Cone and Seed Insect Pest Research: The Role of the Southwide Studies

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Abstract: A reliable supply of genetically improved pine seed is critical to the success of production forestry. The most significant environmental threat to the ability to meet this demand (over 100,000 pounds per year) is insect predation. Cone and seed insect pests can easily destroy half the potential orchard crop, and there have been instances in which 90% of the harvest was lost. Effective insect control is dependent on continued availability of pesticides, both because the economic loss threshold is low, and because alternative control methods have not been successful. Because seed orchards are a minor use, there is limited support from pesticide manufacturers for either efficacy testing or continued product registration. The tree improvement community has responded to this challenge by developing a collaborative working arrangement between entomologists and seed orchard managers that has resulted in a series of southwide efficacy studies. These studies, which have now included evaluations of Guthion®, Asana®, Capture®, and Imidan®, were coordinated through the Seed Orchard Pest Management Subcommittee, a working group of the Southern Forest Tree Improvement Committee.

Southwide studies are the culmination of a multi-step process in which promising pesticide formulations and rates are first identified by USDA Forest Service entomologists through small-scale testing, typically with hydraulic spray applications to single trees. This method of application, while allowing for accurate treatment evaluations, does not reflect operational conditions. It is therefore necessary to evaluate the most promising treatments under operational conditions with aerial applications on large treatment blocks. Results from both published and unpublished studies have underscored the strengths and weaknesses of these large-scale tests. Efficacy studies are difficult to implement and have substantial direct and indirect costs to the participants. Seedbug control is easy to achieve. Coneworm control, however, is much more difficult both to achieve and to accurately document. Interpretation of composite traits such as the number of good seed produced per initial flower can lead to erroneous conclusions when efficacy is primarily due to seedbug control. Despite these deficiencies, southwide studies will continue to be needed to validate cone and seed insect control under operational conditions. Studies that will be needed in the future are discussed.

Keywords: Seed orchards, Coneworms, Seedbugs, Pesticide efficacy studies

INTRODUCTION

Commercial forestry in the southeastern United States is based on plantation management with approximately 2.62 million acres planted in 1998 (Moulton and Hernandez 2000).

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Annual plantation establishment on this scale requires a dependable source of genetically improved seed, most of which is supplied from seed orchards that currently have fifty-years of investment in breeding and progeny testing behind them. Seedlings produced from this source currently exceed the growth rate of woods run seed sources by 20 to 30 percent (Byram et al. 2000, Li et al. 1999, 2000). The differential between seed orchard seed and woods run seed will continue to increase as seed orchards incorporate additional genetic gains from tree improvement programs and new methods of capturing gain such as control mass pollination are implemented. Seed may easily exceed an imputed value of \$100-\$150 per pound per percent genetic improvement based on the discounted value of future wood production (calculated by the method of van Buijtenen 1984). Mature orchards may be expected to yield in excess of 60 pounds of seed per acre per year, this seed may exceed 20 percent improvement in growth rate, and the reproductive biology of pines results in two and sometime three crops being present simultaneously. With these assumptions, the value of the seed orchard crop may easily exceed \$240,000 per acre. Therefore, seed orchard seed is an extremely valuable crop assessed either in terms of sunk costs or in potential growth gains.

Seed yields are notoriously variable, being influenced by both biotic and abiotic factors. One of the most serious causes of seed loss is insect predation, which can result in up to 90% crop damage in a given season (Fatzinger et al. 1980, Hodge et al. 1992). Effective pest management is, therefore, an essential part of seed orchard management. Because economic thresholds are low and alternative non-insecticide based methods have yet to be proven effective, the seed orchard manager is forced to rely on pesticides. This has resulted in what Mangini et al. (*in press*) have referred to as the 'registration dilemma'. Conifer seed orchards are a minor use crop with probably no more than 8,000 to 10,000 acres nationwide and with probably less than 6,000 acres under active production management in any given year (Byram and Lowe 1998). A recent survey showed that only 11,625 pounds active ingredient (ai) of pesticide were applied to southern pine seed orchards in 1999 (unpublished data). Because the total amount of pesticide applied is small compared to most agronomic crops, pesticide manufactures have shown only limited support for efficacy testing or product registration. The tree improvement community has responded to this challenge by developing a collaborative working arrangement between entomologists and seed orchard managers that has resulted in a series of southwide efficacy studies coordinated through the Seed Orchard Pest Management Subcommittee (SOPM), a working group of the southern Forest Tree Improvement Committee.

SOUTHWIDE EFFICACY STUDIES

The southwide studies are the culmination of a multi-step process in which promising pesticide formulations and rates are first identified, candidates are then evaluated in small pilot-scale experiments, and then the results are validated by large operational level tests. Federal and state entomologists have traditionally done the initial screening and pilot-scale experiments. Operational validation has been done by collaboration between entomologists, chemical company representatives, and seed orchard mangers.

The first step in this process, the identification of promising pesticides, has been most productive when it has concentrated on treatments that have been shown to be effective on similar groups of insect pests. By screening chemicals that are already registered for other crops, the likelihood of obtaining an additional registration for conifer seed orchards is enhanced. This is so because these products already have the extremely expensive environmental fate studies required by the Environmental Protection Agency (EPA) and pesticide companies can more easily be persuaded to pursue registration for other uses. This strategy takes advantage of the fact that the SOPM subcommittee successfully lobbied the EPA to classify seed orchards as a terrestrial nonfood crop rather than having orchards grouped with forest sites (J.W. Taylor, *personal communication*). This makes it possible to screen chemicals registered for such crops as cotton rather than being restricted to the much smaller number of pesticides labeled for forestry.

Once candidate pesticides are identified, efficacy screening in seed orchards is required, because effectiveness on the insect pests of row crops in no way guarantees that these chemicals will work in seed orchards. The number and variety of insects causing damage in seed orchards differs from those in row crops. The major pests have life cycles with specialized developmental stages that may be inaccessible to control methods (e.g. dormant coneworm larvae inside cones). Finally, the three dimensional aspect of the cone crop where trees sometimes exceed 80 feet in height makes obtaining adequate coverage difficult. This last problem is probably only shared with one other commodity group: pecan growers. Pilot-scale screening has traditionally been carried out by a small but dedicated number of state and federal entomologists.

After a handful of promising chemicals and rates have been identified, they must be tested under operational application conditions. Treatment blocks have typically had a minimum size of five acres, which limit the number of treatments in any one orchard to no more than four. The only group that has the resources to do this has been the members of the tree improvement cooperatives who actively manage large production seed orchards.

Rationale Behind the Studies

The southwide studies are necessary because research methods used to evaluate pesticide efficacies differ markedly from operational application techniques. Research applications are typically made on single trees with high volume hydraulic sprayers while operational applications are most often made aerially to large acreages. High-volume hydraulic sprayers give good coverage with large volumes of spray and large droplet sizes. Typical treatments may call for spray to runoff or spray until the foliage is thoroughly wet. Aerial applications use much smaller volumes, typically 10 gallons of spray per treated acre. This is only 0.029 fluid ounces of solution per square foot of flat surface area. The problem of obtaining adequate coverage on the pine foliage and cones with aerial applications is particularly difficult since the target (needles and cones) is dispersed vertically, sometimes as much as 80 feet. Furthermore, needles and cones are not flat surfaces. Actual needle area may exceed projected area by more than a factor of three (Johnson 1984, Murthy and Dougherty 1997).

Operational applications have benefits that may offset some of the difficulties inherent in low volume aerial applications. These benefits could possibly result in better control than obtained with the pilot-scale studies. Aerial applications come from the top down placing the coverage in the crown where the majority of crop is located. Most significantly, aerial applications treat large acreages, which may be both a benefit and a drawback. Treating large areas may reduce insect pressures that are exerted by mobile pests from adjacent untreated trees in the single-tree treatment paradigm used in pilot scale studies. On the other hand, it may also reduce the presence of beneficial insects that would otherwise move back onto treated trees from adjacent untreated areas. Detrimental impacts on beneficial insects, which as a group tend to be very mobile, are frequently overlooked in single-tree treatments. Finally, large-scale applications are the only way to calculate cost/benefit ratios for various application alternatives.

Successes

The tree improvement community has now participated in five southwide studies since 1991. These efforts have been supported by the donations of pesticide application costs and personnel and equipment for test installation and evaluation by 19 organizations in a combined total of 32 orchards (Table 1). These studies have included evaluations of Guthion®, Asana®, Capture®, and Imidan®. Some of these studies have been extremely useful in obtaining and maintaining registration as well as refining application rates.

The Capture® study (Lowe et al. 1994) compared applications of Capture® and Guthion®, at the then legal rate of 3 lbs ai/ac, to an untreated control. Treatment with either Guthion® or Capture® were both effective, resulting in more seeds per cone, more sound seeds per cone and less seedbug damage. The beneficial impact of the pesticide treatments was most dramatic when the synthetic trait, the number of sound seeds produced per first-year conelet was analyzed. This trait incorporated conelet survival, cone survival, seed per cone and percent sound seed. This study resulted in Capture® receiving 24C registration for conifer seed orchards in all of the southern states with the exception of North Carolina which already had an alternative chemical with an emergency use registration for cone and seed insect control. The major draw back of the study noted by the authors was that there were very low coneworm populations in the year of the study and very little coneworm damage occurred. Coneworm damage was significantly reduced from 7.6% in the control to 4.2% in the Guthion® treatment and 5.6% in the Capture® treatment (unpublished data). To show statistical significance at these low levels, the control must have been real. Most of the benefits evident in this study; however, could be attributed to the control of seedbugs.

Cooperator	Capture Efficacy 1991	Guthion Rate 1992	Asana Timing 1993	Asana Rate 2001	Imidan/ Capture 2002
Boise Cascade					1
Bowater, Inc.	1	1			
Champion International		2	1		
Chesapeake			1		
Container Corp of America		1			
Deltic Farm and Timber		1			
Florida Division of Forestry				1	
Georgia Forestry Comm.	1				
Georgia Pacific Corp.	2				
International Paper				2	
Mississippi Forestry Comm.		2		1	
North Carolina Division of Forest Resources					1
Plum Creek Corporation					2
Potlatch Corporation	1				
Scott Paper Company			1		
Temple-Inland Forest	2	1		1	
USDA Forest Service	2				
Westvaco		1			
Weyerhaeuser Company			1	1	
Total	9	9	4	6	4

Table 1. Participants in several of the southwide efficacy trials. The numbers of orchards are shown in the table.

The Guthion® rate study (Mangini et al. 1998) was a tremendous undertaking because of the number of rate comparisons included. This required an incomplete block design necessitating the use of a large number of orchards. This study compared rates in 0.5 lbs. ai/ac increments from 1.0 to 3.0 lbs. ai/ac. First-year conelet survival, second-year cone survival, sound seeds per cone and the synthetic trait of sound seeds produced per first-year conelet improved at nearly every rate of Guthion®. Furthermore, there was no linear relationship between protection level and pesticide application rate. This study was used successfully to keep Guthion® registered for pine seed orchards by showing that application rates could be cut in half from 3.0 to 1.5 lbs. ai/ac. Once again, the apparent level of coneworm damage was low, and while whole-tree counts of healthy and coneworm damaged cones were tallied, these data were not included in the study report.

A recently completed rate study for Asana® (manuscript in preparation), compared three rates of pesticide to an untreated control. This study compared rates of 0.03, 0.10 and 0.19 lbs ai/ac/application rates to an untreated control. Any pesticide application reduced damage directly attributed to seedbugs (Figure 1). Only the high rate; however, reduced coneworm damage even in this year with relatively high levels of coneworm damage present. This study will be used to justify keeping the current application rates, which are 1.9 times higher than the next currently labeled use (control of peachtree borer and filbertworm in almonds and filberts).

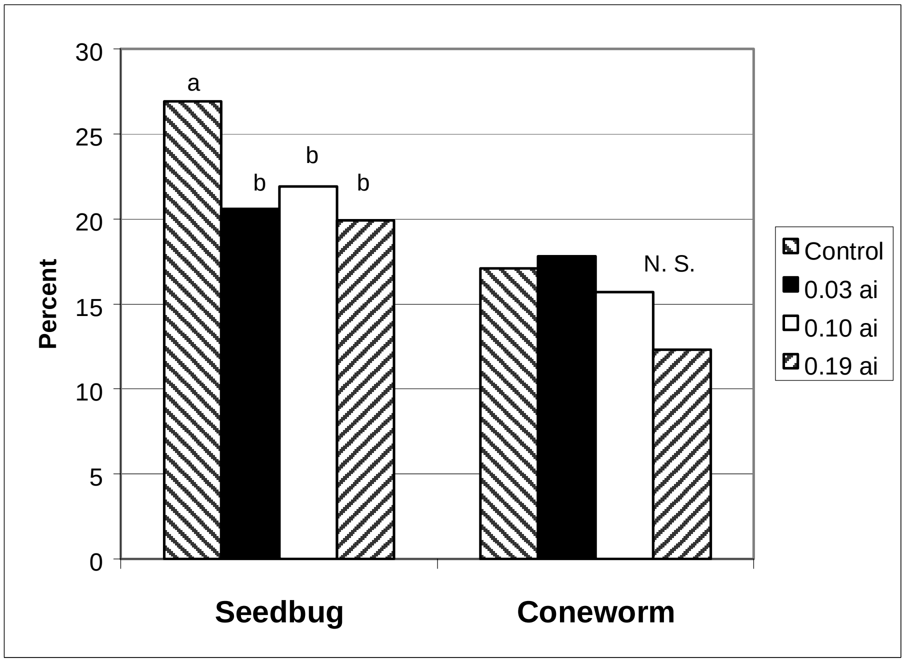

Figure 1. Results from the Asana® rate study showing A) the percent seed damaged by seed bugs as determined by radiographic analysis of seed extracted from healthy cones and B) the percentage of total cones collected damaged by coneworms. (from Byram et al. 2002)

Failures

Not all southwide studies have given clear answers despite the participants' considerable investments in time and resources and careful study implementation. This can happen for a number of reasons. First, insect pressure may be limited making it impossible to judge the differences between treatments. Secondly, because of the size of the treatment blocks, it has been necessary to consider orchards as replications. Therefore, the statistical precision of these tests is low; consequently, small, but operationally important, differences are difficult to detect. Finally, management histories between orchards differ. Protection programs in prior years to the installation of the southwide studies have varied from none to intensive. Cone collection histories have also varied with some orchards having been completely harvested in past years while other orchards have been inactive for a number of years. This can make it difficult for the collection crews making whole tree cone counts to correctly divide the cone crop into the current years healthy and coneworm damaged categories.

Lessons Learned

The tree improvement community has learned a number of lessons in implementing these extensive studies that will guide similar efforts in the future. Several points refer to the application and data collection protocols that have been standard in all of the southwide studies (for more detail see Lowe et al. 1994 and Mangini et al. 1998). Following is a partial list:

1. The spray protocol originally set up for the southwide studies generally works. This includes large treatment blocks (minimum size of five acres) separated by untreated buffers. Examination of damage caused by the easily controlled seedbugs occurring in adjacent blocks indicates that spray drift between treatments is seldom significant (unpublished data).

2. Adequate set up is necessary. Prior to several studies, entomologists worked with applicators to calibrate spray equipment to ensure proper application rate, spray pattern and droplet size. In several instances, applicators were using equipment that was either incorrectly calibrated or worn. To the applicator's credit, help correcting these situations has always been well received. This experience; however, emphasizes the need to periodically verify the proper use of application equipment in all operational programs.

3. Seedbug control is both easy to obtain and to document. Several indexes in the data collected verify seedbug control. These include tallies of first-year conelet survival, tallies of damaged ovules from dissected conelets, per-cone seed yield, and damage revealed by radiography of mature seeds. Almost all studies have shown that seedbugs are controlled by a variety of chemicals and rates and can be controlled by lower rates than those required to control coneworms.

4. Coneworm control is much harder to estimate, and therefore conclusions are less certain. Unlike seedbug damage, which can be estimated several ways, there is only one measure of coneworm damage – the damaged cones themselves. The protocol requires that all the current year's cones are collected on the sample trees and that these cones be divided into healthy and coneworm-damaged categories. This protocol can give spurious results for a number of reasons. First, some coneworm damage is missed as the cones are no longer present at the time of collection, or they are so damaged that they are destroyed in the collection process. Early-season coneworm attacks cause the small cones to become fragile. They fall off early, the cone collectors overlook them, or they crumble apart when collected. Secondly, when orchards have not been completely picked in previous years, some old cones are invariably included in the total. As a result of these factors, the tree improvement community is probably underestimating the damage done by coneworms both operationally and in these studies.

5. It follows that conclusions based on synthetic traits such as overall flower to seed yields may overemphasize the benefits attributable to seedbug control while

underestimating the damage done by coneworms. As seedbugs are easier to control, this can lead to pesticide recommendations that are less than optimal.

6. There is considerable indirect opportunity cost to the participating orchards. Because treatments are designed to include a range of management outcomes, untreated controls are needed for comparison, and untreated buffers must surround each treatment, most of the orchard will be unprotected or under-protected.

7. Inadequately supported studies are seldom worth doing. Statistically rigorous studies are required for submission of the data to chemical companies and the EPA. Studies with small numbers of orchards cause problems in two ways. First, meaningful differences are always difficult to detect when few replications result in small degrees of freedom in the analysis of variance. Secondly, there is no operational backup for situations in which mistakes are made and treatments are invalidated. With small numbers of orchards, any miscommunication between contract spray crews, mechanical failures or any number of failures at one orchard can jeopardize the efforts of all concerned. Fortunately, in practice this has rarely happened.

Future Needs

Despite all the difficulties, costs, and limitations to southwide studies, it is likely that the tree improvement community will need to continue their support for these efforts. The primary reason for this is that these are the only studies that can verify operational effectiveness of proposed control methods. Among the needs that have been identified for the near future is the efficacy of the southwide study protocol itself. Is coneworm damage being correctly evaluated? Are large treatment blocks necessary? Hanula et al. (2002) holds out some hope that large blocks may not be needed. Data collected in an operational spray block next to an area with a designed experiment showed that single-tree treatments may be adequate predictors of control. Ironically, it will probably require a southwide study to show if this is true.

Spray volumes and droplet sizes required by current labels have been challenged. Early work showed that 10 gallons of solution was required to obtain adequate coverage in conifer seed orchards (Barry et al. 1982). This quantity of solution is difficult for most applicators to apply in a single pass resulting in the need for multiple trips across the orchard. Since this spray volume was decided on, a new generation of chemicals with much longer residuals and new types of nozzles with smaller droplet sizes have become available. Because of the unique dynamics of large area treatments, a southwide study may well be needed to resolve this issue.

When new pesticides become available, southwide studies are the only way to verify operational effectiveness. Current examples are Warrior® and Mimic®, which have proven effective in single-tree treatments. They most likely will also be effective in area-wide applications, but at what rates and at what intervals?

Integrated pest management (IPM) systems will be necessary to reduce the reliance on chemical controls. By their very nature, many IPM methods can only be effective when applied to large areas and therefore will require southwide studies for their evaluation. As an example, non-chemical control methods such as mating disruption will only be effective if they disrupt populations over large neighborhoods. Multiple control methods with different methods of action also are likely to require evaluation over large areas. Hanula et al. (2002) has shown that a combination of trapping and spray timing may be adequate to control *D. amatella*, but how this effects other important pests in an operational setting over several orchards in regions with different weather regimes remains to be resolved.

CONCLUSIONS

Southwide studies have been successful in efficacy testing of pesticide treatments and have resulted in the registration of new chemicals and the refining of application rates for older chemicals. This would not have been possible without the single-tree treatment research that first identified likely candidates for operational trials. The southwide studies; however, remain one of the most important tools for verifying operational effectiveness over the many different conditions encountered on a regional basis.

Despite the value of the seed crop and the importance of having a dependable supply of seed, consolidation in the industry and the implementation of cost cutting measures make it more difficult to do this type of expensive and risky research. Failure to invest in these kinds of studies; however, would be extremely short sighted as no one else in the pest control community has any interest in supporting research for such a unique minor-use market.

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