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Regulatory risk and farmers' caution with pesticides in Costa Rica

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Abstract

In a globalizing economy, agri-food regulation in the industrialized world increasingly affects food producing industries and farmers in developing countries. Discussions of these transformations remain mostly disconnected from the literature on pesticide use in developing countries, which emphasizes widespread pesticide misuse and abuse. Previous attempts to consider the relationship between agri-food regulation and farmers' pesticide use are found lacking because they do not situate it deeply enough within the social relations of exchange in contract farming. Using a political ecological approach attentive to this relationship, I found many farmers exercising considerable caution in their pesticide use vis-à-vis residues on mini-squash and chayote, the main export crops in Northern Cartago and the Ujarrás Valley, Costa Rica. Exporters' mediation of regulatory risk—conceptualized as the possibility that an actor's behavior will be subject to state regulation and that out-of-compliance behavior will result in negative consequences that impact the actor—largely explains why this type of caution occurs. A gap between regulation and practice persists, however, because of the local history of residue violations and a related misinterpretation of pesticides' color bands. The conclusion critiques the first world/third world binary that is mapped onto pesticide use research as preventing advancements in understanding farmers' pesticide use, shows the applicability of political ecology's chain of explanation to the local consequences of agri-food regulation from afar, and proposes further engagement between agri-food studies and political ecology to better theorize local-global interactions between land users and the new spatiality of economic governance in agri-food networks.

Key words

export agriculture; political ecology; agri-food studies; regulatory risk; governance; contract farming; pesticide use; Costa Rica

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Introduction

Recent work by geographers and others shows that in a globalizing economy, food regulations in the industrialized world increasingly affect food producing industries and farmers in developing countries. Critical researchers typically find these transformations to be moderately to extremely negative in both the African (Barrett et al., 1999; Freidberg, 2003; Opondo, 2000) and Latin American contexts (Murray and Hoppin, 1992). These effects involve structural changes in the supplying farm base—tighter control over contract farmers or a shift from a reliance on small farmers to large-scale plantation production—and environmental degradation through agrochemical use. For example, in Costa Rica, Thrupp (1991, 2) notes that "the banana companies use heavy applications of fungicides, herbicides and nematicides in order to meet stringent cosmetic standards and production goals demanded by buyers in the U.S. and Europe."

Yet the development of alternative agri-food networks—including organic, fair trade, and eco-certification—may have positive effects on farmers' production practices and communities in the global South (e.g., Melo and Wolf, 2005). In addition to these alternative systems, important segments of conventional agri-food systems have also undergone recent change demanding better environmental and social performance, such as EUREPGAP standards created by European supermarket chains, "private-interest" regulation by UK supermarkets, and vertically integrated agro-export firms in the Africa-to-Europe fresh produce trade (Barrett et al., 1999; Flynn et al., 1994; Freidberg, 2003; Konefal et al., 2005; Marsden et al., 2000; Winter, 1997).

In this age of certification and private standard proliferation in the South-to-North agro-export trade, I find it important to emphasize that agri-food regulation still occurs at the state level in much of the global North and remains important since it acts from afar, applying to almost all produce imported from the global South.[1] In this paper I focus on one specific aspect of state regulation: pesticide residue regulations, which take the form of pesticide tolerances, or maximum residue levels (MRLs) that are permitted on food. While the argument that national pesticide residue regulations are "non-tariff barriers" to trade has been advanced (e.g., Boh, 2003), the World Trade Organization (WTO) has decided that consumer health and safety regulations are some of the few "non-tariff barriers" that are permissible (Freidberg, 2004). Despite its global reach, from Argentinean apples to Zimbabwean cherry tomatoes, we still know little of the specific effects of conventional regulation in the global North on production practices and their environmental consequences in places in the global South distant from the area of enforcement. A thick description and theorization of these effects, I argue, is a necessary addition to both the "under-theorized" field of agri-food studies (Morgan et al., 2006, 5) and a political ecology of globalization (Bebbington and Batterbury, 2001).

Discussions of transformations in and effects of agri-food regulation remain mostly disconnected from the literature on pesticide use in developing countries, which emphasizes widespread pesticide misuse and abuse. As Grossman (1998) points out, the vast majority of this literature emphasizes that farmers indiscriminately use dangerous pesticides and exercise almost no caution (e.g., Abeysekera, 1988; García, 1999; Guan-Soon and Seng-Hock, 1987; Heong et al., 1995; Hui et al., 2003; Yen et al., 1999; Zaidi, 1984). Most studies point to the lack of protective clothing worn, the common use of overdoses and pesticide cocktails, the lack of respect for the time required between application and harvest (known as preharvest interval, or PHI), and the imprudent use of highly toxic organophosphate and carbamate insecticides.

Through an empirical case study this paper connects recent interest in agri-food regulation

[1] State regulation remains more important in the U.S. than in the UK, where much agri-food regulation is now conducted by supermarkets (Flynn et al., 1994).

with a political ecological critique of the farmer pesticide use literature. It examines pesticide use by mini-squash[2] and chayote[3] farmers in Northern Cartago and the Ujarrás Valley, Costa Rica, who produce for the U.S. and Canadian market. In aiming to understand the effects of regulation from afar on export farmers, it uses a political ecological approach focused on farmers' land use decisions, and compares their pesticide use with that of (1) the literature's "typical" developing country farmer and (2) pesticide residue tolerances for produce sold in the U.S., established by the Environmental Protection Agency (EPA) and enforced by the Food and Drug Administration (FDA).[4] The questions addressed below are: What are the effects of pesticide residue regulations in the fresh produce commodity chain on farmers' production practices? And, in light of arguments for contract farmers being "unfree" in their production decision-making processes (Watts, 1992), are contract farmers producing export crops in compliance with the regulations of the export markets?

The paper proceeds as follows. First I present a background to risk and pesticides in which the concept of regulatory risk as experienced by the land user is developed. Methods are discussed at length because of deficiencies in previous pesticide research. I then present results from fieldwork on farmers' caution concerning pesticide residues that remain on harvested produce. Export farmers in the study site are generally careful about pesticide residues in a number of ways, including the selection of insecticides of less residual chemical classes, general respect for recommended pesticide doses, and adherence to PHI requirements for insecticides. The discussion interprets these forms of caution and explains the mismatch between regulation and practice. The

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[2] Mini-squash, a.k.a. "micro-veg" (Freidberg, 2003), refers to scallop squash and zucchini (both *Cucurbita pepo* L.). These were introduced in the 1980s and are part of developing countries' shift from producing classic, non-perishable export commodities like coffee to perishable, high value foods for export (Watts and Goodman, 1997).
[3] Chayote, *Sechium edule* Sw., is a cucurbit of Central American origin that was exported starting in the 1970s. Costa Rica is the largest supplier of the U.S., with production concentrated in the Ujarrás Valley (Lira Saade, 1996).
[4] I leave out Canadian regulation and enforcement for reasons of brevity.

conclusion follows with broader implications, including the future of agro-export sectors in the South, the contribution that combining political ecology and agri-food studies makes to needed research on conventional agri-food networks, the problematic influence of the North/South binary on pesticide research, and the applicability of political ecology's chain of explanation to regulation from afar.

Theorizing risk and pesticides in the context of political ecology and agri-food governance

Pesticides are one the many ghosts that haunt our modern world. Risks from technologies such as pesticides feature prominently in rise of the environmental movement (Carson, [1962] 1994) and in the risk society thesis (Beck, 1992), where environmental risks created by modern industrial society increasingly dominate social debate. These include human health risks like poisoning, neurological damage, cancer, endocrine system disruption, and immune system suppression to workers and farmers in direct contact with pesticide, and also to citizens who can encounter agrochemicals in their drinking water, food, and environment. Environmental risks are clearly important as well (Pimentel and Lehman, 1993).

Pesticide residues in food, legitimated through state-set tolerances, remain vigorously debated. Showing that chronic, low-dose pesticide exposure is safe or harmful is currently beyond the limits of toxicology and epidemiology (Shrader-Frechette, 1985). As Beck (1992, 64) notes, "A central term for 'I don't know either' is 'acceptable level.'" Because the mechanisms by which pesticides affect health are unfamiliar to most citizens, the potentially effects are serious but delayed, and the risk is imposed rather than voluntary, pesticides are a dreaded risk (Slovic, 1987). Thus, great consumer concern over pesticide residues persists (Knight and Warland, 2004).

This paper considers another facet of the intersection of risk and pesticides, one that arises from a focus on farmers and their connections to markets. A vast literature from many disciplines addresses farmers' and rural communities' responses to risks in agriculture. For example, human ecologists have shown that community social structures have developed to act as a resource reservoir for those experiencing crop failure (Kirkby, 1974). Political ecologists have examined farmers' reasons behind planting diverse crops, showing that one rationale is hedging against crop failure in risky mountain climates (Zimmerer, 1996). In response to agricultural marketing risks, small farmers plant a combination of high risk cash crops and lower risk subsistence crops (Barham et al., 1995; Feder, 1980) and maintain social relationships in different marketing channels (Mannon, 2005).

This paper adds to the understanding of risk in agriculture by examining farmers' responses to a relatively new and underappreciated form of risk with a very different geographic dimension: regulatory risk. I define regulatory risk as the possibility that an actor's behavior will be subject to state regulation and that out-of-compliance behavior will result in negative consequences that impact the actor.[5] Regulatory risk arises from the enforcement of non-economic market requirements in agricultural commodity markets of the industrialized nations, most notably phytosanitary and contamination regulation.[6] It is borne by actors in commodity chains and acts on them from afar. The stakes for export firms and farmers in developing countries are quite high: production and post-handling practices can lead to violations of export market food standards, thereby causing economic losses for exporters and potentially resulting in the farmer's loss of access to more lucrative export market channels.

Regulatory risk is an on-the-ground consequence of the changing spatiality of agri-food governance. Whereas land users have been historically sanctioned by communities governing the commons (Blaikie and Brookfield, 1987; Ostrom and Gardner, 1993), regulatory risk arising from

[5] I thank an anonymous reviewer for suggestions about this concept. This use contrasts with business usage where it means regulatory uncertainties that impact firms (Larsen and Bunn, 1999).
[6] Many developing countries have these types of regulations, but the lack of enforcement and punitive measures means that farmers face little risk in not complying.

non-local regulation and mediated through social and economic relationships is a recent phenomenon. It was brought about by the globalization of food (Goodman and Watts, 1997) that occurred in the context of existing regulations protecting consumers and environment. Following Lowe et al. (1994, 2), regulation in agri-food systems should be construed broadly as "economic governance" to avoid "a false antithesis between the state and the market." This economic governance, like environmental governance, acts "to assure the stability of capitalist relations of power and accumulation" (Robertson, 2004, 362). Indeed, a necessary condition to the functioning of globe-spanning, conventional agri-food networks is consumers taking food safety for granted despite ignorance of its production, a situation which states attempt to legitimate through regulation that is non-threatening to—and actually necessary for—capital accumulation. We remain largely ignorant to the effects of this new spatial arrangement of governance on land use practices in specific locales incorporated into conventional agri-food networks.

Political ecology offers a powerful approach to understand farmers' responses to regulatory risk imposed by the new spatial arrangements of agri-food governance. Focusing on the land user, political ecological analysis often follows a "chain of explanation" that extends from the field to the larger-scale political, economic, and ecological actors and processes that affect land users' decisions (Blaikie and Brookfield, 1987). Although the chain of explanation has been successfully applied to the land and water degradation in developing countries, I suggest it is equally useful to apply to agri-food regulation from afar.

Previous research on pesticide use vis-à-vis non-local regulation suffers from weak theorization concerning export farmers' decision making. A considerable literature on Latin American non-traditional agricultural exports (NTAEs) implies that export farmers do not take these regulatory risks seriously because they are not informed about them or must ignore them because they find themselves on the pesticide treadmill or struggling to meet aesthetic requirements

(Conroy et al., 1996; Hamilton and Fischer, 2003; Murray, 1994; Thrupp et al., 1995). Thrupp et al. (1995) provide the most useful framework by showing that export farmers face three relevant U.S. market requirements: (1) conforming to phytosanitary standards that require a complete absence of pests and pathogens, a requirement that pressures toward higher levels of pesticide use; (2) meeting high aesthetic standards for unblemished produce, which also may pressure toward higher pesticide use; and (3) complying with EPA pesticide tolerances, which pressures toward lower or more rational pesticide use. Because of these contradictory pressures, farmers are in a difficult situation in which they are pressured from one side to decrease or use only certain pesticides to comply with tolerances, and on the other side, to use pesticides frequently in high volumes to meet strict phytosanitary and aesthetic requirements.

While a valid conceptualization of contradictory regulatory pressures, theorization of how these contradictions are resolved in specific locales remains wanting since the authors ultimately state, "The immediate pressures to increase pesticide use tend to outweigh other considerations" (Thrupp et al., 1995, 51). We do not know why this would be the case, how it may be prevented, or how it is impacted by various human and non-human actors in the commodity chain. I argue that outcomes will be shaped by a crucial but neglected element: the social relations of exchange in contract farming. In many commodity sectors, exporters impose regulatory risk through policing of land use practices and attempts to directly shape the production process (Watts, 1992; Wolf et al., 2001), arguably with considerable attention paid to farmers' pesticide use. Contract farmers can decide to use pesticides that they know violate regulations, thereby gaining potential productivity benefits, but they run the risk of being caught and sanctioned. Pesticide use decisions, therefore, must be understood in the context of broader social relations and new spatial arrangements of capital accumulation, trade, and economic governance.

Methods

In the face of regulatory risk, farmers can choose to exercise caution in their use of pesticides. While most researchers treat caution with agrochemicals as if it is a binary variable, i.e., farmers are cautious or not cautious, I argue that we must disaggregate it. Since pesticides cause a multitude of problems—including compromised health for farmers, workers, rural residents, and consumers in addition to environmental problems including wildlife and fish kills, surface water contamination, and groundwater contamination—there are many different types of caution that can help ameliorate these different problems. These include caution about: (1) immediate exposure to those people in the field during the application; (2) exposing those living nearby; (3) pesticide residues eaten by those who consume the produce; and (4) the release of pesticides into the environment, which itself can be divided into subcategories, including protecting groundwater, surface water, beneficial insects, and wildlife. For each of the many problems caused by pesticides, one could list a form of caution that could decrease or avoid it. Thus, with some research effort researchers will find almost all farmers who use pesticides to be exercising some form of caution while ignoring other types of caution.

This paper focuses on farmers' caution concerning pesticide residues on their harvested produce as a response to regulation from afar.[7] Many variables affect the amount of a pesticide that remains as residue on food. These include a farmer's decisions about which pesticide to apply, how much to apply, the frequency of applications of the same pesticide, the PHI, and various other factors generally not under the farmers' control, including weather conditions during and after the application, the characteristics of the chemical, and environmental and crop characteristics that determine rate of breakdown (Wargo, 1998). This paper focuses on those factors directly under the farmers' control: the specific pesticides applied, the dose used, and the PHI.

[7] This focus is not meant to imply that farmers' protective clothing is unimportant.

The data on export chayote and mini-squash come primarily from farmer surveys I conducted between late April 2003 and early January 2004 in Northern Cartago and the Ujarrás Valley, Costa Rica. This area is Costa Rica's "vegetable basket" where truck farmers take advantage of a range of environments and fertile volcanic and alluvial soils to produce more than 30 types of vegetables for national and export markets. Of the 148 farmer surveys, fifteen export mini-squash farmers and 20 export chayote farmers participated in the survey.

In addition to the standardized survey, I adopted a political ecological approach resembling Burawoy's extended case method, which involves ethnographic participant observation, interviews, and many other techniques. It is "extended" in four ways, with the extension of (1) the observer into the world of the subject, (2) observations over space and time, (3) the micro situation to macro forces, and (4) findings to inform and modify social theory (Burawoy, 2000). To this end, as compliments to the survey I used informal and semi-standardized interviews and focus group discussions with export farmers. I also utilized participant observation, which included spending time with farmers on their farms, participating in meetings of export farmer organizations, planting vegetable crops, and learning from farmers how to grow and sell them. Semi-standardized interviews of managers of exporting firms and national produce buyers were also conducted. These methods were integrated for an understanding of the local context of pesticide use and its relation to "macro" forces, and the conclusion serves as the extension of theory based on the findings.

Some comments on survey design are required. Data collected by researchers concerning farmers' respect of PHI can be very different depending on how survey questions are asked. Valverde et al. (2001, 34-5), in their study of Costa Rican farmers' practices relating to pesticide residue levels on fresh produce, report that "Practically none of the farmers interviewed mentioned applying pesticides a week before harvest, nor in the post-harvest stage." It is, however, unlikely that farmers were reporting their actual practices because of the crops they grow and the climatic conditions. Many vegetables, such as sweet pepper, chayote, squash, and tomato, consistently produce fruit when they are in their harvest stage, with harvests every two to four days for several months. Additionally, the vegetable varieties available to Costa Rican farmers, with the exception of chayote, were generally created for temperate areas and lack adaptation for tropical climates, resulting in "very high pest damage" (Barbosa, 2000, 105). Costa Rica's tropical climate is extremely conducive to pests and pathogens. Due to these circumstances, farmers in Costa Rica typically spray vegetable crops at least once per week. Even if a vegetable farmer sprays immediately after a harvest, the longest amount of time between the spray and the next harvest is three to four days, not a week or more as the farmers interviewed by Valverde et al. (2001) report.

This discrepancy exists because of the way survey questions are asked. During the course of my interviews I found that farmers rarely voluntarily say they leave only a few days between spraying and harvesting if a researcher asks, "How many days are there between the last spray and the harvest?" as I did in my first few surveys. Farmers typically answered between one to four weeks, even for consecutively harvested crops for which this would be impossible. In contrast, I found that if I asked in regard to these continuously harvested crops, "When during the week do you harvest?" and the response is, "Every Monday, Wednesday, and Friday" and then I followed up with, "So when do you spray?" the answer will be something like "Every Monday after harvest" or "On Saturdays." I interpret this difference in response to mean that farmers do not want to be seen as spraying very close to harvest since it could be taken as a lack of consideration for the health of the consumer, even though they find it a necessary practice to maintain their harvest.

Like obtaining PHI information, acquiring data on the dose of a pesticide used involves a set of questions. In order to calculate dose by pesticide in kilograms of active ingredient (ai) per hectare, I (1) asked farmers how many *estañones* (50 gallon drums) of spraying mixture they used per unit of land, (2) asked farmers how much of a specific pesticide they use per *estañón*, (3) found the label of the pesticide to determine the percentage of active ingredient, and (4) found out the actual measured quantity of each specific pesticide container sold in the area, e.g., 900 grams in a package. The first three pieces of information allowed for the calculation of the amount of active ingredient used per unit of land in a pesticide application while the fourth piece of information is a correctional factor for farmers' tendency to round to the nearest whole unit (e.g., saying a kilogram for 900 grams). Farmers provided the first two sources of information while agrochemical sales places provided the last two.

Below I use data from my farmer surveys concerning pesticide type, dose, and PHI to compare export farmers' pesticide use in the study site to two reference points. The first reference point is the "typical" farmer in developing countries as portrayed by the literature. Grossman's (1992, 1998) political ecological work on pesticides implicitly uses the same reference point. These "typical" farmers often depend on highly toxic organophosphate and carbamate insecticides (e.g., Wright, 1986, 1990), use overdoses, and disregard PHIs (Abeysekera, 1988; Yen et al., 1999). The second reference point I use for comparison is U.S. regulation, specifically EPA pesticide tolerances (EPA 2004) and FDA enforcement for the crops in question (FDA 2005).

Results

While the quantitative data I present below are useful, they alone cannot demonstrate causation (Sayer, 1992). To understand causation, I rely on in-depth interviews with export farmers and exporters and library research.

Most export farmers expressed concern about the possibility of causing rejections due to pesticide residues. The level of concern has increased over time. In the 1970s, the early days of chayote exports, it is unlikely that farmers were seriously concerned with pesticide residues on their produce since it was a new risk, the negative consequences of which had not been felt. As early as 1985, however, chayote farmers held meetings concerning "problems of pesticide residues in the fruit" (Valverde G., 1986, 198). In the mid-1980s, chayote export shipments were rejected at U.S. ports due to illegal pesticide residues—primarily the organophosphate insecticides methamidophos and dimethoate—detected by FDA (FDA Pesticide Program 1988). These rejections caused substantial financial losses for exporters and created the impetus to police pesticide use. Costa Rica's Ministerio de Agricultura y Ganadería (MAG) became involved by testing farmers' fields for the problematic pesticides.

My interviews with the managers of the five major exporters in the area revealed that four suspend purchases from a farmer that causes residue violations. Being cut off from the export market means a loss of income because of the higher prices it offers compared to the national market. Thus, with increased monitoring of pesticide use by export firms and the state, export farmers had to weigh regulatory risk in their decisions starting in the 1980s.

Producing for export has made farmers more aware of pesticide residues. Many explained that the switch to export production required being more cautious with pesticide use. Farmer 6, who used to grow vegetables for the national market, described the changes when he started planting mini-squash for export:

> *Farmer 6*: [It was] in chemicals, more than anything. Before I used more residual products …
> *RG*: Why did you change?
> *Farmer 6*: Because it was a requirement that Exporter B demanded of one. Because it is a product for export. It is for export, so you have to lower the level of residuality of the chemical products. And also for one's own benefit.
> *RG*: If you had not converted to non-traditional [export] products, how would your agricultural production practices be now?
> *Farmer 6*: I would have continued using highly residual [pesticides]. Because it is one way that we can exist with the prices of the commodities and the pests that there are. The prices are low [for national market vegetables], and the pests appear every day. So, you have to be spraying, spraying products that are residual because you cannot get by [without them because they are more effective than less residual ones] (In-depth interview, Farmer 6, December 10, 2003).

Similarly, Breslin (1996, 32) quotes mini-squash farmer Martín Aguilar of Cipreses, Costa Rica, as saying, "Exporting is what puts the quality in our products … Exporting gives us standards we have to meet … .”

Yet choosing pesticides is not merely a matter of farmers trying their best to comply with non-local regulations. While many emphasized that they do their best, others noted the temptation to use methamidophos, a highly toxic and effective insecticide not registered for use on squash in the U.S. or Canada. Many farmers and exporters noted that using methamidophos results in larger harvests, yet it is risky—vis-à-vis regulation—since it has caused past violations. Thus, spraying methamidophos, and organophosphates generally, involves a risk calculation of a low probability-high consequence event by export farmers in the study site: is increased production worth the possibility of losing access to the export market? Importantly, the perception of the risk is amplified through communication of it (cf. Kasperson et al., 1988) from exporters to farmers, i.e., through the social relations of exchange. The data below show the specific ways in which farmers exercise caution in response to regulatory risk.

Export Mini-Squash Farmers' Caution with Pesticide Residues

This section includes data on the pesticide use of 15 farmers who grow mini-squash in Northern Cartago and the Ujarrás Valley for export to the U.S. and Canada. Table 1 reveals that organophosphate and carbamate insecticides, which are generally highly toxic and tend to dominate pesticide use in developing countries, account for 14.9 percent of all insecticide doses used during the growing cycle. The generally less toxic and less residual pyrethroids are the dominant insecticides, making up 39.3 percent of all insecticide doses.

Figure 1 and 2 show export farmers' pesticide use in relation to regulation with the grey fill representing a problematic situation. The dose section on top uses “x's” to plot doses used by each farmer in relation to the maximum recommended dose, which is 100 percent. The number below is the average. A grey fill here means that the dose used exceeds the label's requirements. Of the 59 pesticide active ingredients used, the average dose is within the recommended dose for all but three.

Figure 1's PHI section presents data on farmers' respect of PHI. The numbers are the result of subtracting the maximum required PHI on the label from farmers' reported PHIs. Thus, a zero means that the farmer respects the PHI exactly, while a negative number means that PHI is violated. The "Ave. min. PHI" shows the average of the minimum PHIs reported by mini-squash export farmers who use that pesticide. The grey background means that it violates the PHI required by the Costa Rican label. Export mini-squash farmers' average minimum PHIs comply with the recommended PHI for 68.4 percent of pesticide active ingredients used, excluding herbicides.[8] For insecticides, export mini-squash farmers are within PHI for 75 percent, demonstrating considerable caution in terms of avoiding high levels of residues on their produce. In contrast, 44.8 percent of average minimum PHIs for fungicides violate the PHI recommendations, showing that export mini-squash farmers are much more likely to ignore PHIs for fungicides than insecticides.

Regulatory information is presented below PHI information in Figure 1. The top checkboxes in the section show that 83.1 percent of pesticides used on mini-squash are registered for agricultural use by EPA on some crop. Those pesticides not registered by EPA are ones that have never been registered,[9] rather than representing a pesticide that has been banned. The middle checkboxes—in which a check (signifying tolerance) or dash (showing exemption) means that EPA allows residues of these pesticides to exist on this crop—reveal that only 40.7 percent conform to or are exempt from EPA tolerances on squash. Interestingly, in 2003 FDA tested for residues of only 20.3 percent of the pesticides used, while another 8.5 percent were exempt from tolerances.

Export Chayote Farmers' Caution over Pesticide Residues

This section presents data from the 20 export chayote farmers in the survey who sell to the handful of major exporters in the Ujarrás Valley. Some data are from the very large farming

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[8] Herbicides are excluded since they are not applied directly to the plants.
[9] The reason for lack of registration is difficult to determine. It can mean that registration failed presumably because of health or environmental risks, or the firm that owns the patent has not attempted registration.

operations of the exporting firms, but most are from small- to medium-scale farmers who sell directly to the exporters.

Returning to Table 1, pyrethroids make up two-thirds of all insecticide applications by export chayote farmers. Organophosphates and carbamates comprise only 16.7 percent of the total.

Figure 2's dose section reveals that, on average, export chayote farmers use overdoses of 4 of 47 pesticide active ingredients. As with export mini-squash, the "x's" show that most farmers use doses below the maximum recommendation.

Figure 2 shows that PHIs are, on average, violated for 63.6 percent of pesticide active ingredients used by export chayote farmers (note that PHIs higher than 60 are shown above the graph lines, and herbicides are again excluded). As with export mini-squash farmers, export chayote farmers respect insecticide PHIs more frequently than fungicide PHIs. For insecticides, they comply with PHIs for 56 percent of active ingredients. In contrast, they respect the required PHI for only 5.6 percent of fungicides.

The regulatory section of Figure 2 shows that 91.5 percent of pesticides used on chayote for export are registered by EPA for some agricultural use. Again, pesticides with no tolerance are not banned but rather have not been registered. Considering EPA tolerances, slightly more than half of pesticide active ingredients used have a tolerance on chayote.[10] In 2003 FDA tested for 31.9 percent of the pesticides used, while another 8.5 percent were exempt. Overall, while mini-squash and chayote farmers demonstrate caution about pesticide residues, their pesticide use does not correspond very closely to U.S. regulation.

Cases of Caution with PHIs of Specific Pesticides

Some farmers use pesticides that they know can cause regulatory violations, but do so in a way to minimize this risk. Phorate is one such pesticide. It is used to keep *joboto*, the Costa Rican

[10] EPA considers chayote the same as a summer squash (Carolyn Makovi, pers. comm., October 17, 2005).

name for *Phyllophaga* spp. larvae, from eating crop roots. Farmers know the risk of causing violations, but feel they have no viable alternative. Their solution to this dilemma is to use very low doses when they violate the PHI (see Figures 1 and 2), reasoning that a substantially lower dose that violates the PHI will leave low enough residues to escape detection. While logical, it is risky since any amount of phorate detected by FDA will cause a violation. The same strategy is evident for methamidophos, the pesticide historically responsible for the most violations.

Discussion

The way in which export farmers use pesticides in the study site is very different from how the majority of the literature describes farmers' pesticide use in developing countries. First, while they use some highly toxic organophosphate and carbamate insecticides, these do not dominate. Instead, export farmers rely much more on pyrethroids, which have much shorter PHIs on average because they degrade faster. Second, most export farmers follow the recommended dose for all types of pesticides and many export farmers intentionally use low doses in order to minimize residues. Lastly, both export mini-squash and chayote farmers respect PHIs for insecticides more often than not. Even though both crops are continuously harvested vegetables, which present considerable difficulties in respecting PHIs, export farmers generally adjust their spraying times to extend the PHI by spraying immediately after harvest. In contrast, farmers in both sectors commonly violate fungicide PHIs, the only aspect of their pesticide use vis-à-vis residues that corresponds with the "typical" farmer in developing countries.

Beyond showing the importance of regulatory risk in shaping export farmers' behavior and the differences between export farmers in the study site and "typical" farmers in developing countries, the data presented above raise a number of questions about the gap between regulation and production practices. Why does pesticide use differ substantially from EPA tolerances even after exporters' and the state's attempts to police pesticide on export crops? Why are farmers in both sectors more cautious about insecticides than fungicides? If farmers commonly use pesticides on export crops that do not have EPA tolerances on those crops, why are pesticide residue violations not more frequent? These questions necessitate an understanding of local context.

Pyrethroids and EPA Tolerances

The data point to a previously unrecognized form of caution that export farmers exercise: insecticide choice. For farmers in the study site, the most important response to regulatory risk is using pyrethroids and avoiding organophosphates, especially near and in harvest. Ironically, MAG and exporters' recommendations to use pyrethroids leads to pesticide use that is less compliant with EPA tolerances. Pyrethroids are used to avoid residue rejections, which, paradoxically, is *not* the same as complying with EPA tolerances. EPA has not registered most of the commonly used pyrethroids for the crops on which export farmers use them. Only permethrin, which is one of the six pyrethroids that form the core of export farmers' insecticide regimens, has an EPA tolerance on squash and chayote (EPA 2004). This highlights a broader problem for export farmers: squash, and especially chayote, are minor crops in the U.S., so there is little incentive for agrochemical companies to obtain EPA tolerances for them (Bischoff, 1993; Boh, 2003).

Embracing pyrethroids is based on locally developed knowledge of their residuality. These pesticides have relatively low PHIs on their labels, have been used for more than a decade by export farmers during harvest time, and have never caused residue rejections of local produce. Exporters interpret this to mean that the pyrethroids effectively leave no residues. Since FDA regularly tests for them and they have not caused violations means that this interpretation is likely correct. Residue degradation experiments show that breakdown rates are very fast (up to 50 percent per day) for cypermethrin, deltamethrin, and permethrin (Ripley et al., 2001). Thus, using pyrethroids is a useful adaptation to regulatory risk even though it means not complying with the letter of U.S. law. The question of why export farmers are far less cautious about fungicide residues remains.

Local (Mis)Interpretation of Pesticide Color Bands

A local misunderstanding of pesticide toxicity information presented on pesticide labels modifies farmers' response to regulatory risk. Many farmers interpret a pesticide's label toxicity symbol and color band (Table 2) to indicate the level of hazard to both the pesticide handler *and* the consumer (and, further, to the environment). Based on the assumption that U.S. residue laws would restrict these types of residues, many export farmers interpret a pesticide's color band to symbolize its propensity to cause residue violations on produce exported to the U.S. The problem with this interpretation is that acute toxicity, as represented visually by the color band, is a different chemical property than the amount of residue that a pesticide will leave. Some very acutely toxic pesticides like methomyl have short PHIs because they have short half lives, while other less acutely toxic pesticides, especially some organochlorines, persist as residues for decades.

Yet, the view of color bands representing the threat to consumers exists among some farmers in the study site.[11] For example, Farmer 89, a very knowledgeable export farmer who has been working to convert to organic agriculture, explained the meaning of the color bands:

> They come with a yellow band, red band, green band. Green is that I can spray it today and harvest tomorrow. A yellow band means that if it is sprayed today, you have to give it a space of two or three days. And a red band, it is known that if it is sprayed today, you have to wait 15, 22 days after for harvesting (Farmer Survey, September 25, 2003).

This interpretation partly explains the lack of caution with fungicides since about 80 percent of fungicides sold in the study site have a green band, while insecticides mostly have red and yellow bands. Some farmers interpret this green band to mean that fungicides do not present residue problems, and others consider them to be biopesticides. While farmers' interpretation that color band represents a pesticide's propensity to leave harmful residues may seem illogical, I argue that it is very logical that farmers interpret the color and wording of a pesticide's color band to mean the

[11] The survey did not include questions about label interpretation, so the extent of this interpretation cannot be determined. Other surveys and interviews revealed similar views.

danger to both themselves *and* the consumer. Farmers do not receive information on the finer points of agrochemical characteristics, and the design of the Costa Rican color band symbols (Table 2) contributes to the problem. While red, yellow, and blue color bands all include the word "DANGEROUS," green bands do not. From this labeling scheme, it is logical to conclude that pesticides with green bands are not dangerous.

The understanding that fungicides are not dangerous also developed because of the specific history of residue violations for export crops in the study site and the subsequent enforcement focus of MAG and exporters. Locally, the insecticide methamidophos is the most notorious pesticide for causing residue violations, and it has a red band. Exporters proscribe it and other red-banded, highly toxic pesticides like carbofuran and phorate, as well as some yellow-banded organophosphates and organochlorines like dimethoate and endosulfan. In contrast, green-banded pesticides have never caused residue rejections of export produce from the study site, making it easy, although incorrect, to associate a green band with low regulatory risk.

This explains in part why there is a strong contrast between export farmers' caution with insecticides and caution with fungicides. The last question remains: if export farmers commonly use pesticides that do not have EPA tolerances, why are FDA rejections due to illegal pesticide residues not more frequent? This stems in large part from lax FDA testing. Figures 1 and 2 reveal that FDA residues tests would not detect many commonly used pesticides, especially fungicides. Thus, negative regulatory feedback through residue violations has not occurred for fungicides because FDA would not detect them even if they violate tolerances.

Conclusion

Regulatory risk, arising form U.S. regulation acting from afar and being enforced proximately by exporters and the Costa Rican state, has become a significant influence on the way that export farmers in Northern Cartago and the Ujarrás Valley use pesticides. Due to the low probability-high consequence nature of the risk, export farmers of both mini-squash and chayote exercise considerable caution over their pesticide use vis-à-vis pesticide residues. In this respect, they differ dramatically from the literature's "typical" farmer in Costa Rica and developing countries generally. Export farmers in the study site favor the less residual and less toxic pyrethroid insecticides over the more toxic and often more persistent organophosphate and carbamate insecticides, even though the pyrethroids may be somewhat less effective in pest control. Farmers of both mini-squash and chayote comply with pesticide dose requirements on the label for the vast majority of pesticides. While export farmers are careful in complying with insecticide PHIs, they largely ignore fungicide PHIs, especially in the chayote sector. A logical misinterpretation of the meaning of the pesticide color band—associating green with lack of potential harm to the consumer and a lack of risk in causing pesticide residue violations—and the local history of rejections from pesticide residues—in which red banded, highly toxic insecticides dominate—explain why farmers in both sectors are much less cautious about fungicides. This also stems from inadequate FDA testing that misses potentially violative fungicide residues.

I want to conclude with three broader points relevant to theory and generalizability. The first point concerns the politics of pesticide research and the problematic influence of the first world/third world binary. As normative researchers, political ecologists likely recognize that saying that farmers in developing countries misuse, abuse, or cautiously use pesticides is inherently political because it can play into the agendas of various groups debating the appropriateness of pesticide-dependent agriculture. The agrochemical industry position, called the safe use paradigm by Murray (1994), argues that providing proper training and information to farmers can solve pesticide problems in developing countries. Critics of the pesticide industry respond from a different framework, which I call the inherent problems paradigm, emphasizing the lack of caution with pesticides in developing countries. This paradigm argues that social, economic, and climatic conditions in the South make proper pesticide use impossible (García, 1999; Murray, 1994; Wright, 1986, 1990). Within the inherent problems paradigm, the words "abuse" and "misuse" are almost always used to describe pesticide use in developing countries (e.g., Andreatta, 1997; Grossman, 1992; Williamson, 2003).

I suspect there is a fear among critical researchers that describing any aspect of farmers' pesticide use as cautious plays into the safe use paradigm. While I agree with critical perspectives that the safe use paradigm is grossly inadequate and must be countered, I also believe that we can acknowledge that some aspects of pesticide use by farmers in developing countries can be quite rational without supporting the narratives and goals of agrochemical promoters. Finding and explaining farmers' caution with pesticides is not to downplay pesticides' many negative effects or to paint a rosy picture about chemically-dependent agriculture, but is instead to acknowledge that farmers can effectively respond to regulation to tackle some pesticide problems. In this respect, this paper and Grossman's work (1992, 1998), which challenge consistent reports about land users' irrational pesticide use, follow a tradition in cultural and political ecology of countering common environmental degradation narratives by showing the rationality in farmer's land management (Blaikie and Brookfield, 1987; Scott, 1976).

Disaggregating caution also allows for breaking through an unfortunate binary in pesticide research that is often mapped onto the problematic first world/third world divide. In the parlance of research focused on developing countries, farmers in developing countries typically "abuse" and "misuse" pesticides, implying that farmers in the industrialized world merely "use" them. The distinction hides the fact that pesticide "misuse" exists in industrialized countries as well (Pulido and Pena, 1998) and that even proper pesticide use according to the label has negative impacts on health and the environment. These distinctions are also problematic since they prevent certain questions from being asked in certain places, thereby precluding certain conclusions and the development of theory about their interface, convergence, or divergence. McCarthy (2005, 956) in discussing first world political ecology notes "how much we can learn when we are prepared to recognize and research relations typically assumed not to exist in industrialized countries." The converse is true of third world political ecology: in the case of pesticides, researchers focusing on misuse will inevitably overlook aspects of pesticide use rationalization in developing countries since it is a logical impossibility within the dominant mode of thinking.

The second point of conclusion concerns political ecology's chain of explanation and the functioning of "real" markets in relation to environmental degradation versus agri-food governance. In the study site, non-economic market requirements in conventional fresh produce markets are socially mediated by export firms so that pesticide tolerances in industrialized nations ultimately create regulatory risk to which export farmers respond by their pesticide selection and use. As an increasing number of examples show (Arbona, 1998; Julian et al., 2000; Opondo, 2000; Williamson, 2003), it is when pesticide use threatens capital accumulation and/or the foreign exchange earnings of the state, through actual or threatened rejections of export produce due to illegal residues, that attempts have been made in developing countries to rationalize it. This resonates with one of Blaikie's (1985, 147) major conclusions about the political ecology of soil erosion: "soil erosion in lesser developed countries will not be substantially reduced unless it seriously threatens the accumulation possibilities of the dominant classes."

As others have noted, and as demonstrated above, political ecology's chain of explanation is useful in highlighting the importance of factors external to the farming system and the way that local and national institutions structure access to resources and markets (Batterbury and Bebbington, 1999; Black, 1990). An important critique of the chain of explanation is that Blaikie and Brookfield treat the broader political economy as exogenous, which does not allow for theorizing the influence of local political structures or actors on the state or exogenous world (Black, 1990). In the case presented here, however, U.S. pesticide regulations *are* essentially exogenous—even if endogenously and contingently mediated—since farmers and export firms cannot change them, and must, therefore, adapt in some manner or face serious consequences. Thus, the chain of explanation works well as a framework for understanding the impact of non-local pesticide regulations on export farmer's land use decisions because it is attentive to capital accumulation and external impositions.

Yet, even though Blaikie is clearly interested in "real" markets in contrast to a neoclassical treatment of them, the chain of explanation falls somewhat short in explaining gaps or disconnects between the impacts of regulation and local outcomes. This is in part because it was created to explain environmental degradation, not agri-food regulation. Ribot's (1998, 334) analysis and conceptualization of commodity chains helps, since it argues that "policies tell only part of the story: the other part is told within the space between policy (or law) and outcomes, the space in which a whole array of non-policy mechanisms shape the dynamics of production and exchange." Similarly, since export farmers' pesticide use is more cautious than expected but still different from EPA tolerances, it is evident that a significant lacuna exists between regulation and outcome. This gap arises from local circumstances: the specific history of rejections and local misinterpretations. The disconnect highlights the ever-partial control over land users by capital and the state in contract farming (cf. Clapp, 1994). On the specific topic of pesticides, even when capital accumulation is threatened by export shipment rejections caused by pesticide residue, efforts to rationalize farmers' pesticide use are not always made and, when they are, they can fail (Julian et al., 2000). Thus, even though there is a political economic reason for export farmers to exercise caution over pesticide residues, it does not necessarily determine their pesticide use.

Lastly, as critical researchers devote more attention to alternative agri-food networks and the meaning of green consumption, it remains important to understand the dynamic, conventional production and consumption networks that still dominate the world. My research shows that some farmers in these systems now rely on less toxic insecticides—the pyrethroids—that break down more quickly compared to the organophosphate and carbamate insecticides. Less use of organophosphate and carbamate insecticides has important public health implications, since these pesticides cause the majority of pesticide-induced deaths in areas of developing countries where reasonably reliable data are available (Roberts et al., 2003). These effects of incorporation into export production are not necessarily universal because we do not yet understand export firms' decision making vis-à-vis pesticide policing, i.e., if and how some function without controlling pesticide use. These effects, however, support the argument that understanding and shaping economic governance in conventional agri-food networks should be an important focus for critical researchers and progressive citizen groups.

Understanding the effects of governance in conventional agro-food networks can be accomplished through a deeper engagement of political ecology and agri-food studies. Specifically, political ecology adds strength in understanding local land use decisions within the context of a broader political economy while agri-food studies compliments this with its focus on the roles of government and industry in regulation and the critical nexus of consumption. Many researchers work in both political ecology and agri-food studies (e.g., Jarosz, 2000) and connections are being made concerning consumption (Bryant and Goodman, 2004), but I emphasize the need for continued ethnographic research in places of production because of the importance of local context in shaping outcomes. Examining the interface between local circumstance and socially mediated regulation from afar will further reveal the contours of "glocalization" (Swyngedouw, 1997) and contribute to a political ecology of globalization.

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Figure Captions

Figure 1: Pesticide use on export mini-squash in relation to U.S. regulation, Northern Cartago and the Ujarrás Valley, 2003

Figure 2: Pesticide use on export chayote in relation to U.S. regulation, Ujarrás Valley, 2003

Table Captions

Table 1: Insecticide classes used on export mini-squash and chayote, Northern Cartago and the Ujarrás Valley, 2003

Table 2: Costa Rican pesticide toxicity categories, packaging symbols, and color bands

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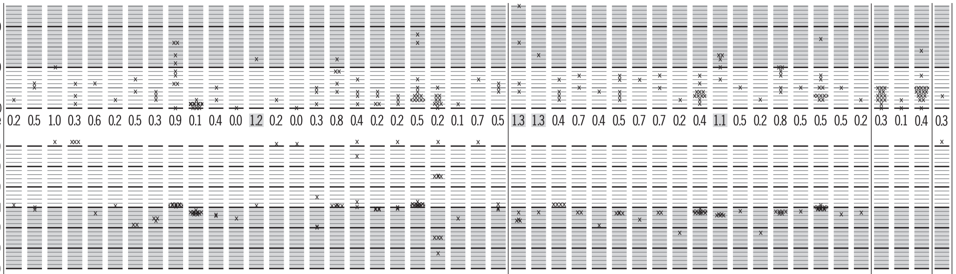
Pesticide active ingredient	Category	EPA registered	EPA tolerance	FDA residue test 2003	Ave. min. PHI	Ave. dose
acephate	Insecticides	☑	☐	☐	33	0.3
avermectin	Insecticides	☑	☑	☐	26	0.1
Bacillus thuringiensis	Insecticides	☑	☑	⊟	2	0.9
carbofuran[1]	Insecticides	☑	☑	☐	47	0.2
cartap	Insecticides	☐	☐	☐	0	0.2
chlofenapyr	Insecticides	☑	☐	☐	2	0.2
chlorpyrifos[1]	Insecticides	☑	☐	☑	32	0.9
cypermethrin	Insecticides	☑	☐	☑	4	0.7
deltamethrin	Insecticides	☑	☐	☑	3	0.0
DDVP (dichlorvos)	Insecticides	☑	☐	☐	-18	0.6
diflubenzuron	Insecticides	☑	☐	☐	-58	1.1
dimethoate	Insecticides	☑	☐	☐	-10	0.2
esfenvalerate	Insecticides	☑	☐	☐	27	0.2
ethioprophos[1]	Insecticides	☑	☐	☑	2	0.4
imidacloprid	Insecticides	☑	☑	☐	-1	0.5
lambda-cyhalothrin	Insecticides	☑	☐	☐	9	0.7
metaldehyde[1]	Insecticides	☑	☐	☐	47	0.1
methamidophos	Insecticides	☑	☐	☑	25	0.2
methomyl	Insecticides	☑	☑	☐	14	0.1
oxamyl	Insecticides	☑	☑	☐	49	0.2
permethrin	Insecticides	☑	☑	☑	5	0.7
phorate[1]	Insecticides	☑	☐	☑	-17	0.2
phoxim	Insecticides	☐	☐	☐	17	0.0
potassium salt, oleic acid	Insecticides	☑	☑	⊟	10	0.2
prothiofos	Insecticides	☐	☐	☑	14	0.3
spinosad	Insecticides	☑	☑	☐	-1	0.6
teflubenzuron	Insecticides	☐	☐	☐	-13	0.8
z-cypermethrin	Insecticides	☑	☐	☑	2	1.1
ascorbic, citric, & lactic acid	Fungicides	☑	☑	⊟	4	0.7
azoxystrobin	Fungicides	☑	☐	☐	2	1.4
benomyl	Fungicides	☑	☑	☐	-6	0.3
captan	Fungicides	☑	☑	☑	-5	0.3
carbendazim	Fungicides	☑	☑	☐	-6	0.5
chlorothalonil	Fungicides	☑	☑	☑	5	0.3
citrus seed extract	Fungicides	☐	☐	☐	3	0.4
copper oxychloride	Fungicides	☑	☑	⊟	2	0.3
copper sulfate (pentahydrate)	Fungicides	☑	☑	⊟	2	0.7
cymoxanil	Fungicides	☑	☑	☐	-8	0.5
dimethomorph	Fungicides	☑	☑	☐	2	0.3
folpet	Fungicides	☑	☐	☑	0	0.8
fosethyl-al	Fungicides	☑	☐	☐	1	0.8
gentamycin, sulfate	Fungicides	☐	☐	☐	-24	0.2
kasugamycin	Fungicides	☐	☐	☐	-13	0.1
mancozeb	Fungicides	☑	☑	☐	-2	0.4
metalaxyl-m (mefenoxam)	Fungicides	☑	☐	☐	2	0.7
myclobutanil	Fungicides	☑	☑	☐	7	0.2
oxycarboxin	Fungicides	☑	☐	☐	3	0.1
oxytetracycline (terramycin)	Fungicides	☑	☐	☐	-2	0.3
oxytetracycline hydrochloride	Fungicides	☑	☐	☐	-24	0.2
prochloraz	Fungicides	☐	☐	☐	2	0.3
propineb	Fungicides	☐	☐	☐	-1	0.6
streptomycin	Fungicides	☑	☐	☐	-2	0.3
sulfur	Fungicides	☑	☑	☐	4	0.4
thiabendazole	Fungicides	☑	☐	☐	1	0.5
thiophanate-methyl	Fungicides	☑	☑	☐	-5	0.4
tolclofos-methyl	Fungicides	☐	☐	☐	52	0.3
ziram	Fungicides	☑	☑	☐	-1	0.4
glyphosate	Herbicides	☑	☑	☐	NA	0.3
paraquat	Herbicides	☑	☑	☐	NA	0.4

[1] Applied as granulated fomulations.

Sources: Author's farmer surveys 2003-04, EPA 2004 for regulatory information, FDA 2005 for residue testing data, and Costa Rican pesticide labels.



Class	Pesticide active ingredient	Ave. dose	Ave. min. PHI	EPA registered	EPA tolerance	FDA residue test 2003
Insecticides	avermectin	0.2	2	☑	☑	☐
Insecticides	bifenthrin	0.5	-1	☑	☑	☑
Insecticides	carbofuran	1.0	122	☑	☑	☐
Insecticides	carbofuran[1]	0.3	128	☑	☑	☐
Insecticides	cartap	0.6	-6	☐	☐	☐
Insecticides	chlofenapyr	0.2	1	☑	☐	☐
Insecticides	chlorpyrifos	0.5	-17	☑	☐	☑
Insecticides	cyfluthrin	0.3	-12	☑	☐	☐
Insecticides	cypermethrin	0.9	2	☑	☐	☑
Insecticides	deltamethrin	0.1	-5	☑	☐	☑
Insecticides	diazinon	0.4	-8	☑	☑	☑
Insecticides	dimethoate	0.0	-11	☑	☐	☐
Insecticides	endosulfan	1.2	1	☑	☑	☑
Insecticides	ethioprophos[1]	0.2	62	☑	☐	☑
Insecticides	fenamiphos[1]	0.0	62	☑	☐	☑
Insecticides	imidacloprid	0.3	-10	☑	☑	☐
Insecticides	lambda-cyhalothrin	0.8	1	☑	☐	☐
Insecticides	methamidophos	0.4	38	☑	☐	☐
Insecticides	methomyl	0.2	-2	☑	☑	☐
Insecticides	oxamyl	0.2	44	☑	☑	☐
Insecticides	permethrin	0.5	2	☑	☑	☑
Insecticides	phorate[1]	0.2	9	☑	☐	☑
Insecticides	prothiofos	0.1	-15	☐	☐	☑
Insecticides	terbufos[1]	0.7	65	☑	☐	☑
Insecticides	thiamethoxam	0.5	0	☑	☑	☐
Fungicides	benomyl	1.3	-11	☑	☑	☐
Fungicides	carbendazim	1.3	-5	☑	☑	☐
Fungicides	chlorothalonil	0.4	3	☑	☑	☑
Fungicides	copper carbonate, basic	0.7	-5	☑	☐	☐
Fungicides	copper hydroxide	0.4	-18	☑	☑	⊟
Fungicides	copper oxychloride	0.5	-6	☑	☑	⊟
Fungicides	copper sulfate	0.7	-12	☑	☑	⊟
Fungicides	copper sulfate, tri-basic	0.7	-5	☑	☑	⊟
Fungicides	gentamycin, sulfate	0.2	-25	☐	☐	☐
Fungicides	mancozeb	0.4	-4	☑	☑	☐
Fungicides	maneb	1.1	-8	☑	☑	☐
Fungicides	oxytetracycline (terramycin)	0.5	-4	☑	☐	☐
Fungicides	oxytetracycline hydrochloride	0.2	-25	☑	☐	☐
Fungicides	propineb	0.8	-5	☐	☐	☐
Fungicides	streptomycin	0.5	-4	☑	☐	☐
Fungicides	sulfur	0.5	-1	☑	☑	☐
Fungicides	thiophanate-methyl	0.5	-7	☑	☑	☐
Fungicides	ziram	0.2	-5	☑	☑	☐
Herbicides	glyphosate	0.3	NA	☑	☑	☐
Herbicides	oxyflourfen	0.1	NA	☑	☐	☑
Herbicides	paraquat	0.4	NA	☑	☑	☐
Fumigants	metam sodium	0.3	128	☑	☐	☐

No. of farmers

[1] Applied as granulated fomulations.

Sources: Author's farmer surveys 2003-04, EPA 2004 for regulatory information, FDA 2005 for residue testing data, and Costa Rican pesticide labels.

	ave. # of insecticide doses	organophosphates & carbamates		pyrethroids	
		ave. # of doses	as % of insecticide doses	ave. # of doses	as % of insecticide doses
mini-squash (n=28)[1]	9.7	1.7	14.9%	3.8	39.3%
chayote (n=20)	37.7	8	17.6%	26.2	66.7%

[1] Some farmers contribute two to the sample number if they grow both scallop squash and zucchini.
Source: Author's farmer surveys 2003-04.

Table 1

WHO acute toxicity category		symbol on package and foldout label		color band on package		oral LD_{50} (mg/kg)		dermal LD_{50} (mg/kg)	
		symbol	wording[1]	color	wording[1]	solid	liquid	solid	liquid
Ia	Extremely Dangerous	☠	VERY TOXIC	red	EXTREMELY DANGEROUS	≤ 5	≤ 20	≤ 10	≤ 40
Ib	Highly Dangerous		TOXIC		HIGHLY DANGEROUS	5-50	20-200	10-100	40-400
II	Moderately Dangerous	✖	HARMFUL	yellow	MODERATELY DANGEROUS	50-500	200-2,000	100-1,000	400-4,000
III	Slightly Dangerous	—	CAUTION	blue	SLIGHTLY DANGEROUS	500-2,000	2,000-3,000	> 1,000	> 4,000
IV	—	—	PRECAUTION	green	—	> 2,000	> 3,000		

Sources: Costa Rican pesticide labels collected by author and Picado and Ramirez 1998: 372.

Table 2