions of the RIM model as well the IWM issues in a southern Australian cropping system. No herbicide resistance restrictions are imposed in the tutorial exercise, which gives students experience with conventional-type cropping systems that generally make extensive use of herbicides. In the second portion of the laboratory, however, the students are required to achieve a specified average net return for the 20-yr period when acetyl-CoA carboxylase, acetolactate synthase, and photosystem II inhibitors are limited to five applications each in the 20 yr, and all other herbicide groups are limited to 15 applications during the same period. Students quickly learn that the optimal cropping system and IWM strategies are vastly different under the herbicide-available and herbicide-restricted scenarios. Although nearly all the IWM strategies developed by students in the herbicide-restricted scenario include extensive use of cultural and mechanical/physical weed management strategies, students within a laboratory section rarely use the same management approach. This illustrates the versatility of the RIM model. To complete this laboratory exercise, students must prepare a concise summary of their management plan. Students that successfully complete the exercise are rewarded with extra credit points on their final class grade. The student in each laboratory section that has the highest average net return for the 20 yr receives additional bonus points. This grading system creates productive competition among the students, which seems to be an effective means to motivate them to do well in this exercise.

Student feedback on the RIM model activity has been largely favorable. Students from agricultural backgrounds or with a sound understanding of agricultural issues tend to do quite well and find the activity intellectually rewarding. A minority of students, however, do not appreciate this activity. These students tend to lack the knowledge of agricultural production issues, and therefore find the activity to be nothing more than manipulating a computer program to achieve a desired outcome. Overall from the instructor's viewpoint, this is an effective means to teach students about the complexities of integrated crop and weed management. In addition to teaching about IWM and herbicide resistance, the RIM model can also be used to conduct sensitivity analysis among such factors as variable and fixed input costs, and crop prices.

Summary

As relatively new instructors in weed science aiming to both better prepare our students and make our own teaching experience more fulfilling, we have repeatedly sought advice and ideas from one another over recent years. Most frequently these interactions focused on the use of experiential approaches to teaching principles of weed biology, ecology, and management that may be applied to IWM systems. It is our intention with this paper to share some of the highlights of our own courses that may prove useful to the community of weed science educators.

Sources of Materials

[1] XID Services, Inc., www.xidservices.com; info@xidservices.com.

[2] Weed Identification, Biology and Management program, bookstore.macdonald@mcgill.ca, 1-514-398-8300.

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