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Factors to Consider when Using Native Biological Control Organisms to Manage Exotic Plants

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ABSTRACT

Biological control of exotic plant populations with native organisms appears to be increasing, even though its success to date has been limited. Although many researchers and managers feel that native organisms are easier to use and present less risk to the environment this may not be true. Developing a successful management program with a native insect is dependent on a number of critical factors that need to be considered. Information is needed on the feeding preference of the agent, agent effectiveness, environmental regulation of the agent, unique requirements of the agent, population maintenance of the agent, and time to desired impact. By understanding these factors, researchers and managers can develop a detailed protocol for using the native biological control agent for a specific target plant.

Key words: non-indigenous plants, insect, native, augmentative release.

INTRODUCTION

Native organisms have potential as biological control agents for exotic plant species when used in an inundative, augmentative, or conservative management strategy. In the inundative approach, large numbers of individuals are released into the environment at a population density sufficient to control a target weed (Harley and Forno 1992). The augmentative approach is similar to the inundative approach, but assumes that an agent population is already present on the target weed. This population is then augmented with sufficient numbers of additional agents to cause a decline in the exotic plant population (McFadyen 1998). The conservative approach attempts to reduce impacts that impede the expansion of native biological control agents so that their population will increase to a level that will produce declines in the target plant (Creed 1998, Newman et al. 1998, McFadyen 1998).

Researchers and managers have attempted to utilize both native insects and pathogens in controlling problem weed populations (Buckingham 1994, Julien and Griffiths 1998). Julien and Griffiths (1998) list 60 native organisms that have been used worldwide as potential biological control agents of weed species. Approximately 20 native pathogens have been used as inundative or augmentative biological control agents of weeds, with a success rate of approximately 55 percent (Julien and Griffiths 1998). Still, pathogen usage worldwide is relatively low (McFadyen 1998). This may be due to the fact that many pathogens reduce target plant populations under research conditions, but must be developed into commercial formulations to gain wide use (Charudattan 1991, Shearer 1997). At the present time, only 3 to 4 commercial formulations are being utilized (Charudattan 1991, Julien and Griffiths 1998).

In the United States, the fungal pathogens *Phytophthora palmivora* and *Colletotrichum gloeosporioides* f.sp. *aeschynomene* have been formulated and used successfully in an inundative approach for noxious weed management (Templeton et al. 1979). *Phytophthora palmivora* has proved effective in managing populations of the exotic plant strangler vine (*Morrenia ordorata* Lindl.) in citrus groves (TeBeest 1993) and *C. gloeosporioides* f.sp. *aeschynomene* has been used to manage populations of northern jointvetch (*Aeschynomene virginica* L.) in rice fields (Tempelton et al. 1979, TeBeest 1993).

Interest in using native insects as biological control agents has also increased (Buckingham 1994, Julien and Griffiths 1998). Julien and Griffiths (1998) list approximately 40 native insects that have been used as biological control agents of weed species. Only 17 percent of these insects were reported to be successful (Julien and Griffiths 1998). If we compare this with the reports that classical insect biocontrol agents have a 25 to 29 percent success rate (Harley and Forno 1992), the native insects present approximately half the level of success. The reason for the lower success rate varies with the agent (Buckingham 1994, McFadyen 1998). Multitudes of interactions occur between insects, plants, and the environment, all of which may influence a management program. High numbers of natural predators or the cost of rearing native insects have contributed to the low success rate. *Bellura densa* (formerly *Arzama densa* WLK), a native North American noctuid moth, was unsuccessful in an augmentative program for management of waterhyacinth populations (Baer and Quimby 1980, Center 1975, Cofrancesco 1982), while *Spodoptera pectinicornis* (formerly *Namangana pectinicornis* Hymps), another noctuid moth, was extremely successful in managing waterlettuce populations in its native Thailand (George 1963, Center 1994).

DISCUSSION

This discussion will focus on factors that need to be considered when native insects are used in biological control programs to manage problem exotic plants. These programs

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should not only evaluate the ability of the agent to impact the target plant but should also consider the direct and indirect ecological effect of the program. Many of the factors or principles addressed are similar to those used in classical biological control programs with insects and pathogens. Information is presented in general order of importance; however, each factor is like a piece of a puzzle. If you know all the factors, you have a clear picture of what is happening; if some pieces are missing, you may not be able to understand the picture.

Feeding Preference of Agent: Agent impact on a native plant host must be understood before using it in a management program. The feeding preference of the native insect needs to be examined prior to releasing mass quantities on an exotic plant population (Newman et al. 1998). In general, insects that pose a monophagy approach to feeding are preferred as biological control agents. The restricted diet of these insects allows the agent to be used to focus in on the target plant. The agent should be one that attacks a native plant species that is closely related to the exotic species. This is the case with *Euhrychiopsis lecontei*, a native weevil that feeds on northern watermilfoil (Creed and Sheldon 1994a), but it is used as a biological control agent of Eurasian watermilfoil.

Although agents are usually released in large monocultures of an exotic plant, their preference for other plant species could alter their impact on the target. The agent may preferentially feed on the native plants before the exotic species. Insects that feed on a wide range of native plants are not generally ideal for a management program because of their potential to impact non-target plants.

In addition to feeding concerns, managers need to ensure they comply with federal and state laws from an ecological aspect. The United States Department of Agriculture (USDA) is charged under the Plant Pest Act to regulate any insect or pathogen that impacts plant populations (Klingman and Coulson 1983, Cofrancesco 1998). The ability of an agent to feed on an agronomically important plant species would be a major consideration and could cause problems in its use in a management program. Its impact to agronomic plants and other non-target populations should be open to review by Federal and state agencies. For instance, before a native insect population is used in an augmentation strategy to stress a species of thistles, its potential impact on artichokes should be evaluated.

The U.S. Fish and Wildlife Service (USFWS) is mandated to protect native plant populations. Under provisions of the Threatened and Endangered Species Act, the USFWS regulates any organism that is deemed to have an impact on a threatened or endangered species. If a native insect has a preference for a plant species that meets the threatened and endangered criteria, the release should be stopped until the impact to the native plant population is understood. For example, would the use of a native insect that feeds on a number of *Cirsium* species be justified for biological control of Canada thistle (*Cirsium arvense*) when it could impact threatened and endangered *Cirsium* species?

Effectiveness of Agent: Any management program using a native insect as a biological control agent of an exotic plant must address effectiveness of the agent. It would seem obvious that if an exotic plant is able to colonize an area and increase its population to problematic levels, it is not significantly stressed by physical, chemical, or biological factors in its new environment. If the proposed agent was present during invasion and expansion of the exotic plant, why would the same organism suddenly become an effective agent against the exotic plant when it became problematic? During the plant establishment phase, density levels of the agent assessed on a per-area basis or in relation to plant biomass were in all likelihood similar to proposed augmentation levels that are necessary to stress a problematic population.

The effectiveness of an agent is tied to a number of factors or conditions, such as density or the way an agent interacts with the target plant and its environment (Newman et al. 1998). Numbers alone are not necessarily the keys to the success of an agent as a management tool. Understanding why a native insect is effective as a biological control agent of an exotic plant is a critical step in the development of an augmentation program (Newman et al. 1998).

Environmental Regulation of Agent: In any environment there are factors that regulate the population of plants and animals. Price (1975) lists three factors that control insect populations; 1) predation or parasitism, 2) suitable food, 3) space for living or breeding. Others group these factors as abiotic (temperature, light, nutrients) or biotic (parasites, predators, or competition). No matter how one classifies the factors, the means by which they influence insect and plant populations must be understood. As insects and plants evolved, many unique behavioral, physiological, and morphological characteristics developed (Jolivet 1998) that allowed insects and plants to coexist in a habitat. In order to utilize agents in a biological control management plan plant/insect interactions must be understood (Newman 1991).

Abiotic factors can have a significant influence on insect populations (Price 1975). Wigglesworth (1974) has indicated that temperature is the most important abiotic factor influencing insect development. Temperature will also influence rate of feeding, egg production, and respiration (Warren 1995, Cofrancesco and Howell 1982). Nitrogen and phosphorous concentrations in plants can regulate the number of eggs some females will produce (Center and Wright 1991, M. Grodowitz, pers. comm.). Even the time of day when insect feeding occurs can influence the levels of sugar obtained from plant leaves (Jolivet 1998). Understanding the effect of abiotic factors on insect development and establishment will aid researchers in the development of more effective management programs.

Studies conducted on *B. densa* illustrate how some biotic factors influenced this biological control agent of waterhyacinth. An augmentation strategy to mass release *Bellura* eggs was attempted. Eggs were collected from laboratory colonies, combined with xanthate gum to ensure attachment to the plant, and the mixture was sprayed onto field plants. This procedure, while efficient, did not consider the oviposition site or the behavioral response of the insect to oviposit its eggs in clusters on the plant. Disregarding the oviposition site and clutch-laying behavior of the female moth (Center 1975) resulted in significant egg parasitism that led to low population numbers and minimal impact to the plants (Baer and Quimby 1984, Cofrancesco 1982). One could speculate that in succeeding generations this increased parasite level could impact the existing population of *Bellura*, and further reduce the effectiveness of this insect on waterhyacinth. The more that is known about insect/plant interactions, the better our capability to effectively use the insect in a management program.

Unique Requirements of Agent: Insects, like other organisms, often have unique requirements for mating, egg placement, larval development, and pupation. In mass-releasing populations of a particular agent, these unique requirements need to be known and understood. If females require a particular surface on which to lay eggs and it is not provided, the development of an extended population of the agent may be hampered. The release methods or life stage released may promote higher levels of predation or parasitism of an agent. Individual eggs of *B. densa* sprayed on waterhyacinth plants seemed more susceptible to parasitism than clutches of eggs deposited naturally by females (Baer and Quimby 1982).

Mechanical harvesting of Eurasian watermilfoil removes key habitat of the native weevil *E. lecontei.* Harvesters clip the plant approximately 1-2 m below the water, removing a critical portion of the plant where weevils feed, lay eggs, and pupate (Creed and Sheldon 1993). Studies have shown that if Eurasian watermilfoil mats are not subjected to mechanical removal, the weevil population in some lakes builds and significantly reduces the plant population (Creed and Sheldon 1994b). If managers limit the amount of harvesting conducted in a lake and provide the habitat needed for the development of weevils, this management strategy can allow the agents the opportunity to grow and impact the vegetation.

Collection and movement of native species must be considered in management programs. Movements may alter the ecological balance or stress the agent being moved. Moving large numbers of an agent may cause other organisms to be inadvertently transported. An agent moved to a different portion of its range may not interact with the endemic population. Temperature preferences for a population of insects from northerly climates may be slightly different than southern populations. Mixing two populations may not give the desired result that is anticipated in the management of the target plant population.

Population Maintenance of the Agent: The native agent must be able to maintain itself on the exotic nuisance plant. If the agent is highly mobile and disperses rapidly, the numbers of individuals maintained at the release site may be too low to manage the target plant population. If an agent prefers a native plant species more than the exotic target, it may not remain on the exotic long enough or develop population densities necessary to have the desired impact. If the native agent is susceptible to parasites or other predators its population may be reduced below a level needed in an inundative or augmentative management program. When *S. pectinicornis* is used as a biological control agent of waterlettuce in Thailand, managers are required to move and maintain the population of the insect in the fields to ensure success (George 1963).

Time to Desired Impact: In developing an inundative or augmentative approach to management of an exotic plant species the length of time required for the desired impact to occur must be considered. The number of agents needed in relation to the plant biomass or study area may influence the timing of impact. If multiple augmentations are required or the population of the agent is expected to build up through generations before achieving the desired result, then other factors need to be examined that could directly or indirectly impact the results. For example, if parasite populations build up 1 month after the release of an agent, this may not be a critical factor if the agent produces the desired impact in 3 weeks. However, if the desired impact to the target population occurs 2 months after the release, the parasite pressure may negate any expected impact by the agent. Agents that produce results quickly may not be subjected to damaging environmental factors, such as parasitism or overwintering requirements.

This paper has presented several factors that need to be considered before using native insect biological control agents. Many of these factors are interdependent and must be considered in relation to one another and to the ecology of the habitat. The decision to use native agents will vary depending on the situation but should be reviewed as to the direct and indirect impact to the overall environment before any management program is developed. Managers and researchers must understand as many pieces of the puzzle as they can to ensure an effective management program that will result in positive impacts to the environment.

It is unrealistic to think that because an agent is native, there will be on problem with its mass release. All habitats can be viewed as a balancing act, where changes in one area may influence many other areas. Monocultures of exotic plants produce stress in the environment, forcing portions of the habitat out of natural balance. Biological control agents should be used to bring the system back into a more natural or balanced state and not produce additional problems or stress. The ecology of a habitat must be considered whenever any management technologies are employed.

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