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Quantifying economic and environmental tradeoffs of walnut arthropod pest management

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ABSTRACT

Many arthropod pesticides used by California walnut growers have been linked to water quality impairment. However lower risk alternatives are often associated with higher costs. The purpose of this paper was to: (1) identify currently practiced pest management strategies with probable high water quality impact, (2) quantify the importance of factors which affect economic tradeoffs associated with reducing water quality impact, and (3) identify pest management strategies that could potentially lower water quality impact with less economic consequence. An integrated analysis using environmental, economic and pesticide use data revealed that 96% of the pest management strategies analyzed were candidates for reducing the impact on water quality. Replacement of current pesticides by alternative pest controls lowered probable impact, but resulted in an economic tradeoff in the form of higher costs for the majority of growers. If biological control could eliminate the need for miticides and aphicides, this tradeoff could be replaced by savings for nearly half of the sample analyzed. This cost savings would most likely be realized by growers who currently have low numbers of pests that are not candidates for biological control, and relatively high use of organophosphates and miticides. The results indicated that if these pest management strategies had been replaced by alternative strategies and biological control, then total organophosphate, pyrethroid, and miticide active ingredient use would have been reduced by an average of 5 kg/hectare per year, while simultaneously lowering the grower's pest management costs by an average of $128/hectare, thus contributing to both economic and environmental long-run sustainability.

1. Introduction

In 2006, California led the United States in agricultural cash farm receipts, totaling $31.4 billion, which represents 13.1% of the national total. Six of the top 10 California counties were in the San Joaquin Valley, an area considered to be one of the most agriculturally productive regions in the world. Fruit and nut crops, many of which are grown exclusively in California, contributed 33% of the state's total receipts (CDFA, 2007). This high level of agricultural productivity has come at a cost, however, with 46 out of 100 impaired waterbodies in the Central Valley resulting from pesticide use (EPA, 2006). This study examines these issues through an analysis of the environmental and economic consequences that would occur if walnut growers were to alter their pest management strategies to lower surface water quality impacts generated by pesticide runoff in the San Joaquin Valley.

Currently, many walnut growers employ conventional, broad spectrum pesticides. While they are cost effective in controlling multiple pests at once, they also pose substantial risks to aquatic ecosystems and water quality through unintended harm to non-pest species. While pesticide use on walnuts during months of high precipitation (November–February) is relatively low, it can be high during the summer months when irrigation runoff facilitates off-site movement of pesticides to waterbodies (Schwankl et al., 2007; CDPR, 2008; CIMIS, 2008). Many newer pesticides have been developed that are believed to have a lower negative impact to water quality than the conventional products. Besides having generally lower toxicity, these soft alternatives differ from their broad spectrum counterparts in that they are more selective, acting against only narrow ranges of species. Thus, if an alternative product enters a waterbody via runoff, the combination of lower

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toxicity and higher selectivity reduces the potential for harm to non-pest species compared with conventional products.

Growers have been slow to adopt these alternative products, however, due to perceived drawbacks such as higher material costs, more applications per season, and/or increased monitoring requirements. These costs may be offset by potential savings associated with secondary pest control if biological control by natural enemies is sufficient to maintain secondary pest populations below economically damaging levels. Many studies have documented higher populations of natural enemies of pests in crops treated with selective controls compared to those treated with broad spectrum pesticides (Zalom et al., 2001; Agnello et al., 2003; Prischmann et al., 2005). Therefore, a grower using alternative selective pest controls will likely have a larger population of natural enemies, and thus a greater potential for effective biological control that can replace the need for certain pesticides and lower costs. Depending on the grower's current practices, the potential savings could make an alternative pest management system economically competitive with conventional systems.

In order for walnut growers to achieve long-run agro-ecological sustainability, pest management must be based on practices that are both economically viable and environmentally sound. Detailed information is therefore needed on both environmental impact and economic considerations associated with production practices. This study attempts to identify the specific tradeoffs between economic and surface water quality impacts associated with different pest management strategies (PSs) in California walnut production systems. The objectives of this paper are as follows: (1) to identify currently practiced PSs with probable high negative water quality impact, (2) to measure potential tradeoffs in the form of increased pest management costs if the grower were to lower impact to water quality through solely using alternative products, and (3) to quantify the relative importance of different factors affecting these tradeoffs, in order to identify the current PSs that could potentially lower impact with the least economic consequence, and thus meet the goals of sustainable agriculture.

2. Materials and methods

2.1. Definitions

In this study, a PS was defined as all insect and mite pest control products used during a year by a grower. A tradeoff was defined as the dollar per hectare amount that the cost of the PS would increase if the grower adopted an alternative PS equivalent in pest control efficacy to their current practices in order to lower water quality impacts to an acceptable level. If the cost decreased or remained the same, both the environment and the grower benefited, and there was not a tradeoff upon adoption of the alternative strategy. The more complex notions of water quality impact measurement, acceptable impact level, and alternative strategies are explained in detail in later sections.

2.2. Commodity, study area and sample

Walnuts were chosen for analysis due to their economic importance in California, their high reliance on broad spectrum conventional pesticides, and the strong potential for risk reduction via the emergence of many newer alternative products (EPA, 1997, 2006; CDFA, 2007). Multiple years and counties were included in the analysis to reflect the broad range of spatial and temporal variation of currently practiced PSs. The study area included the three contiguous counties of San Joaquin, Stanislaus, and Merced, which represent approximately 1/3 of total walnut production in California (CDFA, 2007; CASS, 2008). Data were analyzed over the 5 year time span from 2002 through 2006.

The PS, rather than the grower, was the experimental unit of this analysis. For a PS to be included in the sample, it needed to meet the following two criteria. First, given the economic importance of the primary walnut pest, codling moth (*Cydia pomonella*), only PSs that indicated treatment for codling moth, either alone or with other pests, were chosen for analysis. Second, PSs using solely alternative pest controls were excluded because they represented only about 1% of the potential PSs identified. Thus, all PSs in the sample included conventional products, either alone or in conjunction with alternatives, to treat pests.

Each grower in the study area could contribute from zero to five PSs to the analysis, depending on whether the grower employed a PS meeting the above two criteria in any of the 5 years analyzed. Furthermore, the PSs contributed by a grower could vary from year to year or remain the same, depending on the particular pesticides and use rates employed by the grower during the year. The resulting sample of all three counties over 5 year included 2531 PSs for analysis, representing the practices of 891 growers on approximately 14,164 hectares of walnuts.

2.3. Data sources

2.3.1. Environmental data

Environmental data consisted of environmental indices that are available online for over 300 pesticides as part of the Environmental Impact Quotient (EIQ) model, created by Kovach et al. (1992, 2007). This model has been used by a wide range of international authors and policy makers on a diverse set of crops and locations (Edwards-Jones and Howells, 2001; Gallivan et al., 2001; Smith et al., 2002; Bues et al., 2004; Brimner et al., 2005; Brookes and Barfoot, 2005; Badenes-Perez and Shelton, 2006; Cross and Edwards-Jones, 2006; Kleter et al., 2007). While the EIQ model includes indices for many different environmental mediums, only the surface water quality index, represented by the impact of pesticides on fish, was used in this study. While aquatic systems are comprised of many varied species, fish are generally thought to be good indicators of overall toxicity, with fish toxicity values often correlating well with those of aquatic invertebrates (Kenaga, 1978; Maki, 1979). The water quality index values for a total of 33 different dominant active ingredients of the pesticide products used in the PSs analyzed by this study were downloaded.

The unit-less water quality indices were calculated by Kovach et al. (1992) for each active ingredient as the product of a 96 h LC_{50} rank for fish and a surface loss potential (runoff) rank. Kovach et al. (1992) assigned the LC_{50} rank a value of 1 if the LC_{50} was greater than 10 μl/l or mg/l, a value of 3 if the LC_{50} was between 1 and 10 μl/l or mg/l, and a value of 5 if the LC_{50} was less than 1 μl/l or mg/l. Similarly, the runoff rank was assigned values of 1, 3, or 5, based on whether the runoff potential was small, medium, or large, respectively, according to the Groundwater Loading of Agricultural Management Systems (GLEAMS).

These water quality indices were therefore solely based on active ingredient toxicity and exposure characteristics. They did not take into account the effects of environmental characteristics such as slope, soil, application timing relative to precipitation or irrigation, proximity to waterbodies, and/or the use of best management practices, all of which can influence the probability of a pesticide reaching a waterbody. Furthermore, the indices did not account for other modes of offsite transport to waterbodies, such as airborne drift. The exclusion of environmental characteristics from the model ignores their possible mitigating effects on offsite movement of pesticide from a field to a waterbody, which may lead to over-estimation of impacts. In contrast, the absence of modes of transport in the model other than runoff can lead to an under-estimation of impact if drift is significant.