THE ECOLOGICAL RISK OF VEGETABLE PRODUCTION: MITIGATION STRATEGIES

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Purpose of study

Pesticide use in agricultural production systems and their effects on human and environmental health have been of public concern for many years. Much research has focused on quantifying the potential risks posed by pesticide use including transport beyond the intended target. In the United States, risk assessment procedures for pesticides have frequently focused on meeting the requirements for pesticide registration as described in the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and in the Food Quality Protection Act (FQPA) (http://www.epa.gov/pesticides/regulating/laws.htm). The pesticide registration process in the European Union (EU) also requires risk information and researchers have made significant contributions in modeling potential fate pathways and estimating the potential exposures. A range of detailed approaches has been developed to assess the potential risks of pesticides as they are transported away from the crops [1-5]. Regulators typically use a tiered approach to risk assessment and frequently need to overestimate exposure and toxicity as not all the parameters controlling pesticide fate and bioavailability are readily quantified. Often strategies to mitigate the identified potential and documented negative effects of pesticides need to be developed on a case-by-case basis. These strategies need to consider the properties of the pesticide product, the commodity endpoint(s), cultivation practices, surrounding ecosystems, and organism and human health.

A cultivation method widely accepted by vegetable producers and growers is the use of polyethylene mulch where a thin sheet of black plastic is placed over a raised bed with bare-soil furrows between the beds. Polyethylene mulch is a preferred practice because it can control weeds, warm the soil, and prevent soil from depositing on the crops; however, nearly 50 to 75% of the field is covered with an impervious surface which reduces water infiltration, enhances runoff, and can lead to significant negative environmental effects [6]. To address the environmental aspects of plastic mulch, two field experiments were conducted to examine two alternative management strategies.

Method

In the first experiment, tomatoes were grown in raised beds covered in polyethylene mulch with bare soil furrows between the beds (Poly-Bare) and were compared to tomatoes grown in plots completely covered with a vegetative residue mulch (Vetch) from the cover crop, hairy vetch (*Vicia villosa Roth*). In the second experiment, the Poly-Bare system was compared to tomatoes grown in raised beds covered in polyethylene mulch with a vegetative mulch (cereal rye, *Secale cereale*) covering the soil in the furrows between the beds (Poly-Rye).

Throughout the growing seasons, runoff from precipitation and simulated rain events was measured, collected, and analyzed for soil loss and pesticide residues. In each experiment, several pesticides, endosulfan, chlorothalonil, esfenvalerarate, and copper hydroxide, were applied prophylactically every week to ten days in the latter half of the season to protect the fruit as is customary practice in the Mid-Atlantic Region of the United States. These pesticides have a wide range of toxicological effects on aquatic organisms that are common to this region. Assessment of all three systems, Poly-Bare, Poly-Rye, and Vetch, was conducted relative to the potential effects from pesticide residues contained in the runoff on organisms and the surrounding ecosystem. The potential risks were estimated with respect to pesticide residues in runoff at the edge of the field, in an adjacent creek, and in a theoretical pond with dimensions similar to that used in the US EPA model PRZM-EXAMS (Pesticide Root Zone Model-Exposure Analysis Modeling System, http://www.epa.gov/oppefed1/models/water/).

Results and Conclusions

Overall, maintaining the polyethylene mulch while replacing bare soil furrows with cereal rye planted furrows (Poly-Rye) reduced runoff volumes by more than 40%, soil erosion by more than 80% and insecticide and fungicide losses by 48 to 74% [7, 8]. Substitution of vegetative residue mulch in place of the polyethylene mulch (Vetch) reduced runoff volume, soil, and pesticide losses by 61, 88, and 73 to 93%, respectively. Although the environmental benefits gained by the use of Poly-Rye and Vetch have been demonstrated, one of the most important factors controlling adoption of an alternative management practice is its effect on harvest yield. In addition to the environmental data, yields were measured over the course of the five years of the field experiments. While some differences were observed in yields between years which were reflective of climate variability, there were no significant differences in yield between management practices.

Copper hydroxide is a widely used fungicide-bactericide approved for both organic and conventional agricultural production of vegetable crops for control of diseases. Copper-based pesticides are often viewed as more "natural" than synthetic organic pesticides, but aquatic biota, such as the saltwater bivalve *Mercenaria mercenaria*, are extremely sensitive to low concentrations of copper. Seasonal runoff losses of 20 to 36% of applied copper hydroxide were observed in tomato plots using plastic mulch with bare soil furrows. The addition of vegetative furrows between the raised, polyethylene-covered beds or the replacement of polyethylene mulch with vegetative residue mulch reduced copper loads in runoff by an average of 72 and 88%, respectively, while maintaining harvest yields. Use of these alternative management practices could reduce surface water concentrations in nearby streams from the observed 22 μg/L [6] to approximately 6 and 3 μg/L, respectively, which would be below the median lethal concentration for larval clams (*M. mercenaria* 96 h LC_{50} = 21 μg/L) and close to or below the EPA guidelines to protect aquatic life (24-h average = 5.4 μg /L for fresh water and 4.0 μg /L for salt water) [7].

Pesticide concentrations in surface waters (adjacent creek) corresponding to a 1:15 dilution of the runoff were reduced in the Poly-Rye management practice relative to Poly-Bare, bringing chlorothalonil and endosulfan concentrations below the LC_{50} for a number of organisms evaluated (Poly-Rye, 1:15 dilution: chlorothalonil = 35 μg/L, endosulfan = 10 μg/L, esfenvalerate = 1.0 μg/L). Replacement of the polyethylene mulch with vegetative mulch (Vetch) further reduced pesticide concentrations (Vetch, 1:15 dilution: chlorothalonil = 4.9 μg/L, endosulfan = 5.9 μg/L, esfenvalerate = 0.6 μg/L), which lowered chlorothalonil concentrations to levels below the LC_{50} for all organisms evaluated and endosulfan concentrations below the LC_{50} for *Oryzias latipes*. With the exception of *R. limnocharis* (LC_{50} for esfenvalerate = 28 μg/L), esfenvalerate concentrations remained above the LC_{50} for all organisms evaluated with all management practices [8].

Risk Quotients (RQs) and Hazard Rating (HR) calculations of pesticide residues from vegetable production were reduced substantially when vegetative mulches and buffers are used. In all the assessments, endosulfan was found to present the greatest potential risk followed by esfenvalerate. Runoff from Poly-Bare presents the greatest potential risk to sensitive organisms (RQs) and to ecosystem health (HR) while the use of Vetch minimizes these risks the most [8].

The current evaluation suggests that several of the pesticides may also contribute to the decline of ecosystem health, particularly copper, endosulfan, and esfenvalerate as they are more likely to sorb to soil particles and have high hazard coefficients. Furthermore, these compounds are often tank-mixed and applied together. These calculations do not address the potential synergistic interactions between pesticides which may enhance the toxicity of certain pesticides, other ecosystem components such as phytoplankton, submerged aquatic vegetation, wading birds, and aquatic mammals, or the potential effects on the specific stages within the life cycle of species. The results of this analysis will provide environmental scientists, producers, regulators, and other interested groups with comparative risk information to allow for informed management and regulatory decisions that will protect aquatic species and our soil and water resources.

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