THE INTERPLAY OF AGROECOSYSTEM DIVERSITY AND PESTICIDE USE

John Banks[1] from the University of Washington and John Stark[2] from Washington State University discuss the interplay of vegetation diversity, pesticide use and subsequent sublethal behavior of both pests and natural enemies in crop fields.

Introduction

As the implementation of the U.S. Congress's 1996 Food Quality Protection Act (FQPA) gradually decreases the number of broad-spectrum pesticides available for use, farmers, academics, and policy-makers are increasingly concerned with developing alternative methods of pest management. As a result, there is renewed focus on developing pest control techniques that combine selective pesticides (which are designed to target only specific taxa, *e.g.* a few insect orders at most), with more traditional non-chemical means of pest control. The full spectrum of ecological principles used in organic farming and/or integrated pest management strategies needs to be applied to pest control problems.

Vegetation diversity and insect populations

The use of increased diversity via mixed plantings (*e.g.* inter-cropping or trap cropping) is a time-honored technique to combat outbreaks of insect herbivore pests. Ecological theory stipulates that increases in vegetative diversity may reduce pest outbreaks on crops by interfering with pest colonization as well as tenure-time on host plants (Vandermeer, 1989). Furthermore, more diverse plantings may harbor a broader mix of natural enemies, including predators and parasitoids, further decreasing pest pressure. Over the past few decades, hundreds of experiments have been performed in an attempt to quantify the effects of mixed planting on herbivore populations. While reviews of these experiments have revealed that the effects of increased diversity is not consistent from crop to crop or insect to insect (Tonhasca and Byrne, 1994), there is evidence that in many cases increased diversity leads to a decrease in pest populations.

One common example of increased vegetative diversity in agroecosystems is the incorporation of weeds either directly into or surrounding crop fields. The use of weedy field margins has long been used as a means of enhancing pest control as well as conserving native flora and fauna (Dover, 1991). In addition to providing a means of disrupting insect pest colonization and bolstering natural enemy populations, weedy field margins, unlike intercropping or trap cropping, mesh nicely with standard mechanized harvesting techniques commonly used in temperate farming such as in the United States or Europe. With the loss of many broad-spectrum pesticides in the U.S. and the EU, growers are increasingly turning to selective pesticides in conjunction with weedy field margins as a means of reducing their reliance upon traditional chemical control.

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Field experiments

As part of a larger project aimed at developing IPM protocols for crucifers in Washington State, we performed a series of field experiments exploring the interaction of pesticide disturbance and vegetative diversity on pest populations. We established plots of broccoli surrounded by (i) bare ground or (ii) weedy vegetation, and assessed the impact of weedy margins and selective pesticide use on a typical crucifer pest, *Myzus persicae* (Sulzer), the green peach aphid. We found that broccoli plants in plots surrounded by bare ground had nearly four times as many aphids as broccoli in plots surrounded by weedy margins; furthermore, the densities of alate aphids in bare ground plots was similarly higher (Banks, 2000).

Further studies to assess the impact of natural enemies such as ladybird beetles (*e.g. Coccinella septempunctata*, *C. transversogutta*, *Adalia bipunctata)* and parasitoids (*Diaretilla rapae*) on aphid populations showed that, while decreased colonization may be important in reducing pest loads on broccoli plants, predators/parasitoids may also play an important role, although not necessarily in a very predictable manner (Banks, 2000).

Finally, we introduced treatment with two 'selective' insecticides with different modes of action (triazamate and imidacloprid) at different strengths mid-way through the growing season and monitored effects on aphid numbers. The results illustrated the difficulties inherent in predicting the outcome of pesticide applications across chemical modes of action and landscape configurations. For triazamate treatments, aphids exhibited a 4-fold reduction in density (relative to control plots) when exposed to low levels of pesticide. Plots subjected to high spray levels also exhibited a decrease in aphid densities, albeit not as large, suggesting that perhaps low levels of the pesticide in this case, regardless of margin type, were sufficient to regulate aphid populations.

In contrast, our imidacloprid treatment results were more difficult to interpret. For broccoli plots surrounded by weedy margins, pest densities declined nearly linearly as

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Field experiments at Washington State University. LEFT – John Stark spraying a broccoli patch, surrounded by a weedy margin. Note the exclusion cages on the left, designed to limit access of predators and parasitoids. RIGHT – closeup of a broccoli patch surrounded by a weedy margin.

pesticide concentration increased, but for broccoli plots surrounded by bare ground, there was actually an *increase* in pest densities at the lower rate of pesticide application, accompanied by a *decrease* in pest loads at the higher pesticide concentration level. Although increases in many arthropods, and the green peach aphid in particular, have been documented in both lab and field studies in the past (Yardim & Edwards, 1998; Gordon & McEwen, 1984), it is difficult to differentiate among mechanisms such as growth stimulation in response to low levels of pesticides (*i.e.* hormesis) at the individual level, compensatory increases in reproduction at the population level, or changes in predator/parasitoid pressures at the community level that might explain the aphid response. These field results highlight the importance of attempting to meld different perspectives within the study of a single system. From a toxicological point of view, for instance, these results and others (Stark *et al.,* 1997; Walthall & Stark, 1997) emphasize the necessity of considering population-level endpoints as well as standard dose-response tests when assessing the impact of pesticides. Without such holistic approaches, we will continue to have little understanding of the complex dynamics potentially arising from simple combinations of control techniques in the field—and hence little understanding of how best to deploy such techniques in control programs.

Conclusions

In addition to the potential for reducing our reliance upon chemical control of insect pests, vegetation diversity may play other important roles in agroecosystems with respect to pesticide use. Insect pest resistance to a wide range of registered pesticides is well documented; the advent of the widespread use of genetically engineered anti-herbivore defences, coupled with the phenomenon of cross-resistance, has already led to evidence of insect resistance to new transgenic traits (Chaudry and MacNicoll, 1998). Increasing vegetation diversity by incorporating a "refuge" of non-toxic host plants into a field of sprayed or genetically modified crops has been shown to be an effective means of slowing pest resistance for some crop systems.

Overall, there seem to be benefits to applying mixtures of vegetation diversity and pesticides to insect herbivore pests, but a mechanistic understanding of precisely how these factors interact continues to be elusive. The effect of vegetation diversity alone on insects often represents the complex outcome of a combination of factors, including both physiological and behavioral responses of both pests and natural enemies (Banks & Ekbom, 1999). The additional lethal and sublethal effects of pesticides on pests and their natural enemies throw yet another spanner in the works. Even so-called "selective pesticides" such as imidacloprid have been implicated in the decline of several non-target arthropod species, including natural enemies (Smith & Krischik, 1999). In some cases, these effects may have a significant impact on pest populations in the field. For instance, we found that even imidacloprid doses as low as 1/48th of the label rate decimated laboratory populations of the aphid parasitoid *Diaretiella rapae*, suggesting that even mild field applications may disrupt natural controls of pest populations. More detailed studies documenting the interplay of vegetation diversity, chemical controls, and subsequent sublethal behavior of both pests and natural enemies should go a long way towards elucidating more general patterns of the effects of these combinations of factors on insect populations.

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John Banks is an Assistant Professor of Biology at the University of Washington, Tacoma. Through a combination of field experiments and mathematical modelling, his research explores how the scale and patterning of vegetation diversity affect insect herbivores and their natural enemies. John Stark is a Professor of Entomology at Washington State University. He uses stage-structured population models to develop more accurate assessments of the impact of pesticides on populations, and is especially interested in the merits of comparing individual and population-level endpoints. The collaborative effort described here represents part of an ongoing project conducted by Drs. Banks and Stark to develop IPM protocols for crucifers and other crop systems.

PESTICIDE APPLICATION CONFERENCE

The Association of Applied Biologists (AAB)/British Crop Protection Council (BCPC) conference took place at the University of Surrey, Guildford, UK, on 17–18 January 2000. There were over 140 delegates from all over the world, with 55 scientific papers and posters reporting much of the latest research and development relating to spray application. The conference was divided into 6 sessions:

- Drift
- Measurement
- Adjuvants
- Formulation
- Field crop spraying
- Protected crops spraying

Application of pesticides and other agrochemicals will be an essential part of agricultural and horticultural crop production in the new millennium. Many applications will continue to be made by foliar spraying worldwide. There is still much scope for improving the efficacy, efficiency and environmental safety of spray application, and improving our understanding of its underlying processes. Important areas of progress in spray application in the last 2 years discussed at the conference included:

- Using designs such as the air-induction nozzle system
- Methods of recognising and defining nozzle performance in relation to nozzle developments, particularly relating to the control of spray drift control such that for arable crop sprayers there is information on engineering controls (for both nozzles and complete sprayers) that can be used in Local Environmental Risk Assessment (LERAP) procedures and hence adjust the width of a buffer zone adjacent to surface waters.
- The development of improved control systems, particularly for applications that form part of a precision agriculture approach
- Ways of characterising crop canopies and matching spray applications to parameters of the crop that can be assessed manually or using sensors

Some aspects of spray application remain unresolved. For instance, in fruit spraying, there is wide divergence of opinion about how application rates on pesticide labels should be specified and the effects of canopy structure accounted for.

The proceedings of the conference have been published in *Aspects of Applied Biology* 57, available from the AAB office.

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