

Biological Control, A Component of Integrated Weed Management

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Abstract

Biological control is often considered as an alternative to other control methods rather than a part of an integrated weed management system. There have been some reports of attempts to integrate inoculative agents with other methods of weed control, but in most instances inoculative biological control has been on its own in non-cultivated systems. However, opportunities do exist to integrate inoculative biological control in time and in space with other methods of control. Inundative biological control (bioherbicides) provides the greatest opportunity for integrating biological control with other methods of weed control in arable agriculture where complexes, rather than single weed species, dominate. Although narrow spectrum, bioherbicides are being integrated into crop production systems as sequential and as tank-mix applications with chemical herbicides to provide broad-spectrum weed control.

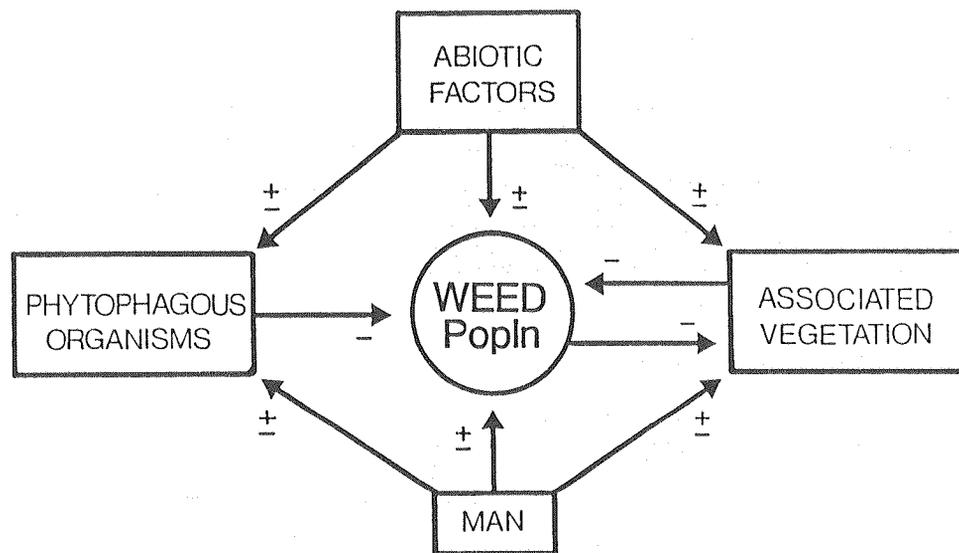
Integrated Weed Management

Integrated weed management is not a new concept. Weeds are a constant component of our environment, and man has utilized combinations of various control techniques in attempts to suppress weed populations. The goal in any weed management system is to maintain an environment detrimental to the weed populations through the use of preventive, managerial, physical, biological, and/or chemical methods. Each particular method of control has its advantages and limitations which are often related to characteristics of the weed or weed-complex resulting in the necessity of integrating two or more methods to obtain satisfactory control. In general, a "good" weed control tactic would: (1) be safe to the user, the environment, and our crops; (2) provide effective (reliable) control; (3) be relatively easy to use; and (4) be cost-effective. Weed control methods can be broadly categorized as broad-spectrum or narrow-spectrum. The relative importance and difference between narrow-spectrum methods (e.g., hand weeding and biological control) and broad-spectrum methods (e.g., tillage and most chemical herbicides) are important aspects when considering the development and implementation of integrated weed management systems in divergent habitats such as rangeland or cropland.

Shaw (1982) defined integrated weed management systems (IWMS) as "... a directed agroecosystem approach for the management and control of weed and other populations at threshold levels that prevent economic damage in the current and future years." Integrated systems are characterized by their increased complexity as compared to relatively simple, single-strategy approaches to pest control. Integration can be viewed as a vertical integration of various control tactics against a single pest (e.g., a weed species) or as a horizontal integration across different pest groups (insects, diseases and weeds) in one crop. This discussion will be concerned primarily with the vertical integration of various tactics to combat individual target weed species. Thus, the weed population is the key component of a model system (Fig. 1). In this model, the weed population is regulated by positive and negative influences of man, associated vegetation, the abiotic environment, and natural enemies (Zwölfer 1973).

Biological Control IWMS

Biological control of weeds has been reviewed by numerous authors (for example, Harris 1986, Schroeder 1983, TeBeest and Templeton 1985, Wapshere 1982, Zwölfer 1973). Information on the integration of biological weed control with other methods of control has been relatively limited. Although Shaw (1982) recognized progress in biological control, he was skeptical of the role of biological control in integrated weed management systems, stating "... the role of biological control in integrated weed management systems, and the extent to which it can help in controlling the world's 30,000 weeds, remains to be seen." He did recognize "... a critical need to develop biological agents ... as control components for use in IWMS ..." (Shaw 1982).



Source: adapted from Zwölfer 1973

Figure 1. Factors affecting weed population regulation.

In most biological control programs, there is a need for integration of biological control with other methods. This need for integration may arise because: (1) the agent(s) are not effective in providing the desired level of control; (2) biological control is inherently narrow-spectrum and the target weed may only be one component of a weed-complex; (3) the crop production system is intensive with many interacting components, one or more of which may be detrimental to the biological control agent; or (4) economic considerations do not justify similar control strategies over the entire distribution of the weed problem.

Integration commonly involves the judicious or timely use of different control methods in a particular area; i.e., integration in time. Because of its unique character, however, biological control may provide utility in IWMS by being used in one area while other methods are used in different areas; i.e., integration in space (Andres 1982, Watson 1985). As reported by Andres (1982), the possibility of integrating biological control with other methods depends on: (1) the weed; (2) the natural enemies; (3) the environment; (4) desired level of attack; and (5) current agricultural technology. In the past, biological weed control has tended to "go it alone," but there are increasing numbers of examples where biological control is being integrated with other methods of weed control (Andres 1982, Charudattan 1986, Quimby and Walker 1982, Smith 1986).

Inoculative Biological Control and IWMS

The role of insects and pathogens in integrated weed management systems was reviewed by Andres (1982) and Quimby and Walker (1982), and at that time more examples involved insects in the inoculative (classical) approach rather than pathogens in either the inoculative or inundative approach to biological control. This reflected the relative use of insects vs. plant pathogens as biological control agents.

Because the target of inoculative biological control is usually a single, dominant weed species in non-cropland situations, attempts to integrate have usually occurred when the biological control agent has not provided effective control. Andres (1982) has proposed the possibility of enhancing the level of insect damage by improving the acceptability of the weed to the insect through fertilization, herbicides, pruning, or by manipulating insect numbers through conservation or augmentation.

The prospects of integrating chemical herbicides with inoculative biological control agents has been directed towards the integration of *Rhinocyllus conicus* Froelich (Coleoptera: Curculionidae), for control of *Carduus* thistles (Asteraceae) with other weed control and production practices (Kok *et al.* 1986, Trumble and Kok 1980, 1982). Integration usually involves the application of herbicides in areas where the agents have not provided adequate control. In these situations the primary concerns are direct toxicity of the herbicide to the insect and possible interference with the insect's life cycle. Thus they may require integration in time. Other examples of integration with chemical herbicides have demonstrated indirect effects of herbicides on the biological control agent. For example, Zimmermann (1979) found that populations of the cochineal *Dactylopius austrinus* De Lotto (Homoptera: Dactylopiidae) were eliminated selectively by a chemical herbicide control program because the herbicides effectively controlled large plants and clumps of *Opuntia aurantiaca* Lindley (Cactaceae), which comprised the main reservoir of cochineal populations. Therefore, he suggested that herbicides be avoided in certain areas to permit build-up of the cochineal populations; i.e., integration in space. The areas with no herbicides then could serve as reservoirs of insects for spread to adjacent areas. The indirect effect of poor quality foliage of herbicide-treated *Rumex obtusifolius* L. (Polygonaceae) plants for feeding by the beetle *Gastrophysa viridula* DeGeer (Coleoptera: Chrysomelidae) has also been demonstrated (Speight and Whittaker 1987).

Waterhyacinth, *Eichhornia crassipes* (Mart.) Solms-Laubach (Pontederiaceae), control in the United States is being obtained with the integration of a pathogen, insects and herbicides (Charudattan 1986). Biological control of waterhyacinth with the introduced *Neochetina* weevils (Coleoptera: Curculionidae) was improved when used in combination with chemical herbicides (Center *et al.* 1982) and the effect of insect attack was enhanced when followed by invasion of pathogens (Charudattan *et al.* 1978). The success and additional control possibility of a three-way integration of pathogens, insects and herbicides should promote greater interest in IWMS for aquatic habitats.

Although inoculative biological weed control has generally been restricted to extensive agriculture (e.g., rangeland) with limited application to intensive crop production systems (Harris 1986), the success of the skeleton weed (*Chondrilla juncea* L.; Asteraceae) : rust (*Puccinia chondrillina* Bubak & Sydenham; Uredinales) project in Australia (Cullen 1978) and the recent success of ragweed (*Ambrosia artemisiifolia* L.; Asteraceae) control in intensively cultivated fields in the Soviet Union with an insect (P. Harris, pers. comm., 1987) strongly suggest that inoculative biological weed control can be integrated into intensive agricultural production systems.

Inundative Biological Weed Control and IWMS

In intensive agriculture production, the inundative approach (primarily bioherbicides) provides greater opportunity for integrating biological control into IWMS. Attempts to integrate bioherbicides into cropping systems have been driven by: (1) agents which are not providing consistent acceptable control; (2) crop production systems involving the intensive

use of pesticides; and (3) in most instances, the target weed is only one component in a weed-complex.

Significant progress has been made in the integration of the mycoherbicide COLLEGO® (*Colletotrichum gloeosporioides* [Penzig] Penzig & Saccardo f. sp. *aeschynomene*; Coelomycetes) (*C.g.a.*) into rice (*Oryza sativa* L.; Poaceae) and soybean (*Glycine max* [L.] Merr.; Papilionaceae) production in the southeastern United States (Smith 1982, 1986, TeBeest 1984, TeBeest and Templeton 1985). The endemic fungus *C.g.a.* was developed and registered for control of northern jointvetch, *Aeschynomene virginica* (L.) Britton, Stern & Poggenburg (Fabaceae) in rice and soybeans. To be used as a mycoherbicide in these crops, *C.g.a.* had to be integrated effectively into disease, insect, and weed control programs (Smith 1986). On its own *C.g.a.* provides good to excellent control of northern jointvetch (TeBeest and Templeton 1985).

In attempts to broaden the spectrum of weed species controlled, *C.g.a.* has been tank mixed with another fungus, *C. gloeosporioides* f. sp. *jussiaeae*, to also provide control of winged waterprimrose, *Jussiaea decurrens* (Watt.) DC. (Onagraceae) (Boyette *et al.* 1979). Herbicides have been tanked mixed with *C.g.a.* to broaden the spectrum of weed species controlled, but tank mixes with some herbicides have interfered with the activity of *C.g.a.* on northern jointvetch (Klerk *et al.* 1985, Smith 1986). Appropriately timed sequential applications were required for the integration of *C.g.a.* with routine fungicide and insecticide sprays used for disease and insect control in rice (Klerk *et al.* 1985). Studies are also underway to develop benomyl (methyl-1-[butylcarbamoyl]-2-benzimidazole carbamate) - tolerant strains of *C.g.a.* (TeBeest and Templeton 1985).

Other endemic fungi are also being evaluated as possible bioherbicides, but many do not provide consistently high levels of control. *Colletotrichum coccodes* (Wallr.) Hughes, a foliar pathogen of velvetleaf (*Abutilon theophrasti* Medicus; Malvaceae) is an effective bioherbicide when environmental conditions are optimum for disease development (Wymore *et al.* 1988). If conditions are less than optimum, inoculated plants may continue to grow after shedding diseased leaves. It has been proposed that preparations of *C. coccodes* may need to be modified by adding chemical herbicides, growth regulators, or other additives to provide reliable control of velvetleaf in the field over a wide range of environmental conditions (Wymore *et al.* 1987). Laboratory, greenhouse and field studies have demonstrated that *C. coccodes* can be tank mixed with the growth regulator thidiazuron to provide effective control of velvetleaf (Hodgson *et al.* 1987, Wymore *et al.* 1986, Wymore *et al.* 1987). Thidiazuron and *C. coccodes* interacted synergistically to increase velvetleaf mortality. Similar studies have been conducted to examine the interaction between *C. coccodes* and various chemical herbicides used in corn (*Zea mays* L.; Poaceae) and soybean production systems (Watson *et al.* 1986, Wymore and Watson 1988). Some of the herbicides tested have interacted with *C. coccodes* in an additive fashion, a few are antagonistic, while several are synergistic. The adverse antagonistic interactions between *C. coccodes* and some herbicides have been overcome with sequential applications (Gotlieb *et al.* 1986). Scheepens (1987) has also reported a positive interaction between the fungus *Cochliobolus lunatus* Nelson and Haasis and sub-lethal levels of atrazine (2-Chloro-4-ethylamino-6-isopropylamino-*s*-triazine) for control of barnyard grass, *Echinochloa crus-galli* (L.) Beauv. (Poaceae).

Because of the narrow-spectrum nature of bioherbicides, most will, of necessity, be used in combination with other control strategies, particularly chemical herbicides. This integration will be required with our present bioherbicide technology to obtain satisfactory control of the dominant weed species as well as control of the complex of weeds associated with cultivated crops.

Conclusions

Integration of biological control with other weed control methods, and integration into modern crop production systems are essential. As our efforts in biological control increase and as our understanding of the agroecosystem improves, biological control will become an increasingly more important component of IWMS.

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