WEED SCIENCE IN SUSTAINABLE AGRICULTURE

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Many voices are encouraging farmers to consider and adopt lowcost, resource conserving, environmentally-sound farming methods. Questions are being raised about modern farming's dependence on nonrenewable production inputs, adverse impact on soil and water ant other natural resources, and growing dependence on agricultural chemicals (28). How should farmers farm? "From time immemorial", Wojcik (25) tells us in his 1989 book - The Arguments of Agriculture, "there has really been only one answer. Farmers should farm so they can farm again tomorrow."

Weed science, a sub-discipline of agriculture, hears the voices and questions and weed scientists are struggling to find acceptable answers. Some of the struggle arises from the science's creation coincident with the development of herbicides that have dominated thought and action. There is also a fundamental belier that controlling weeds is essential to agricultural productivity if food is to be produced for all in sustainable agricultural systems.

Producing enough food locally and worldwide is an egalitarian, agricultural ideal shared by many scientists and institutions. The ideal, often cited as the creed of the U.S. land grant university system, is presented frequently in the words of the king of Broddingnag to Capt. Lemuel Gulliver in Jonathan Swift's, Gulliver's Travels: "He gave it as his opinion, that whoover could make two ears of corn or two blades of grass grow upon a spot of ground where only one grew begore, would deserve better of rankind, and do more essential service to his country than the whole race of politicians put together."(21)

The king's words are used to justify the mission of land grant agricultural universities but now we must ask (2) if the mission may be outdated in high-income societies that have almost no need for more food and where food safety and environmental quality are becoming important. Many suggest agricultural research should shift direction to emlhasize production of the highest quality consumer goods, more nutritious food, and assurance of environmental quality.

Weed scientists have accepted and contributed to the land grant mission. We have not examined the fundamental assumptions of the mission or those that drive the science. I discussed some of these assumptions in 1991 (29) and was guided then and now by ny feeling that weed science is good but can be better. Weed scientists do not often discuss the goodness of their sciencebecause they know producing food is a worthy goal. They don't assume anything is wrong with their science, with the production goal, or the means of achieving it. My thinking about weed science has led me to five ideas about the natura of weed science and its future. Today I want to present and briefly explore my ideas and I hope you will discuss them with ne.

First the five ideas:

1. Weed science has been an economically dominated, technical specialty within the land grant system divorced from its basic support sciences.

2. Weed science wight have been more properly called herbicide science and reliance

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on herbicides has become too great (22, 27).

3. Weed management will benefit as truly integrated, sustainable weed management systems are developed and that can be done best by studying weed biology and the ecological principles that support sustainable management systems.

4. The increasing emphasis on population biology and ecology will be good for weed science.

5. Weed science will benefit as an ethical foundation is developed and debated.

1. WEED SCIENCE AND ITS SUPPORTING SCIENCES

Agricultural science has been looked down on by older academic disciplines because the work is regarded as too practical and applied. Agriculturalists widened the gap by creating their own disciplines rather than working within the established disciplines of botany and zoology (5, 14). Weed science a sub-discipline, had an easy birth and successful adolescence but is experiencing problems with its image as it natures. Weed scientists grew up in a divorced household and conversation with their scientific parents is just beginning. "The lack of a strong continuum of expertise and cooperation between the basic and applied aspects of weed science has been a najor factor in preventing weed science from gaining the stature of" (8) other pest control disciplines.

U.S. agricultural scientists have been comfortable and secure with the mission of the U.S. land grant university system that had withdrawn into itself. They ignored founding sciences, academic colleagues, and public criticism that was regarded as unreasonable (5). But that system is questioned now as never before (2). The land grant model, adopted by many other nations and based on the value of production, was appropriats (15); but is not as appropriate as it once was.

Weed scientists, divorced from their founding disciplines, risk separation from the mainstream of their institution's intellectual life or, as agriculture loses its uniqueness in the academy, they risk entering the mainstream without the required navigational skills. Weed Science is regarded by some of its most devoted adherents as a step child (3). Weed scientists must be actively involved in shaping their future or their mission and identity will be determined by others.

2. Weed Science and Herbicides

Some argue that weed science is not dominated by herbicides and reliance on them is not too great. Others argue that the history of weed science is similar to the well-known story of the drunk who lost his house key in the dark near home but was searching for it under a streetlight because "the light is better here." Herbicides were a new technology that worked so well that most research becane an effort to elaborate the technology. Herbicides directed research. The work was dynamic, rewarding, optimistic, and backed with administrative support (7). There is nothing surprising in the tendency of any scientific community to exploit success. That is how progress is nade. Weed scientists would have been negligent if they ignored or quickly tired of the dramatic successes created by herbicides. Narrowing of attention frequently leads to progress (7) and weed science progressed. One can critique subsequent organizations and scientists that advocated and used herbicides without questioning

their goals or the means of achieving then.

For the reasons mentioned above (7), weed science concentrated 'where the light was better' - on exploration and development of herbicides. The important question for each nation's weed scientists is not what has weed science been doing but what should it do and become? Most weed scientists do not advocate abandoning herbicides that are effective, cheap, reliable, and safe to humans and the environment. Few irreconcilable questions arise about the efficacy or cost of herbicides but serious debate ensues about their reliability and safety. Many questions arise outside the weed science conmunity and involve the most basic aspects of reliability and safety. Safe for whom? Reliable for how long? Who gets decide and what criteria will be used? Who is responsible? There are many who now believe, because o the widely recognized problems with chemical technology, that the balance needs to be shifted away from herbicides. The light has improved in other places!

Two problems worthy of mention here are herbicide resistance and groundwater contamination by herbicides. Both are serious problems in many places and each is worthy of a lengthy discussion. I cannot discuss them in depth and so I will try to illustrate their dimensions within the context of my topic.

In the 50 years that have passed since pesticide use became widespread, the problem of weed resistance to herbicides did not appear until recently 1960s). At least 113 weed species are now resistant to one or more herbicides. More than 500 insects and nite species are immune to one or more insecticides and about 150 plant pathogene are resistant to fungicides. The problem is growing and seems to occur most readily where the same pesticides are used regularly in a monocultural cropping system. Many recommend that part of the solution to this problem is a shift of management strategies away from reliance on chemical control of pests to an integrated approach that does not rely on a single technology.

Pesticides, including herbicides, have been detected in ground, surface, and drinking water samples across the U.S. Most of the herbicide detections involve a few herbicides that are widely used in soybeans and corn (23). The total number of detections is small and the concentrations are small fractions of the levels believed to be harmful to humans and aquatic life. Howerer, fish kills have been reported and pesticide concentrations that exceed human health based drinking water standards have been found in the U.S. corn belt states (23). Agriculture wherever it is practiced causes major environmental change. A new ecosystem is created and it must be maintained by artificial (non-natural) means including herbicides. Most of the world's countries have large regulatory and scientific research systems to manage agricultural systems and reduce their inevitable adverse effects. An underlying premise of these systems is that herbicides and other pesticides may be introduced into the environment only if, for every use of each chemical, estimated risks are not unreasonable and are balanced by benefits that must extend beyond agricultural past control (23). Thus, groundwater contamination is a problem that has occurred and is likely to continue to occur in many places. It is widely regarted by non-agricultural people as a bad thing. The risks exceed the benefits. Weed science must respond to this challenge with good data and reasonable arguments. Presentation of the traditional and expected defense that herbicides are essential production tools, which they are will harm our reputation for objectivity and lead to loss of many herbicides.

I suspect most weed scientists agree that weed control should avoid or eliminate techniques that have a high potential to harm others or to contaminate the environment. Aldo Leopold, the great U.S. conservationist, (12) offered the fundamental ecological principle that "a thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." Herbicides and other weed management

techniques bend nature to human will and, in doing so, may harm it, not preserve it. They, in Leopold's terms, may tend to be wrong. Changing research emphasis away from herbicides requires informed debate about the criteria for reliability and safety of weed management techniques and about the direction weed science should take.

3. INTEGRATED WEED MANAGEMENT TECHNIQUES

The economic or profit orientation of agriculture led to the quest to maximize short term yield, which is often not sustainable. The quest was created, in large part, by government policies that determine what farmers can do and grant programs that determine what research is done. Many argue that U.S. farm-price and farm-income support programs contribute to environmental degradation by encouraging farmers to produce more of some crops (2). These policies also encourage farmers to use more pesticides, farm or graze fragile land, exploit aquifers, and not rotate crops. The policies support research on methods of weed control that may contribute to environmental degradation.

Scientists must be aware of but need not be directed, exclusively, by political and economic agendas. Weed scientists routinely discuss research ideas but availability of research funds frequently restricts the ability to pursus some ideas. For example, is the proper research goal maximum short-tern yield, maximum sustainable yield or maximum yield stability (9, 14), and what weed science techniques are required to achieve the chosen goal? "How should farmers farm (25)?"

Weed science is moving toward integrated, sustainable weed management systems. To develop these systems the botany and ecology of weeds must be studied. Present technology, especially chemical tecnology, cannot be relied upon for all solutions. Many weed scientists are eager to learn what botany, population biology, and ecology can contribute to the development of weed management systems. These disciplines have not contributed much to weed management or modern agriculture because there has been little funding for joint research (24) and because there is little scientific interaction. Plant population biology and the design of agroecosystems are not a usual concern of weed scientists who have not looked to them to solve weed problems (24). Other disciplines, often critical of agricultural practice, have not been eager to understand and cooperatively solve the weed management problems they perceive.

4. POPULATION BIOLOGY AND ECOLOGY

Agricultural practice has changed almost oblivious to ecological concerns. In the world's developed countries, production problems were solved by adding (often in excess) fertilizer, water, and pesticides, or by reshaping the land itself (26) and this created ecological problems. Cheap energy has been the panacea that made it possible to maximize yields and replace any natural plant community with one of several crops or cattle and do so profitably. In earlier times, things were expensive and labor was cheap (26) and sound ecological practices were often the way things were done. As technology advanced, things became cheap and labor became expensive, and weed and other agricultural scientists neglected ecology, evolution, carrying capacity, limiting resources, and limits to growth. Technology rained supreme and weed scientists knew their technology was:

a) socially beneficial because food production increased and
b) environmentally beneficial because there was no obvious harm,
c) or, at the very least, the technology was benign.

They were wrong because technology is never neutral and it induces social change. One should not blame the technology and perhaps not even its developers and users. Harly weed scientists wanted to solve weed problems and when the magic of chemical technology appeared they seized it to replace human and animal energy for weeding and it worked well.

Weed scientists were first reminded about limits by Rachel Carson (4) whose 1962 book (Silent Spring) was dismissed by many, I suspect, without reading it. Her profoundly moral statement tried to convince the reader that life is a miracle beyond comprehension, and we should reverence it even when have to struggle against nature. Chemical control of pests was part of Carson's permissible struggle but she saw it as a misquided, nonecological attempt to control nature. Pesticides were not her first line of defense.

The key to sustainable management of annual weeds is prevention of seed production (11). It is also trus that the life cycle of an annual weed includes seed germination, seedling survival, growth, flowering, seed production and shed, seed predation, and mortality. The effects of microorganisms on weed seed viability has been reviewed (11) and suggests their action could be integrated with other seed management techniques. Weed science has concentrated on control of viable seedlings (Where the light is better!) and too little is known about the rest of the life cycle. Because it is not knows it is impossible to say how such biological knowledge will be integrated into or help create now, sustainable managenent systems and reduce relliance on herbicides. Weed suppressive systems will be developed when research on weed population dynamic and crop-weed interference is integrated with systematic manipulation of each component of cropping systems to isolate and improve specific factors that affect weeds (13). The emerging literature on weed population biology and ecology will be the necessary foundation to create sustainable, integrated weed management systems that reduce herbicide use.

5. ETHICS

Rachel Carson (4) never proposed abandoning pesticides. She proposed accommodation between peste and people and ethics were the means to that end. Meed scientists need to develop an ethical base to support the need for weed management in sustainable agricultural production and the need for a protected environment. Weed scientists want to include ecological thought and guidance in the quest for sustainable weed management systems that accommodate equally valuable and divergent needs.

I suggest the ethical base for weed science, its technology, and its systems must also include consideration of effects often deemed external such as the disappearence of small family farms, the decline of rural communities, reduced water quality, and effects on non-target species. Weed science is part of agricultural science and it will succeed or fail with all of agriculture. Agriculture is part of human culture and must function as part of a shared, sustainable system rather than striving for domination.

I suggest weed science should develop an ethical stance that reflects equivalent care for a productive and protected environment. Weed scientists have solidly based values and ethical views but our conception of ethics needs to be broadened as we work to create the future. I think our conception of ethics is similar to that held by most agriculturalists. We were

not educated to discuss or be concerned about ethical matters. We wonder why we should be concerned about ethics because we have been behaving ethically by helping to feed the world. We are engaged in the world's most important industry, food and fiber production. How could the value of these be questioned? We don't cheat, are honest, work hard to earn our pay, participate in community affairs, and we are morally correct.

Ethics is more than behavior and demands that we question our solutions to problems, our definition of problems, our methods, and our most fundamental assumptions about what we do. Our science is not value free and neutrality on the day's great questions does not equal objectivity. Agriculturalists often think they can't speak on some issues because they won't be regarded as objective and they must be. This reinforces the status que and that is what needs to be thought about, discussed, and perhaps challenged.

The careers of many of today's weed scientists developed while the agricultural research system was moving from being a "revered institution, as little questioned as apple pie or motherhood, to an embattled giant assailed by enemies from without and undermined by critics from within (5)." We are witnessing, if we look, the unraveling of the social consensus that progress is always good and science is always beneficial (5).

A frequent response to critics of the benefits of herbicides and chemically based weed sciencs has been an appeal to the neutrality of objective scientific knowledge. A common theme is: If the public was aware of the extensive safety testing herbicides must undergo and if they understood scientific research they would recognize the need for herbicides and their safety (6). The rationals is that "although chemical pest control is hazardous, it is realistic to accept the minimal degree of risk it presents, since absolute safety is unattainable in any sector of life. (13)" The argument recognizes that risks and benefits must be balanced while incorrectly assuming that the acceptability of any pesticide is only a matter of risk magnitude or physical danger. It ignores risk distribution and the involuntary nature of many risks (19).

The response can be regarded as a defense of the status quo. Many critics of herbicides are competent scientists. Most intelligent critics espouse a different risk preference. A response that cites the unquestioned correctness of science is dismissed it is uttered. Science deals with facts and objetive truth, but scientists cannot stop with that defense. What the public perceives is that once scientists have the objective facts, nothing else is required, no other listening is needed. "The facts, after all, ate the facts. All that remains is to bring others into conformity with the objetive truth (17)."

A response that reflects a desire to cooperatively understand (to listen) would be better. Weed scientists value, promote, and defend their role in production but have not listened carefully or responded well to the social and ethical arguments central to environmental protection (6).

6. FUTURE QUESTIONS AND THOUGHTS

Weed scientists have developed ways to control weeds and will continue to do so. Many weed scientists now believe weed "control" should not dominate and alternative weed 'management' methods are widely discussed. Within weed science it is unusual to ask if agriculture can be done successfully without controlling weeds (20). Can farmers work with weeds rather than against then? The evidence from studies of crop rotation and intercropping (13) living mulches, cover crops, tillage systems (16), and allelopathy indicates the answer is yes for many cropping systems. Pursuing the practice of agriculture by managing rather than

controlling weeds should shift weed science's emphasis toward economically and environmentally sound, integrated, sustainable, weed management systems.

Some argue that weed science cannot continue to insist on a fight to the last weed but many weed scientists and farmers disagree. The goal of 100% control made possible by herbicides is questioned in most cropping systems. Most crop scientists howerer acknowledge that the need for weed management will never end. Weeds will always be with us but weed scientists and farmers should not work against but with them (6, 9). In the future, weeds won't just be controlled, they will be managed.

Weed science, with emphasis on control, has been very successful - most weeds can be controlled in most places. In fact, there is much about weed science that must be praised. Weed scientist's achievements in basic science (8) and their contributions to agricultural production and productivity worldwide are incontestable. The discipline however, has not been integrated into a bolistic view of agriculture and our world and lacks a sustainable ethical base. Weed science has worked with a spotlight not a floodlight. The work has not been illuminated much by associated disciplines nor has it enlightened then and the contribution to agriculture has been truncated by intensive specialization and narrow expertise. Mayer and Mayer (14) accused agriculture of being a "vast, wealthy, powerful intellectual and institutional island empire." Weed scientists are residents of a technologically rich domain in that empire.

The public is well aware that technological problems multiply and remedies don't exist or don't work. Technology is often perceived as something that brings vast rescurces to solve problems, lots of experts and new policies, but few solutions for the problems it creates. Weed science is identified, rightly or wrongly, as a discipline based on chemical technology. When the tools and techniques of chemical technology were chosen, dreams and values were also chosen. Weed scientists need to discuss whether the dominant technology has served their dreams and helped them create appropriate, enduring values or if it has made some of them unobtainable. The public image created by dependence or herbicides is a concern to many and a source of frustration and discouragement to others. Because of the public's image of pesticides, the ensire pest control community often feels under siege. Too often the news includes an example of another pesticide issue that affects all involved in pest management.

For example recent U.S. reports (1) reveal that 86% of Americans think that pesticide residues on food are a serious issue, 84% are concerned about health hazards of pesticides to farmers and other users, 86% believe that water pollution from chemical runoff is a serious environmental issue, 84% cite pesticide use on farms as an environmental concern, and 62% think chemical soil contamination is a serious problem.

I suspect similar data could be found in many countries.

Weed scientists area virtually defenseless against accusations about herbicide reliability or safety when so many people are concerned. If the validity of the concern is denied then those who deny it risk becoming identified as advocates of potentially dangerous chemical technology. If the implications of the concern are affirmed then one wonders why practice doesn't change and why herbicide use doesn't decrease. Scientists may be accused of not understanding where agriculture must go, being poor environmental stewards, and being insufficiently accountable for their science and its technology or accountable to the wrong sectors of society. Weed scientists frequently respond with arguments that emphasize the value and importance of productivity and object when they think politics rather than science determines what happens. There will inevitably be political decisions that take place in the midst of a philosophical reassessment that is coupled with ecological and moral concerns, about how humans should value nature and what techniques should be used to produce food and fiber.

These are not just simple scientific matters. They are inherently political matters "entwined with reforming world views (18)."

Moderns, objective, reductionistic weed science has the capacity to look inward and change. Weed scientists are part of a balief community shaped by its members, their purposes, and the available technology. The justifiable pride in scientific objectivity and rationality should be tempered to include and validate the subjective role of each scientist as it is informed by the community and its commitments. Knowledge is not subjective or objetive but a transcendence of both.

Weed scientists should begin to tell the public and themselves that the quality, not just the quantity of the American food supply is a high priority. A protected and a productive environment are equally important. Weed scientists may not know all the charges needed in their community, but enough is known to get starred. Some criticism of weed science is unfair and ill-informed-but that's not new. Most people don't understand agriculture or weed science.

As weed scientists make changes in their goals and methods they would do well to heed Yale University history professor Paul Kennedy's advice for the future (10). Speaking of education, he said what is needed is "a deep understanding of why our world is changing, of how other people and cultures feel about those changes, of what we all have in common, as well as of what divides cultures, classes, and nations." The "process of inquiry ought if possible to be tolerant" but it "cannot be value-free. Because we are all members of a world citizenry, we also need to equip ourselves with a system of ethics, a sense of fairness, and a sense of proportion as we consider the various ways in which, collectively or individually, we can better prepare for the twenty-first century (10)."

The work weed scientists most proud of and that is easiest to communicate is often not the work the public understands easily or appreciates. The average citizen does not even have a view of what weed scientists do. They are confused by scientific language, and increasingly uncertain about who is right about the technology of weed science. Scientists are often viewed with suspicion and distrust. People react predictably by accepting whatever view fits common sense and their bias. This reaction, while personally rational, is often regarded as illogical and emotional. It frustrates, but does not preclude, thought and wisdom. Weed scientists, like most people, are wary of change, especially when imposed. The science is changing but some changes may be perceived by others as an alteration of form, not content. Weed scientists have always claimed that no weed control technique has ever been abandoned, but it must be asked if new weed management methods can be developed from old ways. New methods will rely on new knowledge derived from different questions about weed-crop relationships.

Weed scientists must begin to debate their science and its technology as they establish an ethical foundation for the science. Through public presentation and debate, ideas will be tested and refined so weed science will continue to contribute to agriculture and society.

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