at this rate would cost $98. It takes approximately nine people 4 h, or 36 labor h, to prepare a similar number of cuttings for planting. Further trials will be conducted to confirm or disprove the results gleaned from this experiment. We feel it is very important to replicate this data repeatedly before switching production methods. Over the past three seasons both the number of varieties and total numbers of cuttings within a given variety have increased and were equally successful. However, there are many more varieties to trial. In addition to a replication of these methods other factors will be investigated to further refine our methods. There is a need to repeat this trial later into the season when the IBA rates we use increase and the propagation wood can be more difficult to root. Reducing volumes and rates could be another tool in the reduction of input costs and may provide equally successful results.

The Essential Bugcrafter: A Practical Primer for Biological Control©

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INTRODUCTION

Long before humans battled pests in greenhouses and nurseries, armed combat occurred daily amongst insects and mites that feed on plants. For millions of years, this leaf-to-leaf combat pitted hungry predators and parasites against a range of insects familiar to us all. It is truly a bug-eat-bug world. How can we harness this activity for our own good? As with anything worth achieving, it involves knowledge, persistence, and focused endeavor to bring about results that are not only worthwhile in suppressing pest outbreaks but might also improve the quality of plants.

Greenhouses, with their controlled environments, provided important study sites for research and implementation of augmentative biological control (Hussey and Scopes, 1985). It is with this early work that useful biological control programs targeting key greenhouse pests such as aphids, fungus gnats, mites, and whiteflies were developed. One can find use of similar programs today in large and small commercial greenhouse facilities throughout the world including sites in North America such as Florida, California, Ohio, New York, Ontario, British Colombia, and here in Oregon.

This paper emphasizes key components of a biological control program without which success is unlikely. Experience working with numerous growers trying to implement biological control in a variety of situations has shown there are important factors contributing to success. Those factors include: pest identification, pest monitoring, prior management planning, proper timing, and evaluation. Not listed, but extremely critical, is the initial attitude of nursery management. Biological control takes commitment on a level surpassing that of ordinary management schemes. It requires enthusiasm, creativity, consistency, good communication, an understanding of the biology of the pest and the biological control agent, and, dogged persistence. Though in the beginning using natural enemies may feel unfamiliar, confusing, and complex the rewards of success can create a biocontrol adherent for life. Let's look more closely at the factors contributing to successful generals in this arthropod warfare.

CORRECTLY IDENTIFY YOUR PEST

It sounds intuitive to know what you're killing. Unfortunately, correct pest identification does not always occur. For many growers, pest identification may be accurate but not very precise. For example, the pest is described as an aphid. That can be useful for many management tactics including chemical control. Biological control programs often require more detailed identifications, often to species. This is due to the sometimes finicky appetite of natural enemies who choose to dine on preferred species. In a way, a specialist natural enemy knows more about the pest than do we. They can see, smell, taste, and feel things on a level imperceptible to the human senses. To be successful we have to match the diner to the dinner.

SET UP A MONITORING PROGRAM

What general would send forth an army without a little reconnaissance beforehand? If you want to conquer your pest problems you must know the activity of your pest. Where does it get started, how many are out there, how many sites are affected, what stage(s) are they in? Populations change over time. Monitoring will help you keep tabs on the population size, dispersal, and changing stages of the pests over time. You want real quantitative data. This requires a commitment to consistent monitoring of the plant material. Very useful monitoring information for key greenhouse pests can be found in many books such as *Integrated Pest Management for Floriculture and Nurseries* (Dreistadt, 2001) and at various websites.

PLAN YOUR COURSE OF ACTION PRIOR TO NEED

A plan is nice. This may require some research. You don't want to have to do this under the threat of impending doom from a pest outbreak. In your plan, you should begin to assemble necessary information such as: which biocontrol agent will be used; who will be the supplier; at what pest threshold will you make your application, what is the rate of release for your selected biocontrol agent, which practices including chemical applications are compatible with your biocontrol agent. Much of this information is available from the resources listed such as the *Natural Enemies Handbook* (Flint and Dreistadt, 1998), *The Green Methods Manual* (Cherim, 1998), *Suppliers of Beneficial Organisms in North America* (Hunter, 2001), or from suppliers of beneficial organisms.

IT'S ALL IN THE TIMING

One of the most critical factors in the success of biological control is the correct timing of the natural enemy release. Too soon and there will be no food available for the establishment of the biocontrol agent. Too late and there are too many pests for the natural enemy to control before damage is evident, decreasing plant quality. The goal of most augmentative biocontrol programs is to suppress rather than control an outbreak. At the outbreak level, damage is likely to occur causing economic losses. This is what we call the economic threshold. There is often a lag time between the onset of the pest and the natural enemies ability to disperse, find, and control the pest populations. We can make up for that lag time by applying at very low populations of the pest. This is what we would call the action threshold. Then we wait. Often it is the progeny of the released natural enemies that have the greatest effect. If everything works well, the pest population is kept at a low general equilibrium. With predator mites a rule of thumb is to try to achieve a ratio of one predator for

every 10 pest mites. In Oregon, we've found a threshold of approximately one pest mite per every five leaves is generally successful in suppressing mite outbreaks.

LESSONS LEARNED

Evaluation of the biological control program is critical and enormously helpful whether the program was successful or not.

The most common failure we have seen experienced by growers is missing their thresholds, allowing the pest population to increase beyond the abilities of the natural enemy to suppress it. The other common problem experienced even by those who have had successes is the loss of institutional memory when key personnel have left. Often the biocontrol program comes to a resounding halt.

Biological control is very site specific and any number of factors can influence the success of the program. Paying attention to the key components listed above and the myriad other learning opportunities that will inevitably come up, will generally greatly enhance the chances for successful implementation.

USEFUL WEBSITES

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